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(54) Titre : PROCEDES ET SYSTEMES DE COLLECTE, D'APPRENTISSAGE ET DE DIFFUSION EN CONTINU DE SIGNAUX DE MACHINE A DES FINS D'ANALYSE ET DE MAINTENANCE A L'AIDE DE L'INTERNET DES OBJETS INDUSTRIEL

(54) Title: METHODS AND SYSTEMS FOR DATA COLLECTION, LEARNING, AND STREAMING OF MACHINE SIGNALS FOR ANALYTICS AND MAINTENANCE USING THE INDUSTRIAL INTERNET OF THINGS

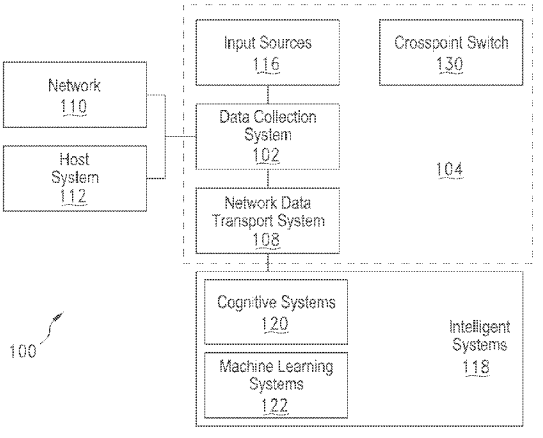

FIG. 6

(57) Abrégé/Abstract:
An industrial machine predictive maintenance system may include an industrial machine data analysis facility that generates streams of industrial machine health monitoring data by applying machine learning to data representative of conditions of portions of industrial machines received via a data collection network. The system may include an industrial machine predictive maintenance facility that produces industrial machine service recommendations responsive to the health monitoring data by applying machine fault detection and classification algorithms thereto. A computerized maintenance management system (CMMS) that produces orders and/or requests for service and parts responsive to the industrial machine service recommendations can be included. The system may include a service and delivery coordination facility that processes information regarding services performed on industrial machines responsive to the orders and/or requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

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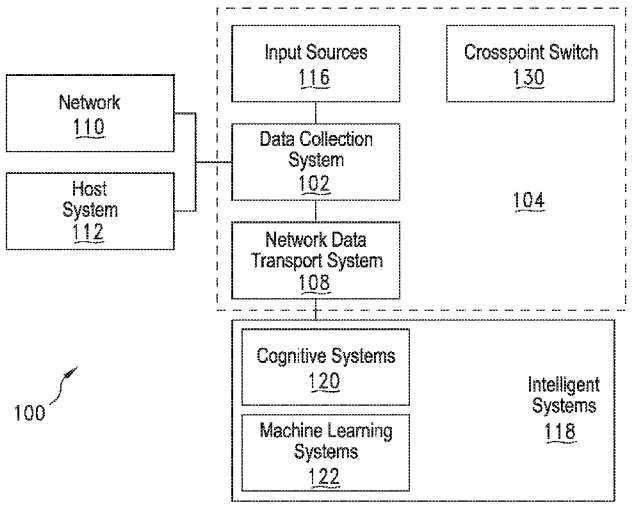

FIG. 6

(57) Abstract: An industrial machine predictive maintenance system may include an industrial machine data analysis facility that generates streams of industrial machine health monitoring data by applying machine learning to data representative of conditions of portions of industrial machines received via a data collection network. The system may include an industrial machine predictive maintenance facility that produces industrial machine service recommendations responsive to the health monitoring data by applying machine fault detection and classification algorithms thereto. A computerized maintenance management system (CMMS) that produces orders and/or requests for service and parts responsive to the industrial machine service recommendations can be included. The system may include a service and delivery coordination facility that processes information regarding services performed on industrial machines

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JUMBO APPLICATIONS/PATENTS

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METHODS AND SYSTEMS FOR DATA COLLECTION, LEARNING, AND STREAMING OF MACHINE SIGNALS FOR ANALYTICS AND MAINTENANCE USING THE INDUSTRIAL INTERNET OF THINGS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application Serial Number 62/714,078 filed August 2, 2018, entitled METHODS AND SYSTEMS FOR STREAMING OF MACHINE SIGNALS FOR ANALYTICS AND MAINTENANCE USING THE INDUSTRIAL INTERNET OF THINGS; U.S. Provisional Patent Application Serial Number 62/713,897 filed August 2, 2018, entitled METHODS AND SYSTEMS FOR DATA COLLECTION AND LEARNING USING THE INDUSTRIAL INTERNET OF THINGS; U.S. Provisional Patent Application Serial Number 62/757,166 filed November 8, 2018, entitled METHODS AND SYSTEMS FOR STREAMING OF MACHINE SIGNALS FOR ANALYTICS AND MAINTENANCE USING THE INDUSTRIAL INTERNET OF THINGS; U.S. Provisional Patent Application Serial Number 62/799,732 filed January 31, 2019, entitled METHODS AND SYSTEMS FOR DATA COLLECTION, LEARNING, AND STREAMING OF MACHINE SIGNALS FOR ANALYTICS AND MAINTENANCE USING THE INDUSTRIAL INTERNET OF THINGS; U.S. Non-Provisional Patent Application Serial Number 16/143,286 filed September 26, 2018, entitled METHODS AND SYSTEMS FOR DETECTION IN AN INDUSTRIAL INTERNET OF THINGS DATA COLLECTION ENVIRONMENT WITH FREQUENCY BAND ADJUSTMENTS FOR DIAGNOSING OIL AND GAS PRODUCTION EQUIPMENT; and U.S. Non-Provisional Patent Application Serial Number 15/973,406 filed May 7, 2018, entitled METHODS AND SYSTEMS FOR DETECTION IN AN INDUSTRIAL INTERNET OF THINGS DATA COLLECTION ENVIRONMENT WITH LARGE DATA SETS.

[0002] U.S. Non-Provisional Patent Application Serial Number 16/143,286 filed September 26, 2018, entitled METHODS AND SYSTEMS FOR DETECTION IN AN INDUSTRIAL INTERNET OF THINGS DATA COLLECTION ENVIRONMENT WITH FREQUENCY BAND ADJUSTMENTS FOR DIAGNOSING OIL AND GAS PRODUCTION EQUIPMENT is a bypass continuation of International Application Number PCT/US2018/045036, filed August 2, 2018, entitled METHODS AND SYSTEMS FOR DETECTION IN AN INDUSTRIAL INTERNET OF THINGS DATA COLLECTION ENVIRONMENT WITH LARGE DATA SETS, published on February 7, 2019, as WO/2019/028269, which claims priority to U.S. Non-Provisional Patent Application Serial Number 15/973,406, filed May 7, 2018, entitled METHODS AND SYSTEMS FOR DETECTION IN AN INDUSTRIAL INTERNET OF THINGS DATA COLLECTION ENVIRONMENT WITH LARGE DATA SETS, which is a bypass continuation-in-part of International Application Number PCT/US2017/031721, filed May 9, 2017, entitled

METHODS AND SYSTEM FOR THE INDUSTRIAL INTERNET OF THINGS, published on November 16, 2017, as WO/2017/196821, and which claims priority to at least U.S. Provisional Patent Application Serial Number 62/333,589, filed May 9, 2016, entitled STRONG FORCE INDUSTRIAL IOT MATRIX; U.S. Provisional Patent Application Serial Number 62/350,672, filed June 15, 2016, entitled STRATEGY FOR HIGH SAMPLING RATE DIGITAL RECORDING OF MEASUREMENT WAVEFORM DATA AS PART OF AN AUTOMATED SEQUENTIAL LIST THAT STREAMS LONG-DURATION AND GAP-FREE WAVEFORM DATA TO STORAGE FOR MORE FLEXIBLE POST-PROCESSING; U.S. Provisional Patent Application Serial Number 62/412,843, filed October 26, 2016, entitled METHODS AND SYSTEMS FOR THE INDUSTRIAL INTERNET OF THINGS; and U.S. Provisional Patent Application Serial Number 62/427,141, filed November 28, 2016, entitled METHODS AND SYSTEMS FOR THE INDUSTRIAL INTERNET OF THINGS, and in which International Application Number PCT/US2018/045036 and U.S. Ser. No. 15/973,406 also claim priority to U.S. Provisional Patent Application Serial Number 62/540,557, filed August 2, 2017, entitled SMART HEATING SYSTEMS IN AN INDUSTRIAL INTERNET OF THINGS; U.S. Provisional Patent Application Serial Number 62/562,487, filed September 24, 2017, entitled METHODS AND SYSTEMS FOR THE INDUSTRIAL INTERNET OF THINGS; and U.S. Provisional Patent Application Serial Number 62/583,487, filed November 8, 2017, entitled METHODS AND SYSTEMS FOR THE INDUSTRIAL INTERNET OF THINGS, and U.S. Provisional Patent Application Serial Number 62/540,513, filed August 2, 2017, entitled SYSTEMS AND METHODS FOR SMART HEATING SYSTEM THAT PRODUCES AND USES HYDROGEN FUEL. This application also claims priority to U.S. Provisional Patent Application Serial Number 62/713,897, filed August 2, 2018, entitled METHODS AND SYSTEMS FOR DATA COLLECTION AND LEARNING USING THE INDUSTRIAL INTERNET OF THINGS, and to U.S. Provisional Patent Application Serial Number 62/757,166, filed November 2, 2018, entitled METHODS AND SYSTEMS FOR STREAMING OF MACHINE SIGNALS FOR ANALYTICS AND MAINTENANCE USING THE INDUSTRIAL INTERNET OF THINGS, which are each a bypass continuation-in-part of International Application Number PCT/US2017/031721, filed: May 9, 2017, entitled METHODS AND SYSTEM FOR THE INDUSTRIAL INTERNET OF THINGS, published on November 16, 2017, as WO/2017/196821, and which claims priority to U.S. Provisional Patent Application Serial Number 62/333,589, filed May 9, 2016, entitled STRONG FORCE INDUSTRIAL IOT MATRIX; U.S. Provisional Patent Application Serial Number 62/350,672, filed June 15, 2016, entitled STRATEGY FOR HIGH SAMPLING RATE DIGITAL RECORDING OF MEASUREMENT WAVEFORM DATA AS PART OF AN AUTOMATED SEQUENTIAL LIST THAT STREAMS

LONG-DURATION AND GAP-FREE WAVEFORM DATA TO STORAGE FOR MORE FLEXIBLE POST-PROCESSING; U.S. Provisional Patent Application Serial Number 62/412,843, filed October 26, 2016, entitled METHODS AND SYSTEMS FOR THE INDUSTRIAL INTERNET OF THINGS; and U.S. Provisional Patent Application Serial Number 62/427,141, filed November 28, 2016, entitled METHODS AND SYSTEMS FOR THE INDUSTRIAL INTERNET OF THINGS. This application also claims priority to U.S. Provisional Patent Application Serial Number 62/540,557, filed August 2, 2017, entitled SMART HEATING SYSTEMS IN AN INDUSTRIAL INTERNET OF THINGS; U.S. Provisional Patent Application Serial Number 62/562,487, filed September 24, 2017, entitled METHODS AND SYSTEMS FOR THE INDUSTRIAL INTERNET OF THINGS; and U.S. Provisional Patent Application Serial Number 62/583,487, filed November 8, 2017, entitled METHODS AND SYSTEMS FOR THE INDUSTRIAL INTERNET OF THINGS. The above applications are each hereby incorporated by reference as if fully set forth herein in their entirety.

BACKGROUND

1. Field

[0003] The present disclosure relates to methods and systems for data collection in industrial environments, as well as methods and systems for leveraging collected data for monitoring, remote control, autonomous action, and other activities in industrial environments.

2. Description of the Related Art

[0004] Heavy industrial environments, such as environments for large scale manufacturing (such as manufacturing of aircraft, ships, trucks, automobiles, and large industrial machines), energy production environments (such as oil and gas plants, renewable energy environments, and others), energy extraction environments (such as mining, drilling, and the like), construction environments (such as for construction of large buildings), and others, involve highly complex machines, devices and systems and highly complex workflows, in which operators must account for a host of parameters, metrics, and the like in order to optimize design, development, deployment, and operation of different technologies in order to improve overall results. Historically, data has been collected in heavy industrial environments by human beings using dedicated data collectors, often recording batches of specific sensor data on media, such as tape or a hard drive, for later analysis. Batches of data have historically been returned to a central office for analysis, such as undertaking signal processing or other analysis on the data collected by various sensors, after which analysis can be used as a basis for diagnosing problems in an environment and/or suggesting ways to improve operations. This work has historically taken place on a time scale of weeks or months, and has been directed to limited data sets.

[0005] The emergence of the Internet of Things (IoT) has made it possible to connect continuously to, and among, a much wider range of devices. Most such devices are consumer devices, such as lights, thermostats, and the like. More complex industrial environments remain more difficult, as the range of available data is often limited, and the complexity of dealing with data from multiple sensors makes it much more difficult to produce "smart" solutions that are effective for the industrial sector. A need exists for improved methods and systems for data collection in industrial environments, as well as for improved methods and systems for using collected data to provide improved monitoring, control, intelligent diagnosis of problems and intelligent optimization of operations in various heavy industrial environments.

[0006] Industrial system in various environments have a number of challenges to utilizing data from a multiplicity of sensors. Many industrial systems have a wide range of computing resources and network capabilities at a location at a given time, for example as parts of the system are upgraded or replaced on varying time scales, as mobile equipment enters or leaves a location, and due to the capital costs and risks of upgrading equipment. Additionally, many industrial systems are positioned in challenging environments, where network connectivity can be variable, where a number of noise sources such as vibrational noise and electro-magnetic (EM) noise sources can be significant and in varied locations, and with portions of the system having high pressure, high noise, high temperature, and corrosive materials. Many industrial processes are subject to high variability in process operating parameters and non-linear responses to off-nominal operations. Accordingly, sensing requirements for industrial processes can vary with time, operating stages of a process, age and degradation of equipment, and operating conditions. Previously known industrial processes suffer from sensing configurations that are conservative, detecting many parameters that are not needed during most operations of the industrial system, or that accept risk in the process, and do not detect parameters that are only occasionally utilized in characterizing the system. Further, previously known industrial systems are not flexible to configuring sensed parameters rapidly and in real-time, and in managing system variance such as intermittent network availability. Industrial systems often use similar components across systems such as pumps, mixers, tanks, and fans. However, previously known industrial systems do not have a mechanism to leverage data from similar components that may be used in a different type of process, and/or that may be unavailable due to competitive concerns. Additionally, previously known industrial systems do not integrate data from offset systems into the sensor plan and execution in real time.

[0007] Industrial environments are widely populated with large, complex, heavy machines that are designed to have very long working lifetimes and have ongoing service requirements, including requirements for scheduled maintenance and for often unanticipated repairs.

[0008] Many of the large industrial machines that require ongoing maintenance, service and repairs are involved in high stakes production processes and other processes, such as energy production, manufacturing, mining, drilling, and transportation, that preferably involve minimal or no interruption. An unanticipated problem, or an extended delay in a service operation that requires a shutdown of a machine that is critical to such a process can cost thousands, or even millions of dollars per day. Embodiments disclosed herein, as well as in the documents incorporated by reference herein, provide for, among many other things, a platform having improved devices, systems, components, processes and methods for collection, processing, and use of data from and about industrial machines, including for purposes of predicting faults, anticipating needs for maintenance, and facilitating repairs. However, in some areas, the workforce that maintains, services and repairs heavy industrial machines is aging. As workers retire, much of their expertise is lost, and new workers often lack even basic factual information about a machine (such as about the internal structure of the machine), operational information (such as about how it is intended to behave in various working modes) and/or procedural information (such as how to perform a routine maintenance task), much less the know-how and expertise to handle a more complex procedure, such as a repair, that may require multi-step procedures that use unfamiliar parts or tools. Another challenge is finding relevant parts and components for an industrial machine, such as ones that may be required for an emergency repair, in a timely manner, so that they are available at the place and time required for the work. Information about the internal structure, parts or components of a machine may be absent, so that a worker may be required to guess about what is wrong, what part is involved, and how a repair needs to be conducted. A repair may require multiple visits, such as one or more to discover the nature of a problem, what parts need to be replaced, and what tools are required, and one or more others to conduct the repair once the relevant parts and tools arrive. This can mean days of delay at massive cost to the operator of the machinery. This process may repeat a few months or years later, as the next worker may have no way of accessing the knowledge acquired about the internal structure, parts or components of the machine that was acquired by an initial worker.

[0009] A need exists for improved methods and systems for collecting, discovering, capturing, disseminating, managing, and processing information about industrial machines, including factual information (such as about internal structures, parts and components), operational information and procedural information, including know-how and other information relevant to maintenance, service and repairs. A need also exists for improved methods and systems for finding a set of workers having relevant know-how and expertise about maintenance, service and repair of a particular machine. A need also exists for improved methods and systems for finding, ordering,

and fulfilling orders for relevant parts and components, so that maintenance, service and repair operations can occur seamlessly, with minimal disruption.

SUMMARY

[0010] In embodiments, an industrial machine predictive maintenance system may include an industrial machine data analysis facility that generates streams of industrial machine health monitoring data by applying machine learning to data representative of conditions of portions of industrial machines received via a data collection network. The system may further include an industrial machine predictive maintenance facility that produces industrial machine service recommendations responsive to the health monitoring data by applying machine fault detection and classification algorithms thereto. The system may further include a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations. And, the system may include a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

[0011] In embodiments, a method of predicting a service event from vibration data may include a set of operational steps including capturing vibration data from at least one vibration sensor disposed to capture vibration of a portion of an industrial machine. The captured vibration data may be processed to determine at least one of a frequency, amplitude, and gravitational force of the captured vibration. Next, a segment of a multi-segment vibration frequency spectra that bounds the captured vibration may be determined, based on, for example the determined frequency. Thus, calculating a vibration severity unit for the captured vibration may be based on the determined segment and at least one of the peak amplitudes and the gravitational force derived from the vibration data. Additionally, the method may include generating a signal in a predictive maintenance circuit for executing a maintenance action on the portion of the industrial machine based on the severity unit.

[0012] In embodiments, zero-gap signal capture at a streaming sample rate may include sampling a signal at the streaming sample rate, thereby producing a plurality of samples of the signal. The plurality of samples of the signal may be allocated with a signal routing circuit that generates a first portion of the plurality of samples of the signal to a first signal analysis circuit, the portion based on a first signal analysis sampling rate that is less than the streaming sample rate. The plurality of samples of the signal may be allocated with a signal routing circuit that generates a second portion of the plurality of samples of the signal to a second signal analysis circuit, the

portion based on a second signal analysis sampling rate that is less than the streaming sample rate. In embodiments, the zero-gap signal capture may further include storing the plurality of samples of the signal, an output of the first signal analysis circuit, and an output of the second signal analysis circuit. In embodiments, the allocated first portion and the second portion of the plurality of samples in the stored plurality of samples are tagged with indicia that references the corresponding stored signal analysis output.

[0013] Methods and systems are provided herein for data collection in industrial environments, as well as for improved methods and systems for using collected data to provide improved monitoring, control, and intelligent diagnosis of problems and intelligent optimization of operations in various heavy industrial environments. These methods and systems include methods, systems, components, devices, workflows, services, processes, and the like that are deployed in various configurations and locations, such as: (a) at the "edge" of the Internet of Things, such as in the local environment of a heavy industrial machine; (b) in data transport networks that move data between local environments of heavy industrial machines and other environments, such as of other machines or of remote controllers, such as enterprises that own or operate the machines or the facilities in which the machines are operated; and (c) in locations where facilities are deployed to control machines or their environments, such as cloud-computing environments and on-premises computing environments of enterprises that own or control heavy industrial environments or the machines, devices or systems deployed in them. These methods and systems include a range of ways for providing improved data include a range of methods and systems for providing improved data collection, as well as methods and systems for deploying increased intelligence at the edge, in the network, and in the cloud or premises of the controller of an industrial environment.

[0014] Methods and systems are disclosed herein for continuous ultrasonic monitoring, including providing continuous ultrasonic monitoring of rotating elements and bearings of an energy production facility; for cloud-based systems including machine pattern recognition based on the fusion of remote, analog industrial sensors or machine pattern analysis of state information from multiple analog industrial sensors to provide anticipated state information for an industrial system; for on-device sensor fusion and data storage for industrial IoT devices, including on-device sensor fusion and data storage for an Industrial IoT device, where data from multiple sensors are multiplexed at the device for storage of a fused data stream; and for self-organizing systems including a self-organizing data marketplace for industrial IoT data, including a self-organizing data marketplace for industrial IoT data, where available data elements are organized in the marketplace for consumption by consumers based on training a self-organizing facility with a training set and feedback from measures of marketplace success, for self-organizing data pools,

including self-organization of data pools based on utilization and/or yield metrics, including utilization and/or yield metrics that are tracked for a plurality of data pools, a self-organized swarm of industrial data collectors, including a self-organizing swarm of industrial data collectors that organize among themselves to optimize data collection based on the capabilities and conditions of the members of the swarm, a self-organizing collector, including a self-organizing, multi-sensor data collector that can optimize data collection, power and/or yield based on conditions in its environment, a self-organizing storage for a multi-sensor data collector, including self-organizing storage for a multi-sensor data collector for industrial sensor data, a self-organizing network coding for a multi-sensor data network, including self-organizing network coding for a data network that transports data from multiple sensors in an industrial data collection environment.

[0015] Methods and systems are disclosed herein for training artificial intelligence ("AI") models based on industry-specific feedback, including training an AI model based on industry-specific feedback that reflects a measure of utilization, yield, or impact, where the AI model operates on sensor data from an industrial environment; for an industrial IoT distributed ledger, including a distributed ledger supporting the tracking of transactions executed in an automated data marketplace for industrial IoT data; for a network-sensitive collector, including a network condition-sensitive, self-organizing, multi-sensor data collector that can optimize based on bandwidth, quality of service, pricing, and/or other network conditions; for a remotely organized universal data collector that can power up and down sensor interfaces based on need and/or conditions identified in an industrial data collection environment; and for a haptic or multi-sensory user interface, including a wearable haptic or multi-sensory user interface for an industrial sensor data collector, with vibration, heat, electrical, and/or sound outputs.

[0016] Methods and systems are disclosed herein for a presentation layer for augmented reality and virtual reality (AR/VR) industrial glasses, where heat map elements are presented based on patterns and/or parameters in collected data; and for condition-sensitive, self-organized tuning of AR/VR interfaces based on feedback metrics and/or training in industrial environments.

[0017] In embodiments, a system for data collection, processing, and utilization of signals from at least a first element in a first machine in an industrial environment includes a platform including a computing environment connected to a local data collection system having at least a first sensor signal and a second sensor signal obtained from at least the first machine in the industrial environment. The system includes a first sensor in the local data collection system configured to be connected to the first machine and a second sensor in the local data collection system. The system further includes a crosspoint switch in the local data collection system having multiple inputs and multiple outputs including a first input connected to the first sensor and a second input connected to the second sensor. Throughout the present disclosure, wherever a crosspoint switch,

multiplexer (MUX) device, or other multiple-input multiple-output data collection or communication device is described, any multi-sensor acquisition device is also contemplated herein. In certain embodiments, a multi-sensor acquisition device includes one or more channels configured for, or compatible with, an analog sensor input. The multiple outputs include a first output and second output configured to be switchable between a condition in which the first output is configured to switch between delivery of the first sensor signal and the second sensor signal and a condition in which there is simultaneous delivery of the first sensor signal from the first output and the second sensor signal from the second output. Each of multiple inputs is configured to be individually assigned to any of the multiple outputs or combined in any subsets of the inputs to the outputs. Unassigned outputs are configured to be switched off, for example by producing a high-impedance state.

[0018] In embodiments, the first sensor signal and the second sensor signal are continuous vibration data about the industrial environment. In embodiments, the second sensor in the local data collection system is configured to be connected to the first machine. In embodiments, the second sensor in the local data collection system is configured to be connected to a second machine in the industrial environment. In embodiments, the computing environment of the platform is configured to compare relative phases of the first and second sensor signals. In embodiments, the first sensor is a single-axis sensor and the second sensor is a three-axis sensor. In embodiments, at least one of the multiple inputs of the crosspoint switch includes internet protocol, front-end signal conditioning, for improved signal-to-noise ratio. In embodiments, the crosspoint switch includes a third input that is configured with a continuously monitored alarm having a pre-determined trigger condition when the third input is unassigned to or undetected at any of the multiple outputs.

[0019] In embodiments, the local data collection system includes multiple multiplexing units and multiple data acquisition units receiving multiple data streams from multiple machines in the industrial environment. In embodiments, the local data collection system includes distributed complex programmable hardware device ("CPLD") chips each dedicated to a data bus for logic control of the multiple multiplexing units and the multiple data acquisition units that receive the multiple data streams from the multiple machines in the industrial environment. In embodiments, the local data collection system is configured to provide high-amperage input capability using solid state relays. In embodiments, the local data collection system is configured to power-down at least one of an analog sensor channel and a component board.

[0020] In embodiments, the local data collection system includes a phase-lock loop band-pass tracking filter configured to obtain slow-speed revolutions per minute ("RPMs") and phase information. In embodiments, the local data collection system is configured to digitally derive phase using on-board timers relative to at least one trigger channel and at least one of the multiple

inputs. In embodiments, the local data collection system includes a peak-detector configured to autoscale using a separate analog-to-digital converter for peak detection. In embodiments, the local data collection system is configured to route at least one trigger channel that is raw and buffered into at least one of the multiple inputs. In embodiments, the local data collection system includes at least one delta-sigma analog-to-digital converter that is configured to increase input oversampling rates to reduce sampling rate outputs and to minimize anti-aliasing filter requirements. In embodiments, the distributed CPLD chips each dedicated to the data bus for logic control of the multiple multiplexing units and the multiple data acquisition units includes as high-frequency crystal clock reference configured to be divided by at least one of the distributed CPLD chips for at least one delta-sigma analog-to-digital converter to achieve lower sampling rates without digital resampling.

[0021] In embodiments, the local data collection system is configured to obtain long blocks of data at a single relatively high-sampling rate as opposed to multiple sets of data taken at different sampling rates. In embodiments, the single relatively high-sampling rate corresponds to a maximum frequency of about forty kilohertz. In embodiments, the long blocks of data are for a duration that is in excess of one minute. In embodiments, the local data collection system includes multiple data acquisition units each having an onboard card set configured to store calibration information and maintenance history of a data acquisition unit in which the onboard card set is located. In embodiments, the local data collection system is configured to plan data acquisition routes based on hierarchical templates.

[0022] In embodiments, the local data collection system is configured to manage data collection bands. In embodiments, the data collection bands define a specific frequency band and at least one of a group of spectral peaks, a true-peak level, a crest factor derived from a time waveform, and an overall waveform derived from a vibration envelope. In embodiments, the local data collection system includes a neural net expert system using intelligent management of the data collection bands. In embodiments, the local data collection system is configured to create data acquisition routes based on hierarchical templates that each include the data collection bands related to machines associated with the data acquisition routes. In embodiments, at least one of the hierarchical templates is associated with multiple interconnected elements of the first machine. In embodiments, at least one of the hierarchical templates is associated with similar elements associated with at least the first machine and a second machine. In embodiments, at least one of the hierarchical templates is associated with at least the first machine being proximate in location to a second machine.

[0023] In embodiments, the local data collection system includes a graphical user interface ("GUI") system configured to manage the data collection bands. In embodiments, the GUI system

includes an expert system diagnostic tool. In embodiments, the platform includes cloud-based, machine pattern analysis of state information from multiple sensors to provide anticipated state information for the industrial environment. In embodiments, the platform is configured to provide self-organization of data pools based on at least one of the utilization metrics and yield metrics. In embodiments, the platform includes a self-organized swarm of industrial data collectors. In embodiments, the local data collection system includes a wearable haptic user interface for an industrial sensor data collector with at least one of vibration, heat, electrical, and sound outputs.

[0024] In embodiments, multiple inputs of the crosspoint switch include a third input connected to the second sensor and a fourth input connected to the second sensor. The first sensor signal is from a single-axis sensor at an unchanging location associated with the first machine. In embodiments, the second sensor is a three-axis sensor. In embodiments, the local data collection system is configured to record gap-free digital waveform data simultaneously from at least the first input, the second input, the third input, and the fourth input. In embodiments, the platform is configured to determine a change in relative phase based on the simultaneously recorded gap-free digital waveform data. In embodiments, the second sensor is configured to be movable to a plurality of positions associated with the first machine while obtaining the simultaneously recorded gap-free digital waveform data. In embodiments, multiple outputs of the crosspoint switch include a third output and fourth output. The second, third, and fourth outputs are assigned together to a sequence of tri-axial sensors each located at different positions associated with the machine. In embodiments, the platform is configured to determine an operating deflection shape based on the change in relative phase and the simultaneously recorded gap-free digital waveform data.

[0025] In embodiments, the unchanging location is a position associated with the rotating shaft of the first machine. In embodiments, tri-axial sensors in the sequence of the tri-axial sensors are each located at different positions on the first machine but are each associated with different bearings in the machine. In embodiments, tri-axial sensors in the sequence of the tri-axial sensors are each located at similar positions associated with similar bearings but are each associated with different machines. In embodiments, the local data collection system is configured to obtain the simultaneously recorded gap-free digital waveform data from the first machine while the first machine and a second machine are both in operation. In embodiments, the local data collection system is configured to characterize a contribution from the first machine and the second machine in the simultaneously recorded gap-free digital waveform data from the first machine. In embodiments, the simultaneously recorded gap-free digital waveform data has a duration that is in excess of one minute.

[0026] In embodiments, a method of monitoring a machine having at least one shaft supported by a set of bearings includes monitoring a first data channel assigned to a single-axis sensor at an

unchanging location associated with the machine. The method includes monitoring second, third, and fourth data channels each assigned to an axis of a three-axis sensor. The method includes recording gap-free digital waveform data simultaneously from all of the data channels while the machine is in operation and determining a change in relative phase based on the digital waveform data.

[0027] In embodiments, the tri-axial sensor is located at a plurality of positions associated with the machine while obtaining the digital waveform. In embodiments, the second, third, and fourth channels are assigned together to a sequence of tri-axial sensors each located at different positions associated with the machine. In embodiments, the data is received from all of the sensors simultaneously. In embodiments, the method includes determining an operating deflection shape based on the change in relative phase information and the waveform data. In embodiments, the unchanging location is a position associated with the shaft of the machine. In embodiments, the tri-axial sensors in the sequence of the tri-axial sensors are each located at different positions and are each associated with different bearings in the machine. In embodiments, the unchanging location is a position associated with the shaft of the machine. The tri-axial sensors in the sequence of the tri-axial sensors are each located at different positions and are each associated with different bearings that support the shaft in the machine.

[0028] In embodiments, the method includes monitoring the first data channel assigned to the single-axis sensor at an unchanging location located on a second machine. The method includes monitoring the second, the third, and the fourth data channels, each assigned to the axis of a three-axis sensor that is located at the position associated with the second machine. The method also includes recording gap-free digital waveform data simultaneously from all of the data channels from the second machine while both of the machines are in operation. In embodiments, the method includes characterizing the contribution from each of the machines in the gap-free digital waveform data simultaneously from the second machine.

[0029] In embodiments, a method for data collection, processing, and utilization of signals with a platform monitoring at least a first element in a first machine in an industrial environment includes obtaining, automatically with a computing environment, at least a first sensor signal and a second sensor signal with a local data collection system that monitors at least the first machine. The method includes connecting a first input of a crosspoint switch of the local data collection system to a first sensor and a second input of the crosspoint switch to a second sensor in the local data collection system. The method includes switching between a condition in which a first output of the crosspoint switch alternates between delivery of at least the first sensor signal and the second sensor signal and a condition in which there is simultaneous delivery of the first sensor signal from the first output and the second sensor signal from a second output of the crosspoint switch. The

method also includes switching off unassigned outputs of the crosspoint switch into a high-impedance state.

[0030] In embodiments, the first sensor signal and the second sensor signal are continuous vibration data from the industrial environment. In embodiments, the second sensor in the local data collection system is connected to the first machine. In embodiments, the second sensor in the local data collection system is connected to a second machine in the industrial environment. In embodiments, the method includes comparing, automatically with the computing environment, relative phases of the first and second sensor signals. In embodiments, the first sensor is a single-axis sensor and the second sensor is a three-axis sensor. In embodiments, at least the first input of the crosspoint switch includes internet protocol front-end signal conditioning for improved signal-to-noise ratio.

[0031] In embodiments, the method includes continuously monitoring at least a third input of the crosspoint switch with an alarm having a pre-determined trigger condition when the third input is unassigned to any of multiple outputs on the crosspoint switch. In embodiments, the local data collection system includes multiple multiplexing units and multiple data acquisition units receiving multiple data streams from multiple machines in the industrial environment. In embodiments, the local data collection system includes distributed CPLD chips each dedicated to a data bus for logic control of the multiple multiplexing units and the multiple data acquisition units that receive the multiple data streams from the multiple machines in the industrial environment. In embodiments, the local data collection system provides high-amperage input capability using solid state relays.

[0032] In embodiments, the method includes powering down at least one of an analog sensor channel and a component board of the local data collection system. In embodiments, the local data collection system includes an external voltage reference for an A/D zero reference that is independent of the voltage of the first sensor and the second sensor. In embodiments, the local data collection system includes a phase-lock loop band-pass tracking filter that obtains slow-speed RPMs and phase information. In embodiments, the method includes digitally deriving phase using on-board timers relative to at least one trigger channel and at least one of multiple inputs on the crosspoint switch.

[0033] In embodiments, the method includes auto-scaling with a peak-detector using a separate analog-to-digital converter for peak detection. In embodiments, the method includes routing at least one trigger channel that is raw and buffered into at least one of multiple inputs on the crosspoint switch. In embodiments, the method includes increasing input oversampling rates with at least one delta-sigma analog-to-digital converter to reduce sampling rate outputs and to minimize anti-aliasing filter requirements. In embodiments, the distributed CPLD chips are each

dedicated to the data bus for logic control of the multiple multiplexing units and the multiple data acquisition units and each include a high-frequency crystal clock reference divided by at least one of the distributed CPLD chips for at least one delta-sigma analog-to-digital converter to achieve lower sampling rates without digital resampling. In embodiments, the method includes obtaining long blocks of data at a single relatively high-sampling rate with the local data collection system as opposed to multiple sets of data taken at different sampling rates. In embodiments, the single relatively high-sampling rate corresponds to a maximum frequency of about forty kilohertz. In embodiments, the long blocks of data are for a duration that is in excess of one minute. In embodiments, the local data collection system includes multiple data acquisition units and each data acquisition unit has an onboard card set that stores calibration information and maintenance history of a data acquisition unit in which the onboard card set is located.

[0034] In embodiments, the method includes planning data acquisition routes based on hierarchical templates associated with at least the first element in the first machine in the industrial environment. In embodiments, the local data collection system manages data collection bands that define a specific frequency band and at least one of a group of spectral peaks, a true-peak level, a crest factor derived from a time waveform, and an overall waveform derived from a vibration envelope. In embodiments, the local data collection system includes a neural net expert system using intelligent management of the data collection bands. In embodiments, the local data collection system creates data acquisition routes based on hierarchical templates that each include the data collection bands related to machines associated with the data acquisition routes. In embodiments, at least one of the hierarchical templates is associated with multiple interconnected elements of the first machine. In embodiments, at least one of the hierarchical templates is associated with similar elements associated with at least the first machine and a second machine. In embodiments, at least one of the hierarchical templates is associated with at least the first machine being proximate in location to a second machine.

[0035] In embodiments, the method includes controlling a GUI system of the local data collection system to manage the data collection bands. The GUI system includes an expert system diagnostic tool. In embodiments, the computing environment of the platform includes cloud-based, machine pattern analysis of state information from multiple sensors to provide anticipated state information for the industrial environment. In embodiments, the computing environment of the platform provides self-organization of data pools based on at least one of the utilization metrics and yield metrics. In embodiments, the computing environment of the platform includes a self-organized swarm of industrial data collectors. In embodiments, each of multiple inputs of the crosspoint switch is individually assignable to any of multiple outputs of the crosspoint switch.

[0036] Methods and systems described herein for industrial machine sensor data streaming, collection, processing, and storage may be configured to operate and integrate with existing data collection, processing and storage systems and may include a method for capturing a plurality of streams of sensed data from sensors deployed to monitor aspects of an industrial machine associated with at least one moving part of the machine; at least one of the streams contains a plurality of frequencies of data. The method may include identifying a subset of data in at least one of the plurality of streams that corresponds to data representing at least one predefined frequency. The at least one predefined frequency is represented by a set of data collected from alternate sensors deployed to monitor aspects of the industrial machine associated with the at least one moving part of the machine. The method may further include processing the identified data with a data processing facility that processes the identified data with an algorithm configured to be applied to the set of data collected from alternate sensors. Lastly, the method may include storing the at least one of the streams of data, the identified subset of data, and a result of processing the identified data in an electronic data set.

[0037] Methods and systems described herein for industrial machine sensor data streaming, collection, processing, and storage may be configured to operate and integrate with existing data collection, processing, and storage systems and may include a method for applying data captured from sensors deployed to monitor aspects of an industrial machine associated with at least one moving part of the machine. The data is captured with predefined lines of resolution covering a predefined frequency range and is sent to a frequency matching facility that identifies a subset of data streamed from other sensors deployed to monitor aspects of the industrial machine associated with at least one moving part of the machine. The streamed data includes a plurality of lines of resolution and frequency ranges. The subset of data identified corresponds to the lines of resolution and predefined frequency range. This method may include storing the subset of data in an electronic data record in a format that corresponds to a format of the data captured with predefined lines of resolution and signaling to a data processing facility the presence of the stored subset of data. This method may, optionally, include processing the subset of data with at least one set of algorithms, models and pattern recognizers that corresponds to algorithms, models and pattern recognizers associated with processing the data captured with predefined lines of resolution covering a predefined frequency range.

[0038] Methods and systems described herein for industrial machine sensor data streaming, collection, processing, and storage may be configured to operate and integrate with existing data collection, processing and storage systems and may include a method for identifying a subset of streamed sensor data, the sensor data captured from sensors deployed to monitor aspects of an industrial machine associated with at least one moving part of the machine, the subset of streamed

sensor data at predefined lines of resolution for a predefined frequency range, and establishing a first logical route for communicating electronically between a first computing facility performing the identifying and a second computing facility. In embodiments, identified subset of the streamed sensor data is communicated exclusively over the established first logical route when communicating the subset of streamed sensor data from the first facility to the second facility. This method may further include establishing a second logical route for communicating electronically between the first computing facility and the second computing facility for at least one portion of the streamed sensor data that is not the identified subset. Additionally, this method may further include establishing a third logical route for communicating electronically between the first computing facility and the second computing facility for at least one portion of the streamed sensor data that includes the identified subset and at least one other portion of the data not represented by the identified subset.

[0039] Methods and systems described herein for industrial machine sensor data streaming, collection, processing, and storage may be configured to operate and integrate with existing data collection, processing and storage systems and may include a first data sensing and processing system that captures first data from a first set of sensors deployed to monitor aspects of an industrial machine associated with at least one moving part of the machine, the first data covering a set of lines of resolution and a frequency range. This system may include a second data sensing and processing system that captures and streams a second set of data from a second set of sensors deployed to monitor aspects of the industrial machine associated with at least one moving part of the machine, the second data covering a plurality of lines of resolution that includes the set of lines of resolution and a plurality of frequencies that includes the frequency range. The system may enable selecting a portion of the second data that corresponds to the set of lines of resolution and the frequency range of the first data and processing the selected portion of the second data with the first data sensing and processing system.

[0040] Methods and systems described herein for industrial machine sensor data streaming, collection, processing, and storage may be configured to operate and integrate with existing data collection, processing and storage systems and may include a method for automatically processing a portion of a stream of sensed data. The sensed data is received from a first set of sensors deployed to monitor aspects of an industrial machine associated with at least one moving part of the machine. The sensed data is in response to an electronic data structure that facilitates extracting a subset of the stream of sensed data that corresponds to a set of sensed data received from a second set of sensors deployed to monitor the aspects of the industrial machine associated with the at least one moving part of the machine. The set of sensed data is constrained to a frequency range. The stream of sensed data includes a range of frequencies that exceeds the frequency range of the set of sensed

data, the processing comprising executing an algorithm on a portion of the stream of sensed data that is constrained to the frequency range of the set of sensed data, the algorithm configured to process the set of sensed data.

[0041] Methods and systems described herein for industrial machine sensor data streaming, collection, processing, and storage may be configured to operate and integrate with existing data collection, processing and storage systems and may include a method for receiving first data from sensors deployed to monitor aspects of an industrial machine associated with at least one moving part of the machine. This method may further include detecting at least one of a frequency range and lines of resolution represented by the first data; receiving a stream of data from sensors deployed to monitor the aspects of the industrial machine associated with the at least one moving part of the machine. The stream of data includes: (1) a plurality of frequency ranges and a plurality of lines of resolution that exceeds the frequency range and the lines of resolution represented by the first data; (2) a set of data extracted from the stream of data that corresponds to at least one of the frequency range and the lines of resolution represented by the first data; and (3) the extracted set of data which is processed with a data processing algorithm that is configured to process data within the frequency range and within the lines of resolution of the first data.

[0042] Methods and systems are provided herein for using mobile devices, including wearable devices, mobile robots, mobile vehicles, and/or handheld devices, to identify states of targets within an industrial environment. The mobile devices include one or more sensors that may be configured to record state-related measurements of the target, for example, based on vibrational, temperature, electrical, magnetic, sound, and/or other measurements. The data captured using some or all of these mobile devices may be processed by intelligent systems onboard those mobile devices and/or at a server in communication with those mobile devices over a network. The intelligent systems include intelligence for processing the data captured using the respective mobile devices. Processing the data can, for example, include identifying a state of a target for which measurements were recorded by comparing the state-related measurements from the wearable device against information stored in a database, which may, for example, be part of a knowledge base associated with the industrial environment. In embodiments, corrective actions may be identified and taken in response to the state-related measurements captured using the mobile devices.

[0043] In embodiments, a method for using a wearable device to identify a state of a target of an industrial environment is disclosed. In embodiments, the method comprises recording a state-related measurement of the target using one or more sensors of the wearable device; transmitting the state-related measurement to a server over a network; using intelligent systems associated with the server to process the state-related measurement against pre-recorded data for the target. In

embodiments, processing the state-related measurement against the pre-recorded data for the target includes identifying the pre-recorded data for the target within a knowledge base associated with the industrial environment; and identifying, as the state of the target, a state indicated by the pre-recorded data for the target within the knowledge base.

[0044] In embodiments, a system for identifying a state of a target of an industrial environment is disclosed. In embodiments, the system comprises a first wearable device including one or more sensors configured to record a first type of state-related measurement; a second wearable device including one or more sensors configured to record a second type of state-related measurement; and a server that receives the first type of state-related measurement from the first wearable device and the second type of state-related measurement from the second wearable device, the server including intelligent systems configured to: process the first type of state-related measurement and the second type of state-related measurement against pre-recorded data stored within a knowledge base to identify the state of the target; and update the pre-recorded data according to at least one of the first type of state-related measurement or the second type of state-related measurement.

[0045] In embodiments, a method for using a mobile data collector to identify a state of a target of an industrial environment is disclosed. In embodiments, the method comprises controlling the mobile data collector to approach a location of the target within the industrial environment; recording a state-related measurement of the target using one or more sensors of the mobile data collector; transmitting the state-related measurement to a server over a network; using intelligent systems associated with the server to process the state-related measurement against pre-recorded data for the target. In embodiments, processing the state-related measurement against the pre-recorded data for the target includes identifying the pre-recorded data for the target within a knowledge base associated with the industrial environment; and identifying, as the state of the target, a state indicated by the pre-recorded data for the target within the knowledge base.

[0046] In embodiments, a system for identifying a state of a target of an industrial environment is disclosed. In embodiments, the system comprises a first mobile data collector including one or more sensors configured to record a first type of state-related measurement; a second mobile data collector including one or more sensors configured to record a second type of state-related measurement; and a server that receives the first type of state-related measurement from the first mobile data collector and the second type of state-related measurement from the second mobile data collector, the server including intelligent systems configured to: process the first type of state-related measurement and the second type of state-related measurement against pre-recorded data stored within a knowledge base to identify the state of the target; and update the pre-recorded data according to at least one of the first type of state-related measurement or the second type of state-related measurement.

[0047] In embodiments, a method for using a handheld device to identify a state of a target of an industrial environment is disclosed. In embodiments, the method comprises recording a state-related measurement of the target using one or more sensors of the handheld device; transmitting the state-related measurement to a server over a network; using intelligent systems associated with the server to process the state-related measurement against pre-recorded data for the target. In embodiments, processing the state-related measurement against the pre-recorded data for the target includes identifying the pre-recorded data for the target within a knowledge base associated with the industrial environment; and identifying, as the state of the target, a state indicated by the pre-recorded data for the target within the knowledge base.

[0048] In embodiments, a system for identifying a state of a target of an industrial environment is disclosed. In embodiments, the system comprises a first handheld device including one or more sensors configured to record a first type of state-related measurement; a second handheld device including one or more sensors configured to record a second type of state-related measurement; and a server that receives the first type of state-related measurement from the first handheld device and the second type of state-related measurement from the second handheld device, the server including intelligent systems configured to: process the first type of state-related measurement and the second type of state-related measurement against pre-recorded data stored within a knowledge base to identify the state of the target; and update the pre-recorded data according to at least one of the first type of state-related measurement or the second type of state-related measurement.

[0049] Methods and systems are provided herein for a computer vision system configured to identify operating characteristics, such as vibration or other suitable characteristics, of one or more industrial IoT devices using input from one or more data capture devices. The one or more data capture devices may include image data capture devices that capture visible and non-visible light, sensors that measure various characteristics of the one or more industrial IoT devices, or other suitable data capture devices. The computer vision system is configured to generate image data sets from the input and to analyze the visual aspects of the image data sets in order to identify operating characteristics of the industrial IoT devices. Further, the computer vision system is configured to determine whether to take corrective action in response to the operating characteristics of the industrial IoT devices.

[0050] In embodiments, an apparatus for detecting operating characteristics of a manufacturing device includes a memory and a processor. The memory includes instructions executable by the processor to generate one or more image data sets using raw data captured by one or more data capture devices. The memory further includes instructions executable by the processor to identify one or more values corresponding to a portion of the manufacturing device within a point of interest represented by the one or more image data sets. The memory further includes instructions

executable by the processor to record the one or more values; compare the recorded one or more values to corresponding predicted values and to generate a variance data set based on the comparison of the recorded one or more values and the corresponding predicted values. The memory further includes instructions executable by the processor to identify an operating characteristic of the manufacturing device based on the variance data and to generate an indication indicating the operating characteristic.

[0051] In embodiments, a method for detecting operating characteristics of a manufacturing device includes generating one or more image data sets using raw data captured by one or more data capture devices. The method also includes identifying one or more values corresponding to a portion of the manufacturing device within a point of interest represented by the one or more image data sets; recording the one or more values and comparing the recorded one or more values to corresponding predicted values. The method also includes generating a variance data set based on the comparison of the recorded on or more values and the corresponding predicted values and identifying an operating characteristic of the manufacturing device based on the variance data. The method also includes generating an indication indicating the operating characteristic.

[0052] In embodiments, a system for detecting operating characteristics of a manufacturing device includes at least one data capture device configured to capture raw data of a point of interest of the manufacturing device, a memory, and a processor. The memory includes instructions executable by the processor to generate one or more image data sets using the raw data captured and to identify one or more values corresponding to a portion of the manufacturing device within the point of interest represented by the one or more image data sets. The memory further includes instructions executable by the processor to record the one or more values and to compare the recorded one or more values to corresponding predicted values. The memory further includes instructions executable by the processor to generate a variance data set based on the comparison of the recorded on or more values and the corresponding predicted values, to identify an operating characteristic of the manufacturing device based on the variance data, and to generate an indication indicating the operating characteristic.

[0053] In embodiments, a computer vision system for detecting operating characteristics of a manufacturing device, includes at least one data capture device configured to capture raw data of a point of interest of the manufacturing device, a memory, and a processor. The memory includes instructions executable by the processor to generate one or more image data sets using the raw data captured and to visually identify one or more values corresponding to a portion of the manufacturing device within the point of interest represented by the one or more image data sets. The memory further includes instructions executable by the processor to record the one or more values and to visually compare the recorded one or more values to corresponding predicted values.

The memory further includes instructions executable by the processor to generate a variance data set based on the comparison of the recorded on or more values and the corresponding predicted values and to identify an operating characteristic of the manufacturing device based on the variance data. The memory further includes instructions executable by the processor to compare the operating characteristic to a threshold and to determine whether the operating characteristic is within a tolerance based on whether the operating characteristic is greater than the threshold. The memory further includes instructions executable by the processor to generate an indication indicating the operating characteristic.

[0054] In embodiments, a computer vision system for detecting operating characteristics of a device, includes at least one data capture device configured to capture raw data of a point of interest of the device, a memory and a processor. The memory includes instructions executable by the processor to generate one or more image data sets using the raw data captured and visually identify one or more values corresponding to a portion of the device within the point of interest represented by the one or more image data sets. The memory further includes instructions executable by the processor to record the one or more values and to visually compare the recorded one or more values to corresponding predicted values. The memory further includes instructions executable by the processor to generate a variance data set based on the comparison of the recorded on or more values and the corresponding predicted values. The memory includes instructions executable by the processor to identify an operating characteristic of the device based on the variance data and to compare the operating characteristic to a threshold. The memory includes instructions executable by the processor to determine whether the operating characteristic is within a tolerance based on whether the operating characteristic is greater than the threshold and to generate an indication indicating the operating characteristic.

[0055] Methods and systems are provided herein as including combinations of embodiments disclosed herein. In embodiments, a method comprises: receiving vibration data representative of a vibration of at least a portion of an industrial machine from a wearable device including at least one vibration sensor used to capture the vibration data; determining a frequency of the captured vibration by processing the captured vibration data; determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the captured vibration; calculating a severity unit for the captured vibration based on the determined segment; and generating a signal in a predictive maintenance circuit for executing a maintenance action on at least the portion of the industrial machine based on the severity unit. In embodiments, the at least one vibration sensor of the wearable device captures the vibration data based on a waveform derived from a vibration envelope associated with at least the portion of the industrial machine. In embodiments, the method further comprises: detecting, using the wearable device, that the

industrial machine is in near proximity to the wearable device; and causing the wearable device to capture the vibration data responsive to detecting the near proximity of the industrial machine to the wearable device. In embodiments, the method further comprises: detecting a vibration level change of at least the portion of the industrial machine using the at least one vibration sensor of the wearable device; and using the wearable device to capture the vibration data responsive to detecting the vibration level change. In embodiments, the method further comprises transmitting the signal to the wearable device to cause the execution of the maintenance action. In embodiments, calculating the severity unit for the captured vibration based on the determined segment comprises: mapping the captured vibration to the severity unit based on the determined segment by: mapping the captured vibration to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the captured vibration to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the captured vibration to a third severity unit when the frequency of the captured vibration corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises training an intelligent system to determine whether a vibration maps to the first severity unit, the second severity unit, or the third severity unit. In embodiments, the severity unit represents an impact on at least the portion of the industrial machine of the maintenance action based on the captured vibration data. In embodiments, the method further comprises determining an amplitude and a gravitational force of the captured vibration data by the processing of the captured vibration data. In embodiments, calculating the severity unit for the captured vibration comprises calculating the severity unit based on the determined segment and at least one of the amplitude or the gravitational force. In embodiments, the severity unit represents the captured vibration independent of the frequency. In embodiments, at least one of the signals or the maintenance action indicates, based on the severity unit, increasing or decreasing a frequency for collection and analysis of further vibration data using the at least one vibration sensor. In embodiments, the maintenance action indicates to perform one of calibration, diagnostic testing, or visual inspection against at least the portion of the industrial machine. In embodiments, the method further comprises transmitting the signal to a component of the industrial machine. In embodiments, the maintenance action indicates to resurvey at least the portion of the industrial machine. In embodiments, the component of the industrial machine causes the execution of the maintenance action responsive to receiving the signal. In embodiments, the wearable device is a first wearable device of a plurality of wearable devices integrated within an industrial platform. In embodiments, a second wearable device of the plurality of wearable devices captures a temperature of the industrial machine using a temperature

sensor. In embodiments, the signal is generated based on the severity unit and based on a second severity unit calculated based on the captured temperature. In embodiments, a third wearable device of the plurality of wearable devices captures an electrical output or electrical use of the industrial machine using an electricity sensor. In embodiments, the signal is generated based on the severity unit and based on a third severity unit calculated based on the captured electrical output or electrical use. In embodiments, a fourth wearable device of the plurality of wearable devices captures a level or change in an electromagnetic field of the industrial machine using a magnetic sensor. In embodiments, the signal is generated based on the severity unit and based on a fourth severity unit calculated based on the captured level or change in the electromagnetic field. In embodiments, a fifth wearable device of the plurality of wearable devices captures a sound wave output from the industrial machine using a sound sensor. In embodiments, the signal is generated based on the severity unit and based on a fifth severity unit calculated based on the captured sound wave. In embodiments, the wearable device is a first wearable device integrated within an article of clothing. In embodiments, the method further comprises using a second wearable device integrated within an accessory article.

[0056] In embodiments, a method comprises: deploying a mobile data collector for detecting and monitoring vibration activity of at least a portion of an industrial machine, the mobile data collector including one or more vibration sensors; determining a severity of the vibration activity relative to timing by processing vibration data representative of the vibration activity and generated using the one or more vibration sensors; and predicting one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity. In embodiments, determining the severity of the vibration data relative to the timing by processing the vibration data representative of the vibration activity and generated using the one or more vibration sensors comprises: determining a frequency of the vibration activity by processing the vibration data; determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the vibration activity; and calculating a severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra. In embodiments, calculating the severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra comprises: mapping the vibration activity to the severity unit based on the determined segment of the multi-segment vibration frequency spectra by: mapping the vibration activity to a first severity unit when the frequency of the vibration activity corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the vibration activity to a second severity unit when the frequency of the vibration activity corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the vibration activity to a third severity unit when the

frequency of the vibration activity corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises causing the at least one of the mobile data collectors to perform the maintenance action. In embodiments, the method further comprises: controlling the mobile data collector to approach a location of the industrial machine within an industrial environment that includes the industrial machine; causing the one or more vibration sensors of the mobile data collector to record one or more measurements of the vibration activity; and transmitting the one or more measurements of the vibration activity as the vibration data to a server over a network. In embodiments, the vibration data is processed at the server to determine the severity of the vibration activity. In embodiments, predicting the one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity comprises: using intelligent systems associated with the server to process the vibration data against pre-recorded data for the industrial machine. In embodiments, processing the vibration data against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with the industrial environment; and identifying an operating characteristic of at least the portion of the machine based on the pre-recorded data for the industrial machine within the knowledge base; and predicting the one or more maintenance actions based on the operating characteristic. In embodiments, the vibration activity is indicative of a waveform derived from a vibration envelope associated with the industrial machine. In embodiments, the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine. In embodiments, the vibration activity represents velocity information for at least the portion of the industrial machine. In embodiments, the vibration activity represents frequency information for at least the portion of the industrial machine. In embodiments, the mobile data collector is a mobile robot. In embodiments, the mobile data collector is a mobile vehicle. In embodiments, the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm. In embodiments, the method further comprises using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within an industrial environment that includes the industrial machine. In embodiments, the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine. In embodiments, using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises controlling the movements of the mobile data collector within the industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors. In embodiments, the mobile data collector is a mobile robot

and at least one other mobile data collector of the plurality of mobile data collectors is a mobile vehicle.

[0057] In embodiments, an industrial machine predictive maintenance system comprises: a mobile data collector swarm comprising one or more mobile data collectors configured to collect health monitoring data representative of conditions of one or more industrial machines located in an industrial environment; an industrial machine predictive maintenance facility that produces industrial machine service recommendations responsive to the health monitoring data by applying machine fault detection and classification algorithms thereto; and a computerized maintenance management system (CMMS) that produces at least one of the orders and requests for service and parts responsive to receiving the industrial machine service recommendations. In embodiments, the industrial machine predictive maintenance system further comprises a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger. In embodiments, the industrial machine predictive maintenance system further comprises a self-organization system that controls movements of the one or more mobile data collectors within the industrial environment. In embodiments, the self-organization system transmits requests for the health monitoring data to the one or more mobile data collectors. In embodiments, the mobile data collectors transmit the health monitoring data to the self-organization system responsive to the requests. In embodiments, the self-organization transmits the health monitoring data to the industrial machine predictive maintenance facility. In embodiments, the industrial machine predictive maintenance system further comprises a data collection router that receives the health monitoring data from the one or more mobile data collectors when the mobile data collectors are in near proximity to the data collection router. In embodiments, the data collection router transmits the health monitoring data to the industrial machine predictive maintenance facility. In embodiments, the one or more mobile data collectors push the health monitoring data to the data collection router. In embodiments, the data collection router pulls the health monitoring data from the one or more mobile data collectors. In embodiments, the industrial machine predictive maintenance system further comprises a self-organization system that controls movements of the

one or more mobile data collectors within the industrial environment. In embodiments, the self-organization system controls communications of the health monitoring data from the one or more mobile data collectors to the data collection router. In embodiments, each mobile data collector of the one or more mobile data collectors is one of a mobile robot including one or more integrated sensors, a mobile robot including one or more coupled sensors, a mobile vehicle with one or more integrated sensors, or a mobile vehicle with one or more coupled sensors. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendations based on severity units calculated for the health monitoring data.

[0058] In embodiments, a system comprises: a plurality of wearable devices integrated within an industrial uniform, each wearable device of the industrial uniform comprising one or more sensors that collect measurements from industrial machines located in an industrial environment, the measurements representative of conditions of the industrial machines; an industrial machine predictive maintenance facility that produces industrial machine service recommendations based on the measurements by applying machine fault detection and classification algorithms thereto; and a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations. In embodiments, the system further comprises a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger. In embodiments, the one or more sensors of a first wearable device of the industrial uniform includes a sensor configured to collect vibration measurements from at least one of the industrial machines. In embodiments, the one or more sensors of a second wearable device of the industrial uniform includes a sensor configured to collect temperature measurements from at least one of the industrial machines. In embodiments, the one or more sensors of a first wearable device of the industrial uniform includes a sensor configured to collect electrical measurements from at least one of the industrial machines. In embodiments, the one or more sensors of a first wearable device of the industrial uniform includes a sensor configured to collect magnetic measurements from at least one of the industrial machines. In embodiments, the one or more sensors of a first wearable

device of the industrial uniform includes a sensor configured to collect sound measurements from at least one of the industrial machines. In embodiments, a first wearable device of the industrial uniform is an article of clothing and a second wearable device of the industrial uniform is an accessory article. In embodiments, the system further comprises a collective processing mind that controls the collection of measurements of the one or more industrial machines by the plurality of wearable devices. In embodiments, the collective processing mind transmits a first command to a wearable device of the industrial uniform to cause the one or more sensors of the wearable device to collect the measurements of the one or more industrial machines. In embodiments, the collective processing mind transmits a second command to the wearable device to cause the wearable device to transmit the measurements to the collective processing mind. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendations based on severity units calculated for the measurements.

[0059] In embodiments, a system comprises: a plurality of wearable devices integrated within an industrial uniform, each wearable device of the industrial uniform comprising one or more sensors that collect measurements from industrial machines located in an industrial environment, the measurements representative of conditions of the industrial machines; an industrial machine predictive maintenance facility that produces industrial machine service recommendations based on the measurements by applying machine fault detection and classification algorithms thereto; a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations; and a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendations based on severity units calculated for the measurements. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure.

[0060] In embodiments, a system comprises: a mobile data collector swarm comprising one or more mobile data collectors configured to collect health monitoring data representative of conditions of one or more industrial machines located in an industrial environment; an industrial machine predictive maintenance facility that produces industrial machine service recommendations responsive to the health monitoring data by applying machine fault detection and classification algorithms thereto; a computerized maintenance management system (CMMS)

that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations; and a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendations based on severity units calculated for the health monitoring data. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure.

[0061] In embodiments, a method comprises: generating, using one or more vibration sensors of a handheld device, vibration data representing measured vibrations of at least a portion of an industrial machine; mapping the vibration data to one or more severity units; and using the severity units for predictive maintenance of the industrial machine by determining a maintenance action to perform on at least the portion of an industrial machine based on the severity units. In embodiments, mapping the vibration data to one or more severity units comprises: mapping portions of the vibration data that have frequencies corresponding to a below the low-end knee threshold-range of a vibration frequency spectra to first severity units; mapping portions of the vibration data that have frequencies corresponding to a mid-range of the vibration frequency spectra to second severity units; and mapping portions of the vibration data that have frequencies corresponding to an above the high-end knee threshold-range of the vibration frequency spectra to third severity units. In embodiments, the mapping of the vibration data to the one or more severity units is performed at the handheld device. In embodiments, the mapping of the vibration data to the one or more severity units is performed at a server. In embodiments, the method further comprises transmitting the vibration data from the handheld device to the server. In embodiments, the method further comprises: detecting, using a collective processing mind associated with the handheld device, that the handheld device is in near proximity to the industrial machine; transmitting, from the collective processing mind, a first command to the handheld device to cause the handheld device to generate the vibration data; and, after the generating of the vibration data, transmitting, from the collective processing mind, a second command to the handheld device to cause the handheld device to transmit the vibration data to the collective processing mind.

[0062] In embodiments, a system comprises: an industrial machine comprising at least one vibration sensor disposed to capture vibration of a portion of the industrial machine; a mobile data collector that generates vibration data by collecting the captured vibration from the at least one vibration sensor; a multi-segment vibration frequency spectra structure that facilitates mapping the

captured vibration to one vibration frequency segment of the multiple segments of vibration frequency; a severity unit algorithm that receives the determined frequency of the vibration and the corresponding mapped segment and produces a severity value which is then mapped to one of a plurality of severity units defined for the corresponding mapped segment; and a signal generating circuit that receives the one of the plurality of severity units, and based thereon, signals a predictive maintenance server to execute a corresponding maintenance action on the portion of the industrial machine.

[0063] In embodiments, a method comprises: using a distributed ledger to track one or more transactions executed in an automated data marketplace for industrial Internet of Things data. In embodiments, the distributed ledger distributes storage for data indicative of the one or more transactions across one or more devices. In embodiments, the data indicative of the one or more transactions corresponds to transaction records; and using one or more mobile data collectors to generate sensor data representative of a condition of an industrial machine. In embodiments, the sensor data is used to determine at least one of orders or requests for service and parts used to resolve an issue associated with the condition of the machine. In embodiments, a transaction record stored in the distributed ledger represents one or more of the sensor data, the condition of the industrial machine, the at least one of the orders or the requests for service and parts, the issue associated with the condition of the machine, or a hash used to identify the transaction record. In embodiments, the distributed ledger uses a blockchain structure to store the transaction records. In embodiments, each of the transaction records is stored as a block in the blockchain structure. In embodiments, each mobile data collector is one of a mobile vehicle, a mobile robot, a handheld device, or a wearable device. In embodiments, the method further comprises: applying machine fault detection and classification algorithms to the sensor data to produce an industrial machine service recommendation; and producing the at least one of the orders or the requests for service and parts based on the industrial machine service recommendation. In embodiments, the one or more mobile data collectors use a computer vision system to generate the sensor data by capturing raw image data using one or more data capture devices and processing the raw image data to generate image set data. In embodiments, the image set data is used to produce the industrial machine service recommendation.

[0064] In embodiments, a system comprises: an IoT network connecting an industrial machine and one or more mobile data collectors, each mobile data collector including one or more sensors for generating sensor data indicative of conditions of the industrial machine; and a server in communication with the IoT network, the server implementing a predictive maintenance platform that uses a distributed ledger to track maintenance transactions related to the industrial machine, the distributed ledger storing transaction records corresponding to the maintenance transactions.

In embodiments, the predictive maintenance platform distributes at least some of the transaction records to the one or more mobile data collectors. In embodiments, the system further comprises a self-organizing storage system that optimizes storage of the transaction records within the distributed ledger. In embodiments, the system further comprises a self-organizing storage system that optimizes storage of maintenance data associated with the industrial machine. In embodiments, the system further comprises a self-organizing storage system that optimizes storage of IoT data associated with the IoT network. In embodiments, the system further comprises a self-organizing storage system that optimizes storage of parts and service data related to the maintenance transactions. In embodiments, the system further comprises a self-organizing storage system that optimizes storage of knowledge base data associated with the industrial machine. In embodiments, each mobile data collector is one of a mobile vehicle, a mobile robot, a handheld device, or a wearable device. In embodiments, the system further comprises an industrial machine predictive maintenance facility that produces an industrial machine service recommendation for the condition by applying machine fault detection and classification algorithms to the sensor data. In embodiments, the system further comprises a severity unit algorithm that produces a severity value for the condition based on the sensor data. In embodiments, the industrial machine service recommendation is produced based on the severity value. In embodiments, at least one of the one or more mobile data collectors use a computer vision system to generate the sensor data by capturing raw image data using one or more data capture devices and processing the raw image data to generate image set data. In embodiments, the image set data is used to produce the industrial machine service recommendation.

[0065] In embodiments, a method comprises: generating, using a mobile data collector, sensor data representing a condition of an industrial machine; determining a severity of the condition of the industrial machine by analyzing the sensor data; predicting a maintenance action to perform against the industrial machine based on the severity of the condition; and storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine. In embodiments, the method further comprises: producing, in connection with the predicted maintenance action, at least one of orders or requests for service and parts used to perform the maintenance action; and including data indicative of the at least one of the orders or requests for service and parts within the transaction record. In embodiments, the mobile data collector is one of a mobile vehicle, a mobile robot, a handheld device, or a wearable device. In embodiments, the method further comprises applying machine learning to data representative of conditions of the industrial machine. In embodiments, determining the severity of the sensor data by analyzing the frequency of the vibrations comprises using the applied machine learning to

determine the severity of the sensor data based on machine learning data associated with the at least one of the frequency or the velocity of the vibrations.

[0066] In embodiments, an industrial machine predictive maintenance system comprises: a computer vision system that generates one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of an industrial machine based on the one or more image data sets; an industrial machine predictive maintenance facility that produces an industrial machine service recommendation by applying machine fault detection and classification algorithms to data indicative of the operating characteristic; a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendation; and a service and delivery coordination facility that receives and processes information regarding services to perform on the industrial machine based on the at least one of orders and requests for service and parts. In embodiments, the service and delivery coordination facility validates the services to perform on the industrial machine while producing a ledger of service activity and results for the industrial machine. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendation using data stored within a knowledge base associated with the industrial machine. In embodiments, the operating characteristic relates to vibrations detected for at least a portion of the industrial machine. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendation according to a severity unit calculated for the detected vibrations. In embodiments, the severity unit is calculated for the detected vibrations by determining a frequency of the detected vibrations, determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations, and calculating the severity unit for the detected vibrations based on the determined segment. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the detected vibrations are mapped to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency

spectra. In embodiments, the detected vibrations are mapped to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra. In embodiments, the detected vibrations are mapped to a third severity unit when the frequency of the captured vibration corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the severity unit indicates that the detected vibrations may lead to a failure of at least the portion of the industrial machine. In embodiments, the industrial machine service recommendation includes a recommendation for preventing or mitigating the failure. In embodiments, the at least one of the orders and the requests for service is for a part or a service used to prevent or mitigate the failure. In embodiments, the one or more data capture devices are external to the computer vision system. In embodiments, the industrial machine predictive maintenance system further comprises a mobile data collector configured to perform a maintenance action corresponding to the industrial machine service recommendation on the industrial machine by using the at least one of orders and requests for service and parts. In embodiments, the service and delivery coordination facility receives a signal from the mobile data collector indicating a performance of the maintenance action. In embodiments, the service and delivery coordination facility uses a ledger to record service activity and results for the industrial machine. In embodiments, the service and delivery coordination facility generates a new record in the ledger based on the signal received from the mobile data collector.

[0067] In embodiments, an industrial machine predictive maintenance system comprises: a computer vision system that generates one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of an industrial machine based on the one or more image data sets; an industrial machine predictive maintenance facility that produces an industrial machine service recommendation by applying machine fault detection and classification algorithms to data indicative of the operating characteristic; and a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendation. In embodiments, the industrial machine predictive maintenance system further comprises a service and delivery coordination facility that receives and processes information regarding services to perform on the industrial machine based on the at least one of orders and requests for service and parts. In embodiments, the service and delivery coordination facility validates the services to perform on the industrial machine while producing a ledger of service activity and results for the industrial machine. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the

CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendation using data stored within a knowledge base associated with the industrial machine. In embodiments, the operating characteristic relates to vibrations detected for at least a portion of the industrial machine. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendation according to a severity unit calculated for the detected vibrations. In embodiments, the severity unit is calculated for the detected vibrations by determining a frequency of the detected vibrations, determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations, and calculating the severity unit for the detected vibrations based on the determined segment. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the detected vibrations are mapped to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the detected vibrations are mapped to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra. In embodiments, the detected vibrations are mapped to a third severity unit when the frequency of the captured vibration corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the severity unit indicates that the detected vibrations may lead to a failure of at least the portion of the industrial machine. In embodiments, the industrial machine service recommendation includes a recommendation for preventing or mitigating the failure. In embodiments, the at least one of the orders and the requests for service is for a part or a service used to prevent or mitigate the failure. In embodiments, the one or more data capture devices are external to the computer vision system. In embodiments, the industrial machine predictive maintenance system further comprises a mobile data collector configured to perform a maintenance action corresponding to the industrial machine service recommendation on the industrial machine by using the at least one of orders and requests for service and parts. In embodiments, the service and delivery coordination facility receives a signal from the mobile data collector indicating a performance of the maintenance action. In embodiments, the service and delivery coordination facility uses a ledger to record service activity and results for the industrial machine. In embodiments, the service and delivery coordination facility generates a new record in

the ledger based on the signal received from the mobile data collector. In embodiments, the mobile data collector is a mobile vehicle. In embodiments, the mobile data collector is a mobile robot. In embodiments, the mobile data collector is a handheld device. In embodiments, the mobile data collector is a wearable device.

[0068] In embodiments, an industrial machine predictive maintenance system comprises: a computer vision system that generates one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of an industrial machine based on the one or more image data sets; an industrial machine predictive maintenance facility that produces an industrial machine service recommendation based on the operating characteristic; and a mobile data collector configured to perform a maintenance action corresponding to the industrial machine service recommendation on the industrial machine. In embodiments, the mobile data collector is one mobile data collector of a swarm of mobile data collectors and the industrial machine predictive maintenance system further comprises a self-organization system of the mobile data collector swarm that controls movements of the mobile data collectors of the swarm within an industrial environment that includes the industrial machine. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendation by applying machine fault detection and classification algorithms to data indicative of the operating characteristic. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendation using data stored within a knowledge base associated with the industrial machine. In embodiments, the operating characteristic relates to vibrations detected for at least a portion of the industrial machine. In embodiments, the industrial machine predictive maintenance facility produces the industrial machine service recommendation according to a severity unit calculated for the detected vibrations. In embodiments, the severity unit is calculated for the detected vibrations by determining a frequency of the detected vibrations, determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations, and calculating the severity unit for the detected vibrations based on the determined segment. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the detected vibrations are mapped to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the detected vibrations are mapped to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra. In embodiments, the detected vibrations are mapped to a third severity

unit when the frequency of the captured vibration corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the severity unit indicates that the detected vibrations may lead to a failure of at least the portion of the industrial machine. In embodiments, the industrial machine service recommendation includes a recommendation for preventing or mitigating the failure. In embodiments, the industrial machine predictive maintenance system further comprises a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendation. In embodiments, the mobile data collector performs the maintenance action by using the at least one of orders and requests for service and parts. In embodiments, the industrial machine predictive maintenance system further comprises a service and delivery coordination facility that receives and processes information regarding services to perform on the industrial machine based on the at least one of orders and requests for service and parts. In embodiments, the service and delivery coordination facility validates the services to perform on the industrial machine while producing a ledger of service activity and results for the industrial machine. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

[0069] In embodiments, a method for industrial machine predictive maintenance comprises: generating data representing a condition of an industrial machine using one or more sensors of a mobile data collector; processing the data to determine a severity of the condition of the industrial machine; determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and generating a signal indicative of the industrial machine service recommendation. In embodiments, the mobile data collector uses a computer vision system that generates, as the data, one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of an industrial machine based on the one or more image data sets. In embodiments, the operating characteristic corresponds to the condition of the industrial machine. In embodiments, the mobile data collector is a mobile robot. In embodiments, the mobile data collector is a mobile vehicle. In embodiments, the mobile data collector is a handheld device. In embodiments, the mobile data collector is a wearable device. In embodiments, determining the industrial machine service recommendation for the condition of the industrial machine based on the severity comprises using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity. In

embodiments, the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, and processing the data to determine the severity of the condition of the industrial machine comprises: determining a frequency of the detected vibrations; determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and calculating the severity for the detected vibrations based on the determined segment. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises transmitting the signal to a mobile robot configured to perform a maintenance action associated with the industrial machine service recommendation. In embodiments, the method further comprises storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine. In embodiments, the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the method further comprises producing at least one of orders or requests for service and parts based on the industrial machine service recommendation. In embodiments, the signal indicates the at least one of the orders or the requests for service and parts.

[0070] In embodiments, a method for industrial machine predictive maintenance comprises: generating data representing a condition of an industrial machine using one or more wearable devices, each wearable device including one or more sensors. In embodiments, a wearable device of the one or more wearable devices generates some or all of the data when the wearable device is in near proximity to the industrial machine; processing the data to determine a severity of the condition of the industrial machine; determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine. In embodiments, the condition of the industrial machine relates to vibrations

detected for at least a portion of the industrial machine, and processing the data to determine the severity of the condition of the industrial machine comprises: determining a frequency of the detected vibrations; determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and calculating the severity for the detected vibrations based on the determined segment. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises: mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, determining the industrial machine service recommendation for the condition of the industrial machine based on the severity comprises using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity. In embodiments, the intelligent system includes a you only look once neural network. In embodiments, the intelligent system includes a you only look once convolutional neural network. In embodiments, the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array. In embodiments, the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array and graphics processing unit hybrid component. In embodiments, the intelligent system includes user configurable series and parallel flow for a hybrid neural network. In embodiments, the intelligent system includes a machine learning system for configuring a topology or workflow for a set of neural networks. In embodiments, the intelligent system includes a deep learning system for configuring a topology or workflow for a set of neural networks. In embodiments, the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the method further comprises: producing at least one of orders or requests for service and parts based on the industrial machine service recommendation. In embodiments, the record for the industrial machine service recommendation stored in the ledger indicates the at least one of the orders or the requests for service and parts. In embodiments, the one or more wearable devices are integrated within an industrial uniform. In embodiments, the

wearable device is integrated within an article of clothing. In embodiments, the wearable device is integrated within an accessory article.

[0071] In embodiments, a method for industrial machine predictive maintenance comprises: generating data representing a condition of an industrial machine using one or more handheld devices, each handheld device including one or more sensors. In embodiments, a handheld device of the one or more handheld devices generates some or all of the data when the handheld device is in near proximity to the industrial machine; processing the data to determine a severity of the condition of the industrial machine; determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine. In embodiments, the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, and processing the data to determine the severity of the condition of the industrial machine comprises: determining a frequency of the detected vibrations; determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and calculating the severity for the detected vibrations based on the determined segment. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises: mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, determining the industrial machine service recommendation for the condition of the industrial machine based on the severity comprises using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity. In embodiments, the intelligent system includes a you only look once neural network. In embodiments, the intelligent system includes a you only look once convolutional neural network. In embodiments, the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array. In embodiments, the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array and graphics processing unit hybrid component. In embodiments, the

intelligent system includes user configurable series and parallel flow for a hybrid neural network. In embodiments, the intelligent system includes a machine learning system for configuring a topology or workflow for a set of neural networks. In embodiments, the intelligent system includes a deep learning system for configuring a topology or workflow for a set of neural networks. In embodiments, the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the method further comprises producing at least one of orders or requests for service and parts based on the industrial machine service recommendation. In embodiments, the record for the industrial machine service recommendation stored in the ledger indicates the at least one of the orders or the requests for service and parts.

[0072] In embodiments, a method for industrial machine predictive maintenance comprises: generating data representing a condition of an industrial machine using one or more mobile robots, each mobile robot including one or more sensors. In embodiments, a mobile robot of the one or more mobile robots generates some or all of the data when the mobile robot is in near proximity to the industrial machine; processing the data to determine a severity of the condition of the industrial machine; determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine. In embodiments, the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, and processing the data to determine the severity of the condition of the industrial machine comprises: determining a frequency of the detected vibrations; determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and calculating the severity for the detected vibrations based on the determined segment. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, determining the industrial machine service

recommendation for the condition of the industrial machine based on the severity comprises using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity. In embodiments, the intelligent system includes a you only look once neural network. In embodiments, the intelligent system includes a you only look once convolutional neural network. In embodiments, the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array. In embodiments, the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array and graphics processing unit hybrid component. In embodiments, the intelligent system includes user configurable series and parallel flow for a hybrid neural network. In embodiments, the intelligent system includes a machine learning system for configuring a topology or workflow for a set of neural networks. In embodiments, the intelligent system includes a deep learning system for configuring a topology or workflow for a set of neural networks. In embodiments, the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the method further comprises producing at least one of orders or requests for service and parts based on the industrial machine service recommendation. In embodiments, the record for the industrial machine service recommendation stored in the ledger indicates the at least one of the orders or the requests for service and parts. In embodiments, the mobile robot is one of a plurality of mobile robots of a mobile data collector swarm. In embodiments, the method further comprises controlling the mobile data collector swarm to cause the mobile robot to approach a location of the industrial machine within an industrial environment. In embodiments, controlling the mobile data collector swarm to cause the mobile robot to approach a location of the industrial machine within an industrial environment comprises using self-organization systems of the mobile data collector swarm to control movements of the mobile robot within the industrial environment based on locations of other mobile robots of the mobile data collector swarm within the industrial environment.

[0073] In embodiments, a method for industrial machine predictive maintenance comprises: generating data representing a condition of an industrial machine using one or more mobile vehicles, each mobile vehicle including one or more sensors. In embodiments, a mobile vehicle of the one or more mobile vehicles generates some or all of the data when the mobile vehicle is in near proximity to the industrial machine; processing the data to determine a severity of the condition of the industrial machine; determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine. In embodiments, the condition of the industrial machine relates to vibrations

detected for at least a portion of the industrial machine, and processing the data to determine the severity of the condition of the industrial machine comprises: determining a frequency of the detected vibrations; determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and calculating the severity for the detected vibrations based on the determined segment. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises: mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, determining the industrial machine service recommendation for the condition of the industrial machine based on the severity comprises using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity. In embodiments, the intelligent system includes a you only look once neural network. In embodiments, the intelligent system includes a you only look once convolutional neural network. In embodiments, the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array. In embodiments, the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array and graphics processing unit hybrid component. In embodiments, the intelligent system includes user configurable series and parallel flow for a hybrid neural network. In embodiments, the intelligent system includes a machine learning system for configuring a topology or workflow for a set of neural networks. In embodiments, the intelligent system includes a deep learning system for configuring a topology or workflow for a set of neural networks. In embodiments, the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the method further comprises producing at least one of orders or requests for service and parts based on the industrial machine service recommendation. In embodiments, the record for the industrial machine service recommendation stored in the ledger indicates the at least one of the orders or the requests for service and parts. In embodiments, the mobile vehicle is one of a plurality of mobile vehicles of a mobile data collector swarm. In

embodiments, the method further comprises controlling the mobile data collector swarm to cause the mobile vehicle to approach a location of the industrial machine within an industrial environment. In embodiments, controlling the mobile data collector swarm to cause the mobile vehicle to approach a location of the industrial machine within an industrial environment comprises using self-organization systems of the mobile data collector swarm to control movements of the mobile vehicle within the industrial environment based on locations of other mobile vehicles of the mobile data collector swarm within the industrial environment.

[0074] In embodiments, a method comprises: training a computer vision system to detect conditions of industrial machines using a training data set comprising at least one of image data or non-image data; detecting a condition of an industrial machine using the trained computer vision and based on a data set generated using one or more data capture devices; determining a severity value for the detected condition, the severity representing an impact of the detected condition on the industrial machine; producing, based on the severity value, at least one of orders or requests for service and parts to use to resolve an issue related to the detected condition of the industrial machine; and storing a record of the issue related to the detected condition of the industrial machine within a ledger associated with the industrial machine. In embodiments, the one or more data capture devices includes a radiation imaging device, a sonic capture device, a LIDAR device, a point cloud capture device, or an infrared inspection device. In embodiments, the detected condition is detected based on vibration characteristics of the industrial machine. In embodiments, the detected condition is detected based on pressure characteristics of the industrial machine. In embodiments, the detected condition is detected based on temperature characteristics of the industrial machine. In embodiments, the detected condition is detected based on chemical characteristics of the industrial machine. In embodiments, training the computer vision system to detect the conditions of the industrial machines using the training data set comprising the at least one of image data or non-image data comprises: using a deep learning system to detect features from the at least one of the image data or non-image data; and using the detected features to train a classification model to learn to detect the conditions of the industrial machines based on characteristics of the detected features and based on outcome feedback. In embodiments, the outcome feedback relates to at least one of maintenance, repair, uptime, downtime, profitability, efficiency, or operational optimization of the industrial machines, of processes for using the industrial machines, or of facilities including the industrial machines. In embodiments, detecting the condition of the industrial machine using the trained computer vision and based on the data set generated using the one or more data capture devices comprises using part recognition to identify one or more components of the industrial machine that will lead to the issue related to the detected condition. In embodiments, the at least one of the orders or the requests for service and parts is for

replacement parts for the one or more components. In embodiments, the at least one of the orders or the requests for service and parts is not produced when the severity value does not meet a threshold. In embodiments, the method further comprises using a predictive maintenance knowledge system to update a predictive maintenance knowledge base according to at least one of the detected condition, the at least one of the orders or the requests for service and parts, or the stored record in the ledger.

[0075] In embodiments, a system comprises: a computerized maintenance management system (CMMS) that produces at least one of orders or requests for service and parts responsive to receiving an industrial machine service recommendation corresponding to an industrial machine and that generates a signal indicative of the produced at least one of the orders or requests for service and parts; and a mobile data collector that receives the signal and indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a worker who uses the mobile data collector. In embodiments, the mobile data collector is a wearable device. In embodiments, the wearable device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the wearable device. In embodiments, the mobile data collector is a handheld device. In embodiments, the handheld device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the handheld device. In embodiments, the system further comprises a service and delivery coordination facility that receives and processes information regarding services performed on the industrial machine responsive to the at least one of orders or requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for the industrial machine. In embodiments, the system further comprises a self-organizing data collector that causes a new record to be stored in the ledger, the new record indicating at least one of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

[0076] In embodiments, a system comprises: a computerized maintenance management system (CMMS) that produces at least one of orders or requests for service and parts responsive to receiving an industrial machine service recommendation corresponding to an industrial machine and that generates a signal indicative of the produced at least one of the orders or requests for service and parts; a mobile data collector that receives the signal and indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a worker who uses the mobile data collector; and a service and delivery coordination facility that receives and processes information regarding services performed on the industrial machine responsive to the at least one of orders or requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for the industrial machine. In embodiments, the mobile data collector is a wearable device. In embodiments, the wearable device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the wearable device. The system of claim 1016. In embodiments, the mobile data collector is a handheld device. In embodiments, the handheld device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the handheld device. In embodiments, the system further comprises a self-organizing data collector that causes a new record to be stored in the ledger, the new record indicating at least one of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

[0077] In embodiments, a system comprises: a computerized maintenance management system (CMMS) that produces at least one of orders or requests for service and parts responsive to receiving an industrial machine service recommendation corresponding to an industrial machine and that generates a signal indicative of the produced at least one of the orders or requests for service and parts; a mobile data collector that receives the signal and indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a worker who uses the mobile data collector; and a self-organizing data collector that

causes a new record to be stored in the ledger, the new record indicating at least one of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts. In embodiments, the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts. In embodiments, each record is stored as a block in the blockchain structure. In embodiments, the mobile data collector is a wearable device. In embodiments, the wearable device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the wearable device. In embodiments, the mobile data collector is a handheld device. In embodiments, the handheld device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the handheld device. In embodiments, the system further comprises a self-organizing data collector that causes a new record to be stored in the ledger, the new record indicating at least one of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts. In embodiments, the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

[0078] In embodiments, a method, comprises: detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector; transmitting data indicative of the operating characteristic to a server over a network; using intelligent systems associated with the server to process the operating characteristic against pre-recorded data for the industrial machine. In embodiments, processing the operating characteristic against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with the industrial environment; identifying, as a condition of the industrial machine, a characteristic indicated by the pre-recorded data for the industrial machine within the knowledge base; determining a severity of the condition, the severity representing an impact of the condition on the industrial machine; predicting a maintenance action to perform against the industrial machine based on the severity of the condition; and storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine. In embodiments, the mobile data collector is a mobile robot. In embodiments, the mobile data collector is a mobile vehicle. In embodiments, the mobile data collector is a handheld device. In embodiments, the mobile data collector is a wearable device. In embodiments,

the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, and determining the severity of the condition comprises: determining a frequency of the vibrations; determining a segment of a multi-segment vibration frequency spectra that bounds the vibrations; and calculating the severity for the detected vibrations based on the determined segment. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises: mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine. In embodiments, each of the transaction records is stored as a block in the blockchain structure. In embodiments, the condition of the industrial machine relates to a temperature detected for at least a portion of the industrial machine. In embodiments, the condition of the industrial machine relates to an electrical output detected for at least a portion of the industrial machine. In embodiments, the condition of the industrial machine relates to a magnetic output detected for at least a portion of the industrial machine. In embodiments, the condition of the industrial machine relates to a sound output detected for at least a portion of the industrial machine.

[0079] In embodiments, a method, comprises: detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector; transmitting data indicative of the operating characteristic to a server over a network; using intelligent systems associated with the server to process the operating characteristic against pre-recorded data for the industrial machine. In embodiments, processing the operating characteristic against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with the industrial environment; identifying, as a condition of the industrial machine, a characteristic indicated by the pre-recorded data for the industrial machine within the knowledge base, the condition of the industrial machine relating to vibrations detected for at least a portion of the industrial machine; determining a severity of the condition, the severity representing an impact of the condition on the industrial machine, based on a segment of a multi-

segment vibration frequency spectra that bounds the vibrations; and predicting a maintenance action to perform against the industrial machine based on the severity of the condition. In embodiments, the mobile data collector is a mobile robot. In embodiments, the mobile data collector is a mobile vehicle. In embodiments, the mobile data collector is a handheld device. In embodiments, the mobile data collector is a wearable device. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises: mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine. In embodiments, the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine. In embodiments, each of the transaction records is stored as a block in the blockchain structure.

[0080] In embodiments, a method comprises: detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector, the operating characteristic of the industrial machine relating to vibrations detected for at least a portion of the industrial machine; determining a severity of the operating characteristic, the severity representing an impact of the operating characteristic on the industrial machine, based on a segment of a multi-segment vibration frequency spectra that bounds the vibrations; and predicting a maintenance action to perform against the industrial machine based on the severity of the operating characteristic. In embodiments, the mobile data collector is a mobile robot. In embodiments, the mobile data collector is a mobile vehicle. In embodiments, the mobile data collector is a handheld device. In embodiments, the mobile data collector is a wearable device. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises: mapping the vibrations to a first severity unit when

the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine. In embodiments, the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine. In embodiments, each of the transaction records is stored as a block in the blockchain structure.

[0081] In embodiments, a method comprises: detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector, the operating characteristic of the industrial machine relating to vibrations detected for at least a portion of the industrial machine; determining a severity of the operating characteristic, the severity representing an impact of the operating characteristic on the industrial machine, based on a segment of a multi-segment vibration frequency spectra that bounds the vibrations; predicting a maintenance action to perform against the industrial machine based on the severity of the operating characteristic; and storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine. In embodiments, the mobile data collector is a mobile robot. In embodiments, the mobile data collector is a mobile vehicle. In embodiments, the mobile data collector is a handheld device. In embodiments, the mobile data collector is a wearable device. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra. In embodiments, the method further comprises: mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine. In embodiments, each of the transaction records is stored as a block in the blockchain structure.

[0082] In embodiments, a method comprises: detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector, the operating characteristic of the industrial machine relating to vibrations detected for at least a portion of the industrial machine; determining a severity of the operating characteristic, the severity representing an impact of the operating characteristic on the industrial machine, based on a segment of a multi-segment vibration frequency spectra that bounds the vibrations. In embodiments, the severity corresponds to a severity unit. In embodiments, the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment. In embodiments, each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra; predicting a maintenance action to perform against the industrial machine based on the severity of the operating characteristic; and storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine. In embodiments, the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine. In embodiments, each of the transaction records is stored as a block in the blockchain structure. In embodiments, the mobile data collector is a mobile robot. In embodiments, the mobile data collector is a mobile vehicle. In embodiments, the mobile data collector is a handheld device. In embodiments, the mobile data collector is a wearable device. In embodiments, determining the severity of the operating characteristic comprises: mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra.

[0083] In embodiments, a method comprises: deploying a mobile data collector for detecting and monitoring vibration activity of at least a portion of an industrial machine, the mobile data collector including one or more vibration sensors; controlling the mobile data collector to approach a location of the industrial machine within an industrial environment that includes the industrial machine; causing the one or more vibration sensors of the mobile data collector to record one or more measurements of the vibration activity; transmitting the one or more measurements of the vibration activity as vibration data to a server over a network; determining, at the server, a severity of the vibration activity relative to timing by processing the vibration data; predicting, at the server, a maintenance action to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity; and transmitting a signal indicative of the maintenance

action to the mobile data collector to cause the mobile data collector to perform the maintenance action. In embodiments, determining the severity of the vibration data relative to the timing by processing the vibration data comprises: determining a frequency of the vibration activity by processing the vibration data; determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the vibration activity; and calculating a severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra. In embodiments, calculating the severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra comprises: mapping the vibration activity to the severity unit based on the determined segment of the multi-segment vibration frequency spectra by: mapping the vibration activity to a first severity unit when the frequency of the vibration activity corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the vibration activity to a second severity unit when the frequency of the vibration activity corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the vibration activity to a third severity unit when the frequency of the vibration activity corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, predicting the one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity comprises: using intelligent systems associated with the server to process the vibration data against pre-recorded data for the industrial machine. In embodiments, processing the vibration data against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with the industrial environment; identifying an operating characteristic of at least the portion of the machine based on the pre-recorded data for the industrial machine within the knowledge base; and predicting the one or more maintenance actions based on the operating characteristic. In embodiments, the vibration activity is indicative of a waveform derived from a vibration envelope associated with the industrial machine. In embodiments, the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine. In embodiments, the vibration activity represents velocity information for at least the portion of the industrial machine. In embodiments, the vibration activity represents frequency information for at least the portion of the industrial machine. In embodiments, the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm. In embodiments, the method further comprises using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within an industrial environment that includes the industrial machine. In embodiments, the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the

industrial machine. In embodiments, using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises controlling the movements of the mobile data collector within the industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors. In embodiments, the mobile data collector is a mobile robot and at least one other mobile data collector of the plurality of mobile data collectors is a mobile vehicle.

[0084] In embodiments, a method comprises: deploying a mobile data collector for detecting and monitoring vibration activity of at least a portion of an industrial machine, the mobile data collector including one or more vibration sensors; controlling the mobile data collector to approach a location of the industrial machine within an industrial environment that includes the industrial machine; causing the one or more vibration sensors of the mobile data collector to record one or more measurements of the vibration activity; transmitting the one or more measurements of the vibration activity as vibration data to a server over a network; determining, at the server, a frequency of the vibration activity by processing the vibration data; determining, at the server and based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the vibration activity; calculating, at the server, a severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra; predicting, at the server, a maintenance action to perform with respect to at least the portion of the industrial machine based on the severity unit; and transmitting a signal indicative of the maintenance action to the mobile data collector to cause the mobile data collector to perform the maintenance action. In embodiments, calculating the severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra comprises: mapping the vibration activity to the severity unit based on the determined segment of the multi-segment vibration frequency spectra by: mapping the vibration activity to a first severity unit when the frequency of the vibration activity corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the vibration activity to a second severity unit when the frequency of the vibration activity corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the vibration activity to a third severity unit when the frequency of the vibration activity corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, predicting the one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity unit comprises: using intelligent systems associated with the server to process the vibration data against pre-recorded data for the industrial machine. In embodiments, processing the vibration data against the pre-recorded data for the industrial machine includes identifying the pre-recorded data

for the industrial machine within a knowledge base associated with the industrial environment; identifying an operating characteristic of at least the portion of the machine based on the pre-recorded data for the industrial machine within the knowledge base; and predicting the one or more maintenance actions based on the operating characteristic. In embodiments, the vibration activity is indicative of a waveform derived from a vibration envelope associated with the industrial machine. In embodiments, the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine. In embodiments, the vibration activity represents velocity information for at least the portion of the industrial machine. In embodiments, the vibration activity represents frequency information for at least the portion of the industrial machine. In embodiments, the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm. In embodiments, the method further comprises using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within an industrial environment that includes the industrial machine. In embodiments, the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine. In embodiments, using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises controlling the movements of the mobile data collector within the industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors. In embodiments, the mobile data collector is a mobile robot and at least one other mobile data collector of the plurality of mobile data collectors is a mobile vehicle.

[0085] In embodiments, a method comprises: deploying a mobile data collector for detecting and monitoring vibration activity of at least a portion of an industrial machine, the mobile data collector including one or more vibration sensors; controlling the mobile data collector to approach a location of the industrial machine within an industrial environment that includes the industrial machine; causing the one or more vibration sensors of the mobile data collector to record one or more measurements of the vibration activity; transmitting the one or more measurements of the vibration activity as vibration data to a server over a network; determining, at the server, a severity of the vibration activity relative to timing by processing the vibration data; predicting, at the server, a maintenance action to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity; transmitting a signal indicative of the maintenance action to the mobile data collector to cause the mobile data collector to perform the maintenance action; and storing a record of the predicted maintenance action within a ledger associated with the industrial machine. In embodiments, determining the severity of the vibration data relative to the timing by processing the vibration data comprises: determining a frequency of the vibration

activity by processing the vibration data; determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the vibration activity; and calculating a severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra. In embodiments, calculating the severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra comprises: mapping the vibration activity to the severity unit based on the determined segment of the multi-segment vibration frequency spectra by: mapping the vibration activity to a first severity unit when the frequency of the vibration activity corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra; mapping the vibration activity to a second severity unit when the frequency of the vibration activity corresponds to a mid-range of the multi-segment vibration frequency spectra; and mapping the vibration activity to a third severity unit when the frequency of the vibration activity corresponds to an above the high-end knee threshold-range of the multi-segment vibration frequency spectra. In embodiments, predicting the one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity comprises: using intelligent systems associated with the server to process the vibration data against pre-recorded data for the industrial machine. In embodiments, processing the vibration data against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with the industrial environment; identifying an operating characteristic of at least the portion of the machine based on the pre-recorded data for the industrial machine within the knowledge base; and predicting the one or more maintenance actions based on the operating characteristic. In embodiments, the vibration activity is indicative of a waveform derived from a vibration envelope associated with the industrial machine. In embodiments, the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine. In embodiments, the vibration activity represents velocity information for at least the portion of the industrial machine. In embodiments, the vibration activity represents frequency information for at least the portion of the industrial machine. In embodiments, the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm. In embodiments, the method further comprises using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within an industrial environment that includes the industrial machine. In embodiments, the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine. In embodiments, using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises controlling the movements of the mobile data collector within the

industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors. In embodiments, the mobile data collector is a mobile robot and at least one other mobile data collector of the plurality of mobile data collectors is a mobile vehicle. In embodiments, the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine. In embodiments, each of the transaction records is stored as a block in the blockchain structure.

BRIEF DESCRIPTION OF THE FIGURES

[0086] Figures 1 through Figure 5 are diagrammatic views that each depicts portions of an overall view of an industrial IoT data collection, monitoring and control system in accordance with the present disclosure.

[0087] Figure 6 is a diagrammatic view of a platform including a local data collection system disposed in an industrial environment for collecting data from or about the elements of the environment, such as machines, components, systems, sub-systems, ambient conditions, states, workflows, processes, and other elements in accordance with the present disclosure.

[0088] Figure 7 is a diagrammatic view that depicts elements of an industrial data collection system for collecting analog sensor data in an industrial environment in accordance with the present disclosure.

[0089] Figure 8 is a diagrammatic view of a rotating or oscillating machine having a data acquisition module that is configured to collect waveform data in accordance with the present disclosure.

[0090] Figure 9 is a diagrammatic view of an exemplary tri-axial sensor mounted to a motor bearing of an exemplary rotating machine in accordance with the present disclosure.

[0091] Figure 10 and Figure 11 are diagrammatic views of an exemplary tri-axial sensor and a single-axis sensor mounted to an exemplary rotating machine in accordance with the present disclosure.

[0092] Figure 12 is a diagrammatic view of multiple machines under survey with ensembles of sensors in accordance with the present disclosure.

[0093] Figure 13 is a diagrammatic view of hybrid relational metadata and a binary storage approach in accordance with the present disclosure.

[0094] Figure 14 is a diagrammatic view of components and interactions of a data collection architecture involving application of cognitive and machine learning systems to data collection and processing in accordance with the present disclosure.

[0095] Figure 15 is a diagrammatic view of components and interactions of a data collection architecture involving application of a platform having a cognitive data marketplace in accordance with the present disclosure.

[0096] Figure 16 is a diagrammatic view of components and interactions of a data collection architecture involving application of a self-organizing swarm of data collectors in accordance with the present disclosure.

[0097] Figure 17 is a diagrammatic view of components and interactions of a data collection architecture involving application of a haptic user interface in accordance with the present disclosure.

[0098] Figure 18 is a diagrammatic view of a multi-format streaming data collection system in accordance with the present disclosure.

[0099] Figure 19 is a diagrammatic view of combining legacy and streaming data collection and storage in accordance with the present disclosure.

[0100] Figure 20 is a diagrammatic view of industrial machine sensing using both legacy and updated streamed sensor data processing in accordance with the present disclosure.

[0101] Figure 21 is a diagrammatic view of an industrial machine sensed data processing system that facilitates portal algorithm use and alignment of legacy and streamed sensor data in accordance with the present disclosure.

[0102] Figure 22 is a diagrammatic view of components and interactions of a data collection architecture involving a streaming data acquisition instrument receiving analog sensor signals from an industrial environment connected to a cloud network facility in accordance with the present disclosure.

[0103] Figure 23 is a diagrammatic view of components and interactions of a data collection architecture involving a streaming data acquisition instrument having an alarms module, expert analysis module, and a driver API to facilitate communication with a cloud network facility in accordance with the present disclosure.

[0104] Figure 24 is a diagrammatic view of components and interactions of a data collection architecture involving a streaming data acquisition instrument and first in, first out memory architecture to provide a real time operating system in accordance with the present disclosure.

[0105] Figure 25 through Figure 30 are diagrammatic views of screens showing four analog sensor signals, transfer functions between the signals, analysis of each signal, and operating controls to move and edit throughout the streaming signals obtained from the sensors in accordance with the present disclosure.

[0106] Figure 31 is a diagrammatic view of components and interactions of a data collection architecture involving a multiple streaming data acquisition instrument receiving analog sensor

signals and digitizing those signals to be obtained by a streaming hub server in accordance with the present disclosure.

[0107] Figure 32 is a diagrammatic view of components and interactions of a data collection architecture involving a master raw data server that processes new streaming data and data already extracted and processed in accordance with the present disclosure.

[0108] Figure 33, Figure 34, and Figure 35 are diagrammatic views of components and interactions of a data collection architecture involving a processing, analysis, report, and archiving server that processes new streaming data and data already extracted and processed in accordance with the present disclosure.

[0109] Figure 36 is a diagrammatic view of components and interactions of a data collection architecture involving a relation database server and data archives and their connectivity with a cloud network facility in accordance with the present disclosure.

[0110] Figure 37 through Figure 42 are diagrammatic views of components and interactions of a data collection architecture involving a virtual streaming data acquisition instrument receiving analog sensor signals from an industrial environment connected to a cloud network facility in accordance with the present disclosure.

[0111] Figure 43 through Figure 50 are diagrammatic views of components and interactions of a data collection architecture involving data channel methods and systems for data collection of industrial machines in accordance with the present disclosure.

[0112] Figure 51 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0113] Figure 52 and Figure 53 are diagrammatic views that depict embodiments of a data monitoring device in accordance with the present disclosure.

[0114] Figure 54 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0115] Figures 55 and 56 are diagrammatic views that depict an embodiment of a system for data collection in accordance with the present disclosure.

[0116] Figures 57 and 58 are diagrammatic views that depict an embodiment of a system for data collection comprising a plurality of data monitoring devices in accordance with the present disclosure.

[0117] Figure 59 depicts an embodiment of a data monitoring device incorporating sensors in accordance with the present disclosure.

[0118] Figures 60 and 61 are diagrammatic views that depict embodiments of a data monitoring device in communication with external sensors in accordance with the present disclosure.

[0119] Figure 62 is a diagrammatic view that depicts embodiments of a data monitoring device with additional detail in the signal evaluation circuit in accordance with the present disclosure.

[0120] Figure 63 is a diagrammatic view that depicts embodiments of a data monitoring device with additional detail in the signal evaluation circuit in accordance with the present disclosure.

[0121] Figure 64 is a diagrammatic view that depicts embodiments of a data monitoring device with additional detail in the signal evaluation circuit in accordance with the present disclosure.

[0122] Figure 65 is a diagrammatic view that depicts embodiments of a system for data collection in accordance with the present disclosure.

[0123] Figure 66 is a diagrammatic view that depicts embodiments of a system for data collection comprising a plurality of data monitoring devices in accordance with the present disclosure.

[0124] Figure 67 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0125] Figures 68 and 69 are diagrammatic views that depict embodiments of a data monitoring device in accordance with the present disclosure.

[0126] Figures 70 and 71 are diagrammatic views that depict embodiments of a data monitoring device in accordance with the present disclosure.

[0127] Figures 72 and 73 are diagrammatic views that depict embodiments of a data monitoring device in accordance with the present disclosure.

[0128] Figures 74 and 75 is a diagrammatic view that depicts embodiments of a system for data collection comprising a plurality of data monitoring devices in accordance with the present disclosure.

[0129] Figure 76 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0130] Figures 77 and 78 are diagrammatic views that depict embodiments of a data monitoring device in accordance with the present disclosure.

[0131] Figure 79 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0132] Figure 80 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0133] Figures 81 and 82 are diagrammatic views that depict embodiments of a system for data collection in accordance with the present disclosure.

[0134] Figures 83 and 84 are diagrammatic views that depict embodiments of a system for data collection comprising a plurality of data monitoring devices in accordance with the present disclosure.

[0135] Figure 85 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0136] Figures 86 and 87 are diagrammatic views that depict embodiments of a data monitoring device in accordance with the present disclosure.

[0137] Figure 88 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0138] Figures 89 and 90 are diagrammatic views that depict embodiments of a system for data collection in accordance with the present disclosure.

[0139] Figures 91 and 92 are diagrammatic views that depict embodiments of a system for data collection comprising a plurality of data monitoring devices in accordance with the present disclosure.

[0140] Figure 93 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0141] Figures 94 and 95 are diagrammatic views that depict embodiments of a data monitoring device in accordance with the present disclosure.

[0142] Figure 96 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0143] Figures 97 and 98 are diagrammatic views that depict embodiments of a system for data collection in accordance with the present disclosure.

[0144] Figures 99 and 100 are diagrammatic views that depict embodiments of a system for data collection comprising a plurality of data monitoring devices in accordance with the present disclosure.

[0145] Figure 101 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0146] Figures 102 and 103 are diagrammatic views that depict embodiments of a data monitoring device in accordance with the present disclosure.

[0147] Figure 104 is a diagrammatic view that depicts embodiments of a data monitoring device in accordance with the present disclosure.

[0148] Figures 105 and 106 are diagrammatic views that depict embodiments of a system for data collection in accordance with the present disclosure.

[0149] Figures 107 and 108 are diagrammatic views that depict embodiments of a system for data collection comprising a plurality of data monitoring devices in accordance with the present disclosure.

[0150] Figure 109 to Figure 136 are diagrammatic views of components and interactions of a data collection architecture involving various neural network embodiments interacting with a streaming

data acquisition instrument receiving analog sensor signals and an expert analysis module in accordance with the present disclosure.

[0151] Figures 137 through Figure 139 are diagrammatic views of components and interactions of a data collection architecture involving a collector of route templates and the routing of data collectors in an industrial environment in accordance with the present disclosure.

[0152] Figure 140 is a diagrammatic view that depicts a monitoring system that employs data collection bands in accordance with the present disclosure.

[0153] Figure 141 is a diagrammatic view that depicts a system that employs vibration and other noise in predicting states and outcomes in accordance with the present disclosure.

[0154] Figure 142 is a diagrammatic view that depicts a system for data collection in an industrial environment in accordance with the present disclosure.

[0155] Figure 143 is a diagrammatic view that depicts an apparatus for data collection in an industrial environment in accordance with the present disclosure.

[0156] Figure 144 is a schematic flow diagram of a procedure for data collection in an industrial environment in accordance with the present disclosure.

[0157] Figure 145 is a diagrammatic view that depicts a system for data collection in an industrial environment in accordance with the present disclosure.

[0158] Figure 146 is a diagrammatic view that depicts an apparatus for data collection in an industrial environment in accordance with the present disclosure.

[0159] Figure 147 is a schematic flow diagram of a procedure for data collection in an industrial environment in accordance with the present disclosure.

[0160] Figure 148 is a diagrammatic view that depicts industry-specific feedback in an industrial environment in accordance with the present disclosure.

[0161] Figure 149 is a diagrammatic view that depicts an exemplary user interface for smart band configuration of a system for data collection in an industrial environment is depicted in accordance with the present disclosure.

[0162] Figure 150 is a diagrammatic view that depicts a graphical approach 11300 for back-calculation in accordance with the present disclosure.

[0163] Figure 151 is a diagrammatic view that depicts a wearable haptic user interface device for providing haptic stimuli to a user that is responsive to data collected in an industrial environment by a system adapted to collect data in the industrial environment in accordance with the present disclosure.

[0164] Figure 152 is a diagrammatic view that depicts an augmented reality display of heat maps based on data collected in an industrial environment by a system adapted to collect data in the environment in accordance with the present disclosure.

[0165] Figure 153 is a diagrammatic view that depicts an augmented reality display including real time data overlaying a view of an industrial environment in accordance with the present disclosure.

[0166] Figure 154 is a diagrammatic view that depicts a user interface display and components of a neural net in a graphical user interface in accordance with the present disclosure.

[0167] Figure 155 is a diagrammatic view of components and interactions of a data collection architecture involving swarming data collectors and sensor mesh protocol in an industrial environment in accordance with the present disclosure.

[0168] Figure 156 through Figure 159 are diagrammatic views mobile sensors platforms in an industrial environment in accordance with the present disclosure.

[0169] Figure 160 is a diagrammatic view of components and interactions of a data collection architecture involving two mobile sensor platforms inspecting a vehicle during assembly in an industrial environment in accordance with the present disclosure.

[0170] Figure 161 and Figure 162 are diagrammatic views one of the mobile sensor platforms in an industrial environment in accordance with the present disclosure.

[0171] Figure 163 is a diagrammatic view of components and interactions of a data collection architecture involving two mobile sensor platforms inspecting a turbine engine during assembly in an industrial environment in accordance with the present disclosure.

[0172] Figure 164 is a diagrammatic view that depicts data collection system according to some aspects of the present disclosure.

[0173] Figure 165 is a diagrammatic view that depicts a system for self-organized, network-sensitive data collection in an industrial environment in accordance with the present disclosure.

[0174] Figure 166 is a diagrammatic view that depicts an apparatus for self-organized, network-sensitive data collection in an industrial environment in accordance with the present disclosure.

[0175] Figure 167 is a diagrammatic view that depicts an apparatus for self-organized, network-sensitive data collection in an industrial environment in accordance with the present disclosure.

[0176] Figure 168 is a diagrammatic view that depicts an apparatus for self-organized, network-sensitive data collection in an industrial environment in accordance with the present disclosure.

[0177] Figure 169 and Figure 170 are diagrammatic views that depict embodiments of transmission conditions in accordance with the present disclosure.

[0178] Figure 171 is a diagrammatic view that depicts embodiments of a sensor data transmission protocol in accordance with the present disclosure.

[0179] Figure 172 and Figure 173 are diagrammatic views that depict embodiments of benchmarking data in accordance with the present disclosure.

[0180] Figure 174 is a diagrammatic view that depicts embodiments of a system for data collection and storage in an industrial environment in accordance with the present disclosure.

[0181] Figure 175 is a diagrammatic view that depicts embodiments of an apparatus for self-organizing storage for data collection for an industrial system in accordance with the present disclosure.

[0182] Figure 176 is a diagrammatic view that depicts embodiments of a storage time definition in accordance with the present disclosure.

[0183] Figure 177 is a diagrammatic view that depicts embodiments of a data resolution description in accordance with the present disclosure.

[0184] Figure 178 and Figure 179 diagrammatic views of an apparatus for self-organizing network coding for data collection for an industrial system in accordance with the present disclosure.

[0185] Figure 180 and Figure 181 diagrammatic views of data marketplace interacting with data collection in an industrial system in accordance with the present disclosure.

[0186] Figure 182 is a diagrammatic view that depicts a smart heating system as an element in a network for in an industrial Internet of Things ecosystem in accordance with the present disclosure.

[0187] Figure 183 is a schematic of a data network including server and client nodes coupled by intermediate networks.

[0188] Figure 184 is a block diagram illustrating the modules that implement TCP-based communication between a client node and a server node.

[0189] Figure 185 is a block diagram illustrating the modules that implement Packet Coding Transmission Communication Protocol (PC-TCP) based communication between a client node and a server node.

[0190] Figure 186 is a schematic diagram of a use of the PC-TCP based communication between a server and a module device on a cellular network.

[0191] Figure 187 is a block diagram of 1 PC-TCP module that uses a conventional UDP module.

[0192] Figure 188 is a block diagram of a PC-TCP module that is partially integrated into a client application and partially implemented using a conventional UDP module.

[0193] Figure 189 is a block diagram or a PC-TCP module that is split with user space and kernel space components.

[0194] Figure 190 is a block diagram for a proxy architecture.

[0195] Figure 191 is a block diagram of a PC-TCP based proxy architecture in which a proxy node communicates using both PC-TCP and conventional TCP.

[0196] Figure 192 is a block diagram of a PC-TCP proxy-based architecture embodied using a gateway device.

[0197] Figure 193 is a block diagram of an alternative proxy architecture embodied within a client node.

[0198] Figure 194 is a block diagram of a second PC-TCP based proxy architecture in which a proxy node communicates using both PC-TCP and conventional TCP.

[0199] Figure 195 is a block diagram of a PC-TCP proxy-based architecture embodied using a wireless access device.

[0200] Figure 196 is a block diagram of a PC-TCP proxy-based architecture embodied cellular network.

[0201] Figure 197 is a block diagram of a PC-TCP proxy-based architecture embodied cable television-based data network.

[0202] Figure 198 is a block diagram of an intermediate proxy that communicates with a client node and with a server node using separate PC-TCP connections.

[0203] Figure 199 is a block diagram of a PC-TCP proxy-based architecture embodied in a network device.

[0204] Figure 200 is a block diagram of an intermediate proxy that recodes communication between a client node and with a server node.

[0205] Figures 201-202 are diagrams that illustrates delivery of common content to multiple destinations.

[0206] Figures 203-213 are schematic diagrams of various embodiments of PC-TCP communication approaches.

[0207] Figure 214 is a block diagram of PC-TCP communication approach that includes window and rate control modules.

[0208] Figure 215 is a schematic of a data network.

[0209] Figures 216-219 are block diagrams illustrating an embodiment PC-TCP communication approach that is configured according to a number of tunable parameters.

[0210] Figure 220 is a diagram showing a network communication system.

[0211] Figure 221 is a schematic diagram illustrating use of stored communication parameters.

[0212] Figure 222 is a schematic diagram illustrating a first embodiment or multi-path content delivery.

[0213] Figures 223-225 are schematic diagrams illustrating a second embodiment of multi-path content delivery.

[0214] Figure 226 is a diagrammatic view depicting an integrated cooktop of intelligent cooking system methods and systems in accordance with the present teachings.

[0215] Figure 227 is a diagrammatic view depicting a single intelligent burner of the intelligent cooking system in accordance with the present teachings.

[0216] Figure 228 is a partial exterior view depicting a solar-powered hydrogen production and storage station in accordance with the present teachings.

[0217] Figure 229 is a diagrammatic view depicting a low-pressure storage system in accordance with the present teachings.

[0218] Figure 230 and Figure 231 are cross-sectional views of a low-pressure storage system.

[0219] Figure 232 is a diagrammatic view depicting an electrolyzer in accordance with the present teachings.

[0220] Figure 233 is a diagrammatic view depicting features of a platform that interact with electronic devices and participants in a related ecosystem of suppliers, content providers, service providers, and regulators in accordance with the present teachings.

[0221] Figure 234 is a diagrammatic view depicting a smart home embodiment of the intelligent cooking system in accordance with the present teachings.

[0222] Figure 235 is a diagrammatic view depicting a hydrogen production and use system in accordance with the present teachings.

[0223] Figure 236 is a diagrammatic view depicting an electrolytic cell in accordance with the present teachings.

[0224] Figure 237 is a diagrammatic view depicting a hydrogen production system integrated into a cooking system in accordance with the present teachings.

[0225] Figure 238 is a diagrammatic view depicting auto switching connectivity in the form of ad hoc Wi-Fi from the cooktop through nearby mobile devices in a normal connectivity mode when Wi-Fi is available in accordance with the present teachings.

[0226] Figure 239 is a diagrammatic view depicting an auto switching connectivity in the form of ad hoc Wi Fi from the cooktop through nearby mobile devices for ad hoc use of the local mobile devices for connectivity to the cloud in accordance with the present teachings.

[0227] Figure 240 is a perspective view depicting a three-element induction smart cooking system in accordance with the present teachings.

[0228] Figure 241 is a perspective view depicting a single burner gas smart cooking system in accordance with the present teachings.

[0229] Figure 242 is a perspective view depicting an electric hot plate smart cooking system in accordance with the present teachings.

[0230] Figure 243 is a perspective view depicting a single induction heating element smart cooking system in accordance with the present teachings.

[0231] Figures 244-251 are views of visual interfaces depicting user interface features of a smart knob in accordance with the present teachings.

[0232] Figure 252 is a perspective view depicting a smart knob deployed on a single heating element cooking system in accordance with the present teachings.

[0233] Figure 253 is a partial perspective view depicting a smart knob deployed on a side of a kitchen appliance for a single heating element cooking system in accordance with the present teachings.

[0234] Figures 254-257 are perspective views depicting smart temperature probes of the smart cooking system in accordance with the present teachings.

[0235] Figures 258-263 are diagrammatic views depicting different docks for compatibility with a range of smart phone and tablet devices in accordance with the present teachings.

[0236] Figure 264 and Figure 266 are diagrammatic views depicting a burner design contemplated for use with a smart cooking system in accordance with the present teachings.

[0237] Figure 265 is a cross sectional view of a burner design contemplated for use with a smart cooking system.

[0238] Figure 267, Figure 269, and Figure 271 are diagrammatic views depicting a burner design contemplated for use with a smart cooking system in accordance with another example of the present teachings.

[0239] Figure 268 and Figure 270 are cross-sectional views of a burner design.

[0240] Figures 272-274 are diagrammatic views depicting a burner design contemplated for use with a smart cooking system in accordance with a further example of the present teachings.

[0241] Figures 275-277 are diagrammatic views depicting a burner design contemplated for use with a smart cooking system in accordance with yet another example of the present teachings.

[0242] Figure 278 and Figure 280 are diagrammatic views depicting a burner design contemplated for use with a smart cooking system in accordance with an additional example of the present teachings.

[0243] Figure 279 is a cross-sectional view of a burner design contemplated for use with a smart cooking system.

[0244] Figure 281 is a flowchart depicting a method associated with a smart kitchen including a smart cooktop and an exhaust fan that may be automatically turned on as water in a pot may begin to boil in accordance with the present teachings.

[0245] Figure 282 is an embodiment method and system related to renewable energy sources for hydrogen production, storage, distribution and use are depicted in accordance with the present teachings in accordance with the present teachings.

[0246] Figure 283 is an alternate embodiment method and system related to renewable energy sources in accordance with the present teachings.

[0247] Figure 284 is an alternate embodiment method and system related to renewable energy sources in accordance with the present teachings.

[0248] Figure 285 depicts environments and manufacturing uses of hydrogen production, storage, distribution and use systems.

[0249] Figures 286-289 are diagrammatic views that depict embodiments of a system for using one or more wearable devices for mobile data collection in accordance with the present disclosure.

[0250] Figures 290-292 are diagrammatic views that depict embodiments of a system for using one or more mobile robots and/or mobile vehicles for mobile data collection in accordance with the present disclosure.

[0251] Figures 293-296 are diagrammatic views that depict embodiments of a system for using one or more handheld devices for mobile data collection in accordance with the present disclosure.

[0252] Figures 297-299 are diagrammatic views that depict embodiments of a computer vision system in accordance with the present disclosure.

[0253] Figures 300-301 are diagrammatic views that depict embodiments of a deep learning system for training a computer vision system in accordance with the present disclosure.

[0254] Figure 302 depicts a predictive maintenance eco system network architecture.

[0255] Figure 303 depicts finding service workers using machine learning for the predictive maintenance eco-system of Figure 302.

[0256] Figure 304 depicts ordering parts and service in a predictive maintenance eco-system.

[0257] Figure 305 depicts deployment of smart RFID elements in an industrial machine environment.

[0258] Figure 306 depicts a generalized data structure for machine information in a smart RFID.

[0259] Figure 307 depicts a block level diagram of the storage structure of a smart RFID.

[0260] Figure 308 depicts an example of data stored in a smart RFID.

[0261] Figure 309 depicts a flow diagram of a method for collecting information from a machine.

[0262] Figure 310 depicts a flow diagram of a method for collecting data from a production environment.

[0263] Figure 311 depicts an on-line maintenance management system with interfaces for data sources updating information in the on-line maintenance management system data storage.

[0264] Figure 312 depicts a distributed ledger for predictive maintenance information with role-specific access thereof.

[0265] Figure 313 depicts a process for capturing images of portions of an industrial machine.

[0266] Figure 314 depicts a process that uses machine learning on images to recognize a likely internal structure of an industrial machine.

[0267] Figure 315 depicts a knowledge graph of the predictive maintenance gathering information.

[0268] Figure 316 depicts an artificial intelligence system generating service recommendations and the like based on predictive maintenance analysis.

[0269] Figure 317 depicts a predictive maintenance timeline superimposed on a preventive maintenance timeline.

[0270] Figure 318 depicts a block diagram of potential sources of diagnostic information.

[0271] Figure 319 depicts a diagram of a process for rating vendors.

[0272] Figure 320 depicts a diagram of a process for rating procedures

[0273] Figure 321 depicts a diagram of Blockchain applied to transactions of a predictive maintenance eco-system.

[0274] Figure 322 depicts a transfer function that facilitates converting vibration data into severity units.

[0275] Figure 323 depicts a table that facilitates mapping vibration data to severity units.

[0276] Figure 324 depicts a composite frequency graph for conventional vibration assessment and severity unit-based assessment.

[0277] Figure 325 depicts a rendering of a portion of an industrial machine for use in an electronic user interface for depicting and discovering severity units and related information about a rotating component of the industrial machine.

[0278] Figure 326 depicts a data table of rotating component design parameters for use in predicting maintenance events.

[0279] Figure 327 a flow chart of predicting maintenance of at least one of a gear, motor and roller bearing based on severity unit and actuator count, such as count of teeth in a gear.

DETAILED DESCRIPTION

[0280] Detailed embodiments of the present disclosure are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the disclosure, which may be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosure in virtually any appropriately detailed structure.

[0281] Methods and systems described herein for industrial machine sensor data streaming, collection, processing, and storage may be configured to operate with existing data collection, processing, and storage systems while preserving access to existing format/frequency range/resolution compatible data. While the industrial machine sensor data streaming facilities described herein may collect a greater volume of data (e.g., longer duration of data collection) from sensors at a wider range of frequencies and with greater resolution than existing data collection systems, methods and systems may be employed to provide access to data from the stream of data that represents one or more ranges of frequency and/or one or more lines of

resolution that are purposely compatible with existing systems. Further, a portion of the streamed data may be identified, extracted, stored, and/or forwarded to existing data processing systems to facilitate operation of existing data processing systems that substantively matches operation of existing data processing systems using existing collection-based data. In this way, a newly deployed system for sensing aspects of industrial machines, such as aspects of moving parts of industrial machines, may facilitate continued use of existing sensed data processing facilities, algorithms, models, pattern recognizers, user interfaces, and the like.

[0282] Through identification of existing frequency ranges, formats, and/or resolution, such as by accessing a data structure that defines these aspects of existing data, higher resolution streamed data may be configured to represent a specific frequency, frequency range, format, and/or resolution. This configured streamed data can be stored in a data structure that is compatible with existing sensed data structures so that existing processing systems and facilities can access and process the data substantially as if it were the existing data. One approach to adapting streamed data for compatibility with existing sensed data may include aligning the streamed data with existing data so that portions of the streamed data that align with the existing data can be extracted, stored, and made available for processing with existing data processing methods. Alternatively, data processing methods may be configured to process portions of the streamed data that correspond, such as through alignment, to the existing data, with methods that implement functions substantially similar to the methods used to process existing data, such as methods that process data that contain a particular frequency range or a particular resolution and the like.

[0283] Methods used to process existing data may be associated with certain characteristics of sensed data, such as certain frequency ranges, sources of data, and the like. As an example, methods for processing bearing sensing information for a moving part of an industrial machine may be capable of processing data from bearing sensors that fall into a particular frequency range. This method can thusly be at least partially identifiable by these characteristics of the data being processed. Therefore, given a set of conditions, such as moving device being sensed, industrial machine type, frequency of data being sensed, and the like, a data processing system may select an appropriate method. Also, given such a set of conditions, an industrial machine data sensing and processing facility may configure elements, such as data filters, routers, processors, and the like, to handle data meeting the conditions.

[0284] Figures 1 through 5 depict portions of an overall view of an industrial IoT data collection, monitoring and control system 10. Figure 2 depicts a mobile ad hoc network ("MANET") 20, which may form a secure, temporal network connection 22 (sometimes connected and sometimes isolated), with a cloud 30 or other remote networking system, so that network functions may occur over the MANET 20 within the environment, without the need for external networks, but at other

times information can be sent to and from a central location. This allows the industrial environment to use the benefits of networking and control technologies, while also providing security, such as preventing cyber-attacks. The MANET 20 may use cognitive radio technologies 40, including those that form up an equivalent to the IP protocol, such as router 42, MAC 44, and physical layer technologies 46. In certain embodiments, the system depicted in Figures 1 through 5 provides network-sensitive or network-aware transport of data over the network to and from a data collection device or a heavy industrial machine.

[0285] Figures 3-4 depict intelligent data collection technologies deployed locally, at the edge of an IoT deployment, where heavy industrial machines are located. This includes various sensors 52, IoT devices 54, data storage capabilities (e.g., data pools 60, or distributed ledger 62) (including intelligent, self-organizing storage), sensor fusion (including self-organizing sensor fusion), and the like. Interfaces for data collection, including multi-sensory interfaces, tablets, smartphones 58, and the like are shown. Figure 3 also shows the data pools 60 that may collect data published by machines or sensors that detect conditions of machines, such as for later consumption by local or remote intelligence. A distributed ledger system 62 may distribute storage across the local storage of various elements of the environment, or more broadly throughout the system. Figure 4 also shows on-device sensor fusion 80, such as for storing on a device data from multiple analog sensors 82, which may be analyzed locally or in the cloud, such as by machine learning 84, including by training a machine based on initial models created by humans that are augmented by providing feedback (such as based on measures of success) when operating the methods and systems disclosed herein.

[0286] Figure 1 depicts a server based portion of an industrial IoT system that may be deployed in the cloud or on an enterprise owner's or operator's premises. The server portion includes network coding (including self-organizing network coding and/or automated configuration) that may configure a network coding model based on feedback measures, network conditions, or the like, for highly efficient transport of large amounts of data across the network to and from data collection systems and the cloud. Network coding may provide a wide range of capabilities for intelligence, analytics, remote control, remote operation, remote optimization, various storage configurations and the like, as depicted in Figure 1. The various storage configurations may include distributed ledger storage for supporting transactional data or other elements of the system.

[0287] Figure 5 depicts a programmatic data marketplace 70, which may be a self-organizing marketplace, such as for making available data that is collected in industrial environments, such as from data collectors, data pools, distributed ledgers, and other elements disclosed herein. Additional detail on the various components and sub-components of Figures 1 through 5 is provided throughout this disclosure.

[0288] With reference to Figure 6, an embodiment of platform 100 may include a local data collection system 102, which may be disposed in an environment 104, such as an industrial environment similar to that shown in Figure 3, for collecting data from or about the elements of the environment, such as machines, components, systems, sub-systems, ambient conditions, states, workflows, processes, and other elements. The platform 100 may connect to or include portions of the industrial IoT data collection, monitoring and control system 10 depicted in Figures 1-5. The platform 100 may include a network data transport system 108, such as for transporting data to and from the local data collection system 102 over a network 110, such as to a host processing system 112, such as one that is disposed in a cloud computing environment or on the premises of an enterprise, or that consists of distributed components that interact with each other to process data collected by the local data collection system 102. The host processing system 112, referred to for convenience in some cases as the host system 112, may include various systems, components, methods, processes, facilities, and the like for enabling automated, or automation-assisted processing of the data, such as for monitoring one or more environments 104 or networks 110 or for remotely controlling one or more elements in a local environment 104 or in the network 110. The platform 100 may include one or more local autonomous systems, such as for enabling autonomous behavior, such as reflecting artificial, or machine-based intelligence or such as enabling automated action based on the applications of a set of rules or models upon input data from the local data collection system 102 or from one or more input sources 116, which may comprise information feeds and inputs from a wide array of sources, including those in the local environment 104, in the network 110, in the host system 112, or in one or more external systems, databases, or the like. The platform 100 may include one or more intelligent systems 118, which may be disposed in, integrated with, or acting as inputs to one or more components of the platform 100. Details of these and other components of the platform 100 are provided throughout this disclosure.

[0289] Intelligent systems 118 may include cognitive systems 120, such as enabling a degree of cognitive behavior as a result of the coordination of processing elements, such as mesh, peer-to-peer, ring, serial, and other architectures, where one or more node elements is coordinated with other node elements to provide collective, coordinated behavior to assist in processing, communication, data collection, or the like. The MANET 20 depicted in Figure 2 may also use cognitive radio technologies, including those that form up an equivalent to the IP protocol, such as router 42, MAC 44, and physical layer technologies 46. In one example, the cognitive system technology stack can include examples disclosed in U.S. Patent Number 8,060,017 to Schlicht et al., issued 15 November 2011 and hereby incorporated by reference as if fully set forth herein.

[0290] Intelligent systems may include machine learning systems 122, such as for learning on one or more data sets. The one or more data sets may include information collected using local data collection systems 102 or other information from input sources 116, such as to recognize states, objects, events, patterns, conditions, or the like that may, in turn, be used for processing by the host system 112 as inputs to components of the platform 100 and portions of the industrial IoT data collection, monitoring and control system 10, or the like. Learning may be human-supervised or fully-automated, such as using one or more input sources 116 to provide a data set, along with information about the item to be learned. Machine learning may use one or more models, rules, semantic understandings, workflows, or other structured or semi-structured understanding of the world, such as for automated optimization of control of a system or process based on feedback or feed forward to an operating model for the system or process. One such machine learning technique for semantic and contextual understandings, workflows, or other structured or semi-structured understandings is disclosed in U.S. Patent Number 8,200,775 to Moore, issued 12 June 2012, and hereby incorporated by reference as if fully set forth herein. Machine learning may be used to improve the foregoing, such as by adjusting one or more weights, structures, rules, or the like (such as changing a function within a model) based on feedback (such as regarding the success of a model in a given situation) or based on iteration (such as in a recursive process). Where sufficient understanding of the underlying structure or behavior of a system is not known, insufficient data is not available, or in other cases where preferred for various reasons, machine learning may also be undertaken in the absence of an underlying model; that is, input sources may be weighted, structured, or the like within a machine learning facility without regard to any a priori understanding of structure, and outcomes (such as those based on measures of success at accomplishing various desired objectives) can be serially fed to the machine learning system to allow it to learn how to achieve the targeted objectives. For example, the system may learn to recognize faults, to recognize patterns, to develop models or functions, to develop rules, to optimize performance, to minimize failure rates, to optimize profits, to optimize resource utilization, to optimize flow (such as flow of traffic), or to optimize many other parameters that may be relevant to successful outcomes (such as outcomes in a wide range of environments). Machine learning may use genetic programming techniques, such as promoting or demoting one or more input sources, structures, data types, objects, weights, nodes, links, or other factors based on feedback (such that successful elements emerge over a series of generations). For example, alternative available sensor inputs for the data collection system 102 may be arranged in alternative configurations and permutations, such that the system may, using generic programming techniques over a series of data collection events, determine what permutations provide successful outcomes based on various conditions (such as conditions of components of the platform 100, conditions of

the network 110, conditions of the data collection system 102, conditions of an environment 104), or the like. In embodiments, local machine learning may turn on or off one or more sensors in a multi-sensor data collector 102 in permutations over time, while tracking success outcomes such as contributing to success in predicting a failure, contributing to a performance indicator (such as efficiency, effectiveness, return on investment, yield, or the like), contributing to optimization of one or more parameters, identification of a pattern (such as relating to a threat, a failure mode, a success mode, or the like) or the like. For example, a system may learn what sets of sensors should be turned on or off under given conditions to achieve the highest value utilization of a data collector 102. In embodiments, similar techniques may be used to handle optimization of transport of data in the platform 100 (such as in the network 110) by using generic programming or other machine learning techniques to learn to configure network elements (such as configuring network transport paths, configuring network coding types and architectures, configuring network security elements), and the like.

[0291] In embodiments, the local data collection system 102 may include a high-performance, multi-sensor data collector having a number of novel features for collection and processing of analog and other sensor data. In embodiments, the local data collection system 102 may be deployed to the industrial facilities depicted in Figure 3. A local data collection system 102 may also be deployed to monitor other machines such as a machine 2300 in Figure 9 and Figure 10, the machines 2400, 2600, 2800, 2950, 3000 depicted in Figure 12, and the machines 3202, 3204 depicted in Figure 13. The data collection system 102 may have on-board intelligent systems 118 (such as for learning to optimize the configuration and operation of the data collector, such as configuring permutations and combinations of sensors based on contexts and conditions). In one example, the data collection system 102 includes a crosspoint switch 130 or other analog switches. Automated, intelligent configuration of the local data collection system 102 may be based on a variety of types of information, such as information from various input sources, including those based on available power, power requirements of sensors, the value of the data collected (such as based on feedback information from other elements of the platform 100), the relative value of information (such as values based on the availability of other sources of the same or similar information), power availability (such as for powering sensors), network conditions, ambient conditions, operating states, operating contexts, operating events, and many others.

[0292] Figure 7 shows elements and sub-components of a data collection and analysis system 1100 for sensor data (such as analog sensor data) collected in industrial environments. As depicted in Figure 7, embodiments of the methods and systems disclosed herein may include hardware that has several different modules starting with the multiplexer ("MUX") main board 1104. In embodiments, there may be a MUX option board 1108. The MUX 114 main board is where the

sensors connect to the system. These connections are on top to enable ease of installation. Then there are numerous settings on the underside of this board as well as on the Mux option board 1108, which attaches to the MUX main board 1104 via two headers one at either end of the board. In embodiments, the Mux option board has the male headers, which mesh together with the female header on the main Mux board. This enables them to be stacked on top of each other taking up less real estate.

[0293] In embodiments, the main Mux board and/or the MUX option board then connects to the mother (e.g., with 4 simultaneous channels) and daughter (e.g., with 4 additional channels for 8 total channels) analog boards 1110 via cables where some of the signal conditioning (such as hardware integration) occurs. The signals then move from the analog boards 1110 to an anti-aliasing board (not shown) where some of the potential aliasing is removed. The rest of the aliasing removal is done on the delta sigma board 1112. The delta sigma board 1112 provides more aliasing protection along with other conditioning and digitizing of the signal. Next, the data moves to the Jennic™ board 1114 for more digitizing as well as communication to a computer via USB or Ethernet. In embodiments, the Jennic™ board 1114 may be replaced with a pic board 1118 for more advanced and efficient data collection as well as communication. Once the data moves to the computer software 1102, the computer software 1102 can manipulate the data to show trending, spectra, waveform, statistics, and analytics.

[0294] In embodiments, the system is meant to take in all types of data from volts to 4-20 mA signals. In embodiments, open formats of data storage and communication may be used. In some instances, certain portions of the system may be proprietary especially some of research and data associated with the analytics and reporting. In embodiments, smart band analysis is a way to break data down into easily analyzed parts that can be combined with other smart bands to make new more simplified yet sophisticated analytics. In embodiments, this unique information is taken and graphics are used to depict the conditions because picture depictions are more helpful to the user. In embodiments, complicated programs and user interfaces are simplified so that any user can manipulate the data like an expert.

[0295] In embodiments, the system in essence, works in a big loop. The system starts in software with a general user interface ("GUI") 1124. In embodiments, rapid route creation may take advantage of hierarchical templates. In embodiments, a GUI is created so any general user can populate the information itself with simple templates. Once the templates are created the user can copy and paste whatever the user needs. In addition, users can develop their own templates for future ease of use and to institutionalize the knowledge. When the user has entered all of the user's information and connected all of the user's sensors, the user can then start the system acquiring data.

[0296] Embodiments of the methods and systems disclosed herein may include unique electrostatic protection for trigger and vibration inputs. In many critical industrial environments where large electrostatic forces, which can harm electrical equipment, may build up, for example rotating machinery or low-speed balancing using large belts, proper transducer and trigger input protection is required. In embodiments, a low-cost but efficient method is described for such protection without the need for external supplemental devices.

[0297] Typically, vibration data collectors are not designed to handle large input voltages due to the expense and the fact that, more often than not, it is not needed. A need exists for these data collectors to acquire many varied types of RPM data as technology improves and monitoring costs plummet. In embodiments, a method is using the already established OptoMOS™ technology which permits the switching up front of high voltage signals rather than using more conventional reed-relay approaches. Many historic concerns regarding non-linear zero crossing or other non-linear solid-state behaviors have been eliminated with regard to the passing through of weakly buffered analog signals. In addition, in embodiments, printed circuit board routing topologies place all of the individual channel input circuitry as close to the input connector as possible. In embodiments, a unique electrostatic protection for trigger and vibration inputs may be placed upfront on the Mux and DAQ hardware in order to dissipate the built up electric charge as the signal passed from the sensor to the hardware. In embodiments, the Mux and analog board may support high-amperage input using a design topology comprising wider traces and solid state relays for upfront circuitry.

[0298] In some systems multiplexers are afterthoughts and the quality of the signal coming from the multiplexer is not considered. As a result of a poor quality multiplexer, the quality of the signal can drop as much as 30 dB or more. Thus, substantial signal quality may be lost using a 24-bit DAQ that has a signal to noise ratio of 110 dB and if the signal to noise ratio drops to 80 dB in the Mux, it may not be much better than a 16-bit system from 20 years ago. In embodiments of this system, an important part at the front of the Mux is upfront signal conditioning on Mux for improved signal-to-noise ratio. Embodiments may perform signal conditioning (such as range/gain control, integration, filtering, etc.) on vibration as well as other signal inputs up front before Mux switching to achieve the highest signal-to-noise ratio.

[0299] In embodiments, in addition to providing a better signal, the multiplexer may provide a continuous monitor alarming feature. Truly continuous systems monitor every sensor all the time but tend to be expensive. Typical multiplexer systems only monitor a set number of channels at one time and switch from bank to bank of a larger set of sensors. As a result, the sensors not being currently collected are not being monitored; if a level increases the user may never know. In embodiments, a multiplexer may have a continuous monitor alarming feature by placing circuitry

on the multiplexer that can measure input channel levels against known alarm conditions even when the data acquisition ("DAQ") is not monitoring the input. In embodiments, continuous monitoring Mux bypass offers a mechanism whereby channels not being currently sampled by the Mux system may be continuously monitored for significant alarm conditions via a number of trigger conditions using filtered peak-hold circuits or functionally similar that are in turn passed on to the monitoring system in an expedient manner using hardware interrupts or other means. This, in essence, makes the system continuously monitoring, although without the ability to instantly capture data on the problem like a true continuous system. In embodiments, coupling this capability to alarm with adaptive scheduling techniques for continuous monitoring and the continuous monitoring system's software adapting and adjusting the data collection sequence based on statistics, analytics, data alarms and dynamic analysis may allow the system to quickly collect dynamic spectral data on the alarming sensor very soon after the alarm sounds.

[0300] Another restriction of typical multiplexers is that they may have a limited number of channels. In embodiments, use of distributed complex programmable logic device ("CPLD") chips with dedicated bus for logic control of multiple Mux and data acquisition sections enables a CPLD to control multiple mux and DAQs so that there is no limit to the number of channels a system can handle. Interfacing to multiple types of predictive maintenance and vibration transducers requires a great deal of switching. This includes AC/DC coupling, 4-20 interfacing, integrated electronic piezoelectric transducer, channel power-down (for conserving op-amp power), single-ended or differential grounding options, and so on. Also required is the control of digital pots for range and gain control, switches for hardware integration, AA filtering and triggering. This logic can be performed by a series of CPLD chips strategically located for the tasks they control. A single giant CPLD requires long circuit routes with a great deal of density at the single giant CPLD. In embodiments, distributed CPLDs not only address these concerns but offer a great deal of flexibility. A bus is created where each CPLD that has a fixed assignment has its own unique device address. In embodiments, multiplexers and DAQs can stack together offering additional input and output channels to the system. For multiple boards (e.g., for multiple Mux boards), jumpers are provided for setting multiple addresses. In another example, three bits permit up to 8 boards that are jumper configurable. In embodiments, a bus protocol is defined such that each CPLD on the bus can either be addressed individually or as a group.

[0301] Typical multiplexers may be limited to collecting only sensors in the same bank. For detailed analysis, this may be limiting as there is tremendous value in being able to simultaneously review data from sensors on the same machine. Current systems using conventional fixed bank multiplexers can only compare a limited number of channels (based on the number of channels per bank) that were assigned to a particular group at the time of installation. The only way to provide

some flexibility is to either overlap channels or incorporate lots of redundancy in the system both of which can add considerable expense (in some cases an exponential increase in cost versus flexibility). The simplest Mux design selects one of many inputs and routes it into a single output line. A banked design would consist of a group of these simple building blocks, each handling a fixed group of inputs and routing to its respective output. Typically, the inputs are not overlapping so that the input of one Mux grouping cannot be routed into another. Unlike conventional Mux chips which typically switch a fixed group or banks of a fixed selection of channels into a single output (e.g., in groups of 2, 4, 8, etc.), a cross point Mux allows the user to assign any input to any output. Previously, crosspoint multiplexers were used for specialized purposes such as RGB digital video applications and were as a practical matter too noisy for analog applications such as vibration analysis; however more recent advances in the technology now make it feasible. Another advantage of the crosspoint Mux is the ability to disable outputs by putting them into a high impedance state. This is ideal for an output bus so that multiple Mux cards may be stacked, and their output buses joined together without the need for bus switches.

[0302] In embodiments, this may be addressed by use of an analog crosspoint switch for collecting variable groups of vibration input channels and providing a matrix circuit, so the system may access any set of eight channels from the total number of input sensors.

[0303] In embodiments, the ability to control multiple multiplexers with use of distributed CPLD chips with dedicated bus for logic control of multiple Mux and data acquisition sections is enhanced with a hierarchical multiplexer which allows for multiple DAQ to collect data from multiple multiplexers. A hierarchical Mux may allow modularly output of more channels, such as 16, 24 or more to multiple of eight channel card sets. In embodiments, this allows for faster data collection as well as more channels of simultaneous data collection for more complex analysis. In embodiments, the Mux may be configured slightly to make it portable and use data acquisition parking features, which turns SV3X DAQ into a protected system embodiment.

[0304] In embodiments, once the signals leave the multiplexer and hierarchical Mux they move to the analog board where there are other enhancements. In embodiments, power saving techniques may be used such as: power-down of analog channels when not in use; powering down of component boards; power-down of analog signal processing op-amps for non-selected channels; powering down channels on the mother and the daughter analog boards. The ability to power down component boards and other hardware by the low-level firmware for the DAQ system makes high-level application control with respect to power-saving capabilities relatively easy. Explicit control of the hardware is always possible but not required by default. In embodiments, this power saving benefit may be of value to a protected system, especially if it is battery operated or solar powered.

[0305] In embodiments, in order to maximize the signal to noise ratio and provide the best data, a peak-detector for auto-scaling routed into a separate A/D will provide the system the highest peak in each set of data so it can rapidly scale the data to that peak. For vibration analysis purposes, the built-in A/D converters in many microprocessors may be inadequate with regards to number of bits, number of channels or sampling frequency versus not slowing the microprocessor down significantly. Despite these limitations, it is useful to use them for purposes of auto-scaling. In embodiments, a separate A/D may be used that has reduced functionality and is cheaper. For each channel of input, after the signal is buffered (usually with the appropriate coupling: AC or DC) but before it is signal conditioned, the signal is fed directly into the microprocessor or low-cost A/D. Unlike the conditioned signal for which range, gain and filter switches are thrown, no switches are varied. This permits the simultaneous sampling of the auto-scaling data while the input data is signal conditioned, fed into a more robust external A/D, and directed into on-board memory using direct memory access (DMA) methods where memory is accessed without requiring a CPU. This significantly simplifies the auto-scaling process by not having to throw switches and then allow for settling time, which greatly slows down the auto-scaling process. Furthermore, the data may be collected simultaneously, which assures the best signal-to-noise ratio. The reduced number of bits and other features is usually more than adequate for auto-scaling purposes. In embodiments, improved integration using both analog and digital methods create an innovative hybrid integration which also improves or maintains the highest possible signal to noise ratio.

[0306] In embodiments, a section of the analog board may allow routing of a trigger channel, either raw or buffered, into other analog channels. This may allow a user to route the trigger to any of the channels for analysis and trouble shooting. Systems may have trigger channels for the purposes of determining relative phase between various input data sets or for acquiring significant data without the needless repetition of unwanted input. In embodiments, digitally controlled relays may be used to switch either the raw or buffered trigger signal into one of the input channels. It may be desirable to examine the quality of the triggering pulse because it may be corrupted for a variety of reasons including inadequate placement of the trigger sensor, wiring issues, faulty setup issues such as a dirty piece of reflective tape if using an optical sensor, and so on. The ability to look at either the raw or buffered signal may offer an excellent diagnostic or debugging vehicle. It also can offer some improved phase analysis capability by making use of the recorded data signal for various signal processing techniques such as variable speed filtering algorithms.

[0307] In embodiments, once the signals leave the analog board, the signals move into the delta-sigma board where precise voltage reference for A/D zero reference offers more accurate direct current sensor data. The delta sigma's high speeds also provide for using higher input oversampling for delta-sigma A/D for lower sampling rate outputs to minimize antialiasing filter

requirements. Lower oversampling rates can be used for higher sampling rates. For example, a 3rd order AA filter set for the lowest sampling requirement for 256 Hz (Fmax of 100 Hz) is then adequate for Fmax ranges of 200 and 500 Hz. Another higher-cutoff AA filter can then be used for Fmax ranges from 1 kHz and higher (with a secondary filter kicking in at 2.56x the highest sampling rate of 128 kHz). In embodiments, a CPLD may be used as a clock-divider for a delta-sigma A/D to achieve lower sampling rates without the need for digital resampling. In embodiments, a high-frequency crystal reference can be divided down to lower frequencies by employing a CPLD as a programmable clock divider. The accuracy of the divided down lower frequencies is even more accurate than the original source relative to their longer time periods. This also minimizes or removes the need for resampling processing by the delta-sigma A/D.

[0308] In embodiments, the data then moves from the delta-sigma board to the Jennic™ board where phase relative to input and trigger channels using on-board timers may be digitally derived. In embodiments, the Jennic™ board also has the ability to store calibration data and system maintenance repair history data in an on-board card set. In embodiments, the Jennic™ board will enable acquiring long blocks of data at high-sampling rate as opposed to multiple sets of data taken at different sampling rates so it can stream data and acquire long blocks of data for advanced analysis in the future.

[0309] In embodiments, after the signal moves through the Jennic™ board it may then be transmitted to the computer. In embodiments, the computer software will be used to add intelligence to the system starting with an expert system GUI. The GUI may offer a graphical expert system with simplified user interface for defining smart bands and diagnoses which facilitate anyone to develop complex analytics. In embodiments, this user interface may revolve around smart bands, which are a simplified approach to complex yet flexible analytics for the general user. In embodiments, the smart bands may pair with a self-learning neural network for an even more advanced analytical approach. In embodiments, this system may use the machine's hierarchy for additional analytical insight. One critical part of predictive maintenance is the ability to learn from known information during repairs or inspections. In embodiments, graphical approaches for back calculations may improve the smart bands and correlations based on a known fault or problem.

[0310] In embodiments, there is a smart route which adapts which sensors it collects simultaneously in order to gain additional correlative intelligence. In embodiments, smart operational data store ("ODS") allows the system to elect to gather data to perform operational deflection shape analysis in order to further examine the machinery condition. In embodiments, adaptive scheduling techniques allow the system to change the scheduled data collected for full spectral analysis across a number (e.g., eight), of correlative channels. In embodiments, the system

may provide data to enable extended statistics capabilities for continuous monitoring as well as ambient local vibration for analysis that combines ambient temperature and local temperature and vibration level changes for identifying machinery issues.

[0311] In embodiments, a data acquisition device may be controlled by a personal computer (PC) to implement the desired data acquisition commands. In embodiments, the DAQ box may be self-sufficient. and can acquire, process, analyze and monitor independent of external PC control. Embodiments may include secure digital (SD) card storage. In embodiments, significant additional storage capability may be provided by utilizing an SD card. This may prove critical for monitoring applications where critical data may be stored permanently. Also, if a power failure should occur, the most recent data may be stored despite the fact that it was not off-loaded to another system.

[0312] A current trend has been to make DAQ systems as communicative as possible with the outside world usually in the form of networks including wireless. In the past it was common to use a dedicated bus to control a DAQ system with either a microprocessor or microcontroller/microprocessor paired with a PC. In embodiments, a DAQ system may comprise one or more microprocessor/microcontrollers, specialized microcontrollers/microprocessors, or dedicated processors focused primarily on the communication aspects with the outside world. These include USB, Ethernet and wireless with the ability to provide an IP address or addresses in order to host a webpage. All communications with the outside world are then accomplished using a simple text based menu. The usual array of commands (in practice more than a hundred) such as InitializeCard, AcquireData, StopAcquisition, RetrieveCalibration Info, and so on, would be provided.

[0313] In embodiments, intense signal processing activities including resampling, weighting, filtering, and spectrum processing may be performed by dedicated processors such as field-programmable gate array ("FPGAs"), digital signal processor ("DSP"), microprocessors, micro-controllers, or a combination thereof. In embodiments, this subsystem may communicate via a specialized hardware bus with the communication processing section. It will be facilitated with dual-port memory, semaphore logic, and so on. This embodiment will not only provide a marked improvement in efficiency but can significantly improve the processing capability, including the streaming of the data as well other high-end analytical techniques. This negates the need for constantly interrupting the main processes which include the control of the signal conditioning circuits, triggering, raw data acquisition using the A/D, directing the A/D output to the appropriate on-board memory and processing that data.

[0314] Embodiments may include sensor overload identification. A need exists for monitoring systems to identify when the sensor is overloading. There may be situations involving high-frequency inputs that will saturate a standard 100 mv/g sensor (which is most commonly used in

the industry) and having the ability to sense the overload improves data quality for better analysis. A monitoring system may identify when their system is overloading, but in embodiments, the system may look at the voltage of the sensor to determine if the overload is from the sensor, enabling the user to get another sensor better suited to the situation, or gather the data again.

[0315] Embodiments may include radio frequency identification ("RFID") and an inclinometer or accelerometer on a sensor so the sensor can indicate what machine/bearing it is attached to and what direction such that the software can automatically store the data without the user input. In embodiments, users could put the system on any machine or machines and the system would automatically set itself up and be ready for data collection in seconds.

[0316] Embodiments may include ultrasonic online monitoring by placing ultrasonic sensors inside transformers, motor control centers, breakers and the like and monitoring, via a sound spectrum, continuously looking for patterns that identify arcing, corona and other electrical issues indicating a break down or issue. Embodiments may include providing continuous ultrasonic monitoring of rotating elements and bearings of an energy production facility. In embodiments, an analysis engine may be used in ultrasonic online monitoring as well as identifying other faults by combining the ultrasonic data with other parameters such as vibration, temperature, pressure, heat flux, magnetic fields, electrical fields, currents, voltage, capacitance, inductance, and combinations (e.g., simple ratios) of the same, among many others.

[0317] Embodiments of the methods and systems disclosed herein may include use of an analog crosspoint switch for collecting variable groups of vibration input channels. For vibration analysis, it is useful to obtain multiple channels simultaneously from vibration transducers mounted on different parts of a machine (or machines) in multiple directions. By obtaining the readings at the same time, for example, the relative phases of the inputs may be compared for the purpose of diagnosing various mechanical faults. Other types of cross channel analyses such as cross-correlation, transfer functions, Operating Deflection Shape ("ODS") may also be performed.

[0318] Embodiments of the methods and systems disclosed herein may include precise voltage reference for A/D zero reference. Some A/D chips provide their own internal zero voltage reference to be used as a mid-scale value for external signal conditioning circuitry to ensure that both the A/D and external op-amps use the same reference. Although this sounds reasonable in principle, there are practical complications. In many cases these references are inherently based on a supply voltage using a resistor-divider. For many current systems, especially those whose power is derived from a PC via USB or similar bus, this provides for an unreliable reference, as the supply voltage will often vary quite significantly with load. This is especially true for delta-sigma A/D chips which necessitate increased signal processing. Although the offsets may drift together with load, a problem arises if one wants to calibrate the readings digitally. It is typical to

modify the voltage offset expressed as counts coming from the A/D digitally to compensate for the DC drift. However, for this case, if the proper calibration offset is determined for one set of loading conditions, they will not apply for other conditions. An absolute DC offset expressed in counts will no longer be applicable. As a result, it becomes necessary to calibrate for all loading conditions which becomes complex, unreliable, and ultimately unmanageable. In embodiments, an external voltage reference is used which is simply independent of the supply voltage to use as the zero offset.

[0319] In embodiments, the system provides a phase-lock-loop band pass tracking filter method for obtaining slow-speed RPMs and phase for balancing purposes to remotely balance slow speed machinery, such as in paper mills, as well as offering additional analysis from its data. For balancing purposes, it is sometimes necessary to balance at very slow speeds. A typical tracking filter may be constructed based on a phase-lock loop or PLL design; however, stability and speed range are overriding concerns. In embodiments, a number of digitally controlled switches are used for selecting the appropriate RC and damping constants. The switching can be done all automatically after measuring the frequency of the incoming tach signal. Embodiments of the methods and systems disclosed herein may include digital derivation of phase relative to input and trigger channels using on-board timers. In embodiments, digital phase derivation uses digital timers to ascertain an exact delay from a trigger event to the precise start of data acquisition. This delay, or offset, then, is further refined using interpolation methods to obtain an even more precise offset which is then applied to the analytically determined phase of the acquired data such that the phase is "in essence" an absolute phase with precise mechanical meaning useful for among other things, one-shot balancing, alignment analysis, and so on.

[0320] Embodiments of the methods and systems disclosed herein may include signal processing firmware/hardware. In embodiments, long blocks of data may be acquired at high-sampling rate as opposed to multiple sets of data taken at different sampling rates. Typically, in modern route collection for vibration analysis, it is customary to collect data at a fixed sampling rate with a specified data length. The sampling rate and data length may vary from route point to point based on the specific mechanical analysis requirements at hand. For example, a motor may require a relatively low sampling rate with high resolution to distinguish running speed harmonics from line frequency harmonics. The practical trade-off here though is that it takes more collection time to achieve this improved resolution. In contrast, some high-speed compressors or gear sets require much higher sampling rates to measure the amplitudes of relatively higher frequency data although the precise resolution may not be as necessary. Ideally, however, it would be better to collect a very long sample length of data at a very high-sampling rate. When digital acquisition devices were first popularized in the early 1980's, the A/D sampling, digital storage, and computational

abilities were not close to what they are today, so compromises were made between the time required for data collection and the desired resolution and accuracy. It was because of this limitation that some analysts in the field even refused to give up their analog tape recording systems, which did not suffer as much from these same digitizing drawbacks. A few hybrid systems were employed that would digitize the play back of the recorded analog data at multiple sampling rates and lengths desired, though these systems were admittedly less automated. The more common approach, as mentioned earlier, is to balance data collection time with analysis capability and digitally acquire the data blocks at multiple sampling rates and sampling lengths and digitally store these blocks separately. In embodiments, a long data length of data can be collected at the highest practical sampling rate (e.g., 102.4 kHz; corresponding to a 40 kHz Fmax) and stored. This long block of data can be acquired in the same amount of time as the shorter length of the lower sampling rates utilized by a priori methods so that there is no effective delay added to the sampling at the measurement point, always a concern in route collection. In embodiments, analog tape recording of data is digitally simulated with such a precision that it can be in effect considered continuous or "analog" for many purposes, including for purposes of embodiments of the present disclosure, except where context indicates otherwise.

[0321] Embodiments of the methods and systems disclosed herein may include storage of calibration data and maintenance history on-board card sets. Many data acquisition devices which rely on interfacing to a PC to function store their calibration coefficients on the PC. This is especially true for complex data acquisition devices whose signal paths are many and therefore whose calibration tables can be quite large. In embodiments, calibration coefficients are stored in flash memory which will remember this data or any other significant information for that matter, for all practical purposes, permanently. This information may include nameplate information such as serial numbers of individual components, firmware or software version numbers, maintenance history, and the calibration tables. In embodiments, no matter which computer the box is ultimately connected to, the DAQ box remains calibrated and continues to hold all of this critical information. The PC or external device may poll for this information at any time for implantation or information exchange purposes.

[0322] Embodiments of the methods and systems disclosed herein may include rapid route creation taking advantage of hierarchical templates. In the field of vibration monitoring, as well as parametric monitoring in general, it is necessary to establish in a database or functional equivalent the existence of data monitoring points. These points are associated with a variety of attributes including the following categories: transducer attributes, data collection settings, machinery parameters and operating parameters. The transducer attributes would include probe type, probe mounting type and probe mounting direction or axis orientation. Data collection attributes

associated with the measurement would involve a sampling rate, data length, integrated electronic piezoelectric probe power and coupling requirements, hardware integration requirements, 4-20 or voltage interfacing, range and gain settings (if applicable), filter requirements, and so on. Machinery parametric requirements relative to the specific point would include such items as operating speed, bearing type, bearing parametric data which for a rolling element bearing includes the pitch diameter, number of balls, inner race, and outer-race diameters. For a tilting pad bearing, this would include the number of pads and so on. For measurement points on a piece of equipment such as a gearbox, needed parameters would include, for example, the number of gear teeth on each of the gears. For induction motors, it would include the number of rotor bars and poles; for compressors, the number of blades and/or vanes; for fans, the number of blades. For belt/pulley systems, the number of belts as well as the relevant belt-passing frequencies may be calculated from the dimensions of the pulleys and pulley center-to-center distance. For measurements near couplings, the coupling type and number of teeth in a geared coupling may be necessary, and so on. Operating parametric data would include operating load, which may be expressed in megawatts, flow (either air or fluid), percentage, horsepower, feet-per-minute, and so on. Operating temperatures both ambient and operational, pressures, humidity, and so on, may also be relevant. As can be seen, the setup information required for an individual measurement point can be quite large. It is also crucial to performing any legitimate analysis of the data. Machinery, equipment, and bearing specific information are essential for identifying fault frequencies as well as anticipating the various kinds of specific faults to be expected. The transducer attributes as well as data collection parameters are vital for properly interpreting the data along with providing limits for the type of analytical techniques suitable. The traditional means of entering this data has been manual and quite tedious, usually at the lowest hierarchical level (for example, at the bearing level with regards to machinery parameters), and at the transducer level for data collection setup information. It cannot be stressed enough, however, the importance of the hierarchical relationships necessary to organize data— both for analytical and interpretive purposes as well as the storage and movement of data. Here, we are focusing primarily on the storage and movement of data. By its nature, the aforementioned setup information is extremely redundant at the level of the lowest hierarchies; however, because of its strong hierarchical nature, it can be stored quite efficiently in that form. In embodiments, hierarchical nature can be utilized when copying data in the form of templates. As an example, hierarchical storage structure suitable for many purposes is defined from general to specific of company, plant or site, unit or process, machine, equipment, shaft element, bearing, and transducer. It is much easier to copy data associated with a particular machine, piece of equipment, shaft element or bearing than it is to copy only at the lowest transducer level. In embodiments, the system not only stores data in this hierarchical fashion, but

robustly supports the rapid copying of data using these hierarchical templates. Similarity of elements at specific hierarchical levels lends itself to effective data storage in hierarchical format. For example, so many machines have common elements such as motors, gearboxes, compressors, belts, fans, and so on. More specifically, many motors can be easily classified as induction, DC, fixed or variable speed. Many gearboxes can be grouped into commonly occurring groupings such as input/output, input pinion/intermediate pinion/output pinion, 4-posters, and so on. Within a plant or company, there are many similar types of equipment purchased and standardized on for both cost and maintenance reasons. This results in an enormous overlapping of similar types of equipment and, as a result, offers a great opportunity for taking advantage of a hierarchical template approach.

[0323] Embodiments of the methods and systems disclosed herein may include smart bands. Smart bands refer to any processed signal characteristics derived from any dynamic input or group of inputs for the purposes of analyzing the data and achieving the correct diagnoses. Furthermore, smart bands may even include mini or relatively simple diagnoses for the purposes of achieving a more robust and complex one. Historically, in the field of mechanical vibration analysis, Alarm Bands have been used to define spectral frequency bands of interest for the purposes of analyzing and/or trending significant vibration patterns. The Alarm Band typically consists of a spectral (amplitude plotted against frequency) region defined between a low and high frequency border. The amplitude between these borders is summed in the same manner for which an overall amplitude is calculated. A Smart Band is more flexible in that it not only refers to a specific frequency band but can also refer to a group of spectral peaks such as the harmonics of a single peak, a true-peak level or crest factor derived from a time waveform, an overall derived from a vibration envelope spectrum or other specialized signal analysis technique or a logical combination (AND, OR, XOR, etc.) of these signal attributes. In addition, a myriad assortment of other parametric data, including system load, motor voltage and phase information, bearing temperature, flow rates, and the like, can likewise be used as the basis for forming additional smart bands. In embodiments, Smart Band symptoms may be used as building blocks for an expert system whose engine would utilize these inputs to derive diagnoses. Some of these mini-diagnoses may then in turn be used as Smart-Band symptoms (smart bands can include even diagnoses) for more generalized diagnoses.

[0324] Embodiments of the methods and systems disclosed herein may include a neural net expert system using smart bands. Typical vibration analysis engines are rule-based (i.e., they use a list of expert rules which, when met, trigger specific diagnoses). In contrast, a neural approach utilizes the weighted triggering of multiple input stimuli into smaller analytical engines or neurons which in turn feed a simplified weighted output to other neurons. The output of these neurons can

be also classified as smart bands which in turn feed other neurons. This produces a more layered approach to expert diagnosing as opposed to the one-shot approach of a rule-based system. In embodiments, the expert system utilizes this neural approach using smart bands; however, it does not preclude rule-based diagnoses being reclassified as smart bands as further stimuli to be utilized by the expert system. From this point-of-view, it can be overviewed as a hybrid approach, although at the highest level it is essentially neural.

[0325] Embodiments of the methods and systems disclosed herein may include use of database hierarchy in analysis smart band symptoms and diagnoses may be assigned to various hierarchical database levels. For example, a smart band may be called "Looseness" at the bearing level, trigger "Looseness" at the equipment level, and trigger "Looseness" at the machine level. Another example would be having a smart band diagnosis called "Horizontal Plane Phase Flip" across a coupling and generate a smart band diagnosis of "Vertical Coupling Misalignment" at the machine level.

[0326] Embodiments of the methods and systems disclosed herein may include expert system GUIs. In embodiments, the system undertakes a graphical approach to defining smart bands and diagnoses for the expert system. The entry of symptoms, rules, or more generally smart bands for creating a particular machine diagnosis, may be tedious and time consuming. One means of making the process more expedient and efficient is to provide a graphical means by use of wiring. The proposed graphical interface consists of four major components: a symptom parts bin, diagnoses bin, tools bin, and graphical wiring area ("GWA"). In embodiments, a symptom parts bin includes various spectral, waveform, envelope and any type of signal processing characteristic or grouping of characteristics such as a spectral peak, spectral harmonic, waveform true-peak, waveform crest-factor, spectral alarm band, and so on. Each part may be assigned additional properties. For example, a spectral peak part may be assigned a frequency or order (multiple) of running speed. Some parts may be pre-defined or user defined such as a 1x, 2x, 3x running speed, 1x, 2x, 3x gear mesh, 1x, 2x, 3x blade pass, number of motor rotor bars x running speed, and so on.

[0327] In embodiments, the diagnoses bin includes various pre-defined as well as user-defined diagnoses such as misalignment, imbalance, looseness, bearing faults, and so on. Like parts, diagnoses may also be used as parts for the purposes of building more complex diagnoses. In embodiments, the tools bin includes logical operations such as AND, OR, XOR, etc. or other ways of combining the various parts listed above such as Find Max, Find Min, Interpolate, Average, other Statistical Operations, etc. In embodiments, a graphical wiring area includes parts from the parts bin or diagnoses from the diagnoses bin and may be combined using tools to create diagnoses.

The various parts, tools and diagnoses will be represented with icons which are simply graphically wired together in the desired manner.

[0328] Embodiments of the methods and systems disclosed herein may include a graphical approach for back-calculation definition. In embodiments, the expert system also provides the opportunity for the system to learn. If one already knows that a unique set of stimuli or smart bands corresponds to a specific fault or diagnosis, then it is possible to back-calculate a set of coefficients that when applied to a future set of similar stimuli would arrive at the same diagnosis. In embodiments, if there are multiple sets of data, a best-fit approach may be used. Unlike the smart band GUI, this embodiment will self-generate a wiring diagram. In embodiments, the user may tailor the back-propagation approach settings and use a database browser to match specific sets of data with the desired diagnoses. In embodiments, the desired diagnoses may be created or custom tailored with a smart band GUI. In embodiments, after that, a user may press the GENERATE button and a dynamic wiring of the symptom-to-diagnosis may appear on the screen as it works through the algorithms to achieve the best fit. In embodiments, when complete, a variety of statistics are presented which detail how well the mapping process proceeded. In some cases, no mapping may be achieved if, for example, the input data was all zero or the wrong data (mistakenly assigned) and so on. Embodiments of the methods and systems disclosed herein may include bearing analysis methods. In embodiments, bearing analysis methods may be used in conjunction with a computer aided design ("CAD"), predictive deconvolution, minimum variance distortionless response ("MVDR") and spectrum sum-of-harmonics.

[0329] In recent years, there has been a strong drive to save power which has resulted in an influx of variable frequency drives and variable speed machinery. In embodiments, a bearing analysis method is provided. In embodiments, torsional vibration detection and analysis is provided utilizing transitory signal analysis to provide an advanced torsional vibration analysis for a more comprehensive way to diagnose machinery where torsional forces are relevant (such as machinery with rotating components). Due primarily to the decrease in cost of motor speed control systems, as well as the increased cost and consciousness of energy-usage, it has become more economically justifiable to take advantage of the potentially vast energy savings of load control. Unfortunately, one frequently overlooked design aspect of this issue is that of vibration. When a machine is designed to run at only one speed, it is far easier to design the physical structure accordingly so as to avoid mechanical resonances both structural and torsional, each of which can dramatically shorten the mechanical health of a machine. This would include such structural characteristics as the types of materials to use, their weight, stiffening member requirements and placement, bearing types, bearing location, base support constraints, etc. Even with machines running at one speed, designing a structure so as to minimize vibration can prove a daunting task, potentially requiring

computer modeling, finite-element analysis, and field testing. By throwing variable speeds into the mix, in many cases, it becomes impossible to design for all desirable speeds. The problem then becomes one of minimization, e.g., by speed avoidance. This is why many modern motor controllers are typically programmed to skip or quickly pass through specific speed ranges or bands. Embodiments may include identifying speed ranges in a vibration monitoring system. Non-torsional, structural resonances are typically fairly easy to detect using conventional vibration analysis techniques. However, this is not the case for torsion. One special area of current interest is the increased incidence of torsional resonance problems, apparently due to the increased torsional stresses of speed change as well as the operation of equipment at torsional resonance speeds. Unlike non-torsional structural resonances which generally manifest their effect with dramatically increased casing or external vibration, torsional resonances generally show no such effect. In the case of a shaft torsional resonance, the twisting motion induced by the resonance may only be discernible by looking for speed and/or phase changes. The current standard methodology for analyzing torsional vibration involves the use of specialized instrumentation. Methods and systems disclosed herein allow analysis of torsional vibration without such specialized instrumentation. This may consist of shutting the machine down and employing the use of strain gauges and/or other special fixturing such as speed encoder plates and/or gears. Friction wheels are another alternative, but they typically require manual implementation and a specialized analyst. In general, these techniques can be prohibitively expensive and/or inconvenient. An increasing prevalence of continuous vibration monitoring systems due to decreasing costs and increasing convenience (e.g., remote access) exists. In embodiments, there is an ability to discern torsional speed and/or phase variations with just the vibration signal. In embodiments, transient analysis techniques may be utilized to distinguish torsionally induced vibrations from mere speed changes due to process control. In embodiments, factors for discernment might focus on one or more of the following aspects: the rate of speed change due to variable speed motor control would be relatively slow, sustained and deliberate; torsional speed changes would tend to be short, impulsive and not sustained; torsional speed changes would tend to be oscillatory, most likely decaying exponentially, process speed changes would not; and smaller speed changes associated with torsion relative to the shaft's rotational speed which suggest that monitoring phase behavior would show the quick or transient speed bursts in contrast to the slow phase changes historically associated with ramping a machine's speed up or down (as typified with Bode or Nyquist plots).

[0330] Embodiments of the methods and systems disclosed herein may include improved integration using both analog and digital methods. When a signal is digitally integrated using software, essentially the spectral low-end frequency data has its amplitude multiplied by a function which quickly blows up as it approaches zero and creates what is known in the industry as a "ski-

slope" effect. The amplitude of the ski-slope is essentially the noise floor of the instrument. The simple remedy for this is the traditional hardware integrator, which can perform at signal-to-noise ratios much greater than that of an already digitized signal. It can also limit the amplification factor to a reasonable level so that multiplication by very large numbers is essentially prohibited. However, at high frequencies where the frequency becomes large, the original amplitude which may be well above the noise floor is multiplied by a very small number (1/f) that plunges it well below the noise floor. The hardware integrator has a fixed noise floor that although low floor does not scale down with the now lower amplitude high-frequency data. In contrast, the same digital multiplication of a digitized high-frequency signal also scales down the noise floor proportionally. In embodiments, hardware integration may be used below the point of unity gain where (at a value usually determined by units and/or desired signal to noise ratio based on gain) and software integration may be used above the value of unity gain to produce an ideal result. In embodiments, this integration is performed in the frequency domain. In embodiments, the resulting hybrid data can then be transformed back into a waveform which should be far superior in signal-to-noise ratio when compared to either hardware integrated or software integrated data. In embodiments, the strengths of hardware integration are used in conjunction with those of digital software integration to achieve the maximum signal-to-noise ratio. In embodiments, the first order gradual hardware integrator high pass filter along with curve fitting allow some relatively low frequency data to get through while reducing or eliminating the noise, allowing very useful analytical data that steep filters kill to be salvaged.

[0331] Embodiments of the methods and systems disclosed herein may include adaptive scheduling techniques for continuous monitoring. Continuous monitoring is often performed with an up-front Mux whose purpose it is to select a few channels of data among many to feed the hardware signal processing, A/D, and processing components of a DAQ system. This is done primarily out of practical cost considerations. The tradeoff is that all of the points are not monitored continuously (although they may be monitored to a lesser extent via alternative hardware methods). In embodiments, multiple scheduling levels are provided. In embodiments, at the lowest level, which is continuous for the most part, all of the measurement points will be cycled through in round-robin fashion. For example, if it takes 30 seconds to acquire and process a measurement point and there are 30 points, then each point is serviced once every 15 minutes; however, if a point should alarm by whatever criteria the user selects, its priority level can be increased so that it is serviced more often. As there can be multiple grades of severity for each alarm, so can there me multiple levels of priority with regards to monitoring. In embodiments, more severe alarms will be monitored more frequently. In embodiments, a number of additional high-level signal processing techniques can be applied at less frequent intervals. Embodiments may take advantage

of the increased processing power of a PC and the PC can temporarily suspend the round-robin route collection (with its multiple tiers of collection) process and stream the required amount of data for a point of its choosing. Embodiments may include various advanced processing techniques such as envelope processing, wavelet analysis, as well as many other signal processing techniques. In embodiments, after acquisition of this data, the DAQ card set will continue with its route at the point it was interrupted. In embodiments, various PC scheduled data acquisitions will follow their own schedules which will be less frequency than the DAQ card route. They may be set up hourly, daily, by number of route cycles (for example, once every 10 cycles) and also increased scheduling-wise based on their alarm severity priority or type of measurement (e.g., motors may be monitored differently than fans).

[0332] Embodiments of the methods and systems disclosed herein may include data acquisition parking features. In embodiments, a data acquisition box used for route collection, real time analysis and in general as an acquisition instrument can be detached from its PC (tablet or otherwise) and powered by an external power supply or suitable battery. In embodiments, the data collector still retains continuous monitoring capability and its on-board firmware can implement dedicated monitoring functions for an extended period of time or can be controlled remotely for further analysis. Embodiments of the methods and systems disclosed herein may include extended statistical capabilities for continuous monitoring.

[0333] Embodiments of the methods and systems disclosed herein may include ambient sensing plus local sensing plus vibration for analysis. In embodiments, ambient environmental temperature and pressure, sensed temperature and pressure may be combined with long/medium term vibration analysis for prediction of any of a range of conditions or characteristics. Variants may add infrared sensing, infrared thermography, ultrasound, and many other types of sensors and input types in combination with vibration or with each other. Embodiments of the methods and systems disclosed herein may include a smart route. In embodiments, the continuous monitoring system's software will adapt/adjust the data collection sequence based on statistics, analytics, data alarms and dynamic analysis. Typically, the route is set based on the channels the sensors are attached to. In embodiments, with the crosspoint switch, the Mux can combine any input Mux channels to the (e.g., eight) output channels. In embodiments, as channels go into alarm or the system identifies key deviations, it will pause the normal route set in the software to gather specific simultaneous data, from the channels sharing key statistical changes, for more advanced analysis. Embodiments include conducting a smart ODS or smart transfer function.

[0334] Embodiments of the methods and systems disclosed herein may include smart ODS and one or more transfer functions. In embodiments, due to a system's multiplexer and crosspoint switch, an ODS, a transfer function, or other special tests on all the vibration sensors attached to a

machine/structure can be performed and show exactly how the machine's points are moving in relationship to each other. In embodiments, 40-50 kHz and longer data lengths (e.g., at least one minute) may be streamed, which may reveal different information than what a normal ODS or transfer function will show. In embodiments, the system will be able to determine, based on the data/statistics/analytics to use, the smart route feature that breaks from the standard route and conducts an ODS across a machine, structure or multiple machines and structures that might show a correlation because the conditions/data directs it. In embodiments, for the transfer functions there may be an impact hammer used on one channel and then compared against other vibration sensors on the machine. In embodiments, the system may use the condition changes such as load, speed, temperature or other changes in the machine or system to conduct the transfer function. In embodiments, different transfer functions may be compared to each other over time. In embodiments, difference transfer functions may be strung together like a movie that may show how the machinery fault changes, such as a bearing that could show how it moves through the four stages of bearing failure and so on. Embodiments of the methods and systems disclosed herein may include a hierarchical Mux.

[0335] With reference to Figure 8, the present disclosure generally includes digitally collecting or streaming waveform data 2010 from a machine 2020 whose operational speed can vary from relatively slow rotational or oscillational speeds to much higher speeds in different situations. The waveform data 2010, at least on one machine, may include data from a single axis sensor 2030 mounted at an unchanging reference location 2040 and from a three-axis sensor 2050 mounted at changing locations (or located at multiple locations), including location 2052. In embodiments, the waveform data 2010 can be vibration data obtained simultaneously from each sensor 2030, 2050 in a gap-free format for a duration of multiple minutes with maximum resolvable frequencies sufficiently large to capture periodic and transient impact events. By way of this example, the waveform data 2010 can include vibration data that can be used to create an operational deflecting shape. It can also be used, as needed, to diagnose vibrations from which a machine repair solution can be prescribed.

[0336] In embodiments, the machine 2020 can further include a housing 2100 that can contain a drive motor 2110 that can drive a shaft 2120. The shaft 2120 can be supported for rotation or oscillation by a set of bearings 2130, such as including a first bearing 2140 and a second bearing 2150. A data collection module 2160 can connect to (or be resident on) the machine 2020. In one example, the data collection module 2160 can be located and accessible through a cloud network facility 2170, can collect the waveform data 2010 from the machine 2020, and deliver the waveform data 2010 to a remote location. A working end 2180 of the drive shaft 2120 of the machine 2020 can drive a windmill, a fan, a pump, a drill, a gear system, a drive system, or other

working element, as the techniques described herein can apply to a wide range of machines, equipment, tools, or the like that include rotating or oscillating elements. In other instances, a generator can be substituted for the motor 2110, and the working end of the drive shaft 2120 can direct rotational energy to the generator to generate power, rather than consume it.

[0337] In embodiments, the waveform data 2010 can be obtained using a predetermined route format based on the layout of the machine 2020. The waveform data 2010 may include data from the single axis sensor 2030 and the three-axis sensor 2050. The single-axis sensor 2030 can serve as a reference probe with its one channel of data and can be fixed at the unchanging location 2040 on the machine under survey. The three-axis sensor 2050 can serve as a tri-axial probe (e.g., three orthogonal axes) with its three channels of data and can be moved along a predetermined diagnostic route format from one test point to the next test point. In one example, both sensors 2030, 2050 can be mounted manually to the machine 2020 and can connect to a separate portable computer in certain service examples. The reference probe can remain at one location while the user can move the tri-axial vibration probe along the predetermined route, such as from bearing-to-bearing on a machine. In this example, the user is instructed to locate the sensors at the predetermined locations to complete the survey (or portion thereof) of the machine.

[0338] With reference to Figure 9, a portion of an exemplary machine 2200 is shown having a tri-axial sensor 2210 mounted to a location 2220 associated with a motor bearing of the machine 2200 with an output shaft 2230 and output member 2240 in accordance with the present disclosure. With reference to Figure 10, the exemplary machine 2300 is shown having a tri-axial sensor 2310 and a single-axis vibration sensor 2320 serving as the reference sensor that is attached on the machine 2300 at an unchanging location for the duration of the vibration survey in accordance with the present disclosure. The tri-axial sensor 2310 and the single-axis vibration sensor 2320 can be connected to a data collection system 2330.

[0339] In further examples, the sensors and data acquisition modules and equipment can be integral to, or resident on, the rotating machine. By way of these examples, the machine can contain many single axis sensors and many tri-axial sensors at predetermined locations. The sensors can be originally installed equipment and provided by the original equipment manufacturer or installed at a different time in a retrofit application. The data collection module 2160, or the like, can select and use one single axis sensor and obtain data from it exclusively during the collection of waveform data 2010 while moving to each of the tri-axial sensors. The data collection module 2160 can be resident on the machine 2020 and/or connect via the cloud network facility 2170.

[0340] With reference to Figure 8, the various embodiments include collecting the waveform data 2010 by digitally recording locally, or streaming over, the cloud network facility 2170. The waveform data 2010 can be collected so as to be gap-free with no interruptions and, in some

respects, can be similar to an analog recording of waveform data. The waveform data 2010 from all of the channels can be collected for one to two minutes depending on the rotating or oscillating speed of the machine being monitored. In embodiments, the data sampling rate can be at a relatively high-sampling rate relative to the operating frequency of the machine 2020.

[0341] In embodiments, a second reference sensor can be used, and a fifth channel of data can be collected. As such, the single-axis sensor can be the first channel and tri-axial vibration can occupy the second, the third, and the fourth data channels. This second reference sensor, like the first, can be a single axis sensor, such as an accelerometer. In embodiments, the second reference sensor, like the first reference sensor, can remain in the same location on the machine for the entire vibration survey on that machine. The location of the first reference sensor (i.e., the single axis sensor) may be different than the location of the second reference sensors (i.e., another single axis sensor). In certain examples, the second reference sensor can be used when the machine has two shafts with different operating speeds, with the two reference sensors being located on the two different shafts. In accordance with this example, further single-axis reference sensors can be employed at additional but different unchanging locations associated with the rotating machine.

[0342] In embodiments, the waveform data can be transmitted electronically in a gap-free free format at a significantly high rate of sampling for a relatively longer period of time. In one example, the period of time is 60 seconds to 120 seconds. In another example, the rate of sampling is 100 kHz with a maximum resolvable frequency (Fmax) of 40 kHz. It will be appreciated in light of this disclosure that the waveform data can be shown to approximate more closely some of the wealth of data available from previous instances of analog recording of waveform data.

[0343] In embodiments, sampling, band selection, and filtering techniques can permit one or more portions of a long stream of data (i.e., one to two minutes in duration) to be under sampled or over sampled to realize varying effective sampling rates. To this end, interpolation and decimation can be used to further realize varying effective sampling rates. For example, oversampling may be applied to frequency bands that are proximal to rotational or oscillational operating speeds of the sampled machine, or to harmonics thereof, as vibration effects may tend to be more pronounced at those frequencies across the operating range of the machine. In embodiments, the digitally-sampled data set can be decimated to produce a lower sampling rate. It will be appreciated in light of the disclosure that decimate in this context can be the opposite of interpolate. In embodiments, decimating the data set can include first applying a low-pass filter to the digitally-sampled data set and then undersampling the data set.

[0344] In one example, a sample waveform at 100 Hz can be undersampled at every tenth point of the digital waveform to produce an effective sampling rate of 10 Hz, but the remaining nine points of that portion of the waveform are effectively discarded and not included in the modeling

of the sample waveform. Moreover, this type of bare undersampling can create ghost frequencies due to the undersampling rate (i.e., 10 Hz) relative to the 100 Hz sample waveform.

[0345] Most hardware for analog-to-digital conversions uses a sample-and-hold circuit that can charge up a capacitor for a given amount of time such that an average value of the waveform is determined over a specific change in time. It will be appreciated in light of the disclosure that the value of the waveform over the specific change in time is not linear but more similar to a cardinal sinusoidal ("sinc") function; therefore, it can be shown that more emphasis can be placed on the waveform data at the center of the sampling interval with exponential decay of the cardinal sinusoidal signal occurring from its center.

[0346] By way of the above example, the sample waveform at 100 Hz can be hardware-sampled at 10 Hz and therefore each sampling point is averaged over 100 milliseconds (e.g., a signal sampled at 100 Hz can have each point averaged over 10 milliseconds). In contrast to the effective discarding of nine out of the ten data points of the sampled waveform as discussed above, the present disclosure can include weighing adjacent data. The adjacent data can refer to the sample points that were previously discarded and the one remaining point that was retained. In one example, a low pass filter can average the adjacent sample data linearly, i.e., determining the sum of every ten points and then dividing that sum by ten. In a further example, the adjacent data can be weighted with a sinc function. The process of weighting the original waveform with the sinc function can be referred to as an impulse function or can be referred to in the time domain as a convolution.

[0347] The present disclosure can be applicable to not only digitizing a waveform signal based on a detected voltage but can also be applicable to digitizing waveform signals based on current waveforms, vibration waveforms, and image processing signals including video signal rasterization. In one example, the resizing of a window on a computer screen can be decimated, albeit in at least two directions. In these further examples, it will be appreciated that undersampling by itself can be shown to be insufficient. To that end, oversampling or upsampling by itself can similarly be shown to be insufficient, such that interpolation can be used like decimation but in lieu of only undersampling by itself.

[0348] It will be appreciated in light of the disclosure that interpolation in this context can refer to first applying a low pass filter to the digitally-sampled waveform data and then upsampling the waveform data. It will be appreciated in light of the disclosure that real-world examples can often require the use of use non-integer factors for decimation or interpolation, or both. To that end, the present disclosure includes interpolating and decimating sequentially in order to realize a non-integer factor rate for interpolating and decimating. In one example, interpolating and decimating sequentially can define applying a low-pass filter to the sample waveform, then interpolating the

waveform after the low-pass filter, and then decimating the waveform after the interpolation. In embodiments, the vibration data can be looped to purposely emulate conventional tape recorder loops, with digital filtering techniques used with the effective splice to facilitate longer analyses. It will be appreciated in light of the disclosure that the above techniques do not preclude waveform, spectrum, and other types of analyses to be processed and displayed with a GUI of the user at the time of collection. It will be appreciated in light of the disclosure that newer systems can permit this functionality to be performed in parallel to the high-performance collection of the raw waveform data.

[0349] With respect to time of collection issues, it will be appreciated that older systems using the compromised approach of improving data resolution, by collecting at different sampling rates and data lengths, do not in fact save as much time as expected. To that end, every time the data acquisition hardware is stopped and started, latency issues can be created, especially when there is hardware auto-scaling performed. The same can be true with respect to data retrieval of the route information (i.e., test locations) that is often in a database format and can be exceedingly slow. The storage of the raw data in bursts to disk (whether solid state or otherwise) can also be undesirably slow.

[0350] In contrast, the many embodiments include digitally streaming the waveform data 2010, as disclosed herein, and also enjoying the benefit of needing to load the route parameter information while setting the data acquisition hardware only once. Because the waveform data 2010 is streamed to only one file, there is no need to open and close files, or switch between loading and writing operations with the storage medium. It can be shown that the collection and storage of the waveform data 2010, as described herein, can be shown to produce relatively more meaningful data in significantly less time than the traditional batch data acquisition approach. An example of this includes an electric motor about which waveform data can be collected with a data length of 4K points (i.e., 4,096) for sufficiently high resolution in order to, among other things, distinguish electrical sideband frequencies. For fans or blowers, a reduced resolution of 1K (i.e., 1,024) can be used. In certain instances, 1K can be the minimum waveform data length requirement. The sampling rate can be 1,280 Hz and that equates to an Fmax of 500 Hz. It will be appreciated in light of the disclosure that oversampling by an industry standard factor of 2.56 can satisfy the necessary two-times (2x) oversampling for the Nyquist Criterion with some additional leeway that can accommodate anti-aliasing filter-rolloff. The time to acquire this waveform data would be 1,024 points at 1,280 hertz, which are 800 milliseconds.

[0351] To improve accuracy, the waveform data can be averaged. Eight averages can be used with, for example, fifty percent overlap. This would extend the time from 800 milliseconds to 3.6 seconds, which is equal to 800 msec x 8 averages x 0.5 (overlap ratio) + 0.5 x 800 msec (non-

overlapped head and tail ends). After collection at Fmax = 500 Hz waveform data, a higher sampling rate can be used. In one example, ten times (10x) the previous sampling rate can be used and Fmax = 10 kHz. By way of this example, eight averages can be used with fifty percent (50%) overlap to collect waveform data at this higher rate that can amount to a collection time of 360 msec or 0.36 seconds. It will be appreciated in light of the disclosure that it can be necessary to read the hardware collection parameters for the higher sampling rate from the route list, as well as permit hardware auto-scaling, or the resetting of other necessary hardware collection parameters, or both. To that end, a few seconds of latency can be added to accommodate the changes in sampling rate. In other instances, introducing latency can accommodate hardware autoscaling and changes to hardware collection parameters that can be required when using the lower sampling rate disclosed herein. In addition to accommodating the change in sampling rate, additional time is needed for reading the route point information from the database (i.e., where to monitor and where to monitor next), displaying the route information, and processing the waveform data. Moreover, display of the waveform data and/or associated spectra can also consume significant time. In light of the above, 15 seconds to 20 seconds can elapse while obtaining waveform data at each measurement point.

[0352] In further examples, additional sampling rates can be added but this can make the total amount time for the vibration survey even longer because time adds up from changeover time from one sampling rate to another and from the time to obtain additional data at different sampling rate. In one example, a lower sampling rate is used, such as a sampling rate of 128 Hz where Fmax = 50 Hz. By way of this example, the vibration survey would, therefore, require an additional 36 seconds for the first set of averaged data at this sampling rate, in addition to others mentioned above, and consequently the total time spent at each measurement point increases even more dramatically. Further embodiments include using similar digital streaming of gap free waveform data as disclosed herein for use with wind turbines and other machines that can have relatively slow speed rotating or oscillating systems. In many examples, the waveform data collected can include long samples of data at a relatively high-sampling rate. In one example, the sampling rate can be 100 kHz and the sampling duration can be for two minutes on all of the channels being recorded. In many examples, one channel can be for the single axis reference sensor and three more data channels can be for the tri-axial three channel sensor. It will be appreciated in light of the disclosure that the long data length can be shown to facilitate detection of extremely low frequency phenomena. The long data length can also be shown to accommodate the inherent speed variability in wind turbine operations. Additionally, the long data length can further be shown to provide the opportunity for using numerous averages such as those discussed herein, to achieve very high spectral resolution, and to make feasible tape loops for certain spectral analyses. Many

multiple advanced analytical techniques can now become available because such techniques can use the available long uninterrupted length of waveform data in accordance with the present disclosure.

[0353] It will also be appreciated in light of the disclosure that the simultaneous collection of waveform data from multiple channels can facilitate performing transfer functions between multiple channels. Moreover, the simultaneous collection of waveform data from multiple channels facilitates establishing phase relationships across the machine so that more sophisticated correlations can be utilized by relying on the fact that the waveforms from each of the channels are collected simultaneously. In other examples, more channels in the data collection can be used to reduce the time it takes to complete the overall vibration survey by allowing for simultaneous acquisition of waveform data from multiple sensors that otherwise would have to be acquired, in a subsequent fashion, moving sensor to sensor in the vibration survey.

[0354] The present disclosure includes the use of at least one of the single-axis reference probes on one of the channels to allow for acquisition of relative phase comparisons between channels. The reference probe can be an accelerometer or other type of transducer that is not moved and, therefore, fixed at an unchanging location during the vibration survey of one machine. Multiple reference probes can each be deployed as at suitable locations fixed in place (i.e., at unchanging locations) throughout the acquisition of vibration data during the vibration survey. In certain examples, up to seven reference probes can be deployed depending on the capacity of the data collection module 2160 or the like. Using transfer functions or similar techniques, the relative phases of all channels may be compared with one another at all selected frequencies. By keeping the one or more reference probes fixed at their unchanging locations while moving or monitoring the other tri-axial vibration sensors, it can be shown that the entire machine can be mapped with regard to amplitude and relative phase. This can be shown to be true even when there are more measurement points than channels of data collection. With this information, an operating deflection shape can be created that can show dynamic movements of the machine in 3 D, which can provide an invaluable diagnostic tool. In embodiments, the one or more reference probes can provide relative phase, rather than absolute phase. It will be appreciated in light of the disclosure that relative phase may not be as valuable absolute phase for some purposes, but the relative phase the information can still be shown to be very useful.

[0355] In embodiments, the sampling rates used during the vibration survey can be digitally synchronized to predetermined operational frequencies that can relate to pertinent parameters of the machine such as rotating or oscillating speed. Doing this, permits extracting even more information using synchronized averaging techniques. It will be appreciated in light of the disclosure that this can be done without the use of a key phasor or a reference pulse from a rotating

shaft, which is usually not available for route collected data. As such, non-synchronous signals can be removed from a complex signal without the need to deploy synchronous averaging using the key phasor. This can be shown to be very powerful when analyzing a particular pinion in a gearbox or generally applied to any component within a complicated mechanical mechanism. In many instances, the key phasor or the reference pulse is rarely available with route collected data, but the techniques disclosed herein can overcome this absence. In embodiments, there can be multiple shafts running at different speeds within the machine being analyzed. In certain instances, there can be a single-axis reference probe for each shaft. In other instances, it is possible to relate the phase of one shaft to another shaft using only one single axis reference probe on one shaft at its unchanging location. In embodiments, variable speed equipment can be more readily analyzed with relatively longer duration of data relative to single speed equipment. The vibration survey can be conducted at several machine speeds within the same contiguous set of vibration data using the same techniques disclosed herein. These techniques can also permit the study of the change of the relationship between vibration and the change of the rate of speed that was not available before.

[0356] In embodiments, there are numerous analytical techniques that can emerge from because raw waveform data can be captured in a gap-free digital format as disclosed herein. The gap-free digital format can facilitate many paths to analyze the waveform data in many ways after the fact to identify specific problems. The vibration data collected in accordance with the techniques disclosed herein can provide the analysis of transient, semi-periodic and very low frequency phenomena. The waveform data acquired in accordance with the present disclosure can contain relatively longer streams of raw gap-free waveform data that can be conveniently played back as needed, and on which many and varied sophisticated analytical techniques can be performed. A large number of such techniques can provide for various forms of filtering to extract low amplitude modulations from transient impact data that can be included in the relatively longer stream of raw gap-free waveform data. It will be appreciated in light of the disclosure that in past data collection practices, these types of phenomena were typically lost by the averaging process of the spectral processing algorithms because the goal of the previous data acquisition module was purely periodic signals; or these phenomena were lost to file size reduction methodologies due to the fact that much of the content from an original raw signal was typically discarded knowing it would not be used.

[0357] In embodiments, there is a method of monitoring vibration of a machine having at least one shaft supported by a set of bearings. The method includes monitoring a first data channel assigned to a single-axis sensor at an unchanging location associated with the machine. The method also includes monitoring a second, third, and fourth data channel assigned to a three-axis sensor. The method further includes recording gap-free digital waveform data simultaneously from

all of the data channels while the machine is in operation; and determining a change in relative phase based on the digital waveform data. The method also includes the tri-axial sensor being located at a plurality of positions associated with the machine while obtaining the digital waveform. In embodiments, the second, third, and fourth channels are assigned together to a sequence of tri-axial sensors each located at different positions associated with the machine. In embodiments, the data is received from all of the sensors on all of their channels simultaneously.

[0358] The method also includes determining an operating deflection shape based on the change in relative phase information and the waveform data. In embodiments, the unchanging location of the reference sensor is a position associated with a shaft of the machine. In embodiments, the tri-axial sensors in the sequence of the tri-axial sensors are each located at different positions and are each associated with different bearings in the machine. In embodiments, the unchanging location is a position associated with a shaft of the machine and the tri-axial sensors in the sequence of the tri-axial sensors are each located at different positions and are each associated with different bearings that support the shaft in the machine. The various embodiments include methods of sequentially monitoring vibration or similar process parameters and signals of a rotating or oscillating machine or analogous process machinery from a number of channels simultaneously, which can be known as an ensemble. In various examples, the ensemble can include one to eight channels. In further examples, an ensemble can represent a logical measurement grouping on the equipment being monitored whether those measurement locations are temporary for measurement, supplied by the original equipment manufacturer, retrofit at a later date, or one or more combinations thereof.

[0359] In one example, an ensemble can monitor bearing vibration in a single direction. In a further example, an ensemble can monitor three different directions (e.g., orthogonal directions) using a tri-axial sensor. In yet further examples, an ensemble can monitor four or more channels where the first channel can monitor a single axis vibration sensor, and the second, the third, and the fourth channels can monitor each of the three directions of the tri-axial sensor. In other examples, the ensemble can be fixed to a group of adjacent bearings on the same piece of equipment or an associated shaft. The various embodiments provide methods that include strategies for collecting waveform data from various ensembles deployed in vibration studies or the like in a relatively more efficient manner. The methods also include simultaneously monitoring of a reference channel assigned to an unchanging reference location associated with the ensemble monitoring the machine. The cooperation with the reference channel can be shown to support a more complete correlation of the collected waveforms from the ensembles. The reference sensor on the reference channel can be a single axis vibration sensor, or a phase reference sensor that can be triggered by a reference location on a rotating shaft or the like. As disclosed herein, the methods

can further include recording gap-free digital waveform data simultaneously from all of the channels of each ensemble at a relatively high rate of sampling so as to include all frequencies deemed necessary for the proper analysis of the machinery being monitored while it is in operation. The data from the ensembles can be streamed gap-free to a storage medium for subsequent processing that can be connected to a cloud network facility, a local data link, Bluetooth™ connectivity, cellular data connectivity, or the like.

[0360] In embodiments, the methods disclosed herein include strategies for collecting data from the various ensembles including digital signal processing techniques that can be subsequently applied to data from the ensembles to emphasize or better isolate specific frequencies or waveform phenomena. This can be in contrast with current methods that collect multiple sets of data at different sampling rates, or with different hardware filtering configurations including integration, that provide relatively less post-processing flexibility because of the commitment to these same (known as a priori hardware configurations). These same hardware configurations can also be shown to increase time of the vibration survey due to the latency delays associated with configuring the hardware for each independent test. In embodiments, the methods for collecting data from various ensembles include data marker technology that can be used for classifying sections of streamed data as homogenous and belonging to a specific ensemble. In one example, a classification can be defined as operating speed. In doing so, a multitude of ensembles can be created from what conventional systems would collect as only one. The many embodiments include post-processing analytic techniques for comparing the relative phases of all the frequencies of interest not only between each channel of the collected ensemble but also between all of the channels of all of the ensembles being monitored, when applicable.

[0361] With reference to Figure 12, the many embodiments include a first machine 2400 having rotating or oscillating components 2410, or both, each supported by a set of bearings 2420 including a bearing pack 2422, a bearing pack 2424, a bearing pack 2426, and more as needed. The first machine 2400 can be monitored by a first sensor ensemble 2450. The first ensemble 2450 can be configured to receive signals from sensors originally installed (or added later) on the first machine 2400. The sensors on the machine 2400 can include single-axis sensors 2460, such as a single-axis sensor 2462, a single-axis sensor 2464, and more as needed. In many examples, the single axis-sensors 2460 can be positioned in the machine 2400 at locations that allow for the sensing of one of the rotating or oscillating components 2410 of the machine 2400.

[0362] The machine 2400 can also have tri-axial (e.g., orthogonal axes) sensors 2480, such as a tri-axial sensor 2482, a tri-axial sensor 2484, and more as needed. In many examples, the tri-axial sensors 2480 can be positioned in the machine 2400 at locations that allow for the sensing of one of each of the bearing packs in the sets of bearings 2420 that is associated with the rotating or

oscillating components of the machine 2400. The machine 2400 can also have temperature sensors 2500, such as a temperature sensor 2502, a temperature sensor 2504, and more as needed. The machine 2400 can also have a tachometer sensor 2510 or more as needed that each detail the RPMs of one of its rotating components. By way of the above example, the first sensor ensemble 2450 can survey the above sensors associated with the first machine 2400. To that end, the first ensemble 2450 can be configured to receive eight channels. In other examples, the first sensor ensemble 2450 can be configured to have more than eight channels, or less than eight channels as needed. In this example, the eight channels include two channels that can each monitor a single-axis reference sensor signal and three channels that can monitor a tri-axial sensor signal. The remaining three channels can monitor two temperature signals and a signal from a tachometer. In one example, the first ensemble 2450 can monitor the single-axis sensor 2462, the single-axis sensor 2464, the tri-axial sensor 2482, the temperature sensor 2502, the temperature sensor 2504, and the tachometer sensor 2510 in accordance with the present disclosure. During a vibration survey on the machine 2400, the first ensemble 2450 can first monitor the tri-axial sensor 2482 and then move next to the tri-axial sensor 2484.

[0363] After monitoring the tri-axial sensor 2484, the first ensemble 2450 can monitor additional tri-axial sensors on the machine 2400 as needed and that are part of the predetermined route list associated with the vibration survey of the machine 2400, in accordance with the present disclosure. During this vibration survey, the first ensemble 2450 can continually monitor the single-axis sensor 2462, the single-axis sensor 2464, the two temperature sensors 2502, 2504, and the tachometer sensor 2510 while the first ensemble 2450 can serially monitor the multiple tri-axial sensors 2480 in the pre-determined route plan for this vibration survey.

[0364] With reference to Figure 12, the many embodiments include a second machine 2600 having rotating or oscillating components 2610, or both, each supported by a set of bearings 2620 including a bearing pack 2622, a bearing pack 2624, a bearing pack 2626, and more as needed. The second machine 2600 can be monitored by a second sensor ensemble 2650. The second ensemble 2650 can be configured to receive signals from sensors originally installed (or added later) on the second machine 2600. The sensors on the machine 2600 can include single-axis sensors 2660, such as a single-axis sensor 2662, a single-axis sensor 2664, and more as needed. In many examples, the single axis-sensors 2660 can be positioned in the machine 2600 at locations that allow for the sensing of one of the rotating or oscillating components 2610 of the machine 2600.

[0365] The machine 2600 can also have tri-axial (e.g., orthogonal axes) sensors 2680, such as a tri-axial sensor 2682, a tri-axial sensor 2684, a tri-axial sensor 2686, a tri-axial sensor 2688, and more as needed. In many examples, the tri-axial sensors 2680 can be positioned in the machine

2600 at locations that allow for the sensing of one of each of the bearing packs in the sets of bearings 2620 that is associated with the rotating or oscillating components of the machine 2600. The machine 2600 can also have temperature sensors 2700, such as a temperature sensor 2702, a temperature sensor 2704, and more as needed. The machine 2600 can also have a tachometer sensor 2710 or more as needed that each detail the RPMs of one of its rotating components.

[0366] By way of the above example, the second sensor ensemble 2650 can survey the above sensors associated with the second machine 2600. To that end, the second ensemble 2650 can be configured to receive eight channels. In other examples, the second sensor ensemble 2650 can be configured to have more than eight channels or less than eight channels as needed. In this example, the eight channels include one channel that can monitor a single-axis reference sensor signal and six channels that can monitor two tri-axial sensor signals. The remaining channel can monitor a temperature signal. In one example, the second ensemble 2650 can monitor the single axis sensor 2662, the tri-axial sensor 2682, the tri-axial sensor 2684, and the temperature sensor 2702. During a vibration survey on the machine 2600 in accordance with the present disclosure, the second ensemble 2650 can first monitor the tri-axial sensor 2682 simultaneously with the tri-axial sensor 2684 and then move onto the tri-axial sensor 2686 simultaneously with the tri-axial sensor 2688.

[0367] After monitoring the tri-axial sensors 2680, the second ensemble 2650 can monitor additional tri-axial sensors (in simultaneous pairs) on the machine 2600 as needed and that are part of the predetermined route list associated with the vibration survey of the machine 2600 in accordance with the present disclosure. During this vibration survey, the second ensemble 2650 can continually monitor the single-axis sensor 2662 at its unchanging location and the temperature sensor 2702 while the second ensemble 2650 can serially monitor the multiple tri-axial sensors in the pre-determined route plan for this vibration survey.

[0368] With continuing reference to Figure 12, the many embodiments include a third machine 2800 having rotating or oscillating components 2810, or both, each supported by a set of bearings 2820 including a bearing pack 2822, a bearing pack 2824, a bearing pack 2826, and more as needed. The third machine 2800 can be monitored by a third sensor ensemble 2850. The third ensemble 2850 can be configured with a single-axis sensor 2860, and two tri-axial (e.g., orthogonal axes) sensors 2880, 2882. In many examples, the single axis-sensor 2860 can be secured by the user on the machine 2800 at a location that allows for the sensing of one of the rotating or oscillating components of the machine 2800. The tri-axial sensors 2880, 2882 can be also be located on the machine 2800 by the user at locations that allow for the sensing of one of each of the bearings in the sets of bearings that each associated with the rotating or oscillating components of the machine 2800. The third ensemble 2850 can also include a temperature sensor 2900. The

third ensemble 2850 and its sensors can be moved to other machines unlike the first and second ensembles 2450, 2650.

[0369] The many embodiments also include a fourth machine 2950 having rotating or oscillating components 2960, or both, each supported by a set of bearings 2970 including a bearing pack 2972, a bearing pack 2974, a bearing pack 2976, and more as needed. The fourth machine 2950 can be also monitored by the third sensor ensemble 2850 when the user moves it to the fourth machine 2950. The many embodiments also include a fifth machine 3000 having rotating or oscillating components 3010, or both. The fifth machine 3000 may not be explicitly monitored by any sensor or any sensor ensembles in operation but it can create vibrations or other impulse energy of sufficient magnitude to be recorded in the data associated with any one of the machines 2400, 2600, 2800, 2950 under a vibration survey.

[0370] The many embodiments include monitoring the first sensor ensemble 2450 on the first machine 2400 through the predetermined route as disclosed herein. The many embodiments also include monitoring the second sensor ensemble 2650 on the second machine 2600 through the predetermined route. The locations of machine 2400 being close to machine 2600 can be included in the contextual metadata of both vibration surveys. The third ensemble 2850 can be moved between machine 2800, machine 2950, and other suitable machines. The machine 3000 has no sensors onboard as configured but could be monitored as needed by the third sensor ensemble 2850. The machine 3000 and its operational characteristics can be recorded in the metadata in relation to the vibration surveys on the other machines to note its contribution due to its proximity.

[0371] The many embodiments include hybrid database adaptation for harmonizing relational metadata and streaming raw data formats. Unlike older systems that utilized traditional database structure for associating nameplate and operational parameters (sometimes deemed metadata) with individual data measurements that are discrete and relatively simple, it will be appreciated in light of the disclosure that more modern systems can collect relatively larger quantities of raw streaming data with higher sampling rates and greater resolutions. At the same time, it will also be appreciated in light of the disclosure that the network of metadata with which to link and obtain this raw data or correlate with this raw data, or both, is expanding at ever-increasing rates.

[0372] In one example, a single overall vibration level can be collected as part of a route or prescribed list of measurement points. This data collected can then be associated with database measurement location information for a point located on a surface of a bearing housing on a specific piece of the machine adjacent to a coupling in a vertical direction. Machinery analysis parameters relevant to the proper analysis can be associated with the point located on the surface. Examples of machinery analysis parameters relevant to the proper analysis can include a running speed of a shaft passing through the measurement point on the surface. Further examples of

machinery analysis parameters relevant to the proper analysis can include one of, or a combination of: running speeds of all component shafts for that piece of equipment and/or machine, bearing types being analyzed such as sleeve or rolling element bearings, the number of gear teeth on gears should there be a gearbox, the number of poles in a motor, slip and line frequency of a motor, roller bearing element dimensions, number of fan blades, or the like. Examples of machinery analysis parameters relevant to the proper analysis can further include machine operating conditions such as the load on the machines and whether load is expressed in percentage, wattage, air flow, head pressure, horsepower, and the like. Further examples of machinery analysis parameters include information relevant to adjacent machines that might influence the data obtained during the vibration study.

[0373] It will be appreciated in light of the disclosure that the vast array of equipment and machinery types can support many different classifications, each of which can be analyzed in distinctly different ways. For example, some machines, like screw compressors and hammer mills, can be shown to run much noisier and can be expected to vibrate significantly more than other machines. Machines known to vibrate more significantly can be shown to require a change in vibration levels that can be considered acceptable relative to quieter machines.

[0374] The present disclosure further includes hierarchical relationships found in the vibrational data collected that can be used to support proper analysis of the data. One example of the hierarchical data includes the interconnection of mechanical componentry such as a bearing being measured in a vibration survey and the relationship between that bearing, including how that bearing connects to a particular shaft on which is mounted a specific pinion within a particular gearbox, and the relationship between the shaft, the pinion, and the gearbox. The hierarchical data can further include in what particular spot within a machinery gear train that the bearing being monitored is located relative to other components in the machine. The hierarchical data can also detail whether the bearing being measured in a machine is in close proximity to another machine whose vibrations may affect what is being measured in the machine that is the subject of the vibration study.

[0375] The analysis of the vibration data from the bearing or other components related to one another in the hierarchical data can use table lookups, searches for correlations between frequency patterns derived from the raw data, and specific frequencies from the metadata of the machine. In some embodiments, the above can be stored in and retrieved from a relational database. In embodiments, National Instrument's Technical Data Management Solution (TDMS) file format can be used. The TDMS file format can be optimized for streaming various types of measurement data (i.e., binary digital samples of waveforms), as well as also being able to handle hierarchical metadata.

[0376] The many embodiments include a hybrid relational metadata - binary storage approach (HRM-BSA). The HRM-BSA can include a structured query language (SQL) based relational database engine. The structured query language based relational database engine can also include a raw data engine that can be optimized for throughput and storage density for data that is flat and relatively structureless. It will be appreciated in light of the disclosure that benefits can be shown in the cooperation between the hierarchical metadata and the SQL relational database engine. In one example, marker technologies and pointer sign-posts can be used to make correlations between the raw database engine and the SQL relational database engine. Three examples of correlations between the raw database engine and the SQL relational database engine linkages include: (1) pointers from the SQL database to the raw data; (2) pointers from the ancillary metadata tables or similar grouping of the raw data to the SQL database; and (3) independent storage tables outside the domain of either the SQL database or raw data technologies.

[0377] With reference to Figure 13, the present disclosure can include pointers for Group 1 and Group 2 that can include associated filenames, path information, table names, database key fields as employed with existing SQL database technologies that can be used to associate a specific database segments or locations, asset properties to specific measurement raw data streams, records with associated time/date stamps, or associated metadata such as operating parameters, panel conditions, and the like. By way of this example, a plant 3200 can include a machine one 3202, a machine two 3204, and many others in the plant 3200. The machine one 3202 can include a gearbox 3210, a motor 3212, and other elements. The machine two 3204 can include a motor 3220, and other elements. Many waveforms 3230 including waveform 3240, waveform 3242, waveform 3244, and additional waveforms as needed can be acquired from the machines 3202, 3204 in the plant 3200. The waveforms 3230 can be associated with the local marker linking tables 3300 and a linking raw data tables 3400. The machines 3202, 3204 and their elements can be associated with linking tables having relational databases 3500. The linking tables raw data tables 3400 and the linking tables having relational databases 3500 can be associated with the linking tables with optional independent storage tables 3600.

[0378] The present disclosure can include markers that can be applied to a time mark or a sample length within the raw waveform data. The markers generally fall into two categories: preset or dynamic. The preset markers can correlate to preset or existing operating conditions (e.g., load, head pressure, air flow cubic feet per minute, ambient temperature, RPMs, and the like.). These preset markers can be fed into the data acquisition system directly. In certain instances, the preset markers can be collected on data channels in parallel with the waveform data (e.g., waveforms for vibration, current, voltage, etc.). Alternatively, the values for the preset markers can be entered manually.

[0379] For dynamic markers such as trending data, it can be important to compare similar data like comparing vibration amplitudes and patterns with a repeatable set of operating parameters. One example of the present disclosure includes one of the parallel channel inputs being a key phasor trigger pulse from an operating shaft that can provide RPM information at the instantaneous time of collection. In this example of dynamic markers, sections of collected waveform data can be marked with appropriate speeds or speed ranges.

[0380] The present disclosure can also include dynamic markers that can correlate to data that can be derived from post processing and analytics performed on the sample waveform. In further embodiments, the dynamic markers can also correlate to post-collection derived parameters including RPMs, as well as other operationally derived metrics such as alarm conditions like a maximum RPM. In certain examples, many modern pieces of equipment that are candidates for a vibration survey with the portable data collection systems described herein do not include tachometer information. This can be true because it is not always practical or cost-justifiable to add a tachometer even though the measurement of RPM can be of primary importance for the vibration survey and analysis. It will be appreciated that for fixed speed machinery obtaining an accurate RPM measurement can be less important especially when the approximate speed of the machine can be ascertained before-hand; however, variable-speed drives are becoming more and more prevalent. It will also be appreciated in light of the disclosure that various signal processing techniques can permit the derivation of RPM from the raw data without the need for a dedicated tachometer signal.

[0381] In many embodiments, the RPM information can be used to mark segments of the raw waveform data over its collection history. Further embodiments include techniques for collecting instrument data following a prescribed route of a vibration study. The dynamic markers can enable analysis and trending software to utilize multiple segments of the collection interval indicated by the markers (e.g., two minutes) as multiple historical collection ensembles, rather than just one as done in previous systems where route collection systems would historically store data for only one RPM setting. This could, in turn, be extended to any other operational parameter such as load setting, ambient temperature, and the like, as previously described. The dynamic markers, however, that can be placed in a type of index file pointing to the raw data stream can classify portions of the stream in homogenous entities that can be more readily compared to previously collected portions of the raw data stream.

[0382] The many embodiments include the hybrid relational metadata-binary storage approach that can use the best of pre-existing technologies for both relational and raw data streams. In embodiments, the hybrid relational metadata - binary storage approach can marry them together with a variety of marker linkages. The marker linkages can permit rapid searches through the

relational metadata and can allow for more efficient analyses of the raw data using conventional SQL techniques with pre-existing technology. This can be shown to permit utilization of many of the capabilities, linkages, compatibilities, and extensions that conventional database technologies do not provide.

[0383] The marker linkages can also permit rapid and efficient storage of the raw data using conventional binary storage and data compression techniques. This can be shown to permit utilization of many of the capabilities, linkages, compatibilities, and extensions that conventional raw data technologies provide such as TDMS (National Instruments), UFF (Universal File Format such as UFF58), and the like. The marker linkages can further permit using the marker technology links where a vastly richer set of data from the ensembles can be amassed in the same collection time as more conventional systems. The richer set of data from the ensembles can store data snapshots associated with predetermined collection criterion and the proposed system can derive multiple snapshots from the collected data streams utilizing the marker technology. In doing so, it can be shown that a relatively richer analysis of the collected data can be achieved. One such benefit can include more trending points of vibration at a specific frequency or order of running speed versus RPM, load, operating temperature, flow rates, and the like, which can be collected for a similar time relative to what is spent collecting data with a conventional system.

[0384] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from machines, elements of the machines and the environment of the machines including heavy duty machines deployed at a local job site or at distributed job sites under common control. The heavy-duty machines may include earthmoving equipment, heavy duty on-road industrial vehicles, heavy duty off-road industrial vehicles, industrial machines deployed in various settings such as turbines, turbomachinery, generators, pumps, pulley systems, manifold and valve systems, and the like. In embodiments, heavy industrial machinery may also include earth-moving equipment, earth-compacting equipment, hauling equipment, hoisting equipment, conveying equipment, aggregate production equipment, equipment used in concrete construction, and piledriving equipment. In examples, earth moving equipment may include excavators, backhoes, loaders, bulldozers, skid steer loaders, trenchers, motor graders, motor scrapers, crawler loaders, and wheeled loading shovels. In examples, construction vehicles may include dumpers, tankers, tippers, and trailers. In examples, material handling equipment may include cranes, conveyors, forklift, and hoists. In examples, construction equipment may include tunnel and handling equipment, road rollers, concrete mixers, hot mix plants, road making machines (compactors), stone crashers, pavers, slurry seal machines, spraying and plastering machines, and heavy-duty pumps. Further examples of heavy industrial equipment may include different systems such as implement traction, structure, power train, control, and

information. Heavy industrial equipment may include many different powertrains and combinations thereof to provide power for locomotion and to also provide power to accessories and onboard functionality. In each of these examples, the platform 100 may deploy the local data collection system 102 into the environment 104 in which these machines, motors, pumps, and the like, operate and directly connected integrated into each of the machines, motors, pumps, and the like.

[0385] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from machines in operation and machines in being constructed such as turbine and generator sets like a Siemens™ SGT6-5000F™ gas turbine, an SST-900™ steam turbine, a SGen6-1000A™ generator, and a SGen6-100A™ generator, and the like. In embodiments, the local data collection system 102 may be deployed to monitor steam turbines as they rotate in the currents caused by hot water vapor that may be directed through the turbine but otherwise generated from a different source such as from gas-fired burners, nuclear cores, molten salt loops and the like. In these systems, the local data collection system 102 may monitor the turbines and the water or other fluids in a closed loop cycle in which water condenses and is then heated until it evaporates again. The local data collection system 102 may monitor the steam turbines separately from the fuel source deployed to heat the water to steam. In examples, working temperatures of steam turbines may be between 500 and 650 °C. In many embodiments, an array of steam turbines may be arranged and configured for high, medium, and low pressure, so they may optimally convert the respective steam pressure into rotational movement.

[0386] The local data collection system 102 may also be deployed in a gas turbines arrangement and therefore not only monitor the turbine in operation but also monitor the hot combustion gases feed into the turbine that may be in excess of 1,500 °C. Because these gases are much hotter than those in steam turbines, the blades may be cooled with air that may flow out of small openings to create a protective film or boundary layer between the exhaust gases and the blades. This temperature profile may be monitored by the local data collection system 102. Gas turbine engines, unlike typical steam turbines, include a compressor, a combustion chamber, and a turbine all of which are journaled for rotation with a rotating shaft. The construction and operation of each of these components may be monitored by the local data collection system 102.

[0387] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from water turbines serving as rotary engines that may harvest energy from moving water and are used for electric power generation. The type of water turbine or hydro-power selected for a project may be based on the height of standing water, often referred to as head, and the flow (or volume of water) at the site. In this example, a generator may be placed at the top of a shaft that connects to the water turbine. As the turbine

catches the naturally moving water in its blade and rotates, the turbine sends rotational power to the generator to generate electrical energy. In doing so, the platform 100 may monitor signals from the generators, the turbines, the local water system, flow controls such as dam windows and sluices. Moreover, the platform 100 may monitor local conditions on the electric grid including load, predicted demand, frequency response, and the like, and include such information in the monitoring and control deployed by platform 100 in these hydroelectric settings.

[0388] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from energy production environments, such as thermal, nuclear, geothermal, chemical, biomass, carbon-based fuels, hybrid-renewable energy plants, and the like. Many of these plants may use multiple forms of energy harvesting equipment like wind turbines, hydro turbines, and steam turbines powered by heat from nuclear, gas-fired, solar, and molten salt heat sources. In embodiments, elements in such systems may include transmission lines, heat exchangers, desulphurization scrubbers, pumps, coolers, recuperators, chillers, and the like. In embodiments, certain implementations of turbomachinery, turbines, scroll compressors, and the like may be configured in arrayed control so as to monitor large facilities creating electricity for consumption, providing refrigeration, creating steam for local manufacture and heating, and the like, and that arrayed control platforms may be provided by the provider of the industrial equipment such as Honeywell and their Experion™ PKS platform. In embodiments, the platform 100 may specifically communicate with and integrate the local manufacturer-specific controls and may allow equipment from one manufacturer to communicate with other equipment. Moreover, the platform 100 provides allows for the local data collection system 102 to collect information across systems from many different manufacturers. In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from marine industrial equipment, marine diesel engines, shipbuilding, oil and gas plants, refineries, petrochemical plant, ballast water treatment solutions, marine pumps and turbines, and the like.

[0389] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from heavy industrial equipment and processes including monitoring one or more sensors. By way of this example, sensors may be devices that may be used to detect or respond to some type of input from a physical environment, such as an electrical, heat, or optical signal. In embodiments, the local data collection system 102 may include multiple sensors such as, without limitation, a temperature sensor, a pressure sensor, a torque sensor, a flow sensor, a heat sensor, a smoke sensor, an arc sensor, a radiation sensor, a position sensor, an acceleration sensor, a strain sensor, a pressure cycle sensor, a pressure sensor, an air temperature sensor, and the like. The torque sensor may encompass a magnetic twist angle sensor.

In one example, the torque and speed sensors in the local data collection system 102 may be similar to those discussed in U.S. Patent Number 8,352,149 to Meachem, issued 8 January 2013 and hereby incorporated by reference as if fully set forth herein. In embodiments, one or more sensors may be provided such as a tactile sensor, a biosensor, a chemical sensor, an image sensor, a humidity sensor, an inertial sensor, and the like.

[0390] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from sensors that may provide signals for fault detection including excessive vibration, incorrect material, incorrect material properties, trueness to the proper size, trueness to the proper shape, proper weight, trueness to balance. Additional fault sensors include those for inventory control and for inspections such as to confirm that parts are packaged to plan, parts are to tolerance in a plan, occurrence of packaging damage or stress, and sensors that may indicate the occurrence of shock or damage in transit. Additional fault sensors may include detection of the lack of lubrication, over lubrication, the need for cleaning of the sensor detection window, the need for maintenance due to low lubrication, the need for maintenance due to blocking or reduced flow in a lubrication region, and the like.

[0391] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 that includes aircraft operations and manufacture including monitoring signals from sensors for specialized applications such as sensors used in an aircraft's Attitude and Heading Reference System (AHRS), such as gyroscopes, accelerometers, and magnetometers. In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from image sensors such as semiconductor charge coupled devices (CCDs), active pixel sensors, in complementary metal–oxide–semiconductor (CMOS) or N-type metal-oxide-semiconductor (NMOS, Live MOS) technologies. In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from sensors such as an infra-red (IR) sensor, an ultraviolet (UV) sensor, a touch sensor, a proximity sensor, and the like. In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from sensors configured for optical character recognition (OCR), reading barcodes, detecting surface acoustic waves, detecting transponders, communicating with home automation systems, medical diagnostics, health monitoring, and the like.

[0392] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from sensors such as a Micro-Electro-Mechanical Systems (MEMS) sensor, such as ST Microelectronic's™ LSM303AH smart MEMS sensor, which may include an ultra-low-power high-performance system-in-package featuring a 3D digital linear acceleration sensor and a 3D digital magnetic sensor.

[0393] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from additional large machines such as turbines, windmills, industrial vehicles, robots, and the like. These large mechanical machines include multiple components and elements providing multiple subsystems on each machine. To that end, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from individual elements such as axles, bearings, belts, buckets, gears, shafts, gear boxes, cams, carriages, camshafts, clutches, brakes, drums, dynamos, feeds, flywheels, gaskets, pumps, jaws, robotic arms, seals, sockets, sleeves, valves, wheels, actuators, motors, servomotor, and the like. Many of the machines and their elements may include servomotors. The local data collection system 102 may monitor the motor, the rotary encoder, and the potentiometer of the servomechanism to provide three-dimensional detail of position, placement, and progress of industrial processes.

[0394] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from gear drives, powertrains, transfer cases, multispeed axles, transmissions, direct drives, chain drives, belt-drives, shaft-drives, magnetic drives, and similar meshing mechanical drives. In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from fault conditions of industrial machines that may include overheating, noise, grinding gears, locked gears, excessive vibration, wobbling, under-inflation, over-inflation, and the like. Operation faults, maintenance indicators, and interactions from other machines may cause maintenance or operational issues may occur during operation, during installation, and during maintenance. The faults may occur in the mechanisms of the industrial machines but may also occur in infrastructure that supports the machine such as its wiring and local installation platforms. In embodiments, the large industrial machines may face different types of fault conditions such as overheating, noise, grinding gears, excessive vibration of machine parts, fan vibration problems, problems with large industrial machines rotating parts.

[0395] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor signals from industrial machinery including failures that may be caused by premature bearing failure that may occur due to contamination or loss of bearing lubricant. In another example, a mechanical defect such as misalignment of bearings may occur. Many factors may contribute to the failure such as metal fatigue, therefore, the local data collection system 102 may monitor cycles and local stresses. By way of this example, the platform 100 may monitor the incorrect operation of machine parts, lack of maintenance and servicing of parts, corrosion of vital machine parts, such as couplings or gearboxes, misalignment of machine parts, and the like. Though the fault occurrences cannot be completely stopped, many industrial

breakdowns may be mitigated to reduce operational and financial losses. The platform 100 provides real-time monitoring and predictive maintenance in many industrial environments where it has been shown to present a cost-savings over regularly-scheduled maintenance processes that replace parts according to a rigid expiration of time and not actual load and wear and tear on the element or machine. To that end, the platform 10 may provide reminders of, or perform some, preventive measures such as adhering to operating manual and mode instructions for machines, proper lubrication, and maintenance of machine parts, minimizing or eliminating overrun of machines beyond their defined capacities, replacement of worn but still functional parts as needed, properly training the personnel for machine use, and the like.

[0396] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 to monitor multiple signals that may be carried by a plurality of physical, electronic, and symbolic formats or signals. The platform 100 may employ signal processing including a plurality of mathematical, statistical, computational, heuristic, and linguistic representations and processing of signals and a plurality of operations needed for extraction of useful information from signal processing operations such as techniques for representation, modeling, analysis, synthesis, sensing, acquisition, and extraction of information from signals. In examples, signal processing may be performed using a plurality of techniques, including but not limited to transformations, spectral estimations, statistical operations, probabilistic and stochastic operations, numerical theory analysis, data mining, and the like. The processing of various types of signals forms the basis of many electrical or computational process. As a result, signal processing applies to almost all disciplines and applications in the industrial environment such as audio and video processing, image processing, wireless communications, process control, industrial automation, financial systems, feature extraction, quality improvements such as noise reduction, image enhancement, and the like. Signal processing for images may include pattern recognition for manufacturing inspections, quality inspection, and automated operational inspection and maintenance. The platform 100 may employ many pattern recognition techniques including those that may classify input data into classes based on key features with the objective of recognizing patterns or regularities in data. The platform 100 may also implement pattern recognition processes with machine learning operations and may be used in applications such as computer vision, speech and text processing, radar processing, handwriting recognition, CAD systems, and the like. The platform 100 may employ supervised classification and unsupervised classification. The supervised learning classification algorithms may be based to create classifiers for image or pattern recognition, based on training data obtained from different object classes. The unsupervised learning classification algorithms may operate by finding hidden structures in unlabeled data using advanced analysis techniques such as segmentation and

clustering. For example, some of the analysis techniques used in unsupervised learning may include K-means clustering, Gaussian mixture models, Hidden Markov models, and the like. The algorithms used in supervised and unsupervised learning methods of pattern recognition enable the use of pattern recognition in various high precision applications. The platform 100 may use pattern recognition in face detection related applications such as security systems, tracking, sports related applications, fingerprint analysis, medical and forensic applications, navigation and guidance systems, vehicle tracking, public infrastructure systems such as transport systems, license plate monitoring, and the like.

[0397] In embodiments, the platform 100 may include the local data collection system 102 deployed in the environment 104 using machine learning to enable derivation-based learning outcomes from computers without the need to program them. The platform 100 may, therefore, learn from and make decisions on a set of data, by making data-driven predictions and adapting according to the set of data. In embodiments, machine learning may involve performing a plurality of machine learning tasks by machine learning systems, such as supervised learning, unsupervised learning, and reinforcement learning. Supervised learning may include presenting a set of example inputs and desired outputs to the machine learning systems. Unsupervised learning may include the learning algorithm itself structuring its input by methods such as pattern detection and/or feature learning. Reinforcement learning may include the machine learning systems performing in a dynamic environment and then providing feedback about correct and incorrect decisions. In examples, machine learning may include a plurality of other tasks based on an output of the machine learning system. In examples, the tasks may also be classified as machine learning problems such as classification, regression, clustering, density estimation, dimensionality reduction, anomaly detection, and the like. In examples, machine learning may include a plurality of mathematical and statistical techniques. In examples, the many types of machine learning algorithms may include decision tree based learning, association rule learning, deep learning, artificial neural networks, genetic learning algorithms, inductive logic programming, support vector machines (SVMs), Bayesian network, reinforcement learning, representation learning, rule-based machine learning, sparse dictionary learning, similarity and metric learning, learning classifier systems (LCS), logistic regression, random forest, K-Means, gradient boost and adaboost, K-nearest neighbors (KNN), a priori algorithms, and the like. In embodiments, certain machine learning algorithms may be used (such as genetic algorithms defined for solving both constrained and unconstrained optimization problems that may be based on natural selection, the process that drives biological evolution). By way of this example, genetic algorithms may be deployed to solve a variety of optimization problems that are not well suited for standard optimization algorithms, including problems in which the objective functions are discontinuous,

not differentiable, stochastic, or highly nonlinear. In an example, the genetic algorithm may be used to address problems of mixed integer programming, where some components restricted to being integer-valued. Genetic algorithms and machine learning techniques and systems may be used in computational intelligence systems, computer vision, Natural Language Processing (NLP), recommender systems, reinforcement learning, building graphical models, and the like. By way of this example, the machine learning systems may be used to perform intelligent computing based control and be responsive to tasks in a wide variety of systems (such as interactive websites and portals, brain-machine interfaces, online security and fraud detection systems, medical applications such as diagnosis and therapy assistance systems, classification of DNA sequences, and the like). In examples, machine learning systems may be used in advanced computing applications (such as online advertising, natural language processing, robotics, search engines, software engineering, speech and handwriting recognition, pattern matching, game playing, computational anatomy, bioinformatics systems and the like). In an example, machine learning may also be used in financial and marketing systems (such as for user behavior analytics, online advertising, economic estimations, financial market analysis, and the like).

[0398] Additional details are provided below in connection with the methods, systems, devices, and components depicted in connection with Figures 1 through 6. In embodiments, methods and systems are disclosed herein for cloud-based, machine pattern recognition based on fusion of remote, analog industrial sensors. For example, data streams from vibration, pressure, temperature, accelerometer, magnetic, electrical field, and other analog sensors may be multiplexed or otherwise fused, relayed over a network, and fed into a cloud-based machine learning facility, which may employ one or more models relating to an operating characteristic of an industrial machine, an industrial process, or a component or element thereof. A model may be created by a human who has experience with the industrial environment and may be associated with a training data set (such as models created by human analysis or machine analysis of data that is collected by the sensors in the environment, or sensors in other similar environments. The learning machine may then operate on other data, initially using a set of rules or elements of a model, such as to provide a variety of outputs, such as classification of data into types, recognition of certain patterns (such as those indicating the presence of faults, orthoses indicating operating conditions, such as fuel efficiency, energy production, or the like). The machine learning facility may take feedback, such as one or more inputs or measures of success, such that it may train, or improve, its initial model (such as improvements by adjusting weights, rules, parameters, or the like, based on the feedback). For example, a model of fuel consumption by an industrial machine may include physical model parameters that characterize weights, motion, resistance, momentum, inertia, acceleration, and other factors that indicate consumption, and chemical model parameters (such as

those that predict energy produced and/or consumed e.g., such as through combustion, through chemical reactions in battery charging and discharging, and the like). The model may be refined by feeding in data from sensors disposed in the environment of a machine, in the machine, and the like, as well as data indicating actual fuel consumption, so that the machine can provide increasingly accurate, sensor-based, estimates of fuel consumption and can also provide output that indicate what changes can be made to increase fuel consumption (such as changing operation parameters of the machine or changing other elements of the environment, such as the ambient temperature, the operation of a nearby machine, or the like). For example, if a resonance effect between two machines is adversely affecting one of them, the model may account for this and automatically provide an output that results in changing the operation of one of the machines (such as to reduce the resonance, to increase fuel efficiency of one or both machines). By continuously adjusting parameters to cause outputs to match actual conditions, the machine learning facility may self-organize to provide a highly accurate model of the conditions of an environment (such as for predicting faults, optimizing operational parameters, and the like). This may be used to increase fuel efficiency, to reduce wear, to increase output, to increase operating life, to avoid fault conditions, and for many other purposes.

[0399] Figure 14 illustrates components and interactions of a data collection architecture involving the application of cognitive and machine learning systems to data collection and processing. Referring to Figure 14, the data collection system 102 may be disposed in an environment (such as an industrial environment where one or more complex systems, such as electro-mechanical systems and machines are manufactured, assembled, or operated). The data collection system 102 may include onboard sensors and may take input, such as through one or more input interfaces or ports 4008, from one or more sensors (such as analog or digital sensors of any type disclosed herein) and from one or more input sources 116 (such as sources that may be available through Wi-Fi, Bluetooth, NFC, or other local network connections or over the Internet). Sensors may be combined and multiplexed (such as with one or more multiplexers 4002). Data may be cached or buffered in a cache/buffer 4022 and made available to external systems, such as a remote host processing system 112 as described elsewhere in this disclosure (which may include an extensive processing architecture 4024, including any of the elements described in connection with other embodiments described throughout this disclosure and in the Figure), though one or more output interfaces and ports 4010 (which may in embodiments be separate from or the same as the input interfaces and ports 4008). The data collection system 102 may be configured to take input from a host processing system 112, such as input from an analytic system 4018, which may operate on data from the data collection system 102 and data from other input sources 116 to provide analytic

results, which in turn may be provided as a learning feedback input 4012 to the data collection system, such as to assist in configuration and operation of the data collection system 102.

[0400] Combination of inputs (including selection of what sensors or input sources to turn "on" or "off") may be performed under the control of machine-based intelligence, such as using a local cognitive input selection system 4004, an optionally remote cognitive input selection system 4114, or a combination of the two. The cognitive input selection systems 4004, 4014 may use intelligence and machine learning capabilities described elsewhere in this disclosure, such as using detected conditions (such as conditions informed by the input sources 116 or sensors), state information (including state information determined by a machine state recognition system 4020 that may determine a state), such as relating to an operational state, an environmental state, a state within a known process or workflow, a state involving a fault or diagnostic condition, or many others. This may include optimization of input selection and configuration based on learning feedback from the learning feedback system 4012, which may include providing training data (such as from the host processing system 112 or from other data collection systems 102 either directly or from the host processing system 112) and may include providing feedback metrics, such as success metrics calculated within the analytic system 4018 of the host processing system 112. For example, if a data stream consisting of a particular combination of sensors and inputs yields positive results in a given set of conditions (such as providing improved pattern recognition, improved prediction, improved diagnosis, improved yield, improved return on investment, improved efficiency, or the like), then metrics relating to such results from the analytic system 4018 can be provided via the learning feedback system 4012 to the cognitive input selection systems 4004, 4014 to help configure future data collection to select that combination in those conditions (allowing other input sources to be de-selected, such as by powering down the other sensors). In embodiments, selection and de-selection of sensor combinations, under control of one or more of the cognitive input selection systems 4004, may occur with automated variation, such as using genetic programming techniques, based on the learning feedback 4012, such as from the analytic system 4018, effective combinations for a given state or set of conditions are promoted, and less effective combinations are demoted, resulting in progressive optimization and adaptation of the local data collection system to each unique environment. Thus, an automatically adapting, multi-sensor data collection system is provided, where cognitive input selection is used (with feedback) to improve the effectiveness, efficiency, or other performance parameters of the data collection system within its particular environment. Performance parameters may relate to overall system metrics (such as financial yields, process optimization results, energy production or usage, and the like), analytic metrics (such as success in recognizing patterns, making predictions, classifying data, or the like), and local system metrics (such as bandwidth utilization, storage utilization, power consumption,

and the like). In embodiments, the analytic system 4018, the state system 4020 and the cognitive input selection system 4114 of a host may take data from multiple data collection systems 102, such that optimization (including of input selection) may be undertaken through coordinated operation of multiple systems 102. For example, the cognitive input selection system 4114 may understand that if one data collection system 102 is already collecting vibration data for an X-axis, the X-axis vibration sensor for the other data collection system might be turned off, in favor of getting Y-axis data from the other data collector 102. Thus, through coordinated collection by the host cognitive input selection system 4114, the activity of multiple collectors 102, across a host of different sensors, can provide for a rich data set for the host processing system 112, without wasting energy, bandwidth, storage space, or the like. As noted above, optimization may be based on overall system success metrics, analytic success metrics, and local system metrics, or a combination of the above.

[0401] Methods and systems are disclosed herein for cloud-based, machine pattern analysis of state information from multiple industrial sensors to provide anticipated state information for an industrial system. In embodiments, machine learning may take advantage of a state machine, such as tracking states of multiple analog and/or digital sensors, feeding the states into a pattern analysis facility, and determining anticipated states of the industrial system based on historical data about sequences of state information. For example, where a temperature state of an industrial machine exceeds a certain threshold and is followed by a fault condition, such as breaking down of a set of bearings, that temperature state may be tracked by a pattern recognizer, which may produce an output data structure indicating an anticipated bearing fault state (whenever an input state of a high temperature is recognized). A wide range of measurement values and anticipated states may be managed by a state machine, relating to temperature, pressure, vibration, acceleration, momentum, inertia, friction, heat, heat flux, galvanic states, magnetic field states, electrical field states, capacitance states, charge and discharge states, motion, position, and many others. States may comprise combined states, where a data structure includes a series of states, each of which is represented by a place in a byte-like data structure. For example, an industrial machine may be characterized by a genetic structure, such as one that provides pressure, temperature, vibration, and acoustic data, the measurement of which takes one place in the data structure, so that the combined state can be operated on as a byte-like structure, such as a structure for compactly characterizing the current combined state of the machine or environment, or compactly characterizing the anticipated state. This byte-like structure can be used by a state machine for machine learning, such as pattern recognition that operates on the structure to determine patterns that reflect combined effects of multiple conditions. A wide variety of such structure can be tracked and used, such as in machine learning, representing various combinations, of various length, of the

different elements that can be sensed in an industrial environment. In embodiments, byte-like structures can be used in a genetic programming technique, such as by substituting different types of data, or data from varying sources, and tracking outcomes over time, so that one or more favorable structures emerges based on the success of those structures when used in real world situations, such as indicating successful predictions of anticipated states, or achievement of success operational outcomes, such as increased efficiency, successful routing of information, achieving increased profits, or the like. That is, by varying what data types and sources are used in byte-like structures that are used for machine optimization over time, a genetic programming-based machine learning facility can "evolve" a set of data structures, consisting of a favorable mix of data types (e.g., pressure, temperature, and vibration), from a favorable mix of data sources (e.g., temperature is derived from sensor X, while vibration comes from sensor Y), for a given purpose. Different desired outcomes may result in different data structures that are best adapted to support effective achievement of those outcomes over time with application of machine learning and promotion of structures with favorable results for the desired outcome in question by genetic programming. The promoted data structures may provide compact, efficient data for various activities as described throughout this disclosure, including being stored in data pools (which may be optimized by storing favorable data structures that provide the best operational results for a given environment), being presented in data marketplaces (such as being presented as the most effective structures for a given purpose), and the like.

[0402] In embodiments, a platform is provided having cloud-based, machine pattern analysis of state information from multiple analog industrial sensors to provide anticipated state information for an industrial system. In embodiments, the host processing system 112, such as disposed in the cloud, may include the state system 4020, which may be used to infer or calculate a current state or to determine an anticipated future state relating to the data collection system 102 or some aspect of the environment in which the data collection system 102 is disposed, such as the state of a machine, a component, a workflow, a process, an event (e.g., whether the event has occurred), an object, a person, a condition, a function, or the like. Maintaining state information allows the host processing system 112 to undertake analysis, such as in one or more analytic systems 4018, to determine contextual information, to apply semantic and conditional logic, and perform many other functions as enabled by the processing architecture 4024 described throughout this disclosure.

[0403] In embodiments, a platform is provided having cloud-based policy automation engine for IoT, with creation, deployment, and management of IoT devices. In embodiments, the platform 100 includes (or is integrated with, or included in) the host processing system 112, such as on a cloud platform, a policy automation engine 4032 for automating creation, deployment, and

management of policies to IoT devices. Polices, which may include access policies, network usage policies, storage usage policies, bandwidth usage policies, device connection policies, security policies, rule-based policies, role-based polices, and others, may be required to govern the use of IoT devices. For example, as IoT devices may have many different network and data communications to other devices, policies may be needed to indicate to what devices a given device can connect, what data can be passed on, and what data can be received. As billions of devices with countless potential connections are expected to be deployed in the near future, it becomes impossible for humans to configure policies for IoT devices on a connection-by-connection basis. Accordingly, the intelligent policy automation engine 4032 may include cognitive features for creating, configuring, and managing policies. The policy automation engine 4032 may consume information about possible policies, such as from a policy database or library, which may include one or more public sources of available policies. These may be written in one or more conventional policy languages or scripts. The policy automation engine 4032 may apply the policies according to one or more models, such as based on the characteristics of a given device, machine, or environment. For example, a large machine, such as a machine for power generation, may include a policy that only a verifiably local controller can change certain parameters of the power generation, thereby avoiding a remote "takeover" by a hacker. This may be accomplished in turn by automatically finding and applying security policies that bar connection of the control infrastructure of the machine to the Internet, by requiring access authentication, or the like. The policy automation engine 4032 may include cognitive features, such as varying the application of policies, the configuration of policies, and the like (such as features based on state information from the state system 4020). The policy automation engine 4032 may take feedback, as from the learning feedback system 4012, such as based on one or more analytic results from the analytic system 4018, such as based on overall system results (such as the extent of security breaches, policy violations, and the like), local results, and analytic results. By variation and selection based on such feedback, the policy automation engine 4032 can, over time, learn to automatically create, deploy, configure, and manage policies across very large numbers of devices, such as managing policies for configuration of connections among IoT devices.

[0404] Methods and systems are disclosed herein for on-device sensor fusion and data storage for industrial IoT devices, including on-device sensor fusion and data storage for an industrial IoT device, where data from multiple sensors is multiplexed at the device for storage of a fused data stream. For example, pressure and temperature data may be multiplexed into a data stream that combines pressure and temperature in a time series, such as in a byte-like structure (where time, pressure, and temperature are bytes in a data structure, so that pressure and temperature remain linked in time, without requiring separate processing of the streams by outside systems), or by

adding, dividing, multiplying, subtracting, or the like, such that the fused data can be stored on the device. Any of the sensor data types described throughout this disclosure can be fused in this manner and stored in a local data pool, in storage, or on an IoT device, such as a data collector, a component of a machine, or the like.

[0405] In embodiments, a platform is provided having on-device sensor fusion and data storage for industrial IoT devices. In embodiments, a cognitive system is used for a self-organizing storage system 4028 for the data collection system 102. Sensor data, and in particular analog sensor data, can consume large amounts of storage capacity, in particular where a data collector 102 has multiple sensor inputs onboard or from the local environment. Simply storing all the data indefinitely is not typically a favorable option, and even transmitting all of the data may strain bandwidth limitations, exceed bandwidth permissions (such as exceeding cellular data plan capacity), or the like. Accordingly, storage strategies are needed. These typically include capturing only portions of the data (such as snapshots), storing data for limited time periods, storing portions of the data (such as intermediate or abstracted forms), and the like. With many possible selections among these and other options, determining the correct storage strategy may be highly complex. In embodiments, the self-organizing storage system 4028 may use a cognitive system, based on the learning feedback 4012, and use various metrics from the analytic system 4018 or other system of the host cognitive input selection system 4114, such as overall system metrics, analytic metrics, and local performance indicators. The self-organizing storage system 4028 may automatically vary storage parameters, such as storage locations (including local storage on the data collection system 102, storage on nearby data collection systems 102 (such as using peer-to-peer organization) and remote storage, such as network-based storage), storage amounts, storage duration, type of data stored (including individual sensors or input sources 116, as well as various combined or multiplexed data, such as selected under the cognitive input selection systems 4004, 4014), storage type (such as using RAM, Flash, or other short-term memory versus available hard drive space), storage organization (such as in raw form, in hierarchies, and the like), and others. Variation of the parameters may be undertaken with feedback, so that over time the data collection system 102 adapts its storage of data to optimize itself to the conditions of its environment, such as a particular industrial environment, in a way that results in it storing the data that is needed in the right amounts and of the right type for availability to users.

[0406] In embodiments, the local cognitive input selection system 4004 may organize fusion of data for various onboard sensors, external sensors (such as in the local environment) and other input sources 116 to the local data collection system 102 into one or more fused data streams, such as using the multiplexer 4002 to create various signals that represent combinations, permutations, mixes, layers, abstractions, data-metadata combinations, and the like of the source analog and/or

digital data that is handled by the data collection system 102. The selection of a particular fusion of sensors may be determined locally by the cognitive input selection system 4004, such as based on learning feedback from the learning feedback system 4012, such as various overall system, analytic system and local system results and metrics. In embodiments, the system may learn to fuse particular combinations and permutations of sensors, such as in order to best achieve correct anticipation of state, as indicated by feedback of the analytic system 4018 regarding its ability to predict future states, such as the various states handled by the state system 4020. For example, the input selection system 4004 may indicate selection of a sub-set of sensors among a larger set of available sensors, and the inputs from the selected sensors may be combined, such as by placing input from each of them into a byte of a defined, multi-bit data structure (such as a combination by taking a signal from each at a given sampling rate or time and placing the result into the byte structure, then collecting and processing the bytes over time), by multiplexing in the multiplexer 4002, such as a combination by additive mixing of continuous signals, and the like. Any of a wide range of signal processing and data processing techniques for combination and fusing may be used, including convolutional techniques, coercion techniques, transformation techniques, and the like. The particular fusion in question may be adapted to a given situation by cognitive learning, such as by having the cognitive input selection system 4004 learn, based on the feedback 4012 from results (such as feedback conveyed by the analytic system 4018), such that the local data collection system 102 executes context-adaptive sensor fusion.

[0407] In embodiments, the analytic system 4018 may apply to any of a wide range of analytic techniques, including statistical and econometric techniques (such as linear regression analysis, use similarity matrices, heat map based techniques, and the like), reasoning techniques (such as Bayesian reasoning, rule-based reasoning, inductive reasoning, and the like), iterative techniques (such as feedback, recursion, feed-forward and other techniques), signal processing techniques (such as Fourier and other transforms), pattern recognition techniques (such as Kalman and other filtering techniques), search techniques, probabilistic techniques (such as random walks, random forest algorithms, and the like), simulation techniques (such as random walks, random forest algorithms, linear optimization and the like), and others. This may include computation of various statistics or measures. In embodiments, the analytic system 4018 may be disposed, at least in part, on the data collection system 102, such that a local analytic system can calculate one or more measures, such as measures relating to any of the items noted throughout this disclosure. For example, measures of efficiency, power utilization, storage utilization, redundancy, entropy, and other factors may be calculated onboard, so that the data collection 102 can enable various cognitive and learning functions noted throughout this disclosure without dependence on a remote (e.g., cloud-based) analytic system.

[0408] In embodiments, the host processing system 112, the data collection system 102, or both, may include, connect to, or integrate with, the self-organizing networking system 4020, which may comprise a cognitive system for providing machine-based, intelligent or organization of network utilization for transport of data in a data collection system, such as for handling analog and other sensor data, or other source data, such as among one or more local data collection systems 102 and a host processing system 112. This may include organizing network utilization for source data delivered to data collection systems, for feedback data, such as analytic data provided to or via the learning feedback system 4012, data for supporting a marketplace (such as described in connection with other embodiments), and output data provided via output interfaces and ports 4010 from one or more data collection systems 102.

[0409] Methods and systems are disclosed herein for a self-organizing data marketplace for industrial IoT data, including where available data elements are organized in the marketplace for consumption by consumers based on training a self-organizing facility with a training set and feedback from measures of marketplace success. A marketplace may be set up initially to make available data collected from one or more industrial environments, such as presenting data by type, by source, by environment, by machine, by one or more patterns, or the like (such as in a menu or hierarchy). The marketplace may vary the data collected, the organization of the data, the presentation of the data (including pushing the data to external sites, providing links, configuring APIs by which the data may be accessed, and the like), the pricing of the data, or the like, such as under machine learning, which may vary different parameters of any of the foregoing. The machine learning facility may manage all of these parameters by self-organization, such as by varying parameters over time (including by varying elements of the data types presented), the data sourced used to obtain each type of data, the data structures presented (such as byte-like structures, fused or multiplexed structures (such as representing multiple sensor types), and statistical structures (such as representing various mathematical products of sensor information), among others), the pricing for the data, where the data is presented, how the data is presented (such as by APIs, by links, by push messaging, and the like), how the data is stored, how the data is obtained, and the like. As parameters are varied, feedback may be obtained as to measures of success, such as number of views, yield (e.g., price paid) per access, total yield, per unit profit, aggregate profit, and many others, and the self-organizing machine learning facility may promote configurations that improve measures of success and demote configurations that do not, so that, over time, the marketplace is progressively configured to present favorable combinations of data types (e.g., those that provide robust prediction of anticipated states of particular industrial environments of a given type), from favorable sources (e.g., those that are reliable, accurate and low priced), with effective pricing (e.g., pricing that tends to provide high aggregate profit from the marketplace).

The marketplace may include spiders, web crawlers, and the like to seek input data sources, such as finding data pools, connected IoT devices, and the like that publish potentially relevant data. These may be trained by human users and improved by machine learning in a manner similar to that described elsewhere in this disclosure.

[0410] In embodiments, a platform is provided having a self-organizing data marketplace for industrial IoT data. Referring to Figure 15, in embodiments, a platform is provided having a cognitive data marketplace 4102, referred to in some cases as a self-organizing data marketplace, for data collected by one or more data collection systems 102 or for data from other sensors or input sources 116 that are located in various data collection environments, such as industrial environments. In addition to data collection systems 102, this may include data collected, handled or exchanged by IoT devices, such as cameras, monitors, embedded sensors, mobile devices, diagnostic devices and systems, instrumentation systems, telematics systems, and the like, such as for monitoring various parameters and features of machines, devices, components, parts, operations, functions, conditions, states, events, workflows and other elements (collectively encompassed by the term "states") of such environments. Data may also include metadata about any of the foregoing, such as describing data, indicating provenance, indicating elements relating to identity, access, roles, and permissions, providing summaries or abstractions of data, or otherwise augmenting one or more items of data to enable further processing, such as for extraction, transforming, loading, and processing data. Such data (such term including metadata except where context indicates otherwise) may be highly valuable to third parties, either as an individual element (such as the instance where data about the state of an environment can be used as a condition within a process) or in the aggregate (such as the instance where collected data, optionally over many systems and devices in different environments can be used to develop models of behavior, to train learning systems, or the like). As billions of IoT devices are deployed, with countless connections, the amount of available data will proliferate. To enable access and utilization of data, the cognitive data marketplace 4102 enables various components, features, services, and processes for enabling users to supply, find, consume, and transact in packages of data, such as batches of data, streams of data (including event streams), data from various data pools 4120, and the like. In embodiments, the cognitive data marketplace 4102 may be included in, connected to, or integrated with, one or more other components of the host processing architecture 4024 of the host processing system 112, such as a cloud-based system, as well as to various sensors, input sources 115, data collection systems 102 and the like. The cognitive data marketplace 4102 may include marketplace interfaces 4108, which may include one or more supplier interfaces by which data suppliers may make data available and one more consumer interfaces by which data may be found and acquired. The consumer interface may include an

interface to a data market search system 4118, which may include features that enable a user to indicate what types of data a user wishes to obtain, such as by entering keywords in a natural language search interface that characterize data or metadata. The search interface can use various search and filtering techniques, including keyword matching, collaborative filtering (such as using known preferences or characteristics of the consumer to match to similar consumers and the past outcomes of those other consumers), ranking techniques (such as ranking based on success of past outcomes according to various metrics, such as those described in connection with other embodiments in this disclosure). In embodiments, a supply interface may allow an owner or supplier of data to supply the data in one or more packages to and through the cognitive data marketplace 4102, such as packaging batches of data, streams of data, or the like. The supplier may pre-package data, such as by providing data from a single input source 116, a single sensor, and the like, or by providing combinations, permutations, and the like (such as multiplexed analog data, mixed bytes of data from multiple sources, results of extraction, loading and transformation, results of convolution, and the like), as well as by providing metadata with respect to any of the foregoing. Packaging may include pricing, such as on a per-batch basis, on a streaming basis (such as subscription to an event feed or other feed or stream), on a per item basis, on a revenue share basis, or other basis. For data involving pricing, a data transaction system 4114 may track orders, delivery, and utilization, including fulfillment of orders. The transaction system 4114 may include rich transaction features, including digital rights management, such as by managing cryptographic keys that govern access control to purchased data, that govern usage (such as allowing data to be used for a limited time, in a limited domain, by a limited set of users or roles, or for a limited purpose). The transaction system 4114 may manage payments, such as by processing credit cards, wire transfers, debits, and other forms of consideration.

[0411] In embodiments, a cognitive data packaging system 4010 of the marketplace 4102 may use machine-based intelligence to package data, such as by automatically configuring packages of data in batches, streams, pools, or the like. In embodiments, packaging may be according to one or more rules, models, or parameters, such as by packaging or aggregating data that is likely to supplement or complement an existing model. For example, operating data from a group of similar machines (such as one or more industrial machines noted throughout this disclosure) may be aggregated together, such as based on metadata indicating the type of data or by recognizing features or characteristics in the data stream that indicate the nature of the data. In embodiments, packaging may occur using machine learning and cognitive capabilities, such as by learning what combinations, permutations, mixes, layers, and the like of input sources 116, sensors, information from data pools 4120 and information from data collection systems 102 are likely to satisfy user requirements or result in measures of success. Learning may be based on the learning feedback

4012, such as learning based on measures determined in the analytic system 4018, such as system performance measures, data collection measures, analytic measures, and the like. In embodiments, success measures may be correlated to marketplace success measures, such as viewing of packages, engagement with packages, purchase or licensing of packages, payments made for packages, and the like. Such measures may be calculated in the analytic system 4018, including associating particular feedback measures with search terms and other inputs, so that a cognitive packaging system 4110 can find and configure packages that are designed to provide increased value to consumers and increased returns for data suppliers. In embodiments, the cognitive data packaging system 4110 can automatically vary packaging, such as using different combinations, permutations, mixes, and the like, and varying weights applied to given input sources, sensors, data pools and the like, using the learning feedback 4012 to promote favorable packages and de-emphasize less favorable packages. This may occur using genetic programming and similar techniques that compare outcomes for different packages. Feedback may include state information from the state system 4020 (such as about various operating states, and the like), as well as about marketplace conditions and states, such as pricing and availability information for other data sources. Thus, an adaptive cognitive data packaging system 4110 is provided that automatically adapts to conditions to provide favorable packages of data for the marketplace 4102.

[0412] In embodiments, a cognitive data pricing system 4112 may be provided to set pricing for data packages. In embodiments, the data pricing system 4112 may use a set of rules, models, or the like, such as setting pricing based on supply conditions, demand conditions, pricing of various available sources, and the like. For example, pricing for a package may be configured to be set based on the sum of the prices of constituent elements (such as input sources, sensor data, or the like), or to be set based on a rule-based discount to the sum of prices for constituent elements, or the like. Rules and conditional logic may be applied, such as rules that factor in cost factors (such as bandwidth and network usage, peak demand factors, scarcity factors, and the like), rules that factor in utilization parameters (such as the purpose, domain, user, role, duration, or the like for a package) and many others. In embodiments, the cognitive data pricing system 4112 may include fully cognitive, intelligent features, such as using genetic programming including automatically varying pricing and tracking feedback on outcomes. Outcomes on which tracking feedback may be based include various financial yield metrics, utilization metrics and the like that may be provided by calculating metrics in the analytic system 4018 on data from the data transaction system 4114.

[0413] Methods and systems are disclosed herein for self-organizing data pools which may include self-organization of data pools based on utilization and/or yield metrics, including utilization and/or yield metrics that are tracked for a plurality of data pools. The data pools may initially

comprise unstructured or loosely structured pools of data that contain data from industrial environments, such as sensor data from or about industrial machines or components. For example, a data pool might take streams of data from various machines or components in an environment, such as turbines, compressors, batteries, reactors, engines, motors, vehicles, pumps, rotors, axles, bearings, valves, and many others, with the data streams containing analog and/or digital sensor data (of a wide range of types), data published about operating conditions, diagnostic and fault data, identifying data for machines or components, asset tracking data, and many other types of data. Each stream may have an identifier in the pool, such as indicating its source, and optionally its type. The data pool may be accessed by external systems, such as through one or more interfaces or APIs (e.g., RESTful APIs), or by data integration elements (such as gateways, brokers, bridges, connectors, or the like), and the data pool may use similar capabilities to get access to available data streams. A data pool may be managed by a self-organizing machine learning facility, which may configure the data pool, such as by managing what sources are used for the pool, managing what streams are available, and managing APIs or other connections into and out of the data pool. The self-organization may take feedback such as based on measures of success that may include measures of utilization and yield. The measures of utilization and yield that may include may account for the cost of acquiring and/or storing data, as well as the benefits of the pool, measured either by profit or by other measures that may include user indications of usefulness, and the like. For example, a self-organizing data pool might recognize that chemical and radiation data for an energy production environment are regularly accessed and extracted, while vibration and temperature data have not been used, in which case the data pool might automatically reorganize, such as by ceasing storage of vibration and/or temperature data, or by obtaining better sources of such data. This automated reorganization can also apply to data structures, such as promoting different data types, different data sources, different data structures, and the like, through progressive iteration and feedback.

[0414] In embodiments, a platform is provided having self-organization of data pools based on utilization and/or yield metrics. In embodiments, the data pools 4120 may be self-organizing data pools 4120, such as being organized by cognitive capabilities as described throughout this disclosure. The data pools 4120 may self-organize in response to the learning feedback 4012, such as based on feedback of measures and results, including calculated in the analytic system 4018. Organization may include determining what data or packages of data to store in a pool (such as representing particular combinations, permutations, aggregations, and the like), the structure of such data (such as in flat, hierarchical, linked, or other structures), the duration of storage, the nature of storage media (such as hard disks, flash memory, SSDs, network-based storage, or the like), the arrangement of storage bits, and other parameters. The content and nature of storage may

be varied, such that a data pool 4120 may learn and adapt, such as based on states of the host processing system 112, one or more data collection systems 102, storage environment parameters (such as capacity, cost, and performance factors), data collection environment parameters, marketplace parameters, and many others. In embodiments, pools 4120 may learn and adapt, such as by variation of the above and other parameters in response to yield metrics (such as return on investment, optimization of power utilization, optimization of revenue, and the like).

[0415] Methods and systems are disclosed herein for training AI models based on industry-specific feedback, including training an AI model based on industry-specific feedback that reflects a measure of utilization, yield, or impact, and where the AI model operates on sensor data from an industrial environment. As noted above, these models may include operating models for industrial environments, machines, workflows, models for anticipating states, models for predicting fault and optimizing maintenance, models for self-organizing storage (on devices, in data pools and/or in the cloud), models for optimizing data transport (such as for optimizing network coding, network-condition-sensitive routing, and the like), models for optimizing data marketplaces, and many others.

[0416] In embodiments, a platform is provided having training AI models based on industry-specific feedback. In embodiments, the various embodiments of cognitive systems disclosed herein may take inputs and feedback from industry-specific and domain-specific input sources 116 (such as relating to optimization of specific machines, devices, components, processes, and the like). Thus, learning and adaptation of storage organization, network usage, combination of sensor and input data, data pooling, data packaging, data pricing, and other features (such as for the marketplace 4102 or for other purposes of the host processing system 112) may be configured by learning on the domain-specific feedback measures of a given environment or application, such as an application involving IoT devices (such as an industrial environment). This may include optimization of efficiency (such as in electrical, electromechanical, magnetic, physical, thermodynamic, chemical and other processes and systems), optimization of outputs (such as for production of energy, materials, products, services and other outputs), prediction, avoidance and mitigation of faults (such as in the aforementioned systems and processes), optimization of performance measures (such as returns on investment, yields, profits, margins, revenues and the like), reduction of costs (including labor costs, bandwidth costs, data costs, material input costs, licensing costs, and many others), optimization of benefits (such as relating to safety, satisfaction, health), optimization of work flows (such as optimizing time and resource allocation to processes), and others.

[0417] Methods and systems are disclosed herein for a self-organized swarm of industrial data collectors, including a self-organizing swarm of industrial data collectors that organize among

themselves to optimize data collection based on the capabilities and conditions of the members of the swarm. Each member of the swarm may be configured with intelligence, and the ability to coordinate with other members. For example, a member of the swarm may track information about what data other members are handling, so that data collection activities, data storage, data processing, and data publishing can be allocated intelligently across the swarm, taking into account conditions of the environment, capabilities of the members of the swarm, operating parameters, rules (such as from a rules engine that governs the operation of the swarm), and current conditions of the members. For example, among four collectors, one that has relatively low current power levels (such as a low battery), might be temporarily allocated the role of publishing data, because it may receive a dose of power from a reader or interrogation device (such as an RFID reader) when it needs to publish the data. A second collector with good power levels and robust processing capability might be assigned more complex functions, such as processing data, fusing data, organizing the rest of the swarm (including self-organization under machine learning, such that the swarm is optimized over time, including by adjusting operating parameters, rules, and the like based on feedback), and the like. A third collector in the swarm with robust storage capabilities might be assigned the task of collecting and storing a category of data, such as vibration sensor data, that consumes considerable bandwidth. A fourth collector in the swarm, such as one with lower storage capabilities, might be assigned the role of collecting data that can usually be discarded, such as data on current diagnostic conditions, where only data on faults needs to be maintained and passed along. Members of a swarm may connect by peer-to-peer relationships by using a member as a "master" or "hub," or by having them connect in a series or ring, where each member passes along data (including commands) to the next, and is aware of the nature of the capabilities and commands that are suitable for the preceding and/or next member. The swarm may be used for allocation of storage across it (such as using memory of each memory as an aggregate data store. In these examples, the aggregate data store may support a distributed ledger, which may store transaction data, such as for transactions involving data collected by the swarm, transactions occurring in the industrial environment, or the like. In embodiments, the transaction data may also include data used to manage the swarm, the environment, or a machine or components thereof. The swarm may self-organize, either by machine learning capability disposed on one or more members of the swarm, or based on instructions from an external machine learning facility, which may optimize storage, data collection, data processing, data presentation, data transport, and other functions based on managing parameters that are relevant to each. The machine learning facility may start with an initial configuration and vary parameters of the swarm relevant to any of the foregoing (also including varying the membership of the swarm), such as iterating based on feedback to the machine learning facility regarding measures of success (such

as utilization measures, efficiency measures, measures of success in prediction or anticipation of states, productivity measures, yield measures, profit measures, and others). Over time, the swarm may be optimized to a favorable configuration to achieve the desired measure of success for an owner, operator, or host of an industrial environment or a machine, component, or process thereof.

[0418] A swarm 4202 may be organized based on a hierarchical organization (such as where a master data collector 102 organizes and directs activities of one or more subservient data collectors 102), a collaborative organization (such as where decision-making for the organization of the swarm 4202 is distributed among the data collectors 102 (such as using various models for decision-making, such as voting systems, points systems, least-cost routing systems, prioritization systems, and the like), and the like.) In embodiments, one or more of the data collectors 102 may have mobility capabilities, such as in cases where a data collector is disposed on or in a mobile robot, drone, mobile submersible, or the like, so that organization may include the location and positioning of the data collectors 102. Data collection systems 102 may communicate with each other and with the host processing system 112, including sharing an aggregate allocated storage space involving storage on or accessible to one or more of the collectors (which in embodiment may be treated as a unified storage space even if physically distributed, such as using virtualization capabilities). Organization may be automated based on one or more rules, models, conditions, processes, or the like (such as embodied or executed by conditional logic), and organization may be governed by policies, such as handled by the policy engine. Rules may be based on industry, application- and domain-specific objects, classes, events, workflows, processes, and systems, such as by setting up the swarm 4202 to collect selected types of data at designated places and times, such as coordinated with the foregoing. For example, the swarm 4202 may assign data collectors 102 to serially collect diagnostic, sensor, instrumentation and/or telematic data from each of a series of machines that execute an industrial process (such as a robotic manufacturing process), such as at the time and location of the input to and output from each of those machines. In embodiments, self-organization may be cognitive, such as where the swarm varies one or more collection parameters and adapts the selection of parameters, weights applied to the parameters, or the like, over time. In examples, this may be in response to learning and feedback, such as from the learning feedback system 4012 that may be based on various feedback measures that may be determined by applying the analytic system 4018 (which in embodiments may reside on the swarm 4202, the host processing system 112, or a combination thereof) to data handled by the swarm 4202 or to other elements of the various embodiments disclosed herein (including marketplace elements and others). Thus, the swarm 4202 may display adaptive behavior, such as adapting to the current state 4020 or an anticipated state of its environment (accounting for marketplace behavior), behavior of various objects (such as IoT devices, machines, components, and systems),

processes (including events, states, workflows, and the like), and other factors at a given time. Parameters that may be varied in a process of variation (such as in a neural net, self-organizing map, or the like), selection, promotion, or the like (such as those enabled by genetic programming or other AI-based techniques). Parameters that may be managed, varied, selected and adapted by cognitive, machine learning may include storage parameters (location, type, duration, amount, structure and the like across the swarm 4202), network parameters (such as how the swarm 4202 is organized, such as in mesh, peer-to-peer, ring, serial, hierarchical and other network configurations as well as bandwidth utilization, data routing, network protocol selection, network coding type, and other networking parameters), security parameters (such as settings for various security applications and services), location and positioning parameters (such as routing movement of mobile data collectors 102 to locations, positioning and orienting collectors 102 and the like relative to points of data acquisition, relative to each other, and relative to locations where network availability may be favorable, among others), input selection parameters (such as input selection among sensors, input sources 116 and the like for each collector 102 and for the aggregate collection), data combination parameters (such as those for sensor fusion, input combination, multiplexing, mixing, layering, convolution, and other combinations), power parameters (such as parameters based on power levels and power availability for one or more collectors 102 or other objects, devices, or the like), states (including anticipated states and conditions of the swarm 4202, individual collection systems 102, the host processing system 112 or one or more objects in an environment), events, and many others. Feedback may be based on any of the kinds of feedback described herein, such that over time the swarm may adapt to its current and anticipated situation to achieve a wide range of desired objectives.

[0419] Methods and systems are disclosed herein for an industrial IoT distributed ledger, including a distributed ledger supporting the tracking of transactions executed in an automated data marketplace for industrial IoT data. A distributed ledger may distribute storage across devices, using a secure protocol, such as those used for cryptocurrencies (such as the Blockchain™ protocol used to support the Bitcoin™ currency). A ledger or similar transaction record, which may comprise a structure where each successive member of a chain stores data for previous transactions, and a competition can be established to determine which of alternative data stored data structures is "best" (such as being most complete), can be stored across data collectors, industrial machines or components, data pools, data marketplaces, cloud computing elements, servers, and/or on the IT infrastructure of an enterprise (such as an owner, operator or host of an industrial environment or of the systems disclosed herein). The ledger or transaction may be optimized by machine learning, such as to provide storage efficiency, security, redundancy, or the like.

[0420] In embodiments, the cognitive data marketplace 4102 may use a secure architecture for tracking and resolving transactions, such as a distributed ledger 4004. In embodiments, transactions in data packages are tracked in a chained, distributed data structure, such as a Blockchain™, allowing forensic analysis and validation where individual devices store a portion of the ledger representing transactions in data packages. The distributed ledger 4004 may be distributed to IoT devices, to data pools 4120, to data collection systems 102, and the like, so that transaction information can be verified without reliance on a single, central repository of information. The transaction system 4114 may be configured to store data in the distributed ledger 4004 and to retrieve data from it (and from constituent devices) in order to resolve transactions. Thus, a distributed ledger 4004 for handling transactions in data, such as for packages of IoT data, is provided. In embodiments, the self-organizing storage system 4028 may be used for optimizing storage of distributed ledger data, as well as for organizing storage of packages of data, such as IoT data, that can be presented in the marketplace 4102.

[0421] Methods and systems are disclosed herein for a network-sensitive collector, including a network condition-sensitive, self-organizing, multi-sensor data collector that can optimize based on bandwidth, quality of service, pricing and/or other network conditions. Network sensitivity can include awareness of the price of data transport (such as allowing the system to pull or push data during off-peak periods or within the available parameters of paid data plans), the quality of the network (such as to avoid periods where errors are likely), the quality of environmental conditions (such as delaying transmission until signal quality is good, such as when a collector emerges from a shielded environment, avoiding wasting use of power when seeking a signal when shielded, such as by large metal structures typically of industrial environments), and the like.

[0422] Methods and systems are disclosed herein for a remotely organized universal data collector that can power up and down sensor interfaces based on need and/or conditions identified in an industrial data collection environment. For example, interfaces can recognize what sensors are available and interfaces and/or processors can be turned on to take input from such sensors, including hardware interfaces that allow the sensors to plug in to the data collector, wireless data interfaces (such as where the collector can ping the sensor, optionally providing some power via an interrogation signal), and software interfaces (such as for handling particular types of data). Thus, a collector that is capable of handling various kinds of data can be configured to adapt to the particular use in a given environment. In embodiments, configuration may be automatic or under machine learning, which may improve configuration by optimizing parameters based on feedback measures over time.

[0423] Methods and systems are disclosed herein for self-organizing storage for a multi-sensor data collector, including self-organizing storage for a multi-sensor data collector for industrial

sensor data. Self-organizing storage may allocate storage based on application of machine learning, which may improve storage configuration based on feedback measure over time. Storage may be optimized by configuring what data types are used (e.g., byte-like structures, structures representing fused data from multiple sensors, structures representing statistics or measures calculated by applying mathematical functions on data, and the like), by configuring compression, by configuring data storage duration, by configuring write strategies (such as by striping data across multiple storage devices, using protocols where one device stores instructions for other devices in a chain, and the like), and by configuring storage hierarchies, such as by providing pre-calculated intermediate statistics to facilitate more rapid access to frequently accessed data items. Thus, highly intelligent storage systems may be configured and optimized, based on feedback, over time.

[0424] Methods and systems are disclosed herein for self-organizing network coding for a multi-sensor data network, including self-organizing network coding for a data network that transports data from multiple sensors in an industrial data collection environment. Network coding, including random linear network coding, can enable highly efficient and reliable transport of large amounts of data over various kinds of networks. Different network coding configurations can be selected, based on machine learning, to optimize network coding and other network transport characteristics based on network conditions, environmental conditions, and other factors, such as the nature of the data being transported, environmental conditions, operating conditions, and the like (including by training a network coding selection model over time based on feedback of measures of success, such as any of the measures described herein).

[0425] In embodiments, a platform is provided having a self-organizing network coding for multi-sensor data network. A cognitive system may vary one or more parameters for networking, such as network type selection (e.g., selecting among available local, cellular, satellite, Wi-Fi, Bluetooth™, NFC, Zigbee® and other networks), network selection (such as selecting a specific network, such as one that is known to have desired security features), network coding selection (such as selecting a type of network coding for efficient transport[such as random linear network coding, fixed coding, and others]), network timing selection (such as configuring delivery based on network pricing conditions, traffic and the like), network feature selection (such as selecting cognitive features, security features, and the like), network conditions (such as network quality based on current environmental or operation conditions), network feature selection (such as enabling available authentication, permission and similar systems), network protocol selection (such as among HTTP, IP, TCP/IP, cellular, satellite, serial, packet, streaming, and many other protocols), and others. Given bandwidth constraints, price variations, sensitivity to environmental factors, security concerns, and the like, selecting the optimal network configuration can be highly

complex and situation dependent. The self-organizing networking system 4030 may vary combinations and permutations of these parameters while taking input from the learning feedback system 4012 such as using information from the analytic system 4018 about various measures of outcomes. In the many examples, outcomes may include overall system measures, analytic success measures, and local performance indicators. In embodiments, input from the learning feedback system 4012 may include information from various sensors and input sources 116, information from the state system 4020 about states (such as events, environmental conditions, operating conditions, and many others, or other information) or taking other inputs. By variation and selection of alternative configurations of networking parameters in different states, the self-organizing networking system may find configurations that are well-adapted to the environment that is being monitored or controlled by the host processing system 112, such as the instance where one or more data collection systems 102 are located and that are well-adapted to emerging network conditions. Thus, a self-organizing, network-condition-adaptive data collection system is provided.

[0426] Referring to Figure 42, the data collection system 102 may have one or more output interfaces and/or ports 4010. These may include network ports and connections, application programming interfaces, and the like. Methods and systems are disclosed herein for a haptic or multi-sensory user interface, including a wearable haptic or multi-sensory user interface for an industrial sensor data collector, with vibration, heat, electrical, and/or sound outputs. For example, an interface may, based on a data structure configured to support the interface, be set up to provide a user with input or feedback, such as based on data from sensors in the environment. For example, if a fault condition based on a vibration data (such as resulting from a bearing being worn down, an axle being misaligned, or a resonance condition between machines) is detected, it can be presented in a haptic interface by vibration of an interface, such as shaking a wrist-worn device. Similarly, thermal data indicating overheating could be presented by warming or cooling a wearable device, such as while a worker is working on a machine and cannot necessarily look at a user interface. Similarly, electrical or magnetic data may be presented by a buzzing, and the like, such as to indicate presence of an open electrical connection or wire, etc. That is, a multi-sensory interface can intuitively help a user (such as a user with a wearable device) get a quick indication of what is going on in an environment, with the wearable interface having various modes of interaction that do not require a user to have eyes on a graphical UI, which may be difficult or impossible in many industrial environments where a user needs to keep an eye on the environment.

[0427] In embodiments, a platform is provided having a wearable haptic user interface for an industrial sensor data collector, with vibration, heat, electrical, and/or sound outputs. In embodiments, a haptic user interface 4302 is provided as an output for the data collection system

102, such as a system for handling and providing information for vibration, heat, electrical, and/or sound outputs, such as to one or more components of the data collection system 102 or to another system, such as a wearable device, mobile phone, or the like. The data collection system 102 may be provided in a form factor suitable for delivering haptic input to a user, such as vibration, warming or cooling, buzzing, or the like, such as input disposed in headgear, an armband, a wristband or watch, a belt, an item of clothing, a uniform, or the like. In such cases, data collection systems 102 may be integrated with gear, uniforms, equipment, or the like worn by users, such as individuals responsible for operating or monitoring an industrial environment. In embodiments, signals from various sensors or input sources (or selective combinations, permutations, mixes, and the like, as managed by one or more of the cognitive input selection systems 4004, 4014) may trigger haptic feedback. For example, if a nearby industrial machine is overheating, the haptic interface may alert a user by warming up, or by sending a signal to another device (such as a mobile phone) to warm up. If a system is experiencing unusual vibrations, the haptic interface may vibrate. Thus, through various forms of haptic input, the data collection system 102 may inform users of the need to attend to one or more devices, machines, or other factors (such as those in an industrial environment) without requiring them to read messages or divert their visual attention away from the task at hand. The haptic interface, and selection of what outputs should be provided, may be considered in the cognitive input selection systems 4004, 4014. For example, user behavior (such as responses to inputs) may be monitored and analyzed in the analytic system 4018, and feedback may be provided through the learning feedback system 4012, so that signals may be provided based on the right collection or package of sensors and inputs, at the right time and in the right manner, to optimize the effectiveness of the haptic system 4202. This may include rule-based or model-based feedback (such as providing outputs that correspond in some logical fashion to the source data that is being conveyed). In embodiments, a cognitive haptic system may be provided, where selection of inputs or triggers for haptic feedback, selection of outputs, timing, intensity levels, durations, and other parameters (or weights applied to them) may be varied in a process of variation, promotion, and selection (such as using genetic programming) with feedback based on real world responses to feedback in actual situations or based on results of simulation and testing of user behavior. Thus, an adaptive haptic interface for the data collection system 102 is provided, which may learn and adapt feedback to satisfy requirements and to optimize the impact on user behavior, such as for overall system outcomes, data collection outcomes, analytic outcomes, and the like.

[0428] Methods and systems are disclosed herein for a presentation layer for AR/VR industrial glasses, where heat map elements are presented based on patterns and/or parameters in collected data. Methods and systems are disclosed herein for condition-sensitive, self-organized tuning of

AR/VR interfaces based on feedback metrics and/or training in industrial environments. In embodiments, any of the data, measures, and the like described throughout this disclosure can be presented by visual elements, overlays, and the like for presentation in the AR/VR interfaces, such as in industrial glasses, on AR/VR interfaces on smart phones or tablets, on AR/VR interfaces on data collectors (which may be embodied in smart phones or tablets), on displays located on machines or components, and/or on displays located in industrial environments.

[0429] In embodiments, a platform is provided having heat maps displaying collected data for AR/VR. In embodiments, a platform is provided having heat maps 4204 displaying collected data from the data collection system 102 for providing input to an AR/VR interface 4208. In embodiments, a heat map interface 4304 is provided as an output for the data collection system 102, such as for handling and providing information for visualization of various sensor data and other data (such as map data, analog sensor data, and other data), such as to one or more components of the data collection system 102 or to another system, such as a mobile device, tablet, dashboard, computer, AR/VR device, or the like. The data collection system 102 may be provided in a form factor suitable for delivering visual input to a user, such as the presentation of a map that includes indicators of levels of analog and digital sensor data (such as data indicating levels of rotation, vibration, heating or cooling, pressure, and many other conditions). In such cases, the data collection systems 102 may be integrated with equipment, or the like that are used by individuals responsible for operating or monitoring an industrial environment. In embodiments, signals from various sensors or input sources (or selective combinations, permutations, mixes, and the like, as managed by one or more of the cognitive input selection systems 4004, 4014) may provide input data to a heat map. Coordinates may include real world location coordinates (such as geo-location or location on a map of an environment), as well as other coordinates, such as time-based coordinates, frequency-based coordinates, or other coordinates that allow for representation of analog sensor signals, digital signals, input source information, and various combinations, in a map-based visualization, such that colors may represent varying levels of input along the relevant dimensions. For example, if a nearby industrial machine is overheating, the heat map interface may alert a user by showing a machine in bright red. If a system is experiencing unusual vibrations, the heat map interface may show a different color for a visual element for the machine, or it may cause an icon or display element representing the machine to vibrate in the interface, calling attention to the element. Clicking, touching, or otherwise interacting with the map can allow a user to drill down and see underlying sensor or input data that is used as an input to the heat map display. Thus, through various forms of display, the data collection system 102 may inform users of the need to attend to one or more devices, machines, or other factors, such as those in an industrial environment, without requiring them to read text-based messages or input. The heat map

interface, and selection of what outputs should be provided, may be considered in the cognitive input selection systems 4004, 4014. For example, user behavior (such as responses to inputs or displays) may be monitored and analyzed in the analytic system 4018, and feedback may be provided through the learning feedback system 4012, so that signals may be provided based on the right collection or package of sensors and inputs, at the right time and in the right manner, to optimize the effectiveness of the heat map UI 4304. This may include rule-based or model-based feedback (such as feedback providing outputs that correspond in some logical fashion to the source data that is being conveyed). In embodiments, a cognitive heat map system may be provided, where selection of inputs or triggers for heat map displays, selection of outputs, colors, visual representation elements, timing, intensity levels, durations and other parameters (or weights applied to them) may be varied in a process of variation, promotion and selection (such as selection using genetic programming) with feedback based on real world responses to feedback in actual situations or based on results of simulation and testing of user behavior. Thus, an adaptive heat map interface for the data collection system 102, or data collected thereby, or data handled by the host processing system 112, is provided, which may learn and adapt feedback to satisfy requirements and to optimize the impact on user behavior and reaction, such as for overall system outcomes, data collection outcomes, analytic outcomes, and the like.

[0430] In embodiments, a platform is provided having automatically tuned AR/VR visualization of data collected by a data collector. In embodiments, a platform is provided having an automatically tuned AR/VR visualization system 4308 for visualization of data collected by the data collection system 102, such as the case where the data collection system 102 has an AR/VR interface 4208 or provides input to an AR/VR interface 4308 (such as a mobile phone positioned in a virtual reality or AR headset, a set of AR glasses, or the like). In embodiments, the AR/VR system 4308 is provided as an output interface of the data collection system 102, such as a system for handling and providing information for visualization of various sensor data and other data (such as map data, analog sensor data, and other data), such as to one or more components of the data collection system 102 or to another system, such as a mobile device, tablet, dashboard, computer, AR/VR device, or the like. The data collection system 102 may be provided in a form factor suitable for delivering AR or VR visual, auditory, or other sensory input to a user, such as by presenting one or more displays such as 3D-realistic visualizations, objects, maps, camera overlays, or other overlay elements, maps and the like that include or correspond to indicators of levels of analog and digital sensor data (such as data indicating levels of rotation, vibration, heating or cooling, pressure and many other conditions, to input sources 116, or the like). In such cases, data collection systems 102 may be integrated with equipment, or the like that are used by individuals responsible for operating or monitoring an industrial environment.

[0431] In embodiments, signals from various sensors or input sources (or selective combinations, permutations, mixes, and the like as managed by one or more of the cognitive input selection systems 4004, 4014) may provide input data to populate, configure, modify, or otherwise determine the AR/VR element. Visual elements may include a wide range of icons, map elements, menu elements, sliders, toggles, colors, shapes, sizes, and the like, for representation of analog sensor signals, digital signals, input source information, and various combinations. In many examples, colors, shapes, and sizes of visual overlay elements may represent varying levels of input along the relevant dimensions for a sensor or combination of sensors. In further examples, if a nearby industrial machine is overheating, an AR element may alert a user by showing an icon representing that type of machine in flashing red color in a portion of the display of a pair of AR glasses. If a system is experiencing unusual vibrations, a virtual reality interface showing visualization of the components of the machine (such as an overlay of a camera view of the machine with 3D visualization elements) may show a vibrating component in a highlighted color, with motion, or the like, to ensure the component stands out in a virtual reality environment being used to help a user monitor or service the machine. Clicking, touching, moving eyes toward, or otherwise interacting with a visual element in an AR/VR interface may allow a user to drilldown and see underlying sensor or input data that is used as an input to the display. Thus, through various forms of display, the data collection system 102 may inform users of the need to attend to one or more devices, machines, or other factors (such as in an industrial environment), without requiring them to read text-based messages or input or divert attention from the applicable environment (whether it is a real environment with AR features or a virtual environment, such as for simulation, training, or the like).

[0432] The AR/VR output interface 4208, and selection and configuration of what outputs or displays should be provided, may be handled in the cognitive input selection systems 4004, 4014. For example, user behavior (such as responses to inputs or displays) may be monitored and analyzed in the analytic system 4018, and feedback may be provided through the learning feedback system 4012, so that AR/VR display signals may be provided based on the right collection or package of sensors and inputs, at the right time and in the right manner, to optimize the effectiveness of the AR/VR UI 4308. This may include rule-based or model-based feedback (such as providing outputs that correspond in some logical fashion to the source data that is being conveyed). In embodiments, a cognitively tuned AR/VR interface control system 4308 may be provided, where selection of inputs or triggers for AR/VR display elements, selection of outputs (such as colors, visual representation elements, timing, intensity levels, durations and other parameters [or weights applied to them]) and other parameters of a VR/AR environment may be varied in a process of variation, promotion and selection (such as the use of genetic programming)

with feedback based on real world responses in actual situations or based on results of simulation and testing of user behavior. Thus, an adaptive, tuned AR/VR interface for the data collection system 102, or data collected thereby 102, or data handled by the host processing system 112, is provided, which may learn and adapt feedback to satisfy requirements and to optimize the impact on user behavior and reaction, such as for overall system outcomes, data collection outcomes, analytic outcomes, and the like.

[0433] As noted above, methods and systems are disclosed herein for continuous ultrasonic monitoring, including providing continuous ultrasonic monitoring of rotating elements and bearings of an energy production facility. Embodiments include using continuous ultrasonic monitoring of an industrial environment as a source for a cloud-deployed pattern recognizer. Embodiments include using continuous ultrasonic monitoring to provide updated state information to a state machine that is used as an input to a cloud-deployed pattern recognizer. Embodiments include making available continuous ultrasonic monitoring information to a user based on a policy declared in a policy engine. Embodiments include storing continuous ultrasonic monitoring data with other data in a fused data structure on an industrial sensor device. Embodiments include making a stream of continuous ultrasonic monitoring data from an industrial environment available as a service from a data marketplace. Embodiments include feeding a stream of continuous ultrasonic monitoring data into a self-organizing data pool. Embodiments include training a machine learning model to monitor a continuous ultrasonic monitoring data stream where the model is based on a training set created from human analysis of such a data stream, and is improved based on data collected on performance in an industrial environment.

[0434] Embodiments include a swarm of data collectors that include at least one data collector for continuous ultrasonic monitoring of an industrial environment and at least one other type of data collector. Embodiments include using a distributed ledger to store time-series data from continuous ultrasonic monitoring across multiple devices. Embodiments include collecting a stream of continuous ultrasonic data in a self-organizing data collector, a network-sensitive data collector, a remotely organized data collector, a data collector having self-organized storage and the like. Embodiments include using self-organizing network coding to transport a stream of ultrasonic data collected from an industrial environment. Embodiments include conveying an indicator of a parameter of a continuously collected ultrasonic data stream via an interface where the interface is one of a sensory interface of a wearable device, a heat map visual interface of a wearable device, an interface that operates with self-organized tuning of the interface layer, and the like.

[0435] As noted above, methods and systems are disclosed herein for cloud-based, machine pattern recognition based on fusion of remote analog industrial sensors. Embodiments include

taking input from a plurality of analog sensors disposed in an industrial environment, multiplexing the sensors into a multiplexed data stream, feeding the data stream into a cloud-deployed machine learning facility, and training a model of the machine learning facility to recognize a defined pattern associated with the industrial environment. Embodiments include using a cloud-based pattern recognizer on input states from a state machine that characterizes states of an industrial environment. Embodiments include deploying policies by a policy engine that govern what data can be used by what users and for what purpose in cloud-based, machine learning. Embodiments include using a cloud-based platform to identify patterns in data across a plurality of data pools that contain data published from industrial sensors. Embodiments include training a model to identify preferred sensor sets to diagnose a condition of an industrial environment, where a training set is created by a human user and the model is improved based on feedback from data collected about conditions in an industrial environment.

[0436] Embodiments include a swarm of data collectors that is governed by a policy that is automatically propagated through the swarm. Embodiments include using a distributed ledger to store sensor fusion information across multiple devices. Embodiments include feeding input from a set of data collectors into a cloud-based pattern recognizer that uses data from multiple sensors for an industrial environment. The data collectors may be self-organizing data collectors, network-sensitive data collectors, remotely organized data collectors, a set of data collectors having self-organized storage, and the like. Embodiments include a system for data collection in an industrial environment with self-organizing network coding for data transport of data fused from multiple sensors in the environment. Embodiments include conveying information formed by fusing inputs from multiple sensors in an industrial data collection system in an interface such as a multi-sensory interface, a heat map interface, an interface that operates with self-organized tuning of the interface layer, and the like.

[0437] As noted above, methods and systems are disclosed herein for cloud-based, machine pattern analysis of state information from multiple analog industrial sensors to provide anticipated state information for an industrial system. Embodiments include using a policy engine to determine what state information can be used for cloud-based machine analysis. Embodiments include feeding inputs from multiple devices that have fused and on-device storage of multiple sensor streams into a cloud-based pattern recognizer to determine an anticipated state of an industrial environment. Embodiments include making an output, such as anticipated state information, from a cloud-based machine pattern recognizer that analyzes fused data from remote, analog industrial sensors available as a data service in a data marketplace. Embodiments include using a cloud-based pattern recognizer to determine an anticipated state of an industrial environment based on data collected from data pools that contain streams of information from machines in the

environment. Embodiments include training a model to identify preferred state information to diagnose a condition of an industrial environment, where a training set is created by a human user and the model is improved based on feedback from data collected about conditions in an industrial environment. Embodiments include a swarm of data collectors that feeds a state machine that maintains current state information for an industrial environment. Embodiments include using a distributed ledger to store historical state information for fused sensor states a self-organizing data collector that feeds a state machine that maintains current state information for an industrial environment. Embodiments include a data collector that feeds a state machine that maintains current state information for an industrial environment where the data collector may be a network sensitive data collector, a remotely organized data collector, a data collector with self-organized storage, and the like. Embodiments include a system for data collection in an industrial environment with self-organizing network coding for data transport and maintains anticipated state information for the environment. Embodiments include conveying anticipated state information determined by machine learning in an industrial data collection system in an interface where the interface may be one or more of a multisensory interface, a heat map interface an interface that operates with self-organized tuning of the interface layer, and the like.

[0438] As noted above, methods and systems are disclosed herein for a cloud-based policy automation engine for IoT, with creation, deployment, and management of IoT devices, including a cloud-based policy automation engine for IoT, enabling creation, deployment and management of policies that apply to IoT devices. Policies can relate to data usage to an on-device storage system that stores fused data from multiple industrial sensors, or what data can be provided to whom in a self-organizing marketplace for IoT sensor data. Policies can govern how a self-organizing swarm or data collector should be organized for a particular industrial environment, how a network-sensitive data collector should use network bandwidth for a particular industrial environment, how a remotely organized data collector should collect, and make available, data relating to a specified industrial environment, or how a data collector should self-organize storage for a particular industrial environment. Policies can be deployed across a set of self-organizing pools of data that contain data streamed from industrial sensing devices to govern use of data from the pools or stored on a device that governs use of storage capabilities of the device for a distributed ledger. Embodiments include training a model to determine what policies should be deployed in an industrial data collection system. Embodiments include a system for data collection in an industrial environment with a policy engine for deploying policy within the system and, optionally, self-organizing network coding for data transport. In certain embodiments, a policy applies to how data will be presented in a multi-sensory interface, a heat map visual interface, or in an interface that operates with self-organized tuning of the interface layer.

[0439] As noted above, methods and systems are disclosed herein for on-device sensor fusion and data storage for industrial IoT devices, such as an industrial data collector, including self-organizing, remotely organized, or network-sensitive industrial data collectors, where data from multiple sensors is multiplexed at the device for storage of a fused data stream. Embodiments include a self-organizing marketplace that presents fused sensor data that is extracted from on-device storage of IoT devices. Embodiments include streaming fused sensor information from multiple industrial sensors and from an on-device data storage facility to a data pool. Embodiments include training a model to determine what data should be stored on a device in a data collection environment. Embodiments include a self-organizing swarm of industrial data collectors that organize among themselves to optimize data collection, where at least some of the data collectors have on-device storage of fused data from multiple sensors. Embodiments include storing distributed ledger information with fused sensor information on an industrial IoT device. Embodiments include a system for data collection with on-device sensor fusion, such as of industrial sensor data and, optionally, self-organizing network coding for data transport, where data structures are stored to support alternative, multi-sensory modes of presentation, visual heat map modes of presentation, and/or an interface that operates with self-organized tuning of the interface layer.

[0440] As noted above, methods and systems are disclosed herein for a self-organizing data marketplace for industrial IoT data, where available data elements are organized in the marketplace for consumption by consumers based on training a self-organizing facility with a training set and feedback from measures of marketplace success. Embodiments include organizing a set of data pools in a self-organizing data marketplace based on utilization metrics for the data pools. Embodiments include training a model to determine pricing for data in a data marketplace. The data marketplace is fed with data streams from a self-organizing swarm of industrial data collectors, a set of industrial data collectors that have self-organizing storage, or self-organizing, network-sensitive, or remotely organized industrial data collectors. Embodiments include using a distributed ledger to store transactional data for a self-organizing marketplace for industrial IoT data. Embodiments include using self-organizing network coding for data transport to a marketplace for sensor data collected in industrial environments. Embodiments include providing a library of data structures suitable for presenting data in alternative, multi-sensory interface modes in a data marketplace, in heat map visualization, and/or in interfaces that operate with self-organized tuning of the interface layer.

[0441] As noted above, methods and systems are disclosed herein for self-organizing data pools such as those that self-organize based on utilization and/or yield metrics that may be tracked for a plurality of data pools. In embodiments, the pools contain data from self-organizing data

collectors. Embodiments include training a model to present the most valuable data in a data marketplace, where training is based on industry-specific measures of success. Embodiments include populating a set of self-organizing data pools with data from a self-organizing swarm of data collectors. Embodiments include using a distributed ledger to store transactional information for data that is deployed in data pools, where the distributed ledger is distributed across the data pools. Embodiments include populating a set of self-organizing data pools with data from a set of network-sensitive or remotely organized data collectors or a set of data collectors having self-organizing storage. Embodiments include a system for data collection in an industrial environment with self-organizing pools for data storage and self-organizing network coding for data transport, such as a system that includes a source data structure for supporting data presentation in a multi-sensory interface, in a heat map interface, and/or in an interface that operates with self-organized tuning of the interface layer.

[0442] As noted above, methods and systems are disclosed herein for training AI models based on industry-specific feedback, such as that reflects a measure of utilization, yield, or impact, where the AI model operates on sensor data from an industrial environment. Embodiments include training a swarm of data collectors, or data collectors, such as remotely organized, self-organizing, or network-sensitive data collectors, based on industry-specific feedback or network and industrial conditions in an industrial environment, such as to configure storage. Embodiments include training an AI model to identify and use available storage locations in an industrial environment for storing distributed ledger information. Embodiments include training a remote organizer for a remotely organized data collector based on industry-specific feedback measures. Embodiments include a system for data collection in an industrial environment with cloud-based training of a network coding model for organizing network coding for data transport or a facility that manages presentation of data in a multi-sensory interface, in a heat map interface, and/or in an interface that operates with self-organized tuning of the interface layer.

[0443] As noted above, methods and systems are disclosed herein for a self-organized swarm of industrial data collectors that organize among themselves to optimize data collection based on the capabilities and conditions of the members of the swarm. Embodiments include deploying distributed ledger data structures across a swarm of data. Data collectors may be network-sensitive data collectors configured for remote organization or have self-organizing storage. Systems for data collection in an industrial environment with a swarm can include a self-organizing network coding for data transport. Systems include swarms that relay information for use in a multi-sensory interface, in a heat map interface, and/or in an interface that operates with self-organized tuning of the interface layer.

[0444] As noted above, methods and systems are disclosed herein for an industrial IoT distributed ledger, including a distributed ledger supporting the tracking of transactions executed in an automated data marketplace for industrial IoT data. Embodiments include a self-organizing data collector that is configured to distribute collected information to a distributed ledger. Embodiments include a network-sensitive data collector that is configured to distribute collected information to a distributed ledger based on network conditions. Embodiments include a remotely organized data collector that is configured to distribute collected information to a distributed ledger based on intelligent, remote management of the distribution. Embodiments include a data collector with self-organizing local storage that is configured to distribute collected information to a distributed ledger. Embodiments include a system for data collection in an industrial environment using a distributed ledger for data storage and self-organizing network coding for data transport. In embodiments, data storage is of a data structure supporting a haptic interface for data presentation, a heat map interface for data presentation, and/or an interface that operates with self-organized tuning of the interface layer.

[0445] As noted above, methods and systems are disclosed herein for a self-organizing collector, including a self-organizing, multi-sensor data collector that can optimize data collection, power and/or yield based on conditions in its environment, and is optionally responsive to remote organization. Embodiments include a self-organizing data collector that organizes at least in part based on network conditions. Embodiments include a self-organizing data collector with self-organizing storage for data collected in an industrial data collection environment. Embodiments include a system for data collection in an industrial environment with self-organizing data collection and self-organizing network coding for data transport. Embodiments include a system for data collection in an industrial environment with a self-organizing data collector that feeds a data structure supporting a haptic or multi-sensory wearable interface for data presentation, a heat map interface for data presentation, and/or an interface that operates with self-organized tuning of the interface layer.

[0446] As noted above, methods and systems are disclosed herein for a network-sensitive collector, including a network condition-sensitive, self-organizing, multi-sensor data collector that can optimize based on bandwidth, quality of service, pricing, and/or other network conditions. Embodiments include a remotely organized, network condition-sensitive universal data collector that can power up and down sensor interfaces based on need and/or conditions identified in an industrial data collection environment, including network conditions. Embodiments include a network-condition sensitive data collector with self-organizing storage for data collected in an industrial data collection environment. Embodiments include a network-condition sensitive data collector with self-organizing network coding for data transport in an industrial data collection

environment. Embodiments include a system for data collection in an industrial environment with a network-sensitive data collector that relays a data structure supporting a haptic wearable interface for data presentation, a heat map interface for data presentation, and/or an interface that operates with self-organized tuning of the interface layer.

[0447] As noted above, methods and systems are disclosed herein for a remotely organized universal data collector that can power up and down sensor interfaces based on need and/or conditions identified in an industrial data collection environment. Embodiments include a remotely organized universal data collector with self-organizing storage for data collected in an industrial data collection environment. Embodiments include a system for data collection in an industrial environment with remote control of data collection and self-organizing network coding for data transport. Embodiments include a remotely organized data collector for storing sensor data and delivering instructions for use of the data in a haptic or multi-sensory wearable interface, in a heat map visual interface, and/or in an interface that operates with self-organized tuning of the interface layer.

[0448] As noted above, methods and systems are disclosed herein for self-organizing storage for a multi-sensor data collector, including self-organizing storage for a multi-sensor data collector for industrial sensor data. Embodiments include a system for data collection in an industrial environment with self-organizing data storage and self-organizing network coding for data transport. Embodiments include a data collector with self-organizing storage for storing sensor data and instructions for translating the data for use in a haptic wearable interface, in a heat map presentation interface, and/or in an interface that operates with self-organized tuning of the interface layer.

[0449] As noted above, methods and systems are disclosed herein for self-organizing network coding for a multi-sensor data network, including self-organizing network coding for a data network that transports data from multiple sensors in an industrial data collection environment. The system includes a data structure supporting a haptic wearable interface for data presentation, a heat map interface for data presentation, and/or self-organized tuning of an interface layer for data presentation.

[0450] As noted above, methods and systems are disclosed herein for a haptic or multi-sensory user interface, including a wearable haptic or multi-sensory user interface for an industrial sensor data collector, with vibration, heat, electrical, and/or sound outputs. Embodiments include a wearable haptic user interface for conveying industrial state information from a data collector, with vibration, heat, electrical, and/or sound outputs. The wearable also has a visual presentation layer for presenting a heat map that indicates a parameter of the data. Embodiments include

condition-sensitive, self-organized tuning of AR/VR interfaces and multi-sensory interfaces based on feedback metrics and/or training in industrial environments.

[0451] As noted above, methods and systems are disclosed herein for a presentation layer for AR/VR industrial glasses, where heat map elements are presented based on patterns and/or parameters in collected data. Embodiments include condition-sensitive, self-organized tuning of a heat map AR/VR interface based on feedback metrics and/or training in industrial environments. As noted above, methods and systems are disclosed herein for condition-sensitive, self-organized tuning of AR/VR interfaces based on feedback metrics and/or training in industrial environments.

[0452] The following illustrative claims describe certain embodiments of the present disclosure. The data collection system mentioned in the following disclosure may be a local data collection system 102, the host processing system 112 (e.g., using a cloud platform), or a combination of a local system and a host system. In embodiments, a data collection system or data collection and processing system is provided having the use of an analog crosspoint switch for collecting data having variable groups of analog sensor inputs and, in some embodiments, having IP front-end-end signal conditioning on a multiplexer for improved signal-to-noise ratio, multiplexer continuous monitoring alarming features, the use of distributed CPLD chips with a dedicated bus for logic control of multiple MUX and data acquisition sections, high-amperage input capability using solid state relays and design topology, power-down capability of at least one of an analog sensor channel and of a component board, unique electrostatic protection for trigger and vibration inputs, and/or precise voltage reference for A/D zero reference.

[0453] In embodiments, a data collection and processing system is provided having the use of an analog crosspoint switch for collecting data having variable groups of analog sensor inputs and having a phase-lock loop band-pass tracking filter for obtaining slow-speed RPMs and phase information, digital derivation of phase relative to input and trigger channels using on-board timers, a peak-detector for auto-scaling that is routed into a separate analog-to-digital converter for peak detection, the routing of a trigger channel that is either raw or buffered into other analog channels, the use of higher input oversampling for delta-sigma A/D for lower sampling rate outputs to minimize AA filter requirements, and/or the use of a CPLD as a clock-divider for a delta-sigma analog-to-digital converter to achieve lower sampling rates without the need for digital resampling.

[0454] In embodiments, a data collection and processing system is provided having the use of an analog crosspoint switch for collecting data having variable groups of analog sensor inputs and having long blocks of data at a high-sampling rate, as opposed to multiple sets of data taken at different sampling rates, storage of calibration data with a maintenance history on-board card set, a rapid route creation capability using hierarchical templates, intelligent management of data

collection bands, and/or a neural net expert system using intelligent management of data collection bands.

[0455] In embodiments, a data collection and processing system is provided having the use of an analog crosspoint switch for collecting data having variable groups of analog sensor inputs and having use of a database hierarchy in sensor data analysis, an expert system GUI graphical approach to defining intelligent data collection bands and diagnoses for the expert system, a graphical approach for back-calculation definition, proposed bearing analysis methods, torsional vibration detection/analysis utilizing transitory signal analysis, and/or improved integration using both analog and digital methods.

[0456] In embodiments, a data collection and processing system is provided having the use of an analog crosspoint switch for collecting data having variable groups of analog sensor inputs and having adaptive scheduling techniques for continuous monitoring of analog data in a local environment, data acquisition parking features, a self-sufficient data acquisition box, SD card storage, extended onboard statistical capabilities for continuous monitoring, the use of ambient, local and vibration noise for prediction, smart route changes based on incoming data or alarms to enable simultaneous dynamic data for analysis or correlation, smart ODS and transfer functions, a hierarchical multiplexer, identification of sensor overload, and/or RF identification and an inclinometer.

[0457] In embodiments, a data collection and processing system is provided having the use of an analog crosspoint switch for collecting data having variable groups of analog sensor inputs and having continuous ultrasonic monitoring, cloud-based, machine pattern recognition based on the fusion of remote, analog industrial sensors, cloud-based, machine pattern analysis of state information from multiple analog industrial sensors to provide anticipated state information for an industrial system, cloud-based policy automation engine for IoT, with creation, deployment, and management of IoT devices, on-device sensor fusion and data storage for industrial IoT devices, a self-organizing data marketplace for industrial IoT data, self-organization of data pools based on utilization and/or yield metrics, training AI models based on industry-specific feedback, a self-organized swarm of industrial data collectors, an IoT distributed ledger, a self-organizing collector, a network-sensitive collector, a remotely organized collector, a self-organizing storage for a multi-sensor data collector, a self-organizing network coding for multi-sensor data network, a wearable haptic user interface for an industrial sensor data collector, with vibration, heat, electrical, and/or sound outputs, heat maps displaying collected data for AR/VR, and/or automatically tuned AR/VR visualization of data collected by a data collector.

[0458] In embodiments, a data collection and processing system is provided having IP front-end signal conditioning on a multiplexer for improved signal-to-noise ratio. In embodiments, a data

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NOM DU FICHIER / FILE NAME :

NOTE POUR LE TOME / VOLUME NOTE:

WHAT IS CLAIMED IS:

1. An industrial machine predictive maintenance system comprising:

an industrial machine data analysis facility that generates streams of industrial machine health monitoring data by applying machine learning to data representative of conditions of portions of industrial machines received via a data collection network;

an industrial machine predictive maintenance facility that produces industrial machine service recommendations responsive to the health monitoring data by applying machine fault detection and classification algorithms thereto;

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations; and

a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

2. The industrial machine predictive maintenance system of claim 1, further comprising:

a worker finding facility that identifies at least one candidate worker for performing a service indicated by the industrial machine service recommendations by correlating information in the recommendation regarding at least one service to be performed with at least one of experience and know-how for industrial service workers in an industrial service worker database.

3. The industrial machine predictive maintenance system of claim 2, further comprising:

machine learning algorithms executing on a processor that improve the correlating based on service-related information for a plurality of services performed on similar industrial machines and worker-related information for a plurality of services performed by the at least one candidate worker.

4. The industrial machine predictive maintenance system of claim 1, wherein the service and delivery coordination facility validates the services to perform on the individual industrial machines while producing the ledger of service activity and results for each of the individual industrial machines.

5. The industrial machine predictive maintenance system of claim 1, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

6. The industrial machine predictive maintenance system of claim 5, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment

readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

7. The industrial machine predictive maintenance system of claim 1, further comprising:

a computer vision system that generates one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of at least one of the individual industrial machines based on the one or more image data sets.

8. The industrial machine predictive maintenance system of claim 7, wherein the operating characteristic relates to vibrations detected for at least a portion of the at least one of the individual industrial machines, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendation according to a severity unit calculated for the detected vibrations.

9. The industrial machine predictive maintenance system of claim 8, wherein the severity unit is calculated for the detected vibrations of an industrial machine by determining a frequency of the detected vibrations, determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations, and calculating the severity unit for the detected vibrations based on the determined segment.

10. The industrial machine predictive maintenance system of claim 9, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

11. The industrial machine predictive maintenance system of claim 10, wherein the detected vibrations are mapped to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a third severity unit when the frequency of the captured vibration corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

12. The industrial machine predictive maintenance system of claim 8, wherein the severity unit indicates that the detected vibrations may lead to a failure of at least the portion of the industrial machine, wherein the industrial machine service recommendation includes a recommendation for preventing or mitigating the failure, wherein the at least one of the orders and the requests for service is for a part or a service used to prevent or mitigate the failure.

13. A system comprising:

an industrial machine predictive maintenance facility that produces industrial machine service recommendations by applying machine fault detection and classification algorithms to industrial machine health monitoring data;

a worker finding facility that identifies at least one candidate worker for performing a service indicated by the industrial machine service recommendations by correlating information in the recommendation regarding at least one service to be performed with at least one of experience and know-how for industrial service workers in an industrial service worker database; and

machine learning algorithms executing on a processor that improve the correlating based on service-related information for a plurality of services performed on similar industrial machines and worker-related information for a plurality of services performed by the at least one candidate worker.

14. The system of claim 13, further comprising:

an industrial machine data analysis facility that generates streams of the industrial machine health monitoring data by applying machine learning to data representative of conditions of portions of industrial machines received via a data collection network.

15. The system of claim 13, further comprising:

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations.

16. The system of claim 15, further comprising:

a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

17. The system of claim 16, wherein the service and delivery coordination facility validates the services to perform on the individual industrial machines while producing a ledger of service activity and results for each of the individual industrial machines, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

18. The system of claim 17, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data,

service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

19. The system of claim 13, further comprising:

a mobile data collector swarm comprising one or more mobile data collectors configured to collect the health monitoring data, wherein the health monitoring data is representative of conditions of one or more industrial machines located in an industrial environment.

20. The system of claim 19, further comprising:

a self-organization system that controls movements of the one or more mobile data collectors within the industrial environment.

21. The system of claim 20, wherein the self-organization system transmits requests for the health monitoring data to the one or more mobile data collectors, wherein the mobile data collectors transmit the health monitoring data to the self-organization system responsive to the requests, wherein the self-organization transmits the health monitoring data to the industrial machine predictive maintenance facility.

22. The system of claim 19, further comprising:

a data collection router that receives the health monitoring data from the one or more mobile data collectors when the mobile data collectors are in near proximity to the data collection router, wherein the data collection router transmits the health monitoring data to the industrial machine predictive maintenance facility.

23. The system of claim 22, wherein the one or more mobile data collectors push the health monitoring data to the data collection router.

24. The system of claim 22, wherein the data collection router pulls the health monitoring data from the one or more mobile data collectors.

25. The system of claim 19, wherein each mobile data collector of the one or more mobile data collectors is one of a mobile robot including one or more integrated sensors, a mobile robot including one or more coupled sensors, a mobile vehicle with one or more integrated sensors, or a mobile vehicle with one or more coupled sensors.

26. A system comprising:

an industrial machine maintenance part and service ordering facility that prepares and controls orders for parts and services responsive to service recommendations received from an industrial machine predictive maintenance facility that produces industrial machine service recommendations by applying machine fault detection and classification algorithms to industrial machine health monitoring data; and

a computerized maintenance management system (CMMS) that analyzes a procedure associated with the service recommendations for generating at least one of the orders for parts and services.

27. The system of claim 26, further comprising:

an industrial machine data analysis facility that generates streams of the industrial machine health monitoring data by applying machine learning to data representative of conditions of portions of industrial machines received via a data collection network.

28. The system of claim 27, wherein the service and delivery coordination facility validates the services to perform on the industrial machines while producing a ledger of service activity and results for each of the industrial machines.

29. The system of claim 28, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and requests for service and parts, wherein each record is stored as a block in the blockchain structure.

30. The system of claim 29, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

31. The system of claim 27, further comprising:

a computer vision system that generates one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of at least one of the industrial machines based on the one or more image data sets.

32. The system of claim 31, wherein the operating characteristic relates to vibrations detected for at least a portion of the at least one of the industrial machines, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendation according to a severity unit calculated for the detected vibrations, wherein the severity unit is calculated for the detected vibrations of an industrial machine by determining a frequency of the detected vibrations, determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations, and calculating the severity unit for the detected vibrations based on the determined segment.

33. The system of claim 26, further comprising:

a mobile data collector swarm comprising one or more mobile data collectors configured to collect the health monitoring data, wherein the health monitoring data is representative of conditions of one or more industrial machines located in an industrial environment.

34. The system of claim 33, further comprising:

a self-organization system that controls movements of the one or more mobile data collectors within the industrial environment.

35. The system of claim 34, wherein the self-organization system transmits requests for the health monitoring data to the one or more mobile data collectors, wherein the mobile data collectors transmit the health monitoring data to the self-organization system responsive to the requests, wherein the self-organization transmits the health monitoring data to the industrial machine predictive maintenance facility.

36. A system comprising:

a smart RFID element configured to capture and store, in a non-volatile computer-accessible memory, operational, physical and diagnostic result information for a portion of an industrial machine by communicatively coupling with at least one sensor configured to monitor a condition of the portion of the industrial machine; and

the smart RFID element further configured to receive, organize, and store information in the non-volatile computer-accessible memory, wherein the information enables execution of at least one service procedure for the industrial machine.

37. The system of claim 36, wherein the smart RFID is configured to facilitate hierarchical access to information about the industrial machine, including a plurality of portions directly accessible from a root entry for the industrial machine, wherein each of the plurality of directly accessible portions is structured to store entries for one portion selected from a list consisting of production information, parts information, quality information, installation information, validation information, procedure information, operational information, and assembly information.

38. The system of claim 37, wherein the production information comprises entries for assembly date, assembly location, machine model number, machine serial number, machine assembly time, machine assembly work order number, customer, and images of portions of the industrial machine.

39. The system of claim 37, wherein the procedure information comprises entries for procedures selected from a list consisting of calibration, shutdown, regulatory, assembly, safety check, image capture, preventive maintenance, part repair, part replacement, and disassembly.

40. The system of claim 36, wherein the system above further comprising a data storage element accessible through a processor, the data storage element comprising a copy of information stored in a plurality of smart RFID elements including the smart RFID element, wherein each copy of information comprises a twin of the information stored in a corresponding one of the plurality of smart RFID elements.

41. The system of claim 36, wherein the smart RFID element is included in an enhanced data collection device.

42. A method of configuring production data in a smart RFID of an industrial machine, comprising:

configuring a smart RFID with a portion of an industrial machine to capture and store in a non-volatile computer-accessible memory operational, physical and diagnostic result information for a corresponding portion of the industrial machine;

communicatively coupling the smart RFID with a processor of the industrial machine and at least one sensor configured to monitor a condition of the portion of the industrial machine;

executing with the processor a self-test of the portion of the industrial machine and storing in the smart RFID a result of the self-test;

coupling the industrial machine through a production access point to a network of testing systems and an industrial machine production server; and

performing production tests on the portion of the industrial machine with the testing systems, a result of which is stored in duplicate on the smart RFID and in a data storage facility accessible by a processor of the production server.

43. The method of claim 42, wherein the duplicate of the testing results stored in the data storage facility is a twin of the corresponding portion of the smart RFID.

44. The method of claim 42, wherein the smart RFID is configured to facilitate hierarchical access to information about the industrial machine, including a plurality of portions directly accessible from a root entry for the industrial machine, wherein each of the plurality of directly accessible portions is structured to store entries for one portion selected from a list consisting of production information, parts information, quality information, installation information, validation information, procedure information, operational information, and assembly information.

45. The method of claim 44, wherein the production information comprises entries for assembly date, assembly location, machine model number, machine serial number, machine assembly time, machine assembly work order number, customer, and images of portions of the industrial machine.

46. The method of claim 44, wherein the procedure information comprises entries for procedures selected from a list consisting of calibration, shutdown, regulatory, assembly, safety check, image capture, preventive maintenance, part repair, part replacement, and disassembly.

47. The method of claim 42, wherein the system above further comprising a data storage element accessible through a processor, the data storage element comprising a copy of information stored in a plurality of smart RFID elements including the smart RFID element, wherein each copy

of information comprises a twin of the information stored in a corresponding one of the plurality of smart RFID elements.

48. The method of claim 42, wherein the smart RFID is included in an enhanced data collection device.

49. An industrial machine predictive maintenance system including a marketplace comprising:

a plurality of parts supplier computing systems configured to maintain industrial machine service marketplace information about industrial machine parts offered for sale;

a plurality of service provider computing systems configured to maintain industrial machine service marketplace information about industrial machine services offered;

at least one computerized maintenance management system (CMMS) that is configured to facilitate access to at least one of services, parts, materials, and tools offered in the marketplace responsive to an industrial machine maintenance recommendation provided by an industrial machine predictive maintenance system; and

a plurality of logistics provider computing systems configured to maintain industrial machine service marketplace information for at least one of shipping and logistics services offered in the marketplace.

50. The industrial machine predictive maintenance system of claim 49, wherein each of the plurality of parts suppliers, service providers, and logistics providers maintain corresponding information for their offerings directly in the marketplace via at least one Application Programming Interface of the marketplace.

51. The industrial machine predictive maintenance system of claim 49, wherein the CMMS adapts offerings of parts, services, and logistics to industrial machine owners based on norms established from analysis of prior orders for the parts, services and logistics.

52. The industrial machine predictive maintenance system of claim 49, wherein maintaining the industrial machine service marketplace information producing a ledger of service activity for each of at least one of shipping and logistics services performed for an industrial machine.

53. The industrial machine predictive maintenance system of claim 52, wherein the ledger uses a blockchain structure to track records of transactions for each of at least one of shipping and logistics services, wherein each record is stored as a block in the blockchain structure.

54. The industrial machine predictive maintenance system of claim 53, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

55. A system comprising:

a plurality of computing systems configured to perform one or more predictive maintenance actions;

a portion of the plurality of computing systems connected via a peer-to-peer communication network; and

a record of industrial machine maintenance actions including a portion of the predictive maintenance actions, wherein the portion of the plurality of computing systems operate the record as a distributed ledger.

56. The system of claim 55, wherein a computing system of the portion of computing systems performs industrial machine data analysis and contributes a result of the analysis to the record.

57. The system of claim 55, wherein a computing system of the portion of computing systems performs industrial machine predictive maintenance recommendations and contributes a portion of the recommendations to the record.

58. The system of claim 55, wherein a computing system of the portion of computing systems performs industrial machine maintenance order management and contributes information about industrial machine orders to the record.

59. The system of claim 55, wherein a computing system of the portion of computing systems performs service delivery and tracking of industrial machine service actions and contributes information about service delivery and tracking thereof to the record.

60. The system of claim 55, wherein a computing system of the portion of computing systems is deployed with an industrial machine and contributes information collected from sensors deployed with the industrial machine to the record.

61. The system of claim 55, wherein a computing system of the portion of computing systems performs industrial machine operation scheduling and contributes industrial machine operation scheduling to the record.

62. A system comprising:

a plurality of computing systems configured to perform one or more predictive maintenance actions;

a portion of the plurality of computing systems connected via a peer-to-peer communication network; and

a role-based control for accessing a record of industrial machine maintenance actions, the record including a portion of the predictive maintenance actions, wherein the portion of the plurality of computing systems operate the record as a distributed ledger.

63. The system of claim 62, wherein the role-based control for accessing a record recognizes an owner role that comprises at least one of an individual and an entity that owns at least a share

of an industrial machine for which a predictive maintenance action is accessible in the distributed ledger.

64. The system of claim 62, wherein the role-based control for accessing a record recognizes a manufacturer role comprising at least one of an individual and an entity that has produced at least a portion of the industrial machine for which a predictive maintenance action is accessible in the distributed ledger.

65. The system of claim 62, wherein the role-based control for accessing a record recognizes an operator role that comprises at least one of an individual and an entity that provides access to use an industrial machine for which a predictive maintenance action is accessible in the distributed ledger.

66. The system of claim 62, wherein the role-based control for accessing a record recognizes a part supplier role comprising at least one of an individual and an entity that provides at least one industrial machine part for an industrial machine for which a predictive maintenance action is accessible in the distributed ledger.

67. The system of claim 62, wherein the role-based control for accessing a record recognizes a service provider role comprising at least one of an individual and an entity that provides services selected from a list of industrial services consisting of contracts for preventive maintenance and repair, emergency repair and upgrades for an industrial machine for which a predictive maintenance action is accessible in the distributed ledger.

68. The system of claim 62, wherein the role-based control for accessing a record recognizes a regional service broker role comprising a regional entity that facilitates automated service activities in specific countries on industrial machines for which a predictive maintenance action is accessible in the distributed ledger.

69. A method of image capture of a portion of an industrial machine, comprising:

updating a procedure for performing a service that implements a predicted maintenance action on an industrial machine, the updating responsive to a trigger condition for capturing an image of a portion of the industrial machine being met;

providing an image capture template in an electronic display overlaying a live image of a portion of the industrial machine to facilitate image capture;

applying augmented reality that indicates a degree of alignment of the live image with the template;

examining an image captured using the updated procedure with machine vision to determine at least one part of the machine present in the captured image; and

responsive to a result of the examination, operating an image capture reward facility to generate a reward for the captured image.

70. The method of claim 69, wherein the updating is responsive to a trigger condition that is based on analysis of industrial machine failure data such that the analysis suggests capturing an image that is not specified in the procedure prior to updating the procedure for performing the service.

71. The method of claim 69, wherein the updating is responsive to the procedure for performing the service being performed on an industrial machine that meets a predictive maintenance criterion associated with the portion of the industrial machine for which an image is to be captured.

72. The method of claim 69, wherein the trigger condition comprises a type of industrial machine associated with the industrial machine for which a service procedure is being performed and a duration of time since the portion of the industrial was captured in an image.

73. The method of claim 69, wherein the trigger condition relates to vibrations detected for at least a portion of industrial machine, wherein an industrial machine service recommendation is produced according to a severity unit calculated for the detected vibrations.

74. The method of claim 73, wherein the severity unit is calculated for the detected vibrations of the industrial machine by determining a frequency of the detected vibrations, determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations, and calculating the severity unit for the detected vibrations based on the determined segment.

75. The method of claim 74, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

76. The method of claim 75, wherein the detected vibrations are mapped to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a third severity unit when the frequency of the captured vibration corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

77. A method of machine learning-based part recognition, comprising:

applying a target part imaging template to an image validating procedure that determines if an image captured meets an image capture validation criterion;

performing image analysis by processing a captured image with image analysis rules that facilitate detecting candidate parts of an industrial machine being present in an image;

recognizing one or more parts of the candidate parts as a part of the industrial machine based on similarity of a candidate part with images of parts of the industrial machine; and

adapting at least one of the target part template, the image analysis rules, and the part recognition based on feedback produced from machine learning of the recognized parts, thereby improving at least one of image capture, image analysis and part recognition.

78. The method of claim 77, wherein the images of parts of the industrial machine are retrieved from a smart RFID element disposed with the industrial machine.

79. The method of claim 77, wherein the images of parts of the industrial machine are retrieved from a network stored digital twin of a smart RFID element disposed with the industrial machine.

80. The method of claim 77, wherein the feedback produced by the machine learning facilitates updating a most recently captured image of the part in a smart RFID deployed with the industrial machine.

81. The method of claim 77, wherein some or all of the method is performed using a computer vision system.

82. The method of claim 81, wherein the computer vision system generates one or more image data sets using captured raw data, identifies one or more values corresponding to a portion of the industrial machine within a point of interest represented by the one or more image data sets, compares the one or more values to corresponding predicted values, generate a variance data set based on the comparison of the one or more values and the corresponding predicted values, detects an operating characteristic of the industrial machine based on the variance data, and generates data indicating the detection of the operating characteristic.

83. A predictive maintenance system comprising:

a predictive maintenance knowledge system that facilitates collecting, discovering, capturing, disseminating, managing and processing information about industrial machines to facilitate taking predictive maintenance actions on industrial machines, comprising:

a plurality of interfaces for receiving information from service providers, parts providers, material providers, machine use schedulers;

a plurality of interfaces for sending information to service ordering facilities, parts ordering facilities, service management facilities, service funding facilities; and

a plurality of interfaces to smart RFID elements on a plurality of industrial machines;

a predictive maintenance knowledge graph that facilitates access by the predictive maintenance knowledge system to information about predictive maintenance service of industrial machines through links among data domains including service providers, parts providers, service requests, service estimates, machine schedules, and predictions of maintenance activity; and

wherein the predictive maintenance knowledge system generates at least one of service recommendations, price-based service options, price estimates, and service estimates.

84. The predictive maintenance system of claim 83, further comprising:

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the at least one of service recommendations, price-based service options, price estimates, and service estimates.

85. The predictive maintenance system of claim 84, further comprising:

a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

86. The predictive maintenance system of claim 85, wherein the service and delivery coordination facility validates the services to perform on the individual industrial machines while producing the ledger of service activity and results for each of the individual industrial machines.

87. The predictive maintenance system of claim 85, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

88. The predictive maintenance system of claim 87, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

89. A method comprising:

improving correlation between results of a plurality of diagnostic tests performed on industrial machines and failure information for failures of similar industrial machines by detecting at least one of patterns in the results of the plurality of diagnostic tests that correlate to machine failures, similarities of diagnostic test results with machine failures, wherein a single type of machine failure correlates to failure results of a subset of the diagnostic tests.

90. The method of claim 89, wherein the machine failures correspond to severities of vibrations detected for the industrial machines.

91. The method of claim 90, further comprising determining a severity of a vibration detected for an industrial machine, wherein the determining of the severity comprises:

receiving vibration data representative of the detected vibration of at least a portion of the industrial machine from a mobile data collector including at least one vibration sensor used to capture the vibration data;

determining a frequency of the detected vibration by processing the captured vibration data;

determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the vibration detected; and

calculating a severity unit for the detected vibration based on the determined segment.

92. The method of claim 91, wherein the mobile data collector is a wearable device.

93. The method of claim 91, wherein the mobile data collector is a handheld device.

94. The method of claim 91, wherein the mobile data collector is a mobile vehicle.

95. The method of claim 91, wherein the mobile data collector is a mobile robot.

96. The method of claim 91, further comprising:

generating a signal indicative of the machine failure based on the severity unit.

97. A method comprising:

determining a rating for an industrial machine service provider by gathering feedback about industrial machine services provided by the service provider and comparing the feedback to a plurality of rating criteria comprising results of diagnostics tests performed after completion of at least one industrial machine service, scheduling the service provider, cost of the service provided, promptness of the service provider, cleanliness of the service provider, adherence to a procedure for the at least one industrial machine service, a measure of experience of the service provider with at least one of the procedure and the industrial machine; and

improving correlation of vendor rating results with rating criteria by applying machine learning to vendor rating results and incorporating an output of the machine learning when rating a vendor.

98. The method of claim 97, further comprising:

determining a rating for an industrial machine service procedure by gathering feedback about the procedure from the service provider and comparing the feedback to a plurality of rating criteria comprising ease of access of the procedure, ease of translation, educational value, accuracy of content, sequence accuracy, ease of following the procedure, and dependence on non-procedure actions.

99. The method of claim 98, further comprising:

improving correlation of procedure rating results with rating criteria by applying machine learning to procedure rating results and incorporating an output of the machine learning when rating a procedure.

100. The method of claim 97, wherein the diagnostic tests correspond to severities of vibrations detected for the industrial machine.

101. The method of claim 100, wherein determining a severity of a vibration detected for the industrial machine comprises:

receiving vibration data representative of the vibration of at least a portion of the industrial machine from a mobile data collector including at least one vibration sensor used to capture the vibration data;

determining a frequency of the captured vibration by processing the captured vibration data;

determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the captured vibration; and

calculating a severity unit for the captured vibration based on the determined segment.

102. The method of claim 101, further comprising:

generating a signal indicative of a machine failure based on the severity unit.

103. A method comprising:

determining a rating for an industrial machine service procedure by gathering feedback about the procedure from service providers who use the procedure to perform an industrial machine service and comparing the feedback to a plurality of rating criteria comprising ease of access of the procedure, ease of translation, educational value, accuracy of content, sequence accuracy, ease of following the procedure, and dependence on non-procedure actions; and

improving correlation of procedure rating results with rating criteria by applying machine learning to procedure rating results and incorporating an output of the machine learning when rating a procedure.

104. The method of claim 103, further comprising:

determining a rating for an industrial machine service provider by gathering feedback about industrial machine services provided by the service provider and comparing the feedback to a plurality of rating criteria comprising results of diagnostics tests performed after completion of at least one industrial machine service, scheduling the service provider, cost of the service provided, promptness of the service provider, cleanliness of the service provider, adherence to a procedure for the at least one industrial machine service, a measure of experience of the service provider with at least one of the procedure and the industrial machine.

105. The method of claim 104, further comprising:

improving correlation of vendor rating results with rating criteria by applying machine learning to vendor rating results and incorporating an output of the machine learning when rating a vendor.

106. The method of claim 103, wherein the industrial machine procedure corresponds to a diagnostic test for detecting severities of vibrations for the industrial machine.

107. The method of claim 106, wherein determining a severity of a vibration detected for the industrial machine comprises:

receiving vibration data representative of the vibration of at least a portion of the industrial machine from a mobile data collector including at least one vibration sensor used to capture the vibration data;

determining a frequency of the captured vibration by processing the captured vibration data;

determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the captured vibration; and

calculating a severity unit for the captured vibration based on the determined segment.

108. The method of claim 107, further comprising:

generating a signal indicative of a machine failure based on the severity unit.

109. A method of accumulating information about an industrial machine, comprising:

initiating a blockchain of industrial machine information for a specific industrial machine by generating an initiating block; and

generating subsequent blocks of the specific industrial machine blockchain by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, and diagnostic activity and a hash of the most recently generated block in the blockchain.

110. The method of claim 109, further comprising generating a first block of the blockchain with shipment readiness information about the specific industrial machine and a hash of the initiated block of the blockchain.

111. The method of claim 110, further comprising generating a second block of the blockchain with installation information about the specific industrial machine and a hash of the first block.

112. The method of claim 111, further comprising generating a third block of the blockchain with operational sensor information about the specific industrial machine and a hash of the second block.

113. The method of claim 112, further comprising generating a fourth block of the blockchain with service event information about the specific industrial machine and a hash of the third block.

114. The method of claim 113, further comprising generating a fifth block of the blockchain with parts and service order information about the specific industrial machine and a hash of the fourth block.

115. The method of claim 114, further comprising generating a sixth block of the blockchain with diagnostic activity information about the specific industrial machine and a hash of the fifth block.

116. A method of predicting a service event from vibration data, comprising:

capturing vibration data from at least one vibration sensor disposed to capture vibration of a portion of an industrial machine;

determining at least one of a frequency, amplitude, and gravitational force of the captured vibration;

determining a segment of a multi-segment vibration frequency spectra that bounds the captured vibration based on the frequency of the captured vibration;

calculating a vibration severity unit for the captured vibration based on the determined segment and at least one of a peak value of the amplitude or the gravitational force; and

generating a signal in a predictive maintenance circuit for executing a maintenance action on the portion of the industrial machine based on the severity unit.

117. The method of claim 116, wherein the segment is determined based on comparing the frequency of the captured vibration to an upper limit and a lower limit of a mid-segment of the multi-segment vibration frequency spectra.

118. The method of claim 116, wherein a first segment of the multi-segment vibration frequency spectra comprises determined frequency values below a lower limit of a mid-segment of the multi-segment vibration frequency spectra.

119. The method of claim 118, wherein the lower limit of the mid-segment of the multi-segment vibration frequency spectra is 1200 kHz.

120. The method of claim 116, wherein a second segment of the multi-segment vibration frequency spectra comprises determined frequency values above an upper limit of a mid-segment of the multi-segment vibration frequency spectra.

121. The method of claim 120, wherein the upper limit of the mid-segment of the multi-segment vibration frequency spectra is 18000 kHz.

122. The method of claim 116, wherein calculating a vibration severity unit comprises producing a severity value by multiplying one of a plurality of severity normalizing parameters by a mid-range severity limit and mapping the severity value to one of a plurality of severity unit ranges of the determined segment.

123. The method of claim 122, wherein a first severity normalizing value of the plurality of normalizing values is calculated by dividing the frequency of the captured vibration by a low-end frequency value of a mid-segment of the multi-segment vibration frequency spectra.

124. The method of claim 123, wherein the one of the plurality of severity normalizing parameters comprises the first severity normalizing value when the frequency of the captured vibration is less than the low-end frequency value.

125. The method of claim 122, wherein a second severity normalizing value of the plurality of normalizing values is calculated by dividing a high-end frequency value of a mid-segment of the multi-segment vibration frequency spectra by the frequency of the captured vibration.

126. The method of claim 125, wherein the one of the plurality of severity normalizing parameters comprises the second severity normalizing value when the frequency of the captured vibration is greater than the high-end frequency value.

127. The method of claim 116, wherein a first segment of the multi-segment vibration frequency spectra is divided into a plurality of severity units based on the amplitude of the captured vibration.

128. The method of claim 116, wherein a second segment of the multi-segment vibration frequency spectra is divided into a plurality of severity units based on the gravitational force of the captured vibration.

129. The method of claim 116, wherein the vibration severity unit is determined based on a peak displacement of the amplitude of the captured vibration for determined vibration frequencies within a first segment of the multi-segment vibration frequency spectra.

130. The method of claim 116, wherein the vibration severity unit is determined based on gravitational force of the captured vibration for determined vibration frequencies within a second segment of the multi-segment vibration frequency spectra.

131. The method of claim 116, wherein the portion of the industrial machine is a moving part.

132. The method of claim 116, wherein the portion of the industrial machine is a structural member supporting a moving part.

133. The method of claim 116, wherein the portion of the industrial machine is a motor.

134. The method of claim 116, wherein the portion of the industrial machine is a drive shaft.

135. A system for predicting a service event from vibration data, comprising:

an industrial machine comprising at least one vibration sensor disposed to capture vibration of a portion of the industrial machine;

a vibration analysis circuit in communication with the at least one vibration sensor and that generates at least one of a frequency, peak amplitude, and gravitational force of the captured vibration;

a multi-segment vibration frequency spectra structure that facilitates mapping the captured vibration to one vibration frequency segment of a multi-segment vibration frequency;

a severity unit algorithm that receives the frequency of the captured vibration and the corresponding vibration frequency segment and produces a severity value which is then mapped to one of a plurality of severity units defined for the corresponding vibration frequency segment; and

a signal generating circuit that receives the one of the plurality of severity units, and based thereon, signals a predictive maintenance server to execute a corresponding maintenance action on the portion of the industrial machine.

136. The system of claim 135, wherein the multi-segment vibration frequency spectra structure facilitates a mapping of the detected vibrations to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra.

137. The system of claim 135, wherein the multi-segment vibration frequency spectra structure facilitates a mapping of the detected vibrations to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra.

138. The system of claim 135, wherein the multi-segment vibration frequency spectra structure facilitates a mapping of the detected vibrations to a third severity unit when the frequency of the captured vibration corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

139. The system of claim 135, wherein the severity units indicate that the detected vibrations may lead to a failure of at least the portion of the industrial machine.

140. The system of claim 135, wherein a first segment of the multi-segment vibration frequency spectra is divided into a plurality of severity units based on the amplitude of the captured vibration.

141. The system of claim 135, wherein a second segment of the multi-segment vibration frequency spectra is divided into a plurality of severity units based on the gravitational force of the captured vibration.

142. The system of claim 135, wherein the severity unit is determined based on a peak displacement of the amplitude of the captured vibration for determined vibration frequencies within a first segment of the multi-segment vibration frequency spectra.

143. The system of claim 135, wherein the severity unit is determined based on gravitational force of the captured vibration for determined vibration frequencies within a second segment of the multi-segment vibration frequency spectra.

144. The system of claim 135, wherein the portion of the industrial machine is a moving part.

145. The system of claim 135, wherein the portion of the industrial machine is a structural member supporting a moving part.

146. The system of claim 135, wherein the portion of the industrial machine is a motor.

147. The system of claim 135, wherein the portion of the industrial machine is a drive shaft.

148. A method comprising:

sampling a signal at a streaming sample rate, thereby producing a plurality of samples of the signal;

allocating, with a signal routing circuit, a first portion of the plurality of samples of the signal to a first signal analysis circuit, the portion selected based on a first signal analysis sampling rate that is less than the streaming sample rate;

allocating, with a signal routing circuit, a second portion of the plurality of samples of the signal to a second signal analysis circuit, the portion selected based on a second signal analysis sampling rate that is less than the streaming sample rate; and

storing the plurality of samples of the signal, an output of the first signal analysis circuit, and an output of the second signal analysis circuit, wherein the allocated first portion in the stored plurality of samples and the allocated second portion in the stored plurality of samples are tagged with indicia that references the corresponding stored signal analysis output.

149. The method of claim 148, wherein allocating with the signal routing circuit comprises integrating a plurality of samples based on a ratio of the signal analysis sampling rate and the streaming sample rate.

150. The method of claim 148, wherein allocating with the signal routing circuit comprises selecting samples of the signal based on a ratio of the signal analysis sampling rate and the streaming sample rate.

151. The method of claim 148, wherein the streaming sample rate is at least twice as fast as a dominant frequency of the signal.

152. The method of claim 148, wherein a ratio of the signal analysis sampling rate to the streaming sample rate determines a number of supplemental binary bits of data of the output of the first and second signal analysis circuits.

153. The method of claim 152, wherein the number of supplemental binary bits comprises one when the streaming sample rate is at least twice and less than four times the signal analysis sampling rate.

154. The method of claim 152, wherein the number of supplemental binary bits comprise two when the streaming sample rate is at least four times and less than eight times the signal analysis sampling rate.

155. A system comprising:

a sensor detecting a condition of an industrial machine, the sensor producing a signal that varies over time and substantially corresponds with the condition;

an analog to digital converter that receives the signal and samples the signal at a streaming sample rate that is at least twice a dominant frequency of the signal, the sampled signal being output from the analog to digital converter as a sequence of data values; and

at least one digital signal router that receives the sequence of data value and a sub-sampling rate, wherein the sub-sampling rate is lower than the streaming sample rate, and produces at least

one sub-sampled output sequence of data comprising select samples from the sequence of samples based on at least one of the sub-sampling rate and a ratio of the streaming sample rate and the sub-sampling rate.

156. The system of claim 155, further comprising a data storage facility that receives the sequence of data values and an analyzed set of data values derived from the sub-sampled output sequence, wherein the analyzed set of data values are stored in association with the sequence of data values such that data values in the sequence of data values that correspond to the sub-sampled output sequence are tagged with indicia that references the corresponding analyzed set of data values.

157. The system of claim 155, wherein producing the at least one sub-sampled output sequence comprises integrating a plurality of samples in the sequence of data values based on a ratio of the sub-sampling rate and the streaming sample rate.

158. The system of claim 155, wherein producing the at least one sub-sampled output sequence comprises selecting samples of the signal based on a ratio of the sub-sampling rate and the streaming sample rate.

159. The system of claim 155, wherein the streaming sample rate is at least twice as fast as a dominant frequency of the signal.

160. The system of claim 155, wherein the ratio of the sub-sampling rate to the streaming sample rate determines a number of supplemental binary bits in the sub-sampled output sequence.

161. The system of claim 160, wherein the number of supplemental binary bits comprises one when the streaming sample rate is at least twice and less than four times the sub-sampling rate.

162. The system of claim 160, wherein the number of supplemental binary bits comprise two when the streaming sample rate is at least four times and less than eight times the sub-sampling rate.

163. A method of predicting maintenance events for industrial machines comprising:

generating streams of industrial machine health monitoring data by applying machine learning to data representative of conditions of portions of industrial machines, the condition representative data comprising vibration data for a least one moving part of the industrial machines and being received via a data collection network;

accessing, from a data storage device disposed with the industrial machine, moving part-specific configuration information for the at least one moving part of the industrial machine;

predicting industrial machine service recommendations responsive to the health monitoring data and the part-specific configuration information by applying machine fault detection and classification algorithms thereto;

producing at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations; and

receiving and processing information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

164. The method of claim 163, wherein the industrial machine service recommendations are for an industrial machine.

165. The method of claim 163, wherein the industrial machine service recommendation is for the at least one moving part.

166. The method of claim 165, wherein the last least one moving part is a rotating part of a machine.

167. The method of claim 165, wherein the at least one moving part is disposed in a gear box of a machine.

168. The method of claim 165, wherein the at least one moving part is a gear of the industrial machine.

169. The method of claim 168, wherein applying machine fault detection algorithms comprises adapting reference data representing an industrial machine maintenance recommendation responsive to comparing a count of gear teeth of the gear of the industrial machine with a count of gear teeth of a corresponding gear in the reference data.

170. The method of claim 169, wherein the reference data being adapted is a timing of a maintenance event identified via the industrial machine maintenance recommendation.

171. The method of claim 168, wherein applying machine fault detection algorithms comprises adapting data representing an industrial machine maintenance recommendation for a similar industrial machine responsive to comparing a count of gear teeth of the gear of the industrial machine with a count of gear of a corresponding gear of the similar machine.

172. The method of claim 171, wherein the similar industrial machine data being adapted is a timing of a maintenance event identified via the industrial machine maintenance recommendation.

173. An industrial machine predictive maintenance system comprising:

an industrial machine data analysis circuit that generates streams of industrial machine health monitoring data by applying machine learning to data representative of conditions of gears of industrial machines received via a data collection network;

a data storage device disposed with the industrial machines, the device storing gear-specific information for at least one gear of the industrial machines;

an industrial machine gear predictive maintenance circuit that accesses the gear-specific configuration information and produces industrial machine gear service recommendations responsive to the health monitoring data and the gear-specific information by applying machine fault detection and classification algorithms thereto;

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine gear service recommendations; and

a service and delivery tracking system that receives and processes information regarding services performed on industrial machine gears responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machine gears.

174. The system of claim 173, wherein the industrial machine predictive maintenance circuit is responsive to a count of gear teeth of a component of a machine for which the predictive maintenance circuit produces a service recommendation.

175. The system of claim 174, wherein the component is a rotating component.

176. The system of claim 174, wherein the component is a gear.

177. The system of claim 174, wherein the industrial machine comprises a gear box and the count of gear teeth is for a gear disposed in the gear box.

178. The system of claim 173, wherein the predictive maintenance circuit processes operational and failure data for a rotating component of the machine and corresponding rotating components of similar machines.

179. The system of claim 173, wherein the predictive maintenance circuit applies machine learning to process a count of gear teeth of a service component of at least one industrial machine along with service information for similar service components across a plurality of industrial machines thereby producing a predictive maintenance adjustment factor.

180. The system of claim 179, wherein the predictive maintenance circuit applies the adjustment factor thereby producing a machine-specific predictive maintenance recommendation.

181. The system of claim 173, wherein the industrial machine predictive maintenance circuit is responsive to a count of rotor bars of a motor rotationally connected to a service component of a machine for which the predictive maintenance circuit produces a service recommendation.

182. The system of claim 173, wherein the predictive maintenance circuit processes operational and failure data for a service component rotationally connected to a motor of the machine and corresponding service components of similar machines.

183. The system of claim 173, wherein the predictive maintenance circuit applied machine learning to process a count of rotor bars of a motor rotationally connected to a service component

of the industrial machine along with service information for similar rotationally connected service components across a plurality of industrial machines thereby producing a predictive maintenance adjustment factor.

184. The system of claim 183, wherein the predictive maintenance circuit applies the adjustment factor thereby producing a machine-specific predictive maintenance recommendation.

185. The system of claim 173, wherein the industrial machine predictive maintenance circuit is responsive to data representing revolutions-per-minute (RPM) of at least one internal machine component linked to a service component of a machine for which the predictive maintenance circuit produces a service recommendation.

186. The system of claim 173, wherein the predictive maintenance circuit processes operational RPM data and failure data associated with a service component of the machine and corresponding service components of similar machines.

187. The system of claim 173, wherein the predictive maintenance circuit applied machine learning to process data representing revolutions-per-minute (RPM) of at least one internal machine component linked to a service component of the industrial machine along with service information for similar linked service components across a plurality of industrial machines thereby producing a predictive maintenance adjustment factor.

188. The system of claim 187, wherein the predictive maintenance circuit applies the adjustment factor thereby producing a machine-specific predictive maintenance recommendation.

189. A roller bearing predictive maintenance system comprising:

a roller bearing data analysis circuit that generates streams of roller bearing health monitoring data by applying machine learning to data representative of conditions of roller bearings integrated with industrial machines, the data received via a data collection network;

a data storage device disposed with the industrial machines, the device storing roller bearing-specific information for at least one roller bearing of the industrial machines;

a roller bearing predictive maintenance circuit that produces roller bearing service recommendations responsive to the health monitoring data and the roller bearing-specific information by applying machine fault detection and classification algorithms thereto;

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the roller bearing service recommendations; and

a service and delivery tracking system that receives and processes information regarding services performed on roller bearings responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

190. The system of claim 189, wherein the roller bearing predictive maintenance circuit predicts a maintenance event for a roller bearing component responsive to at least one aspect of the roller bearing component selected from a list consisting of a number of balls per roller, a ball-to-roller contact angle, inner race dimensions, outer race dimensions, a number of vanes, a number of flutes, and mode shape info.

191. The system of claim 190, wherein the predicted maintenance event is selected from a list of maintenance events consisting of part replacement, machine sub-system replacement, calibration, deep data collection, machine servicing, machine shutdown, and preventive maintenance.

192. The system of claim 190, wherein the at least one aspect of the roller bearing component comprises a portion of digital data structure of roller bearing component production information retrieved through an RFID component disposed with the roller bearing component into an industrial machine.

193. The system of claim 192, wherein the portion of the digital data structure is retrieved by providing a machine-specific key retrieved from the RFID component to an Application Programming Interface function of a predictive maintenance system that facilitates access to roller bearing component production information stored external to the industrial machine.

194. The system of claim 192, wherein the portion of the digital data structure comprises production information retrieved from the RFID component.

195. The system of claim 192, wherein the circuit predicts a maintenance event for the roller bearing component responsive to retrieving the portion of the digital data structure from the RFID component independent of network connectivity of a processor executing the circuit.

196. The system of claim 192, wherein an enhanced data collection device comprises the predictive maintenance circuit.

197. The system of claim 196, wherein the enhanced data collection device predicts a maintenance event for the roller bearing component responsive to retrieving the portion of the digital data structure from the RFID component independent of network connectivity of the data collection device.

198. The system of claim 192, wherein the roller bearing predictive maintenance circuit is embodied in a mobile data collection device.

199. The system of claim 198, wherein the mobile data collection device operates the roller bearing predictive maintenance circuit with data collected from the RFID component to generate at least one roller bearing predictive maintenance recommendation.

200. The system of claim 199, wherein the portion of the digital data structure is specific to the industrial machine with which the roller bearing component is disposed.

201. The system of claim 199, wherein the portion of the digital data structure is retrieved by accessing a network location retrieved from the RFID component and further indexed by a machine-specific identifier retrieved from the RFID component.

202. The system of claim 201, wherein the network location is accessed through a WiFi interface of a data collection device while the data collection device is in short range wireless communication with the RFID component.

203. The system of claim 202, wherein the network location is accessed through a WiFi interface of a data collection device when the data collection device is no longer in short range wireless communication with the RFID component.

204. A method of determining a normalized severity measure of an impact of vibration of a component of an industrial machine, comprising:

capturing vibration data from at least one vibration sensor disposed to capture vibration of a portion of an industrial machine;

determining a frequency, a peak amplitude and gravitational force of the captured vibration;

determining a frequency range-specific segment of a multi-segment vibration frequency spectra that bounds the captured vibration based on the determined frequency;

calculating a vibration severity level for the captured vibration data based on the determined segment and at least one of the peak amplitude and the gravitational force; and

generating a signal in a predictive maintenance circuit for executing a maintenance action on the portion of the industrial machine based on the vibration severity level.

205. The method of claim 204, wherein the generated signal activates a watch state of maintenance prediction of the component.

206. The method of claim 204, wherein the generated signal activates a resurvey state of maintenance prediction of the component.

207. The method of claim 204, wherein the generated signal activates an action-soon state of maintenance prediction of the component.

208. The method of claim 204, wherein the generated signal activates an immediate action state of maintenance prediction of the component.

209. The method of claim 204, wherein the multi-segment vibration frequency spectra comprise a first segment with frequency values below a second segment low-end value and a third segment with frequency values above a second segment high-end value.

210. The method of claim 209, wherein at least one of the low-end value and the high-end value are configured from a type of the component of the industrial machine.

211. The method of claim 210, wherein determining a frequency range-specific segment comprises determining a type of the component of the industrial machine and adjusting at least one of the low-end value and the high-end value.

212. The method of claim 204, wherein generating a signal for executing a maintenance action comprises weighting the vibration severity level based on envelop processing of the captured vibration data.

213. The method of claim 204, wherein determining a frequency, a peak amplitude and gravitational force of the captured vibration comprises envelop processing the captured vibration data and mapping at least one vibration peak value of the envelope processed vibration data to the multi-segment vibration frequency spectra.

214. The method of claim 204, wherein the portion of the industrial machine comprises a plurality of components for which a vibration severity level is calculated and wherein generating a signal is based on an aggregation of the vibration severity levels calculated for the plurality of components.

215. A system for analysis of vibration data, comprising:

a graphical user interface;

a visual representation of at least a portion of an industrial machine rendered in the graphical user interface; and

at least one visual indication of a severity level for at least one component of the portion of the industrial machine rendered in the graphical user interface,

wherein, responsive to a user selection thereof in the user interface, the visual indication is rendered in the graphical user interface by activating a function that retrieves severity level information for the at least one component from a data set of component severity level information in pop-up window in the graphical user interface.

216. The system of claim 215, wherein the severity level for the at least one component of the portion of the industrial machine is determined by:

receiving, at a computing device, vibration data representative of the vibration of at least the portion of the industrial machine from the mobile data collector;

determining, by the computing device, a frequency of the captured vibration by processing the captured vibration data;

determining, by the computing device and based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the captured vibration; and

calculating, by the computing device, a severity unit for the captured vibration based on the determined segment.

217. The system of claim 216, wherein calculating the severity unit for the captured vibration based on the determined segment comprises:

mapping the captured vibration to the severity unit based on the determined segment by:

mapping the captured vibration to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the captured vibration to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the captured vibration to a third severity unit when the frequency of the captured vibration corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

218. The system of claim 215, wherein the severity level represents an impact on the at least one component of the portion of the industrial machine of a condition associated with the captured vibration data.

219. The system of claim 215, wherein the at least one component of the portion of the industrial machine is a moving part.

220. The system of claim 215, wherein the at least one component of the portion of the industrial machine is a structural member supporting a moving part.

221. The system of claim 215, wherein the at least one component of the portion of the industrial machine is a motor.

222. The system of claim 215, wherein the at least one component of the portion of the industrial machine is a drive shaft.

223. A system for determining a normalized severity measure of an impact of vibration of a component of an industrial machine, comprising:

a data set comprising vibration data captured from at least one vibration sensor disposed to capture vibration of a portion of an industrial machine;

a vibration data analysis circuit for determining a frequency, a peak amplitude and gravitational force of the captured vibration;

multi-segment vibration spectra that bound the captured vibration based on the determined frequency into one frequency segment;

a vibration severity level calculating circuit that calculates a vibration severity level for the captured vibration data based on the determined segment and at least one of the peak amplitude and the gravitational force; and

a predictive maintenance signal generation circuit for activating a maintenance action signal for the portion of the industrial machine based on the vibration severity level.

224. The system of claim 223, wherein the maintenance action signal activates a watch state of maintenance prediction of the component.

225. The system of claim 223, wherein the maintenance action signal activates a resurvey state of maintenance prediction of the component.

226. The system of claim 223, wherein the maintenance action signal activates an action-soon state of maintenance prediction of the component.

227. The system of claim 223, wherein the maintenance action signal activates an immediate action state of maintenance prediction of the component.

228. The system of claim 223, wherein the multi-segment vibration frequency spectra comprise a first segment with frequency values below a second segment low-end value and a third segment with frequency values above a second segment high-end value.

229. The system of claim 228, wherein at least one of the low-end value and the high-end value are configured from a type of the component of the industrial machine.

230. The system of claim 229, wherein the multi-segment vibration spectra that bounds the captured vibration is adapted based on a type of the component of the industrial machine including adapting at least one of the low-end value and the high-end value.

231. The system of claim 230, wherein the captured vibration data comprises envelop processed vibration data.

232. The system of claim 230, wherein the vibration data analysis circuit further envelop processes the captured vibration data and maps at least one vibration peak value of the envelop processed vibration data to the multi-segment vibration frequency spectra.

233. A system for detecting operating characteristics of an industrial machine, comprising:

at least one data capture device configured to capture raw data of a point of interest of the industrial machine; and

a computer vision system that generates one or more image data sets using the raw data captured, identifies one or more values corresponding to a portion of the industrial machine within the point of interest represented by the one or more image data sets, compares the one or more values to corresponding predicted values, generate a variance data set based on the comparison of the one or more values and the corresponding predicted values, detects an operating characteristic of the industrial machine based on the variance data, and generates data indicating the detection of the operating characteristic.

234. The system of claim 233, wherein the operating characteristic represents a possible or present issue relating to an operation of the industrial machine, the system further comprising:

a predictive maintenance platform that processes the data indicating the detection of the operating characteristic to identify a maintenance action representing an action which may be taken to prevent or resolve the possible or present issue relating to an operation of the industrial machine.

235. The system of claim 234, wherein the computer vision system generates a signal indicative of the data indicating the detection of the operating characteristic, wherein the predictive maintenance platform predicts the possible or present issue based on the signal.

236. The system of claim 234, further comprising:

a mobile data collector configured to perform the maintenance action,

wherein the predictive maintenance platform or the computer vision system transmits a signal indicative of the maintenance action to the mobile data collector to cause the mobile data collector to perform the maintenance action.

237. The system of claim 236, wherein the at least one data capture device captures the raw data in response to the mobile data collector recording a state-related measurement of the industrial machine.

238. The system of claim 237, wherein the state-related measurement of the industrial machine relates to a vibration of at least the portion of the industrial machine captured using at least one vibration sensor of the mobile data collector.

239. The system of claim 238, wherein the mobile data collector transmits a signal to at least one of the at least one data capture device or the computer vision system to cause the at least one data capture device to capture the raw data, wherein the signal is generated by:

receiving, at a computing device, vibration data representative of the vibration of at least the portion of the industrial machine from the mobile data collector;

determining, by the computing device, a frequency of the captured vibration by processing the captured vibration data;

determining, by the computing device and based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the captured vibration;

calculating, by the computing device, a severity unit for the captured vibration based on the determined segment; and

causing the mobile data collector to generate the signal based on the severity unit.

240. The system of claim 239, wherein calculating the severity unit for the captured vibration based on the determined segment comprises:

mapping the captured vibration to the severity unit based on the determined segment by:

mapping the captured vibration to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the captured vibration to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the captured vibration to a third severity unit when the frequency of the captured vibration corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

241. The system of claim 238, wherein the predictive maintenance platform uses a distributed ledger to track maintenance transactions related to the industrial machine, the distributed ledger storing transaction records corresponding to the maintenance transactions.

242. The system of claim 241, wherein the predictive maintenance platform generates a new transaction record in response to the transmission of the signal by the mobile data collector.

243. The system of claim 241, wherein the predictive maintenance platform generates a new transaction record in response to the generation of the data indicating the detection of the operating characteristic by the computer vision system.

244. The system of claim 238, wherein the at least one vibration sensor of the mobile data collector captures the vibration based on a waveform derived from a vibration envelope associated with at least the portion of the industrial machine.

245. The system of claim 236, wherein the mobile data collector is a mobile robot.

246. The system of claim 234, wherein the predictive maintenance platform uses a distributed ledger to track maintenance transactions related to the industrial machine, the distributed ledger storing transaction records corresponding to the maintenance transactions.

247. The system of claim 246, wherein the predictive maintenance platform generates a new transaction record in response to the capturing of the raw data by the at least one data capture device.

248. The system of claim 246, wherein the predictive maintenance platform generates a new transaction record in response to the generation of the data indicating the detection of the operating characteristic by the computer vision system.

249. The system of claim 234, wherein the predictive maintenance platform trains a machine learning aspect to detect possible or present issues similar to the possible or present issue relating to the operation of the industrial machine based on at least one of the operating characteristic or the maintenance action.

250. The system of claim 233, further comprising:

a visual analyzer including an intelligent system that analyzes the data indicating the detection of the operating characteristic to train a machine learning aspect associated with the computer vision system by:

training the machine learning aspect using a training data set comprising one or more of the operating characteristic the data indicating the detection of the operating characteristic, the raw data of the point of interest of the industrial machine, or the one or more image data sets.

251. The system of claim 250, further comprising:

a training data database that stores the training data set, wherein the visual analyzer trains the machine learning aspect associated with the computer vision system by retrieving the training data set from the training data database.

252. The system of claim 233, wherein the operating characteristic includes a vibration of a component of the industrial machine.

253. The system of claim 233, wherein the operating characteristic includes a shape of a component of the industrial machine.

254. The system of claim 233, wherein the operating characteristic includes a size of a component of the industrial machine.

255. The system of claim 233, wherein the operating characteristic includes a deflection of a component of the industrial machine.

256. The system of claim 233, wherein the operating characteristic includes an electromagnetic emission of a component of the industrial machine.

257. The system of claim 233, wherein the operating characteristic includes a temperature of a component of the industrial machine.

258. The system of claim 233, wherein the operating characteristic includes a temperature of a gas within a component of the industrial machine.

259. The system of claim 233, wherein the operating characteristic includes a temperature of a liquid within a component of the industrial machine.

260. The system of claim 233, wherein the operating characteristic includes a temperature of a solid within a component of the industrial machine.

261. The system of claim 233, wherein the operating characteristic includes a pressure within a component of the industrial machine.

262. The system of claim 233, wherein the operating characteristic includes a pressure of a gas within a component of the industrial machine.

263. The system of claim 233, wherein the operating characteristic includes a pressure of a liquid within a component of the industrial machine.

264. The system of claim 233, wherein the operating characteristic includes a density of a gas within a component of the industrial machine.

265. The system of claim 233, wherein the operating characteristic includes a density of a liquid within a component of the industrial machine.

266. The system of claim 233, wherein the operating characteristic includes a density of a solid within a component of the industrial machine.

267. The system of claim 233, wherein the operating characteristic includes a density of a component manufactured by the industrial machine.

268. The system of claim 267, wherein the component includes a part for a vehicle.

269. The system of claim 267, wherein the component includes a part for a bike.

270. The system of claim 267, wherein the component includes a bike chain.

271. The system of claim 267, wherein the component includes a gasket.

272. The system of claim 267, wherein the component includes a fastener.

273. The system of claim 267, wherein the component includes a part for a screw.

274. The system of claim 267, wherein the component includes a part for a bolt.

275. The system of claim 267, wherein the component includes a part for a printed circuit board.

276. The system of claim 267, wherein the component includes a part for a capacitor.

277. The system of claim 267, wherein the component includes a part for a resistor.

278. The system of claim 267, wherein the component includes a part for an inductor.

279. The system of claim 233, wherein the operating characteristic includes a chemical structure of a gas within a component of the industrial machine.

280. The system of claim 233, wherein the operating characteristic includes a chemical structure of a liquid within a component of the industrial machine.

281. The system of claim 233, wherein the operating characteristic includes a chemical structure of a solid within a component of the industrial machine.

282. The system of claim 233, wherein the operating characteristic includes a chemical structure of a component manufactured by the industrial machine.

283. The system of claim 282, wherein the component includes a part for a vehicle.

284. The system of claim 282, wherein the component includes a part for a bike.

285. The system of claim 282, wherein the component includes a bike chain.

286. The system of claim 282, wherein the component includes a gasket.

287. The system of claim 282, wherein the component includes a fastener.

288. The system of claim 282, wherein the component includes a part for a screw.

289. The system of claim 282, wherein the component includes a part for a bolt.

290. The system of claim 282, wherein the component includes a part for a printed circuit board.

291. The system of claim 282, wherein the component includes a part for a capacitor.

292. The system of claim 282, wherein the component includes a part for a resistor.

293. The system of claim 282, wherein the component includes a part for an inductor.

294. The system of claim 233, wherein the data capture device includes an image capture device.

295. The system of claim 233, wherein the data capture device includes a camera.

296. The system of claim 233, wherein the data capture device includes data measurement device.

297. The system of claim 233, wherein the data capture device includes a sensor.

298. The system of claim 233, wherein the data capture device includes a full spectrum camera.

299. The system of claim 233, wherein the data capture device includes radiation imaging device.

300. The system of claim 233, wherein the data capture device includes an X-ray imaging device.

301. The system of claim 233, wherein the data capture device includes a non-visible light data capture device.

302. The system of claim 233, wherein the data capture device includes a visible light data capture device.

303. The system of claim 233, wherein the data capture device includes sonic data capture device.

304. The system of claim 233, wherein the data capture device includes an image capture device.

305. The system of claim 233, wherein the data capture device includes light imaging, detection, and ranging device.

306. The system of claim 233, wherein the data capture device includes point cloud data capture device.

307. The system of claim 233, wherein the data capture device includes an infrared inspection device.

308. The system of claim 233, wherein the data capture device includes an image capture device.

309. The system of claim 233, wherein the data capture device includes a pressure sensor.

310. The system of claim 233, wherein the data capture device includes a temperature sensor.

311. The system of claim 233, wherein the data capture device includes a chemical sensor.

312. The system of claim 233, wherein the data capture device includes a stand-alone device.

313. The system of claim 233, wherein the data capture device includes a mobile device.

314. The system of claim 313, wherein the mobile device includes a smart phone.

315. The system of claim 313, wherein the mobile device includes a tablet.

316. The system of claim 233, wherein the raw data includes raw image data.

317. The system of claim 233, wherein the raw data includes raw measurement data.

318. The system of claim 233, wherein the portion of the industrial machine within the point of interest includes a component of the industrial machine.

319. The system of claim 233, wherein the portion of the industrial machine within the point of interest includes a belt of the industrial machine.

320. The system of claim 233, wherein the portion of the industrial machine within the point of interest includes a component manufactured by the industrial machine.

321. The system of claim 233, wherein the portion of the industrial machine within the point of interest includes a bike chain manufactured by the industrial machine.

322. A method for detecting operating characteristics of an industrial machine, comprising:

generating one or more image data sets using raw data captured by one or more data capture devices;

identifying one or more values corresponding to a portion of the industrial machine within a point of interest represented by the one or more image data sets;

comparing the one or more values to corresponding predicted values;

generating a variance data set based on the comparison of the one or more values and the corresponding predicted values;

identifying an operating characteristic of the industrial machine based on the variance data; and

generating data indicating a detection of the operating characteristic.

323. The method of claim 322, wherein the operating characteristic represents a possible or present issue relating to an operation of the industrial machine, the method further comprising:

identifying a maintenance action to perform responsive to identifying the operating characteristic, the maintenance action representing action which may be taken to prevent or resolve the possible or present issue relating to the operation of the industrial machine.

324. The method of claim 323, wherein identifying the maintenance action to perform responsive to identifying the operating characteristic comprises:

using predictive maintenance to predict the possible or present issue based on the operating characteristic.

325. The method of claim 323, further comprising:

generating a signal indicative of the maintenance action; and

transmitting the signal to a server to execute the maintenance action.

326. The method of claim 323, further comprising:

generating a signal indicative of the maintenance action; and

transmitting the signal to a mobile robot to cause the mobile robot to perform the maintenance action.

327. The method of claim 323, wherein using the predictive maintenance to predict the possible or present issue based on the operating characteristic comprises:

determining a severity of the possible or present issue based on the operating characteristic, the severity representing an impact of the operating characteristic on the industrial machine, the severity indicating a priority for resolving the possible or present issue.

328. The method of claim 322, wherein the raw data is captured responsive to instructions received from a wearable device worn by a user in an environment of the industrial machine, the method further comprising:

indicating to the user to perform the maintenance action by communicating a signal indicative of the maintenance action to the wearable device.

329. The method of claim 322, wherein the raw data is captured responsive to instructions received from a mobile data collector located in an environment of the industrial machine, the method further comprising:

initiating the maintenance action by communicating a signal indicative of the maintenance action to the mobile data collector.

330. The method of claim 329, wherein the mobile data collector is a mobile robot.

331. The method of claim 322, wherein at least one of the one or more data capture devices is a mobile device including a camera, the method further comprising:

causing the camera of the mobile device to capture the raw data; and

transmitting, from the mobile device, a signal including the raw data to a computer vision system used to generate the one or more image data sets.

332. The method of claim 322, wherein the operating characteristic includes a vibration of a component of the industrial machine.

333. The method of claim 322, wherein the operating characteristic includes a shape of a component of the industrial machine.

334. The method of claim 322, wherein the operating characteristic includes a size of a component of the industrial machine.

335. The method of claim 322, wherein the operating characteristic includes a deflection of a component of the industrial machine.

336. The method of claim 322, wherein the operating characteristic includes an electromagnetic emission of a component of the industrial machine.

337. The method of claim 322, wherein the operating characteristic includes a temperature of a component of the industrial machine.

338. The method of claim 322, wherein the operating characteristic includes a temperature of a gas within a component of the industrial machine.

339. The method of claim 322, wherein the operating characteristic includes a temperature of a liquid within a component of the industrial machine.

340. The method of claim 322, wherein the operating characteristic includes a temperature of a solid within a component of the industrial machine.

341. The method of claim 322, wherein the operating characteristic includes a pressure within a component of the industrial machine.

342. The method of claim 322, wherein the operating characteristic includes a pressure of a gas within a component of the industrial machine.

343. The method of claim 322, wherein the operating characteristic includes a pressure of a liquid within a component of the industrial machine.

344. The method of claim 322, wherein the operating characteristic includes a density of a gas within a component of the industrial machine.

345. The method of claim 322, wherein the operating characteristic includes a density of a liquid within a component of the industrial machine.

346. The method of claim 322, wherein the operating characteristic includes a density of a solid within a component of the industrial machine.

347. The method of claim 322, wherein the operating characteristic includes a density of a component manufactured by the industrial machine.

348. The method of claim 347, wherein the component includes a part for a vehicle.

349. The method of claim 347, wherein the component includes a part for a bike.

350. The method of claim 347, wherein the component includes a bike chain.

351. The method of claim 347, wherein the component includes a gasket.

352. The method of claim 347, wherein the component includes a fastener.

353. The method of claim 347, wherein the component includes a part for a screw.

354. The method of claim 347, wherein the component includes a part for a bolt.

355. The method of claim 347, wherein the component includes a part for a printed circuit board.

356. The method of claim 347, wherein the component includes a part for a capacitor.

357. The method of claim 347, wherein the component includes a part for a resistor.

358. The method of claim 347, wherein the component includes a part for an inductor.

359. The method of claim 322, wherein the operating characteristic includes a chemical structure of a gas within a component of the industrial machine.

360. The method of claim 322, wherein the operating characteristic includes a chemical structure of a liquid within a component of the industrial machine.

361. The method of claim 322, wherein the operating characteristic includes a chemical structure of a solid within a component of the industrial machine.

362. The method of claim 322, wherein the operating characteristic includes a chemical structure of a component manufactured by the industrial machine.

363. The method of claim 362, wherein the component includes a part for a vehicle.

364. The method of claim 362, wherein the component includes a part for a bike.

365. The method of claim 362, wherein the component includes a bike chain.

366. The method of claim 362, wherein the component includes a gasket.

367. The method of claim 362, wherein the component includes a fastener.

368. The method of claim 362, wherein the component includes a part for a screw.

369. The method of claim 362, wherein the component includes a part for a bolt.

370. The method of claim 362, wherein the component includes a part for a printed circuit board.

371. The method of claim 362, wherein the component includes a part for a capacitor.

372. The method of claim 362, wherein the component includes a part for a resistor.

373. The method of claim 362, wherein the component includes a part for an inductor.

374. The method of claim 322, wherein the data capture device includes an image capture device.

375. The method of claim 322, wherein the data capture device includes a camera.

376. The method of claim 322, wherein the data capture device includes data measurement device.

377. The method of claim 322, wherein the data capture device includes a sensor.

378. The method of claim 322, wherein the data capture device includes a full spectrum camera.

379. The method of claim 322, wherein the data capture device includes radiation imaging device.

380. The method of claim 322, wherein the data capture device includes an X-ray imaging device.

381. The method of claim 322, wherein the data capture device includes a non-visible light data capture device.

382. The method of claim 322, wherein the data capture device includes a visible light data capture device.

383. The method of claim 322, wherein the data capture device includes sonic data capture device.

384. The method of claim 322, wherein the data capture device includes an image capture device.

385. The method of claim 322, wherein the data capture device includes light imaging, detection, and ranging device.

386. The method of claim 322, wherein the data capture device includes point cloud data capture device.

387. The method of claim 322, wherein the data capture device includes an infrared inspection device.

388. The method of claim 322, wherein the data capture device includes an image capture device.

389. The method of claim 322, wherein the data capture device includes a pressure sensor.

390. The method of claim 322, wherein the data capture device includes a temperature sensor.

391. The method of claim 322, wherein the data capture device includes a chemical sensor.

392. The method of claim 322, wherein the data capture device includes a stand-alone device.

393. The method of claim 322, wherein the data capture device includes associated with a mobile device.

394. The method of claim 393, wherein the mobile device includes a smart phone.

395. The method of claim 393, wherein the mobile device includes a tablet.

396. The method of claim 322, wherein the raw data includes raw image data.

397. The method of claim 322, wherein the raw data includes raw measurement data.

398. The method of claim 322, wherein the portion of the industrial machine within the point of interest includes a component of the industrial machine.

399. The method of claim 322, wherein the portion of the industrial machine within the point of interest includes a belt of the industrial machine.

400. The method of claim 322, wherein the portion of the industrial machine within the point of interest includes a component manufactured by the industrial machine.

401. The method of claim 322, wherein the portion of the industrial machine within the point of interest includes a bike chain manufactured by the industrial machine.

402. A system for detecting operating characteristics of an industrial machine, comprising:

at least one image data capture device that captures raw data of a point of interest of the industrial machine;

a computing device that generates one or more image data sets using the captured raw data, wherein a portion of the industrial machine associated with the point of interest is represented within the one or more image data sets;

an intelligent system that trains a machine learning aspect associated with the computer device based on the one or more image data sets by:

comparing one or more values from the one or more image data sets to corresponding predicted values;

generating a variance data set based on the comparison of the one or more values and the corresponding predicted values;

identifying an operating characteristic of the industrial machine based on the variance data;

determining whether the operating characteristic is within a tolerance based on whether the operating characteristic is greater than a threshold;

generating training data indicating the operating characteristic; and

training the machine learning aspect according to the training data.

403. The system of claim 402, wherein the intelligent system is a deep learning system.

404. The system of claim 402, wherein the intelligent system comprises one or more of a cognitive learning module, an artificial intelligence module, or a machine learning module.

405. The system of claim 402, wherein the training data includes image data associated with the industrial machine and non-image data associated with the industrial machine.

406. The system of claim 405, wherein the training data is stored in a knowledge base associated with the industrial machine.

407. The system of claim 406, wherein the knowledge base is updated based on output from the intelligent system.

408. A method for using a wearable device to identify a state of a target of an industrial environment, the method comprising:

recording a state-related measurement of the target using one or more sensors of the wearable device;

transmitting the state-related measurement to a server over a network;

using intelligent systems associated with the server to process the state-related measurement against pre-recorded data for the target, wherein processing the state-related measurement against the pre-recorded data for the target includes identifying the pre-recorded data for the target within a knowledge base associated with the industrial environment; and

identifying, as the state of the target, a state indicated by the pre-recorded data for the target within the knowledge base.

409. The method of claim 408, further comprising:

determining an inconsistency between the pre-recorded data for the target and the state-related measurement; and

responsive to determining the inconsistency, updating the knowledge base according to the state-related measurement.

410. The method of claim 409, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

411. The method of claim 409, wherein the knowledge base includes a training data set used to train an artificial intelligence aspect of the intelligent systems.

412. The method of claim 409, wherein the knowledge base includes a training data set used to train a cognitive functioning aspect of the intelligent systems.

413. The method of claim 408, wherein the wearable device includes one sensor.

414. The method of claim 408, wherein the wearable device includes multiple sensors.

415. The method of claim 408, wherein the wearable device is a first wearable device and the state-related measurement is a first state-related measurement, the method further comprising:

using a second wearable device to record a second state-related measurement of the target.

416. The method of claim 415, wherein using the intelligent systems associated with the server to process the state-related measurement against the pre-recorded data for the target comprises:

using the intelligent systems to identify the pre-recorded data based on the first state-related measurement and the second state-related measurement.

417. The method of claim 415, further comprising:

determining an inconsistency between the first state-related measurement and the second state-related measurement; and

comparing each of the first state-related measurement and the second state-related measurement to the pre-recorded data to determine that the first state-related measurement is inconsistent with the pre-recorded data and that the second state-related measurement is consistent with the pre-recorded data.

418. The method of claim 417, further comprising:

responsive to comparing each of the first state-related measurement and the second state-related measurement to the pre-recorded data, discarding the first state-related measurement.

419. The method of claim 417, further comprising:

responsive to comparing each of the first state-related measurement and the second state-related measurement to the pre-recorded data, updating the knowledge base according to the second state-related measurement.

420. The method of claim 419, wherein the one or more sensors includes a plurality of sensors that each record state-related measurements, the method further comprising:

prior to transmitting the state-related measurements to the server, performing sensor fusion against the state-related measurements using an on-device sensor fusion aspect of the wearable device.

421. The method of claim 420, wherein the on-device sensor fusion aspect is a multiplexer.

422. The method of claim 408, wherein recording the state-related measurement of the target using the one or more sensors of the wearable device comprises:

using a host processing system to control the recording of the state-related measurement.

423. The method of claim 422, wherein the host processing system is embodied in a cloud computing system.

424. The method of claim 408, wherein recording the state-related measurement of the target using the one or more sensors of the wearable device comprises:

using a network coding system to control the recording of the state-related measurement.

425. The method of claim 408, wherein recording the state-related measurement of the target using the one or more sensors of the wearable device comprises:

repeating the recoding using the one or more sensors at a fixed interval.

426. The method of claim 408, wherein transmitting the state-related measurement to the server over the network comprises:

transmitting a command to the wearable device from a data collector; and

causing the wearable device to transmit the state-related measurement to the server responsive to the command.

427. The method of claim 426, wherein the data collector transmits the command to the wearable device at a fixed interval.

428. The method of claim 426, wherein the data collector transmits the command to the wearable device at random.

429. The method of claim 408, wherein transmitting the state-related measurement to the server over the network comprises:

using a collective processing mind associated with the wearable device to transmit a command to the wearable device; and

causing the wearable device to transmit the state-related measurement to the server responsive to the command.

430. The method of claim 408, wherein using the collective processing mind associated with the wearable device to transmit the command to the wearable device comprises:

using a detector associated with the collective processing mind to detect a near proximity of the target with respect to the wearable device; and

transmitting the command to the wearable device responsive to detecting the near proximity.

431. The method of claim 408, further comprising:

storing the state-related measurement in a data pool.

432. The method of claim 431, further comprising:

transmitting a request for the state-related measurement from a collective processing mind to a computing device used to implement the data pool, the request including a timestamp

indicative of a last time at which the collective processing mind requested one or more state-related measurements from the data pool;

determining whether the state-related measurement was recorded after the timestamp; and

responsive to determining that the state-related measurement was recorded after the timestamp, transmitting the state-related measurement from the computing device to the server.

433. The method of claim 408, wherein transmitting the state-related measurement to the server over the network comprises:

using a data collection router to transmit the state-related measurement from the wearable device to the server.

434. The method of claim 408, further comprising:

identifying a maintenance action associated with the state of the target.

435. The method of claim 408, wherein the wearable device is one of a plurality of wearable devices integrated within an industrial uniform.

436. The method of claim 408, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a vibration measured with respect to the target.

437. The method of claim 408, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a temperature measured with respect to the target.

438. The method of claim 408, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on an electrical output measured with respect to the target.

439. The method of claim 408, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a magnetic output measured with respect to the target.

440. The method of claim 408, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a sound output measured with respect to the target.

441. The method of claim 408, wherein the wearable device is integrated within an article of clothing.

442. The method of claim 441, wherein the article of clothing is a shirt.

443. The method of claim 441, wherein the article of clothing is a vest.

444. The method of claim 441, wherein the article of clothing is a jacket.

445. The method of claim 441, wherein the article of clothing is pants.

446. The method of claim 441, wherein the article of clothing is shorts.

447. The method of claim 441, wherein the article of clothing is a glove.

448. The method of claim 441, wherein the article of clothing is a sock.

449. The method of claim 441, wherein the article of clothing is a shoe.

450. The method of claim 441, wherein the article of clothing is protective outerwear.

451. The method of claim 441, wherein the article of clothing is an undergarment.

452. The method of claim 441, wherein the article of clothing is an undershirt.

453. The method of claim 441, wherein the article of clothing is a tank top.

454. The method of claim 408, wherein the wearable device is integrated within an accessory article.

455. The method of claim 454, wherein the accessory article is a hat.

456. The method of claim 454, wherein the accessory article is a helmet.

457. The method of claim 454, wherein the accessory article is glasses.

458. The method of claim 454, wherein the accessory article is goggles.

459. The method of claim 454, wherein the accessory article is a vision safety accessory.

460. The method of claim 454, wherein the accessory article is a mask.

461. The method of claim 454, wherein the accessory article is a chest band.

462. The method of claim 454, wherein the accessory article is a belt.

463. The method of claim 454, wherein the accessory article is a lift support garment.

464. The method of claim 454, wherein the accessory article is an antennae.

465. The method of claim 454, wherein the accessory article is a wrist band.

466. The method of claim 454, wherein the accessory article is a ring.

467. The method of claim 454, wherein the accessory article is a necklace.

468. The method of claim 454, wherein the accessory article is a bracelet.

469. The method of claim 454, wherein the accessory article is a watch.

470. The method of claim 454, wherein the accessory article is a brooch.

471. The method of claim 454, wherein the accessory article is a neck strap.

472. The method of claim 454, wherein the accessory article is a backpack.

473. The method of claim 454, wherein the accessory article is a front pack.

474. The method of claim 454, wherein the accessory article is an arm pack.

475. The method of claim 454, wherein the accessory article is a leg pack.

476. The method of claim 454, wherein the accessory article is a lanyard.

477. The method of claim 454, wherein the accessory article is a key ring.

478. The method of claim 454, wherein the accessory article is headphones.

479. The method of claim 454, wherein the accessory article is a hearing safety accessory.

480. The method of claim 454, wherein the accessory article is earbuds.

481. The method of claim 454, wherein the accessory article is an earpiece.

482. The method of claim 408, wherein the wearable device is a first wearable device integrated within an article of clothing, wherein the method further comprises using a second wearable device integrated within an accessory article.

483. The method of claim 408, wherein the one or more sensors include an image sensor, wherein the recording of the state-related measurement using the image sensor is controlled by a camera vision system in communication with the wearable device over the network.

484. A system for identifying a state of a target of an industrial environment, the system comprising:

a first wearable device including one or more sensors configured to record a first type of state-related measurement;

a second wearable device including one or more sensors configured to record a second type of state-related measurement; and

a server that receives the first type of state-related measurement from the first wearable device and the second type of state-related measurement from the second wearable device, the server including intelligent systems configured to:

process the first type of state-related measurement and the second type of state-related measurement against pre-recorded data stored within a knowledge base to identify the state of the target; and

update the pre-recorded data according to at least one of the first type of state-related measurement or the second type of state-related measurement.

485. The system of claim 484, wherein the first wearable device and the second wearable device are integrated within an industrial uniform.

486. The system of claim 484, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on a temperature measured with respect to the target.

487. The system of claim 484, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on an electrical output measured with respect to the target.

488. The system of claim 484, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on a magnetic output measured with respect to the target.

489. The system of claim 484, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

490. The system of claim 484, wherein the first type of state-related measurement is based on a temperature measured with respect to the target and the second type of state-related measurement is based on an electrical output measured with respect to the target.

491. The system of claim 484, wherein the first type of state-related measurement is based on a temperature measured with respect to the target and the second type of state-related measurement is based on a magnetic output measured with respect to the target.

492. The system of claim 484, wherein the first type of state-related measurement is based on a temperature measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

493. The system of claim 484, wherein the first type of state-related measurement is based on an electrical output measured with respect to the target and the second type of state-related measurement is based on a magnetic output measured with respect to the target.

494. The system of claim 484, wherein the first type of state-related measurement is based on an electrical output measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

495. The system of claim 484, wherein the first type of state-related measurement is based on a magnetic output measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

496. The system of claim 484, wherein the intelligent systems are configured to:

identify a maintenance action associated with the state of the target.

497. The system of claim 484, wherein the one or more sensors of the first wearable device include an image sensor, wherein the recording of the first type of the state-related measurement using the image sensor is controlled by a camera vision system in communication with the first wearable device.

498. The system of claim 484, further comprising:

a collective processing mind that transmits a command to at least one of the first wearable device or the second wearable device.

499. The system of claim 498, wherein the collective processing mind includes a detector for detecting a near proximity of the target with respect to the at least one of the first wearable device or the second wearable device.

500. The system of claim 498, wherein the collective processing mind uses adaptive scheduling to control a continuous monitoring of the target using the at least one of the first wearable device or the second wearable device.

501. The system of claim 484, wherein the intelligent systems are configured to:

update the knowledge base responsive to an inconsistency determined between the pre-recorded data and the at least one of the first type of state-related measurement or the second type of state-related measurement.

502. The system of claim 484, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

503. The system of claim 484, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

504. The system of claim 484, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

505. The system of claim 484, wherein the first wearable device is integrated within an article of clothing and the second wearable device is integrated within an accessory article.

506. The system of claim 484, wherein the first wearable device is integrated within a first article of clothing and the second wearable device is integrated within a second article of clothing.

507. The system of claim 484, wherein the first wearable device is integrated within a first accessory article and the second wearable device is integrated within a second accessory article.

508. The system of claim 484, wherein the first wearable device is integrated within an article of clothing.

509. The system of claim 508, wherein the article of clothing is a shirt.

510. The system of claim 508, wherein the article of clothing is a vest.

511. The system of claim 508, wherein the article of clothing is a jacket.

512. The system of claim 508, wherein the article of clothing is pants.

513. The system of claim 508, wherein the article of clothing is shorts.

514. The system of claim 508, wherein the article of clothing is a glove.

515. The system of claim 508, wherein the article of clothing is a sock.

516. The system of claim 508, wherein the article of clothing is a shoe.

517. The system of claim 508, wherein the article of clothing is protective outerwear.

518. The system of claim 508, wherein the article of clothing is an undergarment.

519. The system of claim 508, wherein the article of clothing is an undershirt.

520. The system of claim 508, wherein the article of clothing is a tank top.

521. The system of claim 484, wherein the first wearable device is integrated within an accessory article.

522. The system of claim 521, wherein the accessory article is a hat.

523. The system of claim 521, wherein the accessory article is a helmet.

524. The system of claim 521, wherein the accessory article is glasses.

525. The system of claim 521, wherein the accessory article is goggles.

526. The system of claim 521, wherein the accessory article is a vision safety accessory.

527. The system of claim 521, wherein the accessory article is a mask.

528. The system of claim 521, wherein the accessory article is a chest band.

529. The system of claim 521, wherein the accessory article is a belt.

530. The system of claim 521, wherein the accessory article is a lift support garment.

531. The system of claim 521, wherein the accessory article is an antennae.

532. The system of claim 521, wherein the accessory article is a wrist band.

533. The system of claim 521, wherein the accessory article is a ring.

534. The system of claim 521, wherein the accessory article is a necklace.

535. The system of claim 521, wherein the accessory article is a bracelet.

536. The system of claim 521, wherein the accessory article is a watch.

537. The system of claim 521, wherein the accessory article is a brooch.

538. The system of claim 521, wherein the accessory article is a neck strap.

539. The system of claim 521, wherein the accessory article is a backpack.

540. The system of claim 521, wherein the accessory article is a front pack.

541. The system of claim 521, wherein the accessory article is an arm pack.

542. The system of claim 521, wherein the accessory article is a leg pack.

543. The system of claim 521, wherein the accessory article is a lanyard.

544. The system of claim 521, wherein the accessory article is a key ring.

545. The system of claim 521, wherein the accessory article is headphones.

546. The system of claim 521, wherein the accessory article is a hearing safety accessory.

547. The system of claim 521, wherein the accessory article is earbuds.

548. The system of claim 521, wherein the accessory article is an earpiece.

549. A method for using a mobile data collector to identify a state of a target of an industrial environment, the method comprising:

controlling the mobile data collector to approach a location of the target within the industrial environment;

recording a state-related measurement of the target using one or more sensors of the mobile data collector;

transmitting the state-related measurement to a server over a network;

using intelligent systems associated with the server to process the state-related measurement against pre-recorded data for the target, wherein processing the state-related measurement against the pre-recorded data for the target includes identifying the pre-recorded data for the target within a knowledge base associated with the industrial environment; and

identifying, as the state of the target, a state indicated by the pre-recorded data for the target within the knowledge base.

550. The method of claim 549, wherein the mobile data collector is a mobile robot.

551. The method of claim 550, wherein the one or more sensors are integrated within the mobile robot.

552. The method of claim 550, wherein the one or more sensors are coupled to the mobile robot.

553. The method of claim 550, wherein the mobile robot is a robotic arm.

554. The method of claim 550, wherein the mobile robot is an android robot.

555. The method of claim 550, wherein the mobile robot is a small autonomous robot.

556. The method of claim 550, wherein the mobile robot is a large autonomous robot.

557. The method of claim 550, wherein the mobile robot is a remote-controlled robot.

558. The method of claim 550, wherein the mobile robot is a programmably configured robot.

559. The method of claim 550, wherein the one or more sensors are integrated within the mobile robot.

560. The method of claim 550, wherein the one or more sensors are coupled to the mobile robot.

561. The method of claim 549, wherein the mobile data collector is a mobile vehicle.

562. The method of claim 559, wherein the mobile vehicle is a heavy-duty machine.

563. The method of claim 559, wherein the mobile vehicle is a heavy-duty on-road industrial vehicle.

564. The method of claim 559, wherein the mobile vehicle is a heavy-duty off-road industrial vehicle.

565. The method of claim 559, wherein the mobile vehicle includes an industrial machine.

566. The method of claim 559, wherein the mobile vehicle includes earth-moving equipment.

567. The method of claim 559, wherein the mobile vehicle includes earth-compacting equipment.

568. The method of claim 559, wherein the mobile vehicle includes hauling equipment.

569. The method of claim 559, wherein the mobile vehicle includes hoisting equipment.

570. The method of claim 559, wherein the mobile vehicle includes conveying equipment.

571. The method of claim 559, wherein the mobile vehicle includes aggregate production equipment.

572. The method of claim 559, wherein the mobile vehicle includes equipment used in concrete construction.

573. The method of claim 559, wherein the mobile vehicle includes piledriving equipment.

574. The method of claim 559, wherein the mobile vehicle includes construction equipment.

575. The method of claim 559, wherein the mobile vehicle is a personnel transport vehicle.

576. The method of claim 559, wherein the mobile vehicle is an unmanned vehicle.

577. The method of claim 549, wherein the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm.

578. The method of claim 577, wherein controlling the mobile data collector to approach the location of the target within the industrial environment comprises:

using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within the industrial environment.

579. The method of claim 578, wherein using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises:

controlling the movements of the mobile data collector within the industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors.

580. The method of claim 549, further comprising:

determining an inconsistency between the pre-recorded data for the target and the state-related measurement; and

responsive to determining the inconsistency, updating the knowledge base according to the state-related measurement.

581. The method of claim 549, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

582. The method of claim 549, wherein the knowledge base includes a training data set used to train an artificial intelligence aspect of the intelligent systems.

583. The method of claim 549, wherein the knowledge base includes a training data set used to train a cognitive functioning aspect of the intelligent systems.

584. The method of claim 549, wherein the mobile data collector includes one sensor.

585. The method of claim 549, wherein the mobile data collector includes multiple sensors.

586. The method of claim 549, wherein the mobile data collector is a first mobile data collector and the state-related measurement is a first state-related measurement, the method further comprising:

using a second mobile data collector to record a second state-related measurement of the target.

587. The method of claim 586, wherein using the intelligent systems associated with the server to process the state-related measurement against the pre-recorded data for the target comprises:

using the intelligent systems to identify the pre-recorded data based on the first state-related measurement and the second state-related measurement.

588. The method of claim 586, further comprising:

determining an inconsistency between the first state-related measurement and the second state-related measurement; and

comparing each of the first state-related measurement and the second state-related measurement to the pre-recorded data to determine that the first state-related measurement is inconsistent with the pre-recorded data and that the second state-related measurement is consistent with the pre-recorded data.

589. The method of claim 588, further comprising:

responsive to comparing each of the first state-related measurement and the second state-related measurement to the pre-recorded data, discarding the first state-related measurement.

590. The method of claim 588, further comprising:

responsive to comparing each of the first state-related measurement and the second state-related measurement to the pre-recorded data, updating the knowledge base according to the second state-related measurement.

591. The method of claim 586, wherein the first mobile data collector is a mobile robot and the second mobile data collector is a mobile vehicle.

592. The method of claim 549, wherein the one or more sensors includes a plurality of sensors that each record state-related measurements, the method further comprising:

prior to transmitting the state-related measurements to the server, performing sensor fusion against the state-related measurements using an on-device sensor fusion aspect of the mobile data collector.

593. The method of claim 592, wherein the on-device sensor fusion aspect is a multiplexer.

594. The method of claim 549, further comprising:

storing the state-related measurement in a data pool.

595. The method of claim 549, wherein transmitting the state-related measurement to the server over the network comprises:

using a data collection router to transmit the state-related measurement from the mobile data collector to the server.

596. The method of claim 549, further comprising:

identifying a maintenance action associated with the state of the target.

597. The method of claim 549, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a vibration measured with respect to the target.

598. The method of claim 549, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a temperature measured with respect to the target.

599. The method of claim 549, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on an electrical output measured with respect to the target.

600. The method of claim 549, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a magnetic output measured with respect to the target.

601. The method of claim 549, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a sound output measured with respect to the target.

602. The method of claim 549, wherein the one or more sensors include an image sensor, wherein the recording of the state-related measurement using the image sensor is controlled by a camera vision system in communication with the mobile data collector over the network.

603. A system for identifying a state of a target of an industrial environment, the system comprising:

a first mobile data collector including one or more sensors configured to record a first type of state-related measurement;

a second mobile data collector including one or more sensors configured to record a second type of state-related measurement; and

a server that receives the first type of state-related measurement from the first mobile data collector and the second type of state-related measurement from the second mobile data collector, the server including intelligent systems configured to:

process the first type of state-related measurement and the second type of state-related measurement against pre-recorded data stored within a knowledge base to identify the state of the target; and

update the pre-recorded data according to at least one of the first type of state-related measurement or the second type of state-related measurement.

604. The system of claim 603, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on a temperature measured with respect to the target.

605. The system of claim 603, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on an electrical output measured with respect to the target.

606. The system of claim 603, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on a magnetic output measured with respect to the target.

607. The system of claim 603, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

608. The system of claim 603, wherein the first type of state-related measurement is based on a temperature measured with respect to the target and the second type of state-related measurement is based on an electrical output measured with respect to the target.

609. The system of claim 603, wherein the first type of state-related measurement is based on a temperature measured with respect to the target and the second type of state-related measurement is based on a magnetic output measured with respect to the target.

610. The system of claim 603, wherein the first type of state-related measurement is based on a temperature measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

611. The system of claim 603, wherein the first type of state-related measurement is based on an electrical output measured with respect to the target and the second type of state-related measurement is based on a magnetic output measured with respect to the target.

612. The system of claim 603, wherein the first type of state-related measurement is based on an electrical output measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

613. The system of claim 603, wherein the first type of state-related measurement is based on a magnetic output measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

614. The system of claim 603, wherein the intelligent systems are configured to:

identify a maintenance action associated with the state of the target.

615. The system of claim 603, wherein the one or more sensors of the first mobile data collector include an image sensor, wherein the recording of the first type of the state-related measurement using the image sensor is controlled by a camera vision system in communication with the first mobile data collector.

616. The system of claim 603, wherein the intelligent systems are configured to:

update the knowledge base responsive to an inconsistency determined between the pre-recorded data and the at least one of the first type of state-related measurement or the second type of state-related measurement.

617. The system of claim 603, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

618. The system of claim 603, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

619. The system of claim 603, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

620. The system of claim 603, wherein the first mobile data collector is a mobile robot and the second mobile data collector is a mobile vehicle.

621. The system of claim 603, wherein the first mobile data collector is a first mobile robot and the second mobile data collector is a second mobile robot.

622. The system of claim 603, wherein the first mobile data collector is a first mobile vehicle and the second mobile data collector is a second mobile vehicle.

623. The system of claim 603, wherein the one or more sensors of the first mobile data collector are integrated within the first mobile data collector, wherein the one or more sensors of the second mobile data collector are integrated within the second mobile data collector.

624. The system of claim 603, wherein the one or more sensors of the first mobile data collector are integrated within the first mobile data collector, wherein the one or more sensors of the second mobile data collector are coupled to the second mobile data collector.

625. The system of claim 603, wherein the one or more sensors of the first mobile data collector are coupled to the first mobile data collector, wherein the one or more sensors of the second mobile data collector are integrated within the second mobile data collector.

626. The system of claim 603, wherein the one or more sensors of the first mobile data collector are coupled to the first mobile data collector, wherein the one or more sensors of the second mobile data collector are coupled to the second mobile data collector.

627. The system of claim 603, wherein the first mobile data collector is a mobile robot.

628. The system of claim 627, wherein the mobile robot is a robotic arm.

629. The system of claim 627, wherein the mobile robot is an android robot.

630. The system of claim 627, wherein the mobile robot is a small autonomous robot.

631. The system of claim 627, wherein the mobile robot is a large autonomous robot.

632. The system of claim 627, wherein the mobile robot is a remote-controlled robot.

633. The system of claim 627, wherein the mobile robot is a programmably configured robot.

634. The system of claim 627, wherein the one or more sensors are integrated within the mobile robot.

635. The system of claim 627, wherein the one or more sensors are coupled to the mobile robot.

636. The system of claim 603, wherein the mobile data collector is a mobile vehicle.

637. The system of claim 636, wherein the mobile vehicle is a heavy-duty machine.

638. The system of claim 636, wherein the mobile vehicle is a heavy-duty on-road industrial vehicle.

639. The system of claim 636, wherein the mobile vehicle is a heavy-duty off-road industrial vehicle.

640. The system of claim 636, wherein the mobile vehicle includes an industrial machine.

641. The system of claim 636, wherein the mobile vehicle includes earth-moving equipment.

642. The system of claim 636, wherein the mobile vehicle includes earth-compacting equipment.

643. The system of claim 636, wherein the mobile vehicle includes hauling equipment.

644. The system of claim 636, wherein the mobile vehicle includes hoisting equipment.

645. The system of claim 636, wherein the mobile vehicle includes conveying equipment.

646. The system of claim 636, wherein the mobile vehicle includes aggregate production equipment.

647. The system of claim 636, wherein the mobile vehicle includes equipment used in concrete construction.

648. The system of claim 636, wherein the mobile vehicle includes piledriving equipment.

649. The system of claim 636, wherein the mobile vehicle includes construction equipment.

650. The system of claim 636, wherein the mobile vehicle is a personnel transport vehicle.

651. The system of claim 636, wherein the mobile vehicle is an unmanned vehicle.

652. The system of claim 603, wherein the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm.

653. The system of claim 652, wherein controlling the mobile data collector to approach a location of the target within the industrial environment comprises:

using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within the industrial environment.

654. The system of claim 653, wherein using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises:

controlling the movements of the mobile data collector within the industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors.

655. A method for using a handheld device to identify a state of a target of an industrial environment, the method comprising:

recording a state-related measurement of the target using one or more sensors of the handheld device;

transmitting the state-related measurement to a server over a network;

using intelligent systems associated with the server to process the state-related measurement against pre-recorded data for the target, wherein processing the state-related measurement against the pre-recorded data for the target includes identifying the pre-recorded data for the target within a knowledge base associated with the industrial environment; and

identifying, as the state of the target, a state indicated by the pre-recorded data for the target within the knowledge base.

656. The method of claim 655, further comprising:

determining an inconsistency between the pre-recorded data for the target and the state-related measurement; and

responsive to determining the inconsistency, updating the knowledge base according to the state-related measurement.

657. The method of claim 656, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

658. The method of claim 656, wherein the knowledge base includes a training data set used to train an artificial intelligence aspect of the intelligent systems.

659. The method of claim 656, wherein the knowledge base includes a training data set used to train a cognitive functioning aspect of the intelligent systems.

660. The method of claim 655, wherein the handheld device includes one sensor.

661. The method of claim 655, wherein the handheld device includes multiple sensors.

662. The method of claim 655, wherein the handheld device is a first handheld device and the state-related measurement is a first state-related measurement, the method further comprising:

using a second handheld device to record a second state-related measurement of the target.

663. The method of claim 662, wherein using the intelligent systems associated with the server to process the state-related measurement against the pre-recorded data for the target comprises:

using the intelligent systems to identify the pre-recorded data based on the first state-related measurement and the second state-related measurement.

664. The method of claim 662, further comprising:

determining an inconsistency between the first state-related measurement and the second state-related measurement; and

comparing each of the first state-related measurement and the second state-related measurement to the pre-recorded data to determine that the first state-related measurement is inconsistent with the pre-recorded data and that the second state-related measurement is consistent with the pre-recorded data.

665. The method of claim 664, further comprising:

responsive to comparing each of the first state-related measurement and the second state-related measurement to the pre-recorded data, discarding the first state-related measurement.

666. The method of claim 664, further comprising:

responsive to comparing each of the first state-related measurement and the second state-related measurement to the pre-recorded data, updating the knowledge base according to the second state-related measurement.

667. The method of claim 666, wherein the one or more sensors includes a plurality of sensors that each record state-related measurements, the method further comprising:

prior to transmitting the state-related measurements to the server, performing sensor fusion against the state-related measurements using an on-device sensor fusion aspect of the handheld device.

668. The method of claim 667, wherein the on-device sensor fusion aspect is a multiplexer.

669. The method of claim 655, wherein recording the state-related measurement of the target using the one or more sensors of the handheld device comprises:

using a host processing system to control the recording of the state-related measurement.

670. The method of claim 669, wherein the host processing system is embodied in a cloud computing system.

671. The method of claim 655, wherein recording the state-related measurement of the target using the one or more sensors of the handheld device comprises:

using a network coding system to control the recording of the state-related measurement.

672. The method of claim 655, wherein recording the state-related measurement of the target using the one or more sensors of the handheld device comprises:

repeating the recoding using the one or more sensors at a fixed interval.

673. The method of claim 655, wherein transmitting the state-related measurement to the server over the network comprises:

transmitting a command to the handheld device from a data collector; and

causing the handheld device to transmit the state-related measurement to the server responsive to the command.

674. The method of claim 673, wherein the data collector transmits the command to the handheld device at a fixed interval.

675. The method of claim 673, wherein the data collector transmits the command to the handheld device at random.

676. The method of claim 655, wherein transmitting the state-related measurement to the server over the network comprises:

using a collective processing mind associated with the handheld device to transmit a command to the handheld device; and

causing the handheld device to transmit the state-related measurement to the server responsive to the command.

677. The method of claim 655, wherein using the collective processing mind associated with the handheld device to transmit the command to the handheld device comprises:

using a detector associated with the collective processing mind to detect a near proximity of the target with respect to the handheld device; and

transmitting the command to the handheld device responsive to detecting the near proximity.

678. The method of claim 655, further comprising:

storing the state-related measurement in a data pool.

679. The method of claim 678, further comprising:

transmitting a request for the state-related measurement from a collective processing mind to a computing device used to implement the data pool, the request including a timestamp indicative of a last time at which the collective processing mind requested one or more state-related measurements from the data pool;

determining whether the state-related measurement was recorded after the timestamp; and

responsive to determining that the state-related measurement was recorded after the timestamp, transmitting the state-related measurement from the computing device to the server.

680. The method of claim 655, wherein transmitting the state-related measurement to the server over the network comprises:

using a data collection router to transmit the state-related measurement from the handheld device to the server.

681. The method of claim 655, further comprising:

identifying a maintenance action associated with the state of the target.

682. The method of claim 655, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a vibration measured with respect to the target.

683. The method of claim 655, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a temperature measured with respect to the target.

684. The method of claim 655, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on an electrical output measured with respect to the target.

685. The method of claim 655, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a magnetic output measured with respect to the target.

686. The method of claim 655, wherein the one or more sensors includes a sensor configured to record the state-related measurement based on a sound output measured with respect to the target.

687. The method of claim 655, wherein the handheld device is a mobile phone.

688. The method of claim 655, wherein the handheld device is a laptop computer.

689. The method of claim 655, wherein the handheld device is a tablet computer.

690. The method of claim 655, wherein the handheld device is a personal digital assistant.

691. The method of claim 655, wherein the handheld device is a walkie-talkie.

692. The method of claim 655, wherein the handheld device is a radio.

693. The method of claim 655, wherein the handheld device is a long-range communication device.

694. The method of claim 655, wherein the handheld device is a short-range communication device.

695. The method of claim 655, wherein the handheld device is a flashlight.

696. The method of claim 655, wherein the one or more sensors include an image sensor, wherein the recording of the state-related measurement using the image sensor is controlled by a camera vision system in communication with the handheld device over the network.

697. A system for identifying a state of a target of an industrial environment, the system comprising:

a first handheld device including one or more sensors configured to record a first type of state-related measurement;

a second handheld device including one or more sensors configured to record a second type of state-related measurement; and

a server that receives the first type of state-related measurement from the first handheld device and the second type of state-related measurement from the second handheld device, the server including intelligent systems configured to:

process the first type of state-related measurement and the second type of state-related measurement against pre-recorded data stored within a knowledge base to identify the state of the target; and

update the pre-recorded data according to at least one of the first type of state-related measurement or the second type of state-related measurement.

698. The system of claim 697, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on a temperature measured with respect to the target.

699. The system of claim 697, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on an electrical output measured with respect to the target.

700. The system of claim 697, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on a magnetic output measured with respect to the target.

701. The system of claim 697, wherein the first type of state-related measurement is based on a vibration measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

702. The system of claim 697, wherein the first type of state-related measurement is based on a temperature measured with respect to the target and the second type of state-related measurement is based on an electrical output measured with respect to the target.

703. The system of claim 697, wherein the first type of state-related measurement is based on a temperature measured with respect to the target and the second type of state-related measurement is based on a magnetic output measured with respect to the target.

704. The system of claim 697, wherein the first type of state-related measurement is based on a temperature measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

705. The system of claim 697, wherein the first type of state-related measurement is based on an electrical output measured with respect to the target and the second type of state-related measurement is based on a magnetic output measured with respect to the target.

706. The system of claim 697, wherein the first type of state-related measurement is based on an electrical output measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

707. The system of claim 697, wherein the first type of state-related measurement is based on a magnetic output measured with respect to the target and the second type of state-related measurement is based on a sound output measured with respect to the target.

708. The system of claim 697, wherein the intelligent systems are configured to:

identify a maintenance action associated with the state of the target.

709. The system of claim 697, wherein the one or more sensors of the first handheld device include an image sensor, wherein the recording of the first type of the state-related measurement

using the image sensor is controlled by a camera vision system in communication with the first handheld device.

710. The system of claim 697, further comprising:

a collective processing mind that transmits a command to at least one of the first handheld device or the second handheld device.

711. The system of claim 710, wherein the collective processing mind includes a detector for detecting a near proximity of the target with respect to the at least one of the first handheld device or the second handheld device.

712. The system of claim 710, wherein the collective processing mind uses adaptive scheduling to control a continuous monitoring of the target using the at least one of the first handheld device or the second handheld device.

713. The system of claim 697, wherein the intelligent systems are configured to:

update the knowledge base responsive to an inconsistency determined between the pre-recorded data and the at least one of the first type of state-related measurement or the second type of state-related measurement.

714. The system of claim 697, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

715. The system of claim 697, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

716. The system of claim 697, wherein the knowledge base includes a training data set used to train a machine learning aspect of the intelligent systems.

717. The system of claim 697, wherein the handheld device is a mobile phone.

718. The system of claim 697, wherein the handheld device is a laptop computer.

719. The system of claim 697, wherein the handheld device is a tablet computer.

720. The system of claim 697, wherein the handheld device is a personal digital assistant.

721. The system of claim 697, wherein the handheld device is a walkie-talkie.

722. The system of claim 697, wherein the handheld device is a radio.

723. The system of claim 697, wherein the handheld device is a long-range communication device.

724. The system of claim 697, wherein the handheld device is a short-range communication device.

725. The system of claim 697, wherein the handheld device is a flashlight.

726. A method comprising:

receiving vibration data representative of a vibration of at least a portion of an industrial machine from a wearable device including at least one vibration sensor used to capture the vibration data;

determining a frequency of the captured vibration by processing the captured vibration data;

determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the captured vibration;

calculating a severity unit for the captured vibration based on the determined segment; and

generating a signal in a predictive maintenance circuit for executing a maintenance action on at least the portion of the industrial machine based on the severity unit.

727. The method of claim 726, wherein the at least one vibration sensor of the wearable device captures the vibration data based on a waveform derived from a vibration envelope associated with at least the portion of the industrial machine.

728. The method of claim 726, further comprising:

detecting, using the wearable device, that the industrial machine is in near proximity to the wearable device; and

causing the wearable device to capture the vibration data responsive to detecting the near proximity of the industrial machine to the wearable device.

729. The method of claim 726, further comprising:

detecting a vibration level change of at least the portion of the industrial machine using the at least one vibration sensor of the wearable device; and

using the wearable device to capture the vibration data responsive to detecting the vibration level change.

730. The method of claim 729, wherein the at least one vibration sensor of the wearable device detects the vibration level change based on a waveform derived from a vibration envelope associated with at least the portion of the industrial machine.

731. The method of claim 726, further comprising:

transmitting the signal to the wearable device to cause the execution of the maintenance action.

732. The method of claim 726, wherein calculating the severity unit for the captured vibration based on the determined segment comprises:

mapping the captured vibration to the severity unit based on the determined segment by:

mapping the captured vibration to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the captured vibration to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the captured vibration to a third severity unit when the frequency of the captured vibration corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

733. The method of claim 732, further comprising:

training an intelligent system to determine whether a vibration maps to the first severity unit, the second severity unit, or the third severity unit.

734. The method of claim 726, wherein the severity unit represents an impact on at least the portion of the industrial machine of the maintenance action based on the captured vibration data.

735. The method of claim 726, further comprising:

determining an amplitude and a gravitational force of the captured vibration data by the processing of the captured vibration data,

wherein calculating the severity unit for the captured vibration comprises:

calculating the severity unit based on the determined segment and at least one of the amplitude or the gravitational force, wherein the severity unit represents the captured vibration independent of the frequency.

736. The method of claim 726, wherein at least one of the signal or the maintenance action indicates, based on the severity unit, increasing or decreasing a frequency for collection and analysis of further vibration data using the at least one vibration sensor.

737. The method of claim 726, wherein the maintenance action indicates to perform one of calibration, diagnostic testing, or visual inspection against at least the portion of the industrial machine.

738. The method of claim 726, further comprising:

transmitting the signal to a component of the industrial machine, wherein the maintenance action indicates to resurvey at least the portion of the industrial machine, wherein the component of the industrial machine causes the execution of the maintenance action responsive to receiving the signal.

739. The method of claim 726, wherein the wearable device is a first wearable device of a plurality of wearable devices integrated within an industrial platform.

740. The method of claim 739, wherein a second wearable device of the plurality of wearable devices captures a temperature of the industrial machine using a temperature sensor, wherein the signal is generated based on the severity unit and based on a second severity unit calculated based on the captured temperature.

741. The method of claim 739, wherein a third wearable device of the plurality of wearable devices captures an electrical output or electrical use of the industrial machine using an electricity sensor, wherein the signal is generated based on the severity unit and based on a third severity unit calculated based on the captured electrical output or electrical use.

742. The method of claim 739, wherein a fourth wearable device of the plurality of wearable devices captures a level or change in an electromagnetic field of the industrial machine using a magnetic sensor, wherein the signal is generated based on the severity unit and based on a fourth severity unit calculated based on the captured level or change in the electromagnetic field.

743. The method of claim 739, wherein a fifth wearable device of the plurality of wearable devices captures a sound wave output from the industrial machine using a sound sensor, wherein the signal is generated based on the severity unit and based on a fifth severity unit calculated based on the captured sound wave.

744. The method of claim 726, wherein the wearable device is integrated within an article of clothing.

745. The method of claim 744, wherein the article of clothing is a shirt.

746. The method of claim 744, wherein the article of clothing is a vest.

747. The method of claim 744, wherein the article of clothing is a jacket.

748. The method of claim 744, wherein the article of clothing is pants.

749. The method of claim 744, wherein the article of clothing is shorts.

750. The method of claim 744, wherein the article of clothing is a glove.

751. The method of claim 744, wherein the article of clothing is a sock.

752. The method of claim 744, wherein the article of clothing is a shoe.

753. The method of claim 744, wherein the article of clothing is protective outerwear.

754. The method of claim 744, wherein the article of clothing is an undergarment.

755. The method of claim 744, wherein the article of clothing is an undershirt.

756. The method of claim 744, wherein the article of clothing is a tank top.

757. The method of claim 726, wherein the wearable device is integrated within an accessory article.

758. The method of claim 757, wherein the accessory article is a hat.

759. The method of claim 757, wherein the accessory article is a helmet.

760. The method of claim 757, wherein the accessory article is glasses.

761. The method of claim 757, wherein the accessory article is goggles.

762. The method of claim 757, wherein the accessory article is a vision safety accessory.

763. The method of claim 757, wherein the accessory article is a mask.

764. The method of claim 757, wherein the accessory article is a chest band.

765. The method of claim 757, wherein the accessory article is a belt.

766. The method of claim 757, wherein the accessory article is a lift support garment.

767. The method of claim 757, wherein the accessory article is an antennae.

768. The method of claim 757, wherein the accessory article is a wrist band.

769. The method of claim 757, wherein the accessory article is a ring.

770. The method of claim 757, wherein the accessory article is a necklace.

771. The method of claim 757, wherein the accessory article is a bracelet.

772. The method of claim 757, wherein the accessory article is a watch.

773. The method of claim 757, wherein the accessory article is a brooch.

774. The method of claim 757, wherein the accessory article is a neck strap.

775. The method of claim 757, wherein the accessory article is a backpack.

776. The method of claim 757, wherein the accessory article is a front pack.

777. The method of claim 757, wherein the accessory article is an arm pack.

778. The method of claim 757, wherein the accessory article is a leg pack.

779. The method of claim 757, wherein the accessory article is a lanyard.

780. The method of claim 757, wherein the accessory article is a key ring.

781. The method of claim 757, wherein the accessory article is headphones.

782. The method of claim 757, wherein the accessory article is a hearing safety accessory.

783. The method of claim 757, wherein the accessory article is earbuds.

784. The method of claim 757, wherein the accessory article is an earpiece.

785. The method of claim 726, wherein the wearable device is a first wearable device integrated within an article of clothing, wherein the method further comprises using a second wearable device integrated within an accessory article.

786. A method comprising:

deploying a mobile data collector for detecting and monitoring vibration activity of at least a portion of an industrial machine, the mobile data collector including one or more vibration sensors;

determining a severity of the vibration activity relative to timing by processing vibration data representative of the vibration activity and generated using the one or more vibration sensors; and

predicting one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity.

787. The method of claim 786, wherein determining the severity of the vibration data relative to the timing by processing the vibration data representative of the vibration activity and generated using the one or more vibration sensors comprises:

determining a frequency of the vibration activity by processing the vibration data;

determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the vibration activity; and

calculating a severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra.

788. The method of claim 787, wherein calculating the severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra comprises:

mapping the vibration activity to the severity unit based on the determined segment of the multi-segment vibration frequency spectra by:

mapping the vibration activity to a first severity unit when the frequency of the vibration activity corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibration activity to a second severity unit when the frequency of the vibration activity corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibration activity to a third severity unit when the frequency of the vibration activity corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

789. The method of claim 786, further comprising:

causing the at least one of the mobile data collectors to perform the maintenance action.

790. The method of claim 786, further comprising:

controlling the mobile data collector to approach a location of the industrial machine within an industrial environment that includes the industrial machine;

causing the one or more vibration sensors of the mobile data collector to record one or more measurements of the vibration activity; and

transmitting the one or more measurements of the vibration activity as the vibration data to a server over a network, wherein the vibration data is processed at the server to determine the severity of the vibration activity.

791. The method of claim 790, wherein predicting the one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity comprises:

using intelligent systems associated with the server to process the vibration data against pre-recorded data for the industrial machine, wherein processing the vibration data against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with the industrial environment; and

identifying an operating characteristic of at least the portion of the machine based on the pre-recorded data for the industrial machine within the knowledge base; and

predicting the one or more maintenance actions based on the operating characteristic.

792. The method of claim 786, wherein the vibration activity is indicative of a waveform derived from a vibration envelope associated with the industrial machine, wherein the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine.

793. The method of claim 786, wherein the vibration activity represents velocity information for at least the portion of the industrial machine.

794. The method of claim 786, wherein the vibration activity represents frequency information for at least the portion of the industrial machine.

795. The method of claim 786, wherein the mobile data collector is a mobile robot.

796. The method of claim 795, wherein the one or more sensors are integrated within the mobile robot.

797. The method of claim 795, wherein the one or more sensors are coupled to the mobile robot.

798. The method of claim 795, wherein the mobile robot is a robotic arm.

799. The method of claim 795, wherein the mobile robot is an android robot.

800. The method of claim 795, wherein the mobile robot is a small autonomous robot.

801. The method of claim 795, wherein the mobile robot is a large autonomous robot.

802. The method of claim 795, wherein the mobile robot is a remote-controlled robot.

803. The method of claim 795, wherein the mobile robot is a programmably configured robot.

804. The method of claim 786, wherein the mobile data collector is a mobile vehicle.

805. The method of claim 804, wherein the one or more sensors are integrated within the mobile vehicle.

806. The method of claim 804, wherein the one or more sensors are coupled to the mobile vehicle.

807. The method of claim 804, wherein the mobile vehicle is a heavy-duty machine.

808. The method of claim 804, wherein the mobile vehicle is a heavy-duty on-road industrial vehicle.

809. The method of claim 804, wherein the mobile vehicle is a heavy-duty off-road industrial vehicle.

810. The method of claim 804, wherein the mobile vehicle includes an industrial machine.

811. The method of claim 804, wherein the mobile vehicle includes earth-moving equipment.

812. The method of claim 804, wherein the mobile vehicle includes earth-compacting equipment.

813. The method of claim 804, wherein the mobile vehicle includes hauling equipment.

814. The method of claim 804, wherein the mobile vehicle includes hoisting equipment.

815. The method of claim 804, wherein the mobile vehicle includes conveying equipment.

816. The method of claim 804, wherein the mobile vehicle includes aggregate production equipment.

817. The method of claim 804, wherein the mobile vehicle includes equipment used in concrete construction.

818. The method of claim 804, wherein the mobile vehicle includes piledriving equipment.

819. The method of claim 804, wherein the mobile vehicle includes construction equipment.

820. The method of claim 804, wherein the mobile vehicle is a personnel transport vehicle.

821. The method of claim 804, wherein the mobile vehicle is an unmanned vehicle.

822. The method of claim 786, wherein the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm.

823. The method of claim 822, further comprising:

using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within an industrial environment that includes the industrial machine,

wherein the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine.

824. The method of claim 823, wherein using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises:

controlling the movements of the mobile data collector within the industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors.

825. The method of claim 822, wherein the mobile data collector is a mobile robot and at least one other mobile data collector of the plurality of mobile data collectors is a mobile vehicle.

826. An industrial machine predictive maintenance system comprising:

a mobile data collector swarm comprising one or more mobile data collectors configured to collect health monitoring data representative of conditions of one or more industrial machines located in an industrial environment;

an industrial machine predictive maintenance facility that produces industrial machine service recommendations responsive to the health monitoring data by applying machine fault detection and classification algorithms thereto; and

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations.

827. The industrial machine predictive maintenance system of claim 826, further comprising:

a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

828. The industrial machine predictive maintenance system of claim 827, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

829. The industrial machine predictive maintenance system of claim 828, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

830. The industrial machine predictive maintenance system of claim 826, further comprising:

a self-organization system that controls movements of the one or more mobile data collectors within the industrial environment.

831. The industrial machine predictive maintenance system of claim 830, wherein the self-organization system transmits requests for the health monitoring data to the one or more mobile data collectors, wherein the mobile data collectors transmit the health monitoring data to the self-organization system responsive to the requests, wherein the self-organization transmits the health monitoring data to the industrial machine predictive maintenance facility.

832. The industrial machine predictive maintenance system of claim 826, further comprising:

a data collection router that receives the health monitoring data from the one or more mobile data collectors when the mobile data collectors are in near proximity to the data collection

router, wherein the data collection router transmits the health monitoring data to the industrial machine predictive maintenance facility.

833. The industrial machine predictive maintenance system of claim 832, wherein the one or more mobile data collectors push the health monitoring data to the data collection router.

834. The industrial machine predictive maintenance system of claim 832, wherein the data collection router pulls the health monitoring data from the one or more mobile data collectors.

835. The industrial machine predictive maintenance system of claim 832, further comprising:

a self-organization system that controls movements of the one or more mobile data collectors within the industrial environment.

836. The industrial machine predictive maintenance system of claim 835, wherein the self-organization system controls communications of the health monitoring data from the one or more mobile data collectors to the data collection router.

837. The industrial machine predictive maintenance system of claim 826, wherein each mobile data collector of the one or more mobile data collectors is one of a mobile robot including one or more integrated sensors, a mobile robot including one or more coupled sensors, a mobile vehicle with one or more integrated sensors, or a mobile vehicle with one or more coupled sensors.

838. The industrial machine predictive maintenance system of claim 826, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendations based on severity units calculated for the health monitoring data.

839. A system comprising:

a plurality of wearable devices integrated within an industrial uniform, each wearable device of the industrial uniform comprising one or more sensors that collect measurements from industrial machines located in an industrial environment, the measurements representative of conditions of the industrial machines;

an industrial machine predictive maintenance facility that produces industrial machine service recommendations based on the measurements by applying machine fault detection and classification algorithms thereto; and

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations.

840. The system of claim 839, further comprising:

a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

841. The system of claim 840, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

842. The system of claim 841, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

843. The system of claim 839, wherein the one or more sensors of a first wearable device of the industrial uniform includes a sensor configured to collect vibration measurements from at least one of the industrial machines.

844. The system of claim 839, wherein the one or more sensors of a second wearable device of the industrial uniform includes a sensor configured to collect temperature measurements from at least one of the industrial machines.

845. The system of claim 839, wherein the one or more sensors of a first wearable device of the industrial uniform includes a sensor configured to collect electrical measurements from at least one of the industrial machines.

846. The system of claim 839, wherein the one or more sensors of a first wearable device of the industrial uniform includes a sensor configured to collect magnetic measurements from at least one of the industrial machines.

847. The system of claim 839, wherein the one or more sensors of a first wearable device of the industrial uniform includes a sensor configured to collect sound measurements from at least one of the industrial machines.

848. The system of claim 839, wherein a first wearable device of the industrial uniform is an article of clothing and a second wearable device of the industrial uniform is an accessory article.

849. The system of claim 839, further comprising:

a collective processing mind that controls the collection of measurements of the one or more industrial machines by the plurality of wearable devices.

850. The system of claim 849, wherein the collective processing mind transmits a first command to a wearable device of the industrial uniform to cause the one or more sensors of the wearable device to collect the measurements of the one or more industrial machines, wherein the collective processing mind transmits a second command to the wearable device to cause the wearable device to transmit the measurements to the collective processing mind.

851. The system of claim 839, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendations based on severity units calculated for the measurements.

852. A system comprising:

a plurality of wearable devices integrated within an industrial uniform, each wearable device of the industrial uniform comprising one or more sensors that collect measurements from industrial machines located in an industrial environment, the measurements representative of conditions of the industrial machines;

an industrial machine predictive maintenance facility that produces industrial machine service recommendations based on the measurements by applying machine fault detection and classification algorithms thereto;

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations; and

a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

853. The system of claim 852, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendations based on severity units calculated for the measurements.

854. The system of claim 852, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

855. The system of claim 854, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

856. The system of claim 855, wherein the CMMS generates a first block of the blockchain with shipment readiness information about the specific industrial machine and a hash of an initiated block of the blockchain.

857. The system of claim 856, wherein the CMMS generates a second block of the blockchain with installation information about the specific industrial machine and a hash of the first block.

858. The system of claim 857, wherein the CMMS generates a third block of the blockchain with operational sensor information about the specific industrial machine and a hash of the second block.

859. The system of claim 858, wherein the CMMS generates a fourth block of the blockchain with service event information about the specific industrial machine and a hash of the third block.

860. The system of claim 859, wherein the CMMS generates a fifth block of the blockchain with parts and service order information about the specific industrial machine and a hash of the fourth block.

861. The system of claim 860, wherein the CMMS generates a sixth block of the blockchain with diagnostic activity information about the specific industrial machine and a hash of the fifth block.

862. The system of claim 852, further comprising:

a worker finding facility that identifies at least one candidate worker for performing a service indicated by the industrial machine service recommendations by correlating information in the recommendation regarding at least one service to be performed with at least one of experience and know-how for industrial service workers in an industrial service worker database.

863. The system of claim 862, further comprising:

machine learning algorithms executing on a processor that improve the correlating based on service-related information for a plurality of services performed on similar industrial machines and worker-related information for a plurality of services performed by the at least one candidate worker.

864. A system comprising:

a mobile data collector swarm comprising one or more mobile data collectors configured to collect health monitoring data representative of conditions of one or more industrial machines located in an industrial environment;

an industrial machine predictive maintenance facility that produces industrial machine service recommendations responsive to the health monitoring data by applying machine fault detection and classification algorithms thereto;

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendations; and

a service and delivery coordination facility that receives and processes information regarding services performed on industrial machines responsive to the at least one of orders and requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for individual industrial machines.

865. The system of claim 864, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendations based on severity units calculated for the health monitoring data.

866. The system of claim 864, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

867. The system of claim 866, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

868. The system of claim 867, wherein the CMMS generates a first block of the blockchain with shipment readiness information about the specific industrial machine and a hash of an initiated block of the blockchain.

869. The system of claim 868, wherein the CMMS generates a second block of the blockchain with installation information about the specific industrial machine and a hash of the first block.

870. The system of claim 869, wherein the CMMS generates a third block of the blockchain with operational sensor information about the specific industrial machine and a hash of the second block.

871. The system of claim 870, wherein the CMMS generates a fourth block of the blockchain with service event information about the specific industrial machine and a hash of the third block.

872. The system of claim 871, wherein the CMMS generates a fifth block of the blockchain with parts and service order information about the specific industrial machine and a hash of the fourth block.

873. The system of claim 872, wherein the CMMS generates a sixth block of the blockchain with diagnostic activity information about the specific industrial machine and a hash of the fifth block.

874. The system of claim 864, further comprising:

a worker finding facility that identifies at least one candidate worker for performing a service indicated by the industrial machine service recommendations by correlating information in the recommendation regarding at least one service to be performed with at least one of experience and know-how for industrial service workers in an industrial service worker database.

875. The system of claim 874, further comprising:

machine learning algorithms executing on a processor that improve the correlating based on service-related information for a plurality of services performed on similar industrial machines and worker-related information for a plurality of services performed by the at least one candidate worker.

876. A method comprising:

generating, using one or more vibration sensors of a handheld device, vibration data representing measured vibrations of at least a portion of an industrial machine;

mapping the vibration data to one or more severity units; and

using the severity units for predictive maintenance of the industrial machine by determining a maintenance action to perform on at least the portion of an industrial machine based on the severity units.

877. The method of claim 876, wherein mapping the vibration data to one or more severity units comprises:

mapping portions of the vibration data that have frequencies corresponding to a below a low-end knee threshold-range of a vibration frequency spectra to first severity units;

mapping portions of the vibration data that have frequencies corresponding to a mid-range of the vibration frequency spectra to second severity units; and

mapping portions of the vibration data that have frequencies corresponding to an above a high-end knee threshold-range of the vibration frequency spectra to third severity units.

878. The method of claim 876, wherein the mapping of the vibration data to the one or more severity units is performed at the handheld device.

879. The method of claim 876, wherein the mapping of the vibration data to the one or more severity units is performed at a server, wherein the method further comprises transmitting the vibration data from the handheld device to the server.

880. The method of claim 876, further comprising:

detecting, using a collective processing mind associated with the handheld device, that the handheld device is in near proximity to the industrial machine;

transmitting, from the collective processing mind, a first command to the handheld device to cause the handheld device to generate the vibration data; and

after the generating of the vibration data, transmitting, from the collective processing mind, a second command to the handheld device to cause the handheld device to transmit the vibration data to the collective processing mind.

881. The method of claim 876, wherein the handheld device is a mobile phone.

882. The method of claim 876, wherein the handheld device is a laptop computer.

883. The method of claim 876, wherein the handheld device is a tablet computer.

884. The method of claim 876, wherein the handheld device is a personal digital assistant.

885. The method of claim 876, wherein the handheld device is a walkie-talkie.

886. The method of claim 876, wherein the handheld device is a radio.

887. The method of claim 876, wherein the handheld device is a long-range communication device.

888. The method of claim 876, wherein the handheld device is a short-range communication device.

889. The method of claim 876, wherein the handheld device is a flashlight.

890. A system comprising:

an industrial machine comprising at least one vibration sensor disposed to capture vibration of a portion of the industrial machine;

a mobile data collector that generates vibration data by collecting the captured vibration from the at least one vibration sensor;

a multi-segment vibration frequency spectra structure that facilitates mapping the captured vibration to one vibration frequency segment of a multi-segment vibration frequency;

a severity unit algorithm that receives the frequency of the vibration and the corresponding vibration frequency segment and produces a severity value which is then mapped to one of a plurality of severity units defined for the corresponding vibration frequency segment; and

a signal generating circuit that receives the one of the plurality of severity units, and based thereon, signals a predictive maintenance server to execute a corresponding maintenance action on the portion of the industrial machine.

891. The system of claim 890, wherein the mobile data collector is a mobile robot.

892. The system of claim 890, wherein the mobile data collector is a mobile vehicle.

893. The system of claim 890, wherein the mobile data collector is a handheld device.

894. The system of claim 890, wherein the mobile data collector is a wearable device.

895. The system of claim 890, wherein the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

896. The system of claim 895,wherein the severity unit algorithm maps the captured vibration to one vibration frequency segment of a multi-segment vibration frequency by:

mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

897. A method comprising:

using a distributed ledger to track one or more transactions executed in an automated data marketplace for industrial Internet of Things data, wherein the distributed ledger distributes storage for data indicative of the one or more transactions across one or more devices, wherein the data indicative of the one or more transactions corresponds to transaction records; and

using one or more mobile data collectors to generate sensor data representative of a condition of an industrial machine, wherein the sensor data is used to determine at least one of orders or requests for service and parts used to resolve an issue associated with the condition of the machine,

wherein a transaction record stored in the distributed ledger represents one or more of the sensor data, the condition of the industrial machine, the at least one of the orders or the requests for service and parts, the issue associated with the condition of the machine, or a hash used to identify the transaction record.

898. The method of claim 897, wherein the distributed ledger uses a blockchain structure to store the transaction records, wherein each of the transaction records is stored as a block in the blockchain structure.

899. The method of claim 898, wherein using the blockchain structure to store the transaction records comprises:

initiating a blockchain of industrial machine information for a specific industrial machine by generating an initiating block; and

generating subsequent blocks of the specific industrial machine blockchain by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, and diagnostic activity and a hash of the most recently generated block in the blockchain.

900. The method of claim 897, wherein each mobile data collector is one of a mobile vehicle, a mobile robot, a handheld device, or a wearable device.

901. The method of claim 897, further comprising:

applying machine fault detection and classification algorithms to the sensor data to produce an industrial machine service recommendation; and

producing the at least one of the orders or the requests for service and parts based on the industrial machine service recommendation.

902. The method of claim 901, wherein the one or more mobile data collectors use a computer vision system to generate the sensor data by capturing raw image data using one or more data capture devices and processing the raw image data to generate image set data, wherein the image set data is used to produce the industrial machine service recommendation.

903. A system comprising:

an industrial Internet of Things (IoT) network connecting an industrial machine and one or more mobile data collectors, each mobile data collector including one or more sensors for generating sensor data indicative of conditions of the industrial machine; and

a server in communication with the IoT network, the server implementing a predictive maintenance platform that uses a distributed ledger to track maintenance transactions related to the industrial machine, the distributed ledger storing transaction records corresponding to the maintenance transactions, wherein the predictive maintenance platform distributes at least some of the transaction records to the one or more mobile data collectors.

904. The system of claim 903, further comprising:

a self-organizing storage system that optimizes storage of the transaction records within the distributed ledger.

905. The system of claim 903, further comprising:

a self-organizing storage system that optimizes storage of maintenance data associated with the industrial machine.

906. The system of claim 903, further comprising:

a self-organizing storage system that optimizes storage of IoT data associated with the IoT network.

907. The system of claim 903, further comprising:

a self-organizing storage system that optimizes storage of parts and service data related to the maintenance transactions.

908. The system of claim 903, further comprising:

a self-organizing storage system that optimizes storage of knowledge base data associated with the industrial machine.

909. The system of claim 903, wherein each mobile data collector is one of a mobile vehicle, a mobile robot, a handheld device, or a wearable device.

910. The system of claim 903, further comprising:

an industrial machine predictive maintenance facility that produces an industrial machine service recommendation for the condition by applying machine fault detection and classification algorithms to the sensor data.

911. The system of claim 910, further comprising:

a severity unit algorithm that produces a severity value for the condition based on the sensor data, wherein the industrial machine service recommendation is produced based on the severity value.

912. The system of claim 910, wherein at least one of the one or more mobile data collectors uses a computer vision system to generate the sensor data by capturing raw image data using one or more data capture devices and processing the raw image data to generate image set data, wherein the image set data is used to produce the industrial machine service recommendation.

913. A method comprising:

generating, using a mobile data collector, sensor data representing a condition of an industrial machine;

determining a severity of the condition of the industrial machine by analyzing the sensor data;

predicting a maintenance action to perform against the industrial machine based on the severity of the condition; and

storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine.

914. The method of claim 913, further comprising:

producing, in connection with the predicted maintenance action, at least one of orders or requests for service and parts used to perform the maintenance action; and

including data indicative of the at least one of the orders or requests for service and parts within the transaction record.

915. The method of claim 913, wherein the mobile data collector is one of a mobile vehicle, a mobile robot, a handheld device, or a wearable device.

916. The method of claim 913, further comprising:

applying machine learning to data representative of conditions of the industrial machine,

wherein determining the severity of the sensor data by analyzing the sensor data comprises:

using the applied machine learning to determine the severity of the sensor data based on machine learning data associated with the at least one of a frequency or a velocity of vibrations of the industrial machine measured in the sensor data.

917. The method of claim 913, wherein determining the severity of the condition of the industrial machine by analyzing the sensor data comprises:

determining a frequency of the captured vibration by processing the captured vibration data;

determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the captured vibration; and

calculating a severity unit for the captured vibration based on the determined segment.

918. The method of claim 917, wherein predicting the maintenance action to perform against the industrial machine based on the severity of the condition comprises:

using a signal generated based on the severity unit in a predictive maintenance circuit to determine the maintenance action.

919. The method of claim 913, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of orders and requests for service and parts, wherein each record is stored as a block in the blockchain structure.

920. An industrial machine predictive maintenance system comprising:

a computer vision system that generates one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of an industrial machine based on the one or more image data sets;

an industrial machine predictive maintenance facility that produces an industrial machine service recommendation by applying machine fault detection and classification algorithms to data indicative of the operating characteristic;

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendation; and

a service and delivery coordination facility that receives and processes information regarding services to perform on the industrial machine based on the at least one of orders and requests for service and parts.

921. The industrial machine predictive maintenance system of claim 920, wherein the service and delivery coordination facility validates the services to perform on the industrial machine while producing a ledger of service activity and results for the industrial machine.

922. The industrial machine predictive maintenance system of claim 921, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

923. The industrial machine predictive maintenance system of claim 922, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

924. The industrial machine predictive maintenance system of claim 920, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendation using data stored within a knowledge base associated with the industrial machine.

925. The industrial machine predictive maintenance system of claim 920, wherein the operating characteristic relates to vibrations detected for at least a portion of the industrial machine, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendation according to a severity unit calculated for the detected vibrations.

926. The industrial machine predictive maintenance system of claim 925, wherein the severity unit is calculated for the detected vibrations by determining a frequency of the detected vibrations, determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations, and calculating the severity unit for the detected vibrations based on the determined segment.

927. The industrial machine predictive maintenance system of claim 926, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

928. The industrial machine predictive maintenance system of claim 927, wherein the detected vibrations are mapped to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a third severity unit when the frequency of the captured vibration corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

929. The industrial machine predictive maintenance system of claim 925, wherein the severity unit indicates that the detected vibrations may lead to a failure of at least the portion of the industrial machine, wherein the industrial machine service recommendation includes a recommendation for preventing or mitigating the failure, wherein the at least one of the orders and the requests for service is for a part or a service used to prevent or mitigate the failure.

930. The industrial machine predictive maintenance system of claim 920, wherein the one or more data capture devices are external to the computer vision system.

931. The industrial machine predictive maintenance system of claim 920, further comprising:

a mobile data collector configured to perform a maintenance action corresponding to the industrial machine service recommendation on the industrial machine by using the at least one of orders and requests for service and parts.

932. The industrial machine predictive maintenance system of claim 931, wherein the service and delivery coordination facility receives a signal from the mobile data collector indicating a performance of the maintenance action.

933. The industrial machine predictive maintenance system of claim 932, wherein the service and delivery coordination facility uses a ledger to record service activity and results for the industrial machine, wherein the service and delivery coordination facility generates a new record in the ledger based on the signal received from the mobile data collector.

934. An industrial machine predictive maintenance system comprising:

a computer vision system that generates one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of an industrial machine based on the one or more image data sets;

an industrial machine predictive maintenance facility that produces an industrial machine service recommendation by applying machine fault detection and classification algorithms to data indicative of the operating characteristic; and

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendation.

935. The industrial machine predictive maintenance system of claim 934, further comprising:

a service and delivery coordination facility that receives and processes information regarding services to perform on the industrial machine based on the at least one of orders and requests for service and parts.

936. The industrial machine predictive maintenance system of claim 935, wherein the service and delivery coordination facility validates the services to perform on the industrial machine while producing a ledger of service activity and results for the industrial machine.

937. The industrial machine predictive maintenance system of claim 936, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

938. The industrial machine predictive maintenance system of claim 937, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

939. The industrial machine predictive maintenance system of claim 934, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendation using data stored within a knowledge base associated with the industrial machine.

940. The industrial machine predictive maintenance system of claim 934, wherein the operating characteristic relates to vibrations detected for at least a portion of the industrial machine, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendation according to a severity unit calculated for the detected vibrations.

941. The industrial machine predictive maintenance system of claim 940, wherein the severity unit is calculated for the detected vibrations by determining a frequency of the detected vibrations, determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations, and calculating the severity unit for the detected vibrations based on the determined segment.

942. The industrial machine predictive maintenance system of claim 941, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

943. The industrial machine predictive maintenance system of claim 942, wherein the detected vibrations are mapped to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a third severity unit when the frequency of the captured vibration corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

944. The industrial machine predictive maintenance system of claim 940, wherein the severity unit indicates that the detected vibrations may lead to a failure of at least the portion of the industrial machine, wherein the industrial machine service recommendation includes a recommendation for preventing or mitigating the failure, wherein the at least one of the orders and the requests for service is for a part or a service used to prevent or mitigate the failure.

945. The industrial machine predictive maintenance system of claim 934, wherein the one or more data capture devices are external to the computer vision system.

946. The industrial machine predictive maintenance system of claim 934, further comprising:

a mobile data collector configured to perform a maintenance action corresponding to the industrial machine service recommendation on the industrial machine by using the at least one of orders and requests for service and parts.

947. The industrial machine predictive maintenance system of claim 946, wherein the service and delivery coordination facility receives a signal from the mobile data collector indicating a performance of the maintenance action.

948. The industrial machine predictive maintenance system of claim 947, wherein the service and delivery coordination facility uses a ledger to record service activity and results for the industrial machine, wherein the service and delivery coordination facility generates a new record in the ledger based on the signal received from the mobile data collector.

949. The industrial machine predictive maintenance system of claim 946, wherein the mobile data collector is a mobile vehicle.

950. The industrial machine predictive maintenance system of claim 946, wherein the mobile data collector is a mobile robot.

951. The industrial machine predictive maintenance system of claim 946, wherein the mobile data collector is a handheld device.

952. The industrial machine predictive maintenance system of claim 946, wherein the mobile data collector is a wearable device.

953. An industrial machine predictive maintenance system comprising:

a computer vision system that generates one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of an industrial machine based on the one or more image data sets;

an industrial machine predictive maintenance facility that produces an industrial machine service recommendation based on the operating characteristic; and

a mobile data collector configured to perform a maintenance action corresponding to the industrial machine service recommendation on the industrial machine.

954. The industrial machine predictive maintenance system of claim 953, wherein the mobile data collector is one mobile data collector of a swarm of mobile data collectors, the industrial machine predictive maintenance system further comprising:

a self-organization system of the mobile data collector swarm that controls movements of the mobile data collectors of the swarm within an industrial environment that includes the industrial machine.

955. The industrial machine predictive maintenance system of claim 953, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendation

by applying machine fault detection and classification algorithms to data indicative of the operating characteristic.

956. The industrial machine predictive maintenance system of claim 953, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendation using data stored within a knowledge base associated with the industrial machine.

957. The industrial machine predictive maintenance system of claim 953, wherein the operating characteristic relates to vibrations detected for at least a portion of the industrial machine, wherein the industrial machine predictive maintenance facility produces the industrial machine service recommendation according to a severity unit calculated for the detected vibrations.

958. The industrial machine predictive maintenance system of claim 957, wherein the severity unit is calculated for the detected vibrations by determining a frequency of the detected vibrations, determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations, and calculating the severity unit for the detected vibrations based on the determined segment.

959. The industrial machine predictive maintenance system of claim 958, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

960. The industrial machine predictive maintenance system of claim 959, wherein the detected vibrations are mapped to a first severity unit when the frequency of the captured vibration corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a second severity unit when the frequency of the captured vibration corresponds to a mid-range of the multi-segment vibration frequency spectra, wherein the detected vibrations are mapped to a third severity unit when the frequency of the captured vibration corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

961. The industrial machine predictive maintenance system of claim 957, wherein the severity unit indicates that the detected vibrations may lead to a failure of at least the portion of the industrial machine, wherein the industrial machine service recommendation includes a recommendation for preventing or mitigating the failure.

962. The industrial machine predictive maintenance system of claim 953, further comprising:

a computerized maintenance management system (CMMS) that produces at least one of orders and requests for service and parts responsive to receiving the industrial machine service recommendation,

wherein the mobile data collector performs the maintenance action by using the at least one of orders and requests for service and parts.

963. The industrial machine predictive maintenance system of claim 962, further comprising:

a service and delivery coordination facility that receives and processes information regarding services to perform on the industrial machine based on the at least one of orders and requests for service and parts.

964. The industrial machine predictive maintenance system of claim 963, wherein the service and delivery coordination facility validates the services to perform on the industrial machine while producing a ledger of service activity and results for the industrial machine.

965. The industrial machine predictive maintenance system of claim 964, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

966. The industrial machine predictive maintenance system of claim 965, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

967. A method for industrial machine predictive maintenance comprising:

generating data representing a condition of an industrial machine using one or more sensors of a mobile data collector;

processing the data to determine a severity of the condition of the industrial machine;

determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and

generating a signal indicative of the industrial machine service recommendation.

968. The method of claim 967, wherein the mobile data collector uses a computer vision system that generates, as the data, one or more image data sets using raw data captured by one or more data capture devices and that detects an operating characteristic of an industrial machine based on the one or more image data sets, wherein the operating characteristic corresponds to the condition of the industrial machine.

969. The method of claim 967, wherein the mobile data collector is a mobile robot.

970. The method of claim 967, wherein the mobile data collector is a mobile vehicle.

971. The method of claim 967, wherein the mobile data collector is a handheld device.

972. The method of claim 967, wherein the mobile data collector is a wearable device.

973. The method of claim 967, wherein determining the industrial machine service recommendation for the condition of the industrial machine based on the severity comprises:

using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity.

974. The method of claim 967, wherein the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, wherein processing the data to determine the severity of the condition of the industrial machine comprises:

determining a frequency of the detected vibrations;

determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and

calculating the severity for the detected vibrations based on the determined segment.

975. The method of claim 974, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

976. The method of claim 975, further comprising:

mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

977. The method of claim 967, further comprising:

transmitting the signal to a mobile robot configured to perform a maintenance action associated with the industrial machine service recommendation.

978. The method of claim 967, further comprising:

storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine.

979. The method of claim 978, wherein the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine, wherein each record is stored as a block in the blockchain structure.

980. The method of claim 967, further comprising:

producing at least one of orders or requests for service and parts based on the industrial machine service recommendation, wherein the signal indicates the at least one of the orders or the requests for service and parts.

981. A method for industrial machine predictive maintenance comprising:

generating data representing a condition of an industrial machine using one or more wearable devices, each wearable device including one or more sensors, wherein a wearable device of the one or more wearable devices generates some or all of the data when the wearable device is in near proximity to the industrial machine;

processing the data to determine a severity of the condition of the industrial machine;

determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and

storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine.

982. The method of claim 981, wherein the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, wherein processing the data to determine the severity of the condition of the industrial machine comprises:

determining a frequency of the detected vibrations;

determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and

calculating the severity for the detected vibrations based on the determined segment.

983. The method of claim 982, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

984. The method of claim 983, further comprising:

mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

985. The method of claim 981, wherein determining the industrial machine service recommendation for the condition of the industrial machine based on the severity comprises:

using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity.

986. The method of claim 985, wherein the intelligent system includes a you only look once neural network.

987. The method of claim 985, wherein the intelligent system includes a you only look once convolutional neural network.

988. The method of claim 985, wherein the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array.

989. The method of claim 985, wherein the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array and graphics processing unit hybrid component.

990. The method of claim 985, wherein the intelligent system includes user configurable series and parallel flow for a hybrid neural network.

991. The method of claim 985, wherein the intelligent system includes a machine learning system for configuring a topology or workflow for a set of neural networks.

992. The method of claim 985, wherein the intelligent system includes a deep learning system for configuring a topology or workflow for a set of neural networks.

993. The method of claim 981, wherein the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine, wherein each record is stored as a block in the blockchain structure.

994. The method of claim 993, further comprising:

producing at least one of orders or requests for service and parts based on the industrial machine service recommendation, wherein the records for the industrial machine service recommendation stored in the ledger indicate the at least one of the orders or the requests for service and parts.

995. The method of claim 981, wherein the one or more wearable devices are integrated within an industrial uniform.

996. The method of claim 981, wherein the wearable device is integrated within an article of clothing.

997. The method of claim 996, wherein the article of clothing is a shirt.

998. The method of claim 996, wherein the article of clothing is a vest.

999. The method of claim 996, wherein the article of clothing is a jacket.

1000. The method of claim 996, wherein the article of clothing is pants.

1001. The method of claim 996, wherein the article of clothing is shorts.

1002. The method of claim 996, wherein the article of clothing is a glove.

1003. The method of claim 996, wherein the article of clothing is a sock.

1004. The method of claim 996, wherein the article of clothing is a shoe.

1005. The method of claim 996, wherein the article of clothing is protective outerwear.

1006. The method of claim 996, wherein the article of clothing is an undergarment.

1007. The method of claim 996, wherein the article of clothing is an undershirt.

1008. The method of claim 996, wherein the article of clothing is a tank top.

1009. The method of claim 981, wherein the wearable device is integrated within an accessory article.

1010. The method of claim 1009, wherein the accessory article is a hat.

1011. The method of claim 1009, wherein the accessory article is a helmet.

1012. The method of claim 1009, wherein the accessory article is glasses.

1013. The method of claim 1009, wherein the accessory article is goggles.

1014. The method of claim 1009, wherein the accessory article is a vision safety accessory.

1015. The method of claim 1009, wherein the accessory article is a mask.

1016. The method of claim 1009, wherein the accessory article is a chest band.

1017. The method of claim 1009, wherein the accessory article is a belt.

1018. The method of claim 1009, wherein the accessory article is a lift support garment.

1019. The method of claim 1009, wherein the accessory article is an antennae.

1020. The method of claim 1009, wherein the accessory article is a wrist band.

1021. The method of claim 1009, wherein the accessory article is a ring.

1022. The method of claim 1009, wherein the accessory article is a necklace.

1023. The method of claim 1009, wherein the accessory article is a bracelet.

1024. The method of claim 1009, wherein the accessory article is a watch.

1025. The method of claim 1009, wherein the accessory article is a brooch.

1026. The method of claim 1009, wherein the accessory article is a neck strap.

1027. The method of claim 1009, wherein the accessory article is a backpack.

1028. The method of claim 1009, wherein the accessory article is a front pack.

1029. The method of claim 1009, wherein the accessory article is an arm pack.

1030. The method of claim 1009, wherein the accessory article is a leg pack.

1031. The method of claim 1009, wherein the accessory article is a lanyard.

1032. The method of claim 1009, wherein the accessory article is a key ring.

1033. The method of claim 1009, wherein the accessory article is headphones.

1034. The method of claim 1009, wherein the accessory article is a hearing safety accessory.

1035. The method of claim 1009, wherein the accessory article is earbuds.

1036. The method of claim 1009, wherein the accessory article is an earpiece.

1037. A method for industrial machine predictive maintenance comprising:

generating data representing a condition of an industrial machine using one or more handheld devices, each handheld device including one or more sensors, wherein a handheld device of the one or more handheld devices generates some or all of the data when the handheld device is in near proximity to the industrial machine;

processing the data to determine a severity of the condition of the industrial machine;

determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and

storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine.

1038. The method of claim 1037, wherein the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, wherein processing the data to determine the severity of the condition of the industrial machine comprises:

determining a frequency of the detected vibrations;

determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and

calculating the severity for the detected vibrations based on the determined segment.

1039. The method of claim 1038, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

1040. The method of claim 1039, further comprising:

mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1041. The method of claim 1037, wherein determining the industrial machine service recommendation for the condition of the industrial machine based on the severity comprises:

using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity.

1042. The method of claim 1041, wherein the intelligent system includes a you only look once neural network.

1043. The method of claim 1041, wherein the intelligent system includes a you only look once convolutional neural network.

1044. The method of claim 1041, wherein the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array.

1045. The method of claim 1041, wherein the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array and graphics processing unit hybrid component.

1046. The method of claim 1041, wherein the intelligent system includes user configurable series and parallel flow for a hybrid neural network.

1047. The method of claim 1041, wherein the intelligent system includes a machine learning system for configuring a topology or workflow for a set of neural networks.

1048. The method of claim 1041, wherein the intelligent system includes a deep learning system for configuring a topology or workflow for a set of neural networks.

1049. The method of claim 1037, wherein the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine, wherein each record is stored as a block in the blockchain structure.

1050. The method of claim 1049, further comprising:

producing at least one of orders or requests for service and parts based on the industrial machine service recommendations, wherein the record for a industrial machine service recommendation stored in the ledger indicates the at least one of the orders or the requests for service and parts.

1051. The method of claim 1037, wherein the handheld device is a mobile phone.

1052. The method of claim 1037, wherein the handheld device is a laptop computer.

1053. The method of claim 1037, wherein the handheld device is a tablet computer.

1054. The method of claim 1037, wherein the handheld device is a personal digital assistant.

1055. The method of claim 1037, wherein the handheld device is a walkie-talkie.

1056. The method of claim 1037, wherein the handheld device is a radio.

1057. The method of claim 1037, wherein the handheld device is a long-range communication device.

1058. The method of claim 1037, wherein the handheld device is a short-range communication device.

1059. The method of claim 1037, wherein the handheld device is a flashlight.

1060. A method for industrial machine predictive maintenance comprising:

generating data representing a condition of an industrial machine using one or more mobile robots, each mobile robot including one or more sensors, wherein a mobile robot of the one or more mobile robots generates some or all of the data when the mobile robot is in near proximity to the industrial machine;

processing the data to determine a severity of the condition of the industrial machine;

determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and

storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine.

1061. The method of claim 1060, wherein the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, wherein processing the data to determine the severity of the condition of the industrial machine comprises:

determining a frequency of the detected vibrations;

determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and

calculating the severity for the detected vibrations based on the determined segment.

1062. The method of claim 1061, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

1063. The method of claim 1062, further comprising:

mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1064. The method of claim 1060, wherein determining the industrial machine service recommendation for the condition of the industrial machine based on the severity comprises:

using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity.

1065. The method of claim 1064, wherein the intelligent system includes a you only look once neural network.

1066. The method of claim 1064, wherein the intelligent system includes a you only look once convolutional neural network.

1067. The method of claim 1064, wherein the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array.

1068. The method of claim 1064, wherein the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array and graphics processing unit hybrid component.

1069. The method of claim 1064, wherein the intelligent system includes user configurable series and parallel flow for a hybrid neural network.

1070. The method of claim 1064, wherein the intelligent system includes a machine learning system for configuring a topology or workflow for a set of neural networks.

1071. The method of claim 1064, wherein the intelligent system includes a deep learning system for configuring a topology or workflow for a set of neural networks.

1072. The method of claim 1060, wherein the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine, wherein each record is stored as a block in the blockchain structure.

1073. The method of claim 1072, further comprising:

producing at least one of orders or requests for service and parts based on the industrial machine service recommendations, wherein the record for a industrial machine service recommendation stored in the ledger indicates the at least one of the orders or the requests for service and parts.

1074. The method of claim 1060, wherein the mobile robot is one of a plurality of mobile robots of a mobile data collector swarm.

1075. The method of claim 1074, further comprising:

controlling the mobile data collector swarm to cause the mobile robot to approach a location of the industrial machine within an industrial environment.

1076. The method of claim 1075, wherein controlling the mobile data collector swarm to cause the mobile robot to approach a location of the industrial machine within an industrial environment comprises:

using self-organization systems of the mobile data collector swarm to control movements of the mobile robot within the industrial environment based on locations of other mobile robots of the mobile data collector swarm within the industrial environment.

1077. The method of claim 1060, wherein the mobile robot is a robotic arm.

1078. The method of claim 1060, wherein the mobile robot is an android robot.

1079. The method of claim 1060, wherein the mobile robot is a small autonomous robot.

1080. The method of claim 1060, wherein the mobile robot is a large autonomous robot.

1081. The method of claim 1060, wherein the mobile robot is a remote-controlled robot.

1082. The method of claim 1060, wherein the mobile robot is a programmably configured robot.

1083. A method for industrial machine predictive maintenance comprising:

generating data representing a condition of an industrial machine using one or more mobile vehicles, each mobile vehicle including one or more sensors, wherein a mobile vehicle of the one or more mobile vehicles generates some or all of the data when the mobile vehicle is in near proximity to the industrial machine;

processing the data to determine a severity of the condition of the industrial machine;

determining an industrial machine service recommendation for the condition of the industrial machine based on the severity; and

storing a record of the industrial machine service recommendation within a ledger of service activity associated with the industrial machine.

1084. The method of claim 1083, wherein the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, wherein processing the data to determine the severity of the condition of the industrial machine comprises:

determining a frequency of the detected vibrations;

determining a segment of a multi-segment vibration frequency spectra that bounds the detected vibrations; and

calculating the severity for the detected vibrations based on the determined segment.

1085. The method of claim 1084, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the detected vibrations is determined by mapping the detected vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

1086. The method of claim 1085, further comprising:

mapping the detected vibrations to a first severity unit when the frequency of the detected vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the detected vibrations to a second severity unit when the frequency of the detected vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the detected vibrations to a third severity unit when the frequency of the detected vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1087. The method of claim 1083, wherein determining the industrial machine service recommendation for the condition of the industrial machine based on the severity comprises:

using an intelligent system to apply machine fault detection and classification algorithms to the data and the severity.

1088. The method of claim 1087, wherein the intelligent system includes a you only look once neural network.

1089. The method of claim 1087, wherein the intelligent system includes a you only look once convolutional neural network.

1090. The method of claim 1087, wherein the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array.

1091. The method of claim 1087, wherein the intelligent system includes a set of neural networks configured to operate on or from a field programmable gate array and graphics processing unit hybrid component.

1092. The method of claim 1087, wherein the intelligent system includes user configurable series and parallel flow for a hybrid neural network.

1093. The method of claim 1087, wherein the intelligent system includes a machine learning system for configuring a topology or workflow for a set of neural networks.

1094. The method of claim 1087, wherein the intelligent system includes a deep learning system for configuring a topology or workflow for a set of neural networks.

1095. The method of claim 1083, wherein the ledger uses a blockchain structure to track records of industrial machine service recommendations for the industrial machine, wherein each record is stored as a block in the blockchain structure.

1096. The method of claim 1095, further comprising:

producing at least one of orders or requests for service and parts based on the industrial machine service recommendation, wherein the record for the industrial machine service recommendation stored in the ledger indicates the at least one of the orders or the requests for service and parts.

1097. The method of claim 1083, wherein the mobile vehicle is one of a plurality of mobile vehicles of a mobile data collector swarm.

1098. The method of claim 1097, further comprising:

controlling the mobile data collector swarm to cause the mobile vehicle to approach a location of the industrial machine within an industrial environment.

1099. The method of claim 1098, wherein controlling the mobile data collector swarm to cause the mobile vehicle to approach a location of the industrial machine within an industrial environment comprises:

using self-organization systems of the mobile data collector swarm to control movements of the mobile vehicle within the industrial environment based on locations of other mobile vehicles of the mobile data collector swarm within the industrial environment.

1100. The method of claim 1083, wherein the mobile vehicle is a heavy-duty machine.

1101. The method of claim 1083, wherein the mobile vehicle is a heavy-duty on-road industrial vehicle.

1102. The method of claim 1083, wherein the mobile vehicle is a heavy-duty off-road industrial vehicle.

1103. The method of claim 1083, wherein the mobile vehicle includes an industrial machine.

1104. The method of claim 1083, wherein the mobile vehicle includes earth-moving equipment.

1105. The method of claim 1083, wherein the mobile vehicle includes earth-compacting equipment.

1106. The method of claim 1083, wherein the mobile vehicle includes hauling equipment.

1107. The method of claim 1083, wherein the mobile vehicle includes hoisting equipment.

1108. The method of claim 1083, wherein the mobile vehicle includes conveying equipment.

1109. The method of claim 1083, wherein the mobile vehicle includes aggregate production equipment.

1110. The method of claim 1083, wherein the mobile vehicle includes equipment used in concrete construction.

1111. The method of claim 1083, wherein the mobile vehicle includes piledriving equipment.

1112. The method of claim 1083, wherein the mobile vehicle includes construction equipment.

1113. The method of claim 1083, wherein the mobile vehicle is a personnel transport vehicle.

1114. The method of claim 1083, wherein the mobile vehicle is an unmanned vehicle.

1115. A method comprising:

training a computer vision system to detect conditions of industrial machines using a training data set comprising at least one of image data or non-image data;

detecting a condition of an industrial machine using the trained computer vision and based on a data set generated using one or more data capture devices;

determining a severity value for the detected condition, the severity representing an impact of the detected condition on the industrial machine;

producing, based on the severity value, at least one of orders or requests for service and parts to use to resolve an issue related to the detected condition of the industrial machine; and

storing a record of the issue related to the detected condition of the industrial machine within a ledger associated with the industrial machine.

1116. The method of claim 1115, wherein the one or more data capture devices includes a radiation imaging device, a sonic capture device, a LIDAR device, a point cloud capture device, or an infrared inspection device.

1117. The method of claim 1115, wherein the detected condition is detected based on vibration characteristics of the industrial machine.

1118. The method of claim 1115, wherein the detected condition is detected based on pressure characteristics of the industrial machine.

1119. The method of claim 1115, wherein the detected condition is detected based on temperature characteristics of the industrial machine.

1120. The method of claim 1115, wherein the detected condition is detected based on chemical characteristics of the industrial machine.

1121. The method of claim 1115, wherein training the computer vision system to detect the conditions of the industrial machines using the training data set comprising the at least one of image data or non-image data comprises:

using a deep learning system to detect features from the at least one of the image data or non-image data; and

using the detected features to train a classification model to learn to detect the conditions of the industrial machines based on characteristics of the detected features and based on outcome feedback.

1122. The method of claim 1121, wherein the outcome feedback relates to at least one of maintenance, repair, uptime, downtime, profitability, efficiency, or operational optimization of the industrial machines, of processes for using the industrial machines, or of facilities including the industrial machines.

1123. The method of claim 1115, wherein detecting the condition of the industrial machine using the trained computer vision and based on the data set generated using the one or more data capture devices comprises:

using part recognition to identify one or more components of the industrial machine that will lead to the issue related to the detected condition, wherein the at least one of the orders or the requests for service and parts is for replacement parts for the one or more components.

1124. The method of claim 1123, wherein the at least one of the orders or the requests for service and parts is not produced when the severity value does not meet a threshold.

1125. The method of claim 1115, further comprising:

using a predictive maintenance knowledge system to update a predictive maintenance knowledge base according to at least one of the detected condition, the at least one of the orders or the requests for service and parts, or the stored record in the ledger.

1126. A system comprising:

a computerized maintenance management system (CMMS) that produces at least one of orders or requests for service and parts responsive to receiving an industrial machine service recommendation corresponding to an industrial machine and that generates a signal indicative of the produced at least one of the orders or requests for service and parts; and

a mobile data collector that receives the signal and indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a worker who uses the mobile data collector.

1127. The system of claim 1126, wherein the mobile data collector is a wearable device, wherein the wearable device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the wearable device.

1128. The system of claim 1126, wherein the mobile data collector is a handheld device, wherein the handheld device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the handheld device.

1129. The system of claim 1126, further comprising:

a service and delivery coordination facility that receives and processes information regarding services performed on the industrial machine responsive to the at least one of orders or requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for the industrial machine.

1130. The system of claim 1129, further comprising:

a self-organizing data collector that causes a new record to be stored in the ledger, the new record indicating at least one of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts.

1131. The system of claim 1129, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

1132. The system of claim 1131, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

1133. A system comprising:

a computerized maintenance management system (CMMS) that produces at least one of orders or requests for service and parts responsive to receiving an industrial machine service recommendation corresponding to an industrial machine and that generates a signal indicative of the produced at least one of the orders or requests for service and parts;

a mobile data collector that receives the signal and indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a worker who uses the mobile data collector; and

a service and delivery coordination facility that receives and processes information regarding services performed on the industrial machine responsive to the at least one of orders or requests for service and parts, thereby validating the services performed while producing a ledger of service activity and results for the industrial machine.

1134. The system of claim 1133, wherein the mobile data collector is a wearable device, wherein the wearable device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the wearable device.

1135. The system of claim 1133, wherein the mobile data collector is a handheld device, wherein the handheld device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the handheld device.

1136. The system of claim 1133, further comprising:

a self-organizing data collector that causes a new record to be stored in the ledger, the new record indicating at least one of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts.

1137. The system of claim 1133, wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

1138. The system of claim 1137, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

1139. A system comprising:

a computerized maintenance management system (CMMS) that produces at least one of orders or requests for service and parts responsive to receiving an industrial machine service recommendation corresponding to an industrial machine and that generates a signal indicative of the produced at least one of the orders or requests for service and parts;

a mobile data collector that receives the signal and indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a worker who uses the mobile data collector; and

a self-organizing data collector that causes a new record to be stored in a ledger, the new record indicating at least one of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts,

wherein the ledger uses a blockchain structure to track records of transactions for each of the at least one of the orders and the requests for service and parts, wherein each record is stored as a block in the blockchain structure.

1140. The system of claim 1139, wherein the mobile data collector is a wearable device, wherein the wearable device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the wearable device.

1141. The system of claim 1139, wherein the mobile data collector is a handheld device, wherein the handheld device indicates the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to the worker by outputting data indicative of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts to a display of the handheld device.

1142. The system of claim 1139, further comprising:

a self-organizing data collector that causes a new record to be stored in the ledger, the new record indicating at least one of the industrial machine service recommendation or the produced at least one of the orders or requests for service and parts.

1143. The system of claim 1139, wherein the CMMS generates subsequent blocks of the ledger by combining data from at least one of shipment readiness, installation, operational sensor data, service events, parts orders, service orders, or diagnostic activity with a hash of a most recently generated block in the ledger.

1144. The system of claim 1139, further comprising:

an industrial machine predictive maintenance facility that produces the industrial machine service recommendation based on industrial machine health monitoring data by applying machine fault detection and classification algorithms thereto.

1145. The system of claim 1144, further comprising:

an industrial machine data analysis facility that generates streams of the industrial machine health monitoring data by applying machine learning to data representative of conditions of portions of the industrial machine received via a data collection network.

1146. A method, comprising:

detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector;

transmitting data indicative of the operating characteristic to a server over a network;

using intelligent systems associated with the server to process the operating characteristic against pre-recorded data for the industrial machine, wherein processing the operating characteristic against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with an industrial environment that includes the industrial machine;

identifying, as a condition of the industrial machine, a characteristic indicated by the pre-recorded data for the industrial machine within the knowledge base;

determining a severity of the condition, the severity representing an impact of the condition on the industrial machine;

predicting a maintenance action to perform against the industrial machine based on the severity of the condition; and

storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine.

1147. The method of claim 1146, wherein the mobile data collector is a mobile robot.

1148. The method of claim 1146, wherein the mobile data collector is a mobile vehicle.

1149. The method of claim 1146, wherein the mobile data collector is a handheld device.

1150. The method of claim 1146, wherein the mobile data collector is a wearable device.

1151. The method of claim 1146, wherein the condition of the industrial machine relates to vibrations detected for at least a portion of the industrial machine, wherein determining the severity of the condition comprises:

determining a frequency of the vibrations;

determining a segment of a multi-segment vibration frequency spectra that bounds the vibrations; and

calculating the severity for the detected vibrations based on the determined segment.

1152. The method of claim 1151, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

1153. The method of claim 1152, further comprising:

mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1154. The method of claim 1146, wherein the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine, wherein each of the transaction records is stored as a block in the blockchain structure.

1155. The method of claim 1146, wherein the condition of the industrial machine relates to a temperature detected for at least a portion of the industrial machine.

1156. The method of claim 1146, wherein the condition of the industrial machine relates to an electrical output detected for at least a portion of the industrial machine.

1157. The method of claim 1146, wherein the condition of the industrial machine relates to a magnetic output detected for at least a portion of the industrial machine.

1158. The method of claim 1146, wherein the condition of the industrial machine relates to a sound output detected for at least a portion of the industrial machine.

1159. A method, comprising:

detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector;

transmitting data indicative of the operating characteristic to a server over a network;

using intelligent systems associated with the server to process the operating characteristic against pre-recorded data for the industrial machine, wherein processing the operating characteristic against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with an industrial environment that includes the industrial machine;

identifying, as a condition of the industrial machine, a characteristic indicated by the pre-recorded data for the industrial machine within the knowledge base, the condition of the industrial machine relating to vibrations detected for at least a portion of the industrial machine;

determining a severity of the condition, the severity representing an impact of the condition on the industrial machine, based on a segment of a multi-segment vibration frequency spectra that bounds the vibrations; and

predicting a maintenance action to perform against the industrial machine based on the severity of the condition.

1160. The method of claim 1159, wherein the mobile data collector is a mobile robot.

1161. The method of claim 1159, wherein the mobile data collector is a mobile vehicle.

1162. The method of claim 1159, wherein the mobile data collector is a handheld device.

1163. The method of claim 1159, wherein the mobile data collector is a wearable device.

1164. The method of claim 1159, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

1165. The method of claim 1164, further comprising:

mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1166. The method of claim 1159, further comprising:

storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine.

1167. The method of claim 1166, wherein the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine, wherein each of the transaction records is stored as a block in the blockchain structure.

1168. A method comprising:

detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector, the operating characteristic of the industrial machine relating to vibrations detected for at least a portion of the industrial machine;

determining a severity of the operating characteristic, the severity representing an impact of the operating characteristic on the industrial machine, based on a segment of a multi-segment vibration frequency spectra that bounds the vibrations; and

predicting a maintenance action to perform against the industrial machine based on the severity of the operating characteristic.

1169. The method of claim 1168, wherein the mobile data collector is a mobile robot.

1170. The method of claim 1168, wherein the mobile data collector is a mobile vehicle.

1171. The method of claim 1168, wherein the mobile data collector is a handheld device.

1172. The method of claim 1168, wherein the mobile data collector is a wearable device.

1173. The method of claim 1168, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

1174. The method of claim 1173, further comprising:

mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1175. The method of claim 1168, further comprising:

storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine.

1176. The method of claim 1175, wherein the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine, wherein each of the transaction records is stored as a block in the blockchain structure.

1177. A method comprising:

detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector, the operating characteristic of the industrial machine relating to vibrations detected for at least a portion of the industrial machine;

determining a severity of the operating characteristic, the severity representing an impact of the operating characteristic on the industrial machine, based on a segment of a multi-segment vibration frequency spectra that bounds the vibrations;

predicting a maintenance action to perform against the industrial machine based on the severity of the operating characteristic; and

storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine.

1178. The method of claim 1177, wherein the mobile data collector is a mobile robot.

1179. The method of claim 1177, wherein the mobile data collector is a mobile vehicle.

1180. The method of claim 1177, wherein the mobile data collector is a handheld device.

1181. The method of claim 1177, wherein the mobile data collector is a wearable device.

1182. The method of claim 1177, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra.

1183. The method of claim 1182, further comprising:

mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1184. The method of claim 1177, wherein the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine, wherein each of the transaction records is stored as a block in the blockchain structure.

1185. A method comprising:

detecting an operating characteristic of an industrial machine using one or more sensors of a mobile data collector, the operating characteristic of the industrial machine relating to vibrations detected for at least a portion of the industrial machine;

determining a severity of the operating characteristic, the severity representing an impact of the operating characteristic on the industrial machine, based on a segment of a multi-segment vibration frequency spectra that bounds the vibrations, wherein the severity corresponds to a severity unit, wherein the segment of a multi-segment vibration frequency spectra that bounds the vibrations is determined by mapping the vibrations to one of a number of severity units based on the determined segment, wherein each of the severity units corresponds to a different range of the multi-segment vibration frequency spectra;

predicting a maintenance action to perform against the industrial machine based on the severity of the operating characteristic; and

storing a transaction record of the predicted maintenance action within a ledger of service activity associated with the industrial machine, wherein the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine, wherein each of the transaction records is stored as a block in the blockchain structure.

1186. The method of claim 1185, wherein the mobile data collector is a mobile robot.

1187. The method of claim 1185, wherein the mobile data collector is a mobile vehicle.

1188. The method of claim 1185, wherein the mobile data collector is a handheld device.

1189. The method of claim 1185, wherein the mobile data collector is a wearable device.

1190. The method of claim 1185, wherein determining the severity of the operating characteristic comprises:

mapping the vibrations to a first severity unit when the frequency of the vibrations corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibrations to a second severity unit when the frequency of the vibrations corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibrations to a third severity unit when the frequency of the vibrations corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1191. A method comprising:

deploying a mobile data collector for detecting and monitoring vibration activity of at least a portion of an industrial machine, the mobile data collector including one or more vibration sensors;

controlling the mobile data collector to approach a location of the industrial machine within an industrial environment that includes the industrial machine;

causing the one or more vibration sensors of the mobile data collector to record one or more measurements of the vibration activity;

transmitting the one or more measurements of the vibration activity as vibration data to a server over a network;

determining, at the server, a severity of the vibration activity relative to timing by processing the vibration data;

predicting, at the server, a maintenance action to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity; and

transmitting a signal indicative of the maintenance action to the mobile data collector to cause the mobile data collector to perform the maintenance action.

1192. The method of claim 1191, wherein determining the severity of the vibration data relative to the timing by processing the vibration data comprises:

determining a frequency of the vibration activity by processing the vibration data;

determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the vibration activity; and

calculating a severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra.

1193. The method of claim 1192, wherein calculating the severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra comprises:

mapping the vibration activity to the severity unit based on the determined segment of the multi-segment vibration frequency spectra by:

mapping the vibration activity to a first severity unit when the frequency of the vibration activity corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibration activity to a second severity unit when the frequency of the vibration activity corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibration activity to a third severity unit when the frequency of the vibration activity corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1194. The method of claim 1191, wherein predicting the one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity comprises:

using intelligent systems associated with the server to process the vibration data against pre-recorded data for the industrial machine, wherein processing the vibration data against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with the industrial environment;

identifying an operating characteristic of at least the portion of the machine based on the pre-recorded data for the industrial machine within the knowledge base; and

predicting the one or more maintenance actions based on the operating characteristic.

1195. The method of claim 1191, wherein the vibration activity is indicative of a waveform derived from a vibration envelope associated with the industrial machine, wherein the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine.

1196. The method of claim 1191, wherein the vibration activity represents velocity information for at least the portion of the industrial machine.

1197. The method of claim 1191, wherein the vibration activity represents frequency information for at least the portion of the industrial machine.

1198. The method of claim 1191, wherein the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm.

1199. The method of claim 1198, further comprising:

using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within an industrial environment that includes the industrial machine,

wherein the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine.

1200. The method of claim 1199, wherein using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises:

controlling the movements of the mobile data collector within the industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors.

1201. The method of claim 1198, wherein the mobile data collector is a mobile robot and at least one other mobile data collector of the plurality of mobile data collectors is a mobile vehicle.

1202. A method comprising:

deploying a mobile data collector for detecting and monitoring vibration activity of at least a portion of an industrial machine, the mobile data collector including one or more vibration sensors;

controlling the mobile data collector to approach a location of the industrial machine within an industrial environment that includes the industrial machine;

causing the one or more vibration sensors of the mobile data collector to record one or more measurements of the vibration activity;

transmitting the one or more measurements of the vibration activity as vibration data to a server over a network;

determining, at the server, a frequency of the vibration activity by processing the vibration data;

determining, at the server and based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the vibration activity;

calculating, at the server, a severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra;

predicting, at the server, a maintenance action to perform with respect to at least the portion of the industrial machine based on the severity unit; and

transmitting a signal indicative of the maintenance action to the mobile data collector to cause the mobile data collector to perform the maintenance action.

1203. The method of claim 1202, wherein calculating the severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra comprises:

mapping the vibration activity to the severity unit based on the determined segment of the multi-segment vibration frequency spectra by:

mapping the vibration activity to a first severity unit when the frequency of the vibration activity corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibration activity to a second severity unit when the frequency of the vibration activity corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibration activity to a third severity unit when the frequency of the vibration activity corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1204. The method of claim 1202, wherein predicting the one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity unit comprises:

using intelligent systems associated with the server to process the vibration data against pre-recorded data for the industrial machine, wherein processing the vibration data against the pre-

recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with the industrial environment;

identifying an operating characteristic of at least the portion of the machine based on the pre-recorded data for the industrial machine within the knowledge base; and

predicting the one or more maintenance actions based on the operating characteristic.

1205. The method of claim 1202, wherein the vibration activity is indicative of a waveform derived from a vibration envelope associated with the industrial machine, wherein the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine.

1206. The method of claim 1202, wherein the vibration activity represents velocity information for at least the portion of the industrial machine.

1207. The method of claim 1202, wherein the vibration activity represents frequency information for at least the portion of the industrial machine.

1208. The method of claim 1202, wherein the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm.

1209. The method of claim 1208, further comprising:

using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within an industrial environment that includes the industrial machine,

wherein the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine.

1210. The method of claim 1209, wherein using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises:

controlling the movements of the mobile data collector within the industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors.

1211. The method of claim 1208, wherein the mobile data collector is a mobile robot and at least one other mobile data collector of the plurality of mobile data collectors is a mobile vehicle.

1212. A method comprising:

deploying a mobile data collector for detecting and monitoring vibration activity of at least a portion of an industrial machine, the mobile data collector including one or more vibration sensors;

controlling the mobile data collector to approach a location of the industrial machine within an industrial environment that includes the industrial machine;

causing the one or more vibration sensors of the mobile data collector to record one or more measurements of the vibration activity;

transmitting the one or more measurements of the vibration activity as vibration data to a server over a network;

determining, at the server, a severity of the vibration activity relative to timing by processing the vibration data;

predicting, at the server, a maintenance action to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity;

transmitting a signal indicative of the maintenance action to the mobile data collector to cause the mobile data collector to perform the maintenance action; and

storing a record of the predicted maintenance action within a ledger associated with the industrial machine.

1213. The method of claim 1212, wherein determining the severity of the vibration data relative to the timing by processing the vibration data comprises:

determining a frequency of the vibration activity by processing the vibration data;

determining, based on the frequency, a segment of a multi-segment vibration frequency spectra that bounds the vibration activity; and

calculating a severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra.

1214. The method of claim 1213, wherein calculating the severity unit for the vibration activity based on the determined segment of the multi-segment vibration frequency spectra comprises:

mapping the vibration activity to the severity unit based on the determined segment of the multi-segment vibration frequency spectra by:

mapping the vibration activity to a first severity unit when the frequency of the vibration activity corresponds to a below a low-end knee threshold-range of the multi-segment vibration frequency spectra;

mapping the vibration activity to a second severity unit when the frequency of the vibration activity corresponds to a mid-range of the multi-segment vibration frequency spectra; and

mapping the vibration activity to a third severity unit when the frequency of the vibration activity corresponds to an above a high-end knee threshold-range of the multi-segment vibration frequency spectra.

1215. The method of claim 1212, wherein predicting the one or more maintenance actions to perform with respect to at least the portion of the industrial machine based on the severity of the vibration activity comprises:

using intelligent systems associated with the server to process the vibration data against pre-recorded data for the industrial machine, wherein processing the vibration data against the pre-recorded data for the industrial machine includes identifying the pre-recorded data for the industrial machine within a knowledge base associated with the industrial environment;

identifying an operating characteristic of at least the portion of the machine based on the pre-recorded data for the industrial machine within the knowledge base; and

predicting the one or more maintenance actions based on the operating characteristic.

1216. The method of claim 1212, wherein the vibration activity is indicative of a waveform derived from a vibration envelope associated with the industrial machine, wherein the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine.

1217. The method of claim 1212, wherein the vibration activity represents velocity information for at least the portion of the industrial machine.

1218. The method of claim 1212, wherein the vibration activity represents frequency information for at least the portion of the industrial machine.

1219. The method of claim 1212, wherein the mobile data collector is one of a plurality of mobile data collectors of a mobile data collector swarm.

1220. The method of claim 1219, further comprising:

using self-organization systems of the mobile data collector swarm to control movements of the mobile data collector within an industrial environment that includes the industrial machine,

wherein the one or more vibration sensors detect the vibration activity when the mobile data collector is in near proximity to the industrial machine.

1221. The method of claim 1220, wherein using the self-organization systems of the mobile data collector swarm to control the movements of the mobile data collector within the industrial environment comprises:

controlling the movements of the mobile data collector within the industrial environment based on movements of at least one other mobile data collector of the plurality of mobile data collectors.

1222. The method of claim 1219, wherein the mobile data collector is a mobile robot and at least one other mobile data collector of the plurality of mobile data collectors is a mobile vehicle.

1223. The method of claim 1222, wherein the ledger uses a blockchain structure to track transaction records for predicted maintenance actions for the industrial machine, wherein each of the transaction records is stored as a block in the blockchain structure.

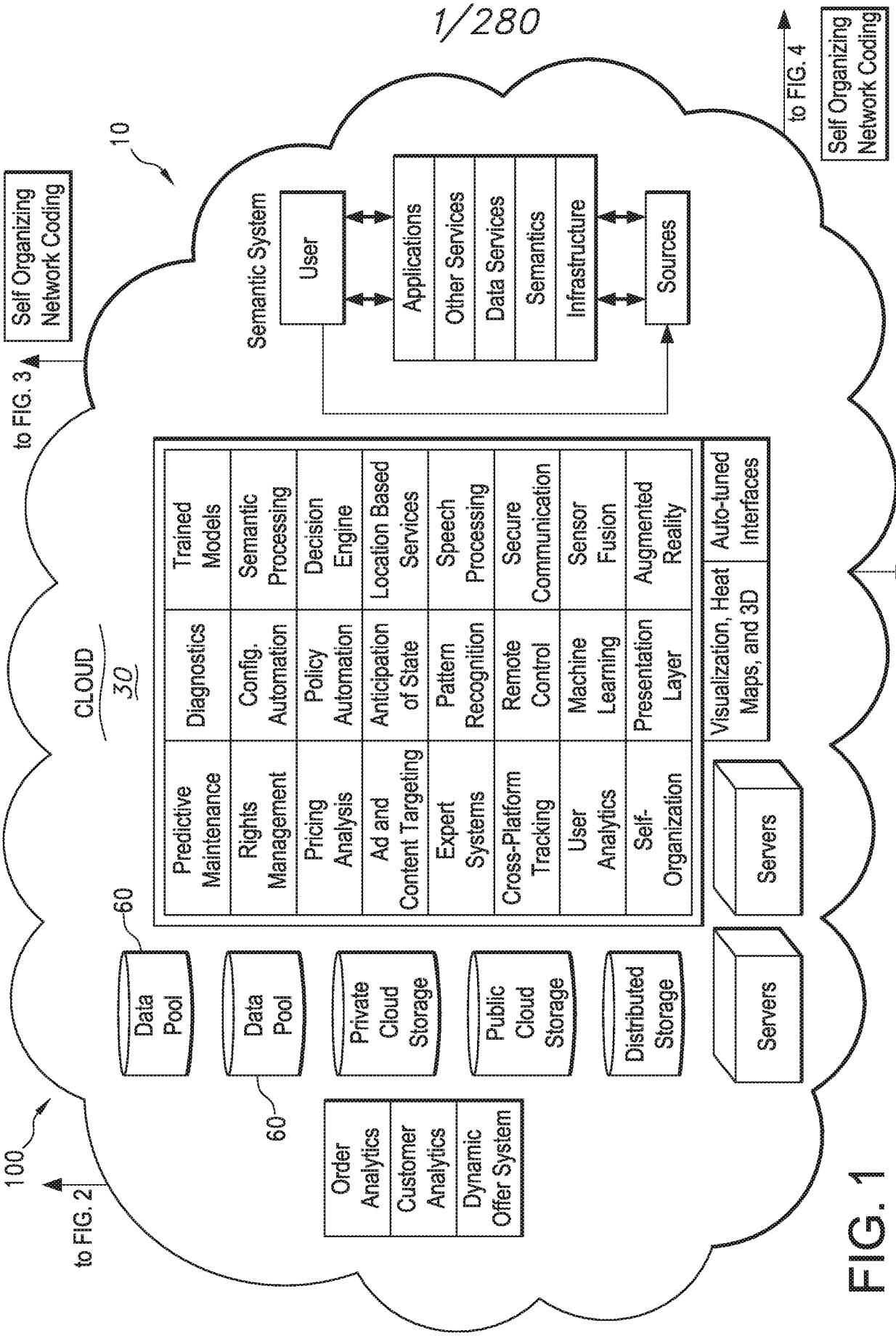

1/280
10
100
CLOUD
30
60
60
Self Organizing Network Coding
to FIG. 3
to FIG. 4
Self Organizing Network Coding
to FIG. 5
to FIG. 2
Semantic System
User
Applications
Other Services
Data Services
Semantics
Infrastructure
Sources
Predictive Maintenance
Rights Management
Pricing Analysis
Ad and Content Targeting
Expert Systems
Cross-Platform Tracking
User Analytics
Self-Organization
Diagnostics
Config. Automation
Policy Automation
Anticipation of State
Pattern Recognition
Remote Control
Machine Learning
Presentation Layer
Trained Models
Semantic Processing
Decision Engine
Location Based Services
Speech Processing
Secure Communication
Sensor Fusion
Augmented Reality
Visualization, Heat Maps, and 3D
Auto-tuned Interfaces
Data Pool
Data Pool
Private Cloud Storage
Public Cloud Storage
Distributed Storage
Servers
Servers
Order Analytics
Customer Analytics
Dynamic Offer System

FIG. 1

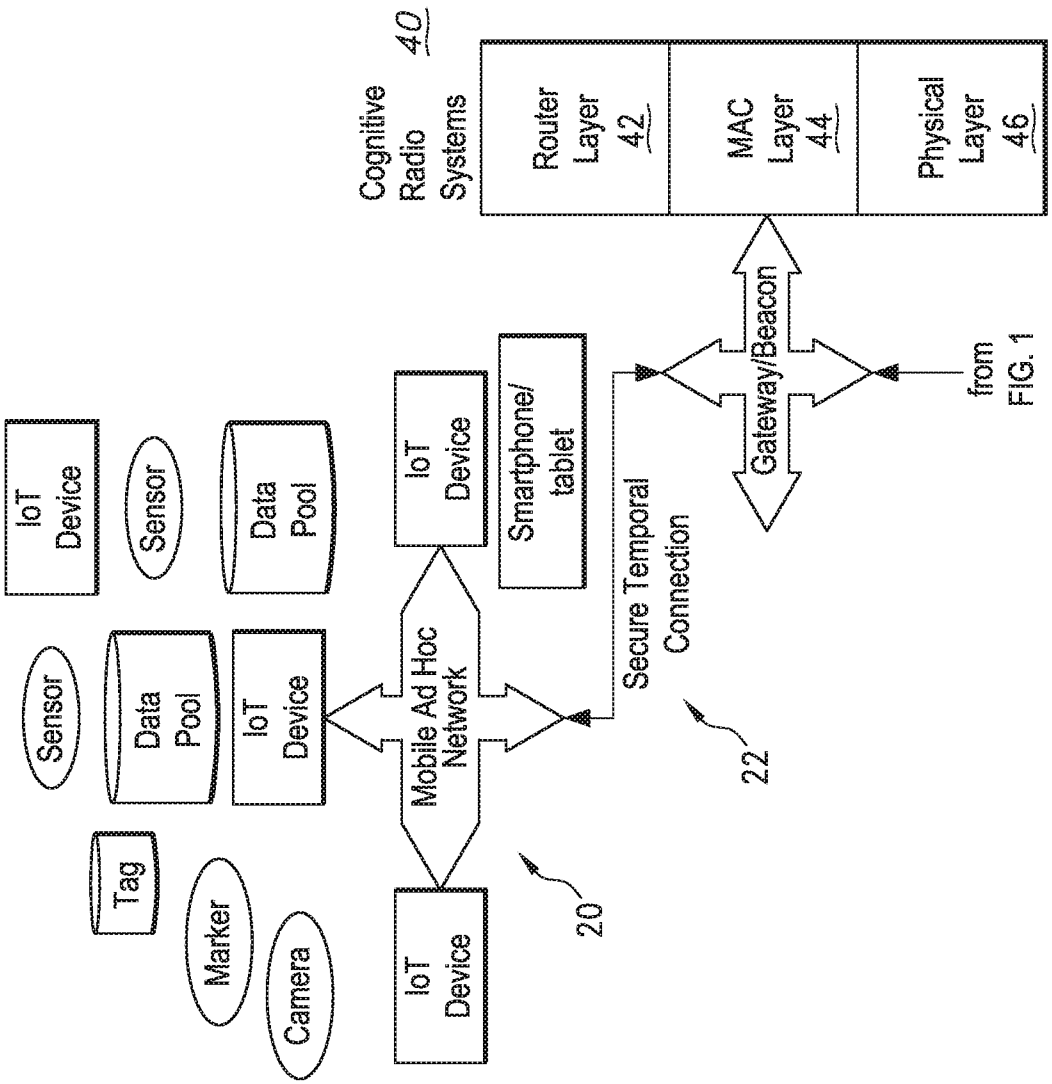

Cognitive Radio Systems
40
Router Layer 42
MAC Layer 44
Physical Layer 46
Gateway/Beacon
from FIG. 1
Secure Temporal Connection
22
20
Mobile Ad Hoc Network
IoT Device
Smartphone/ tablet
IoT Device
Data Pool
Sensor
IoT Device
Data Pool
Sensor
IoT Device
Tag
Marker
Camera

FIG. 2

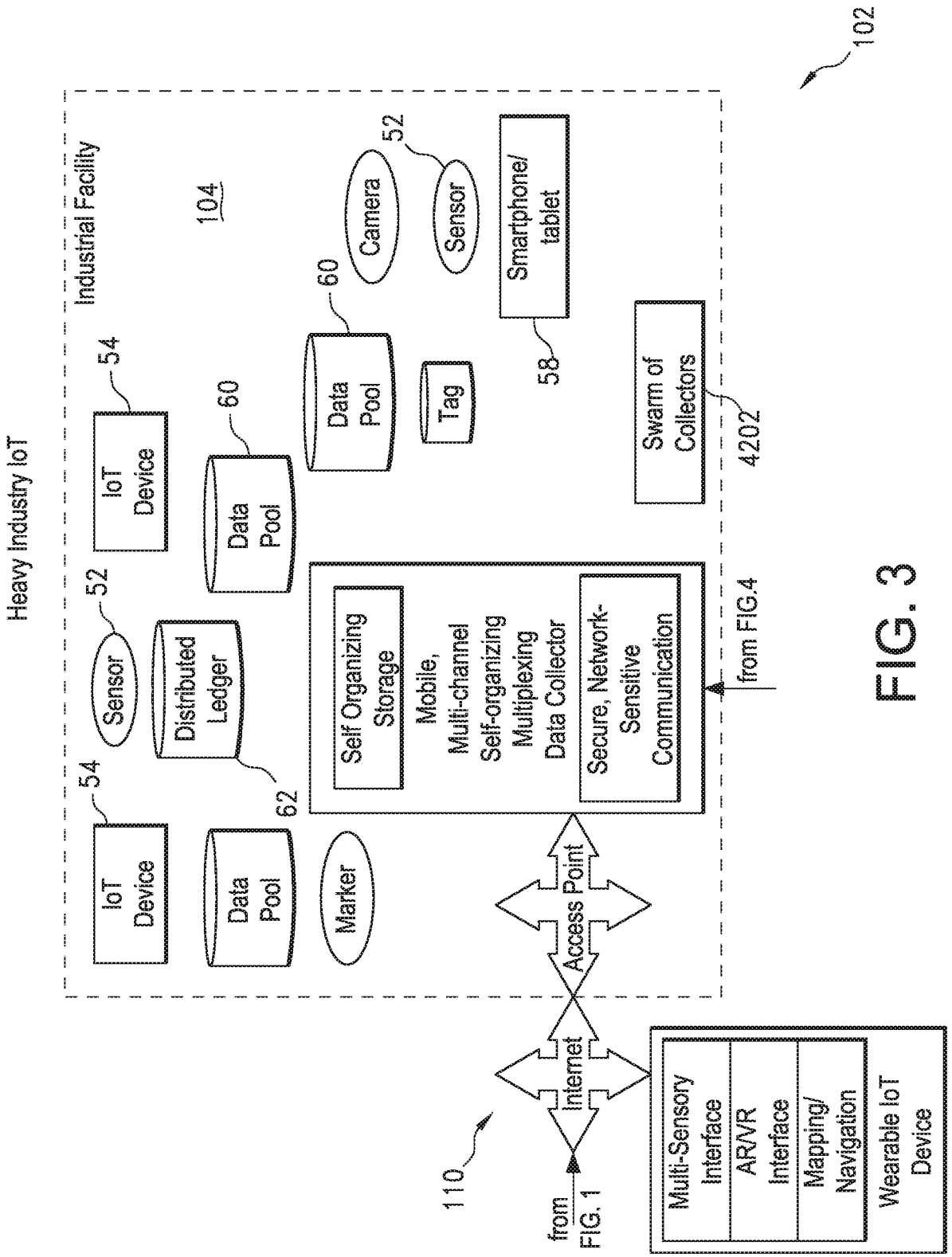

Heavy Industry IoT
Industrial Facility
104
102
IoT Device
54
Sensor
52
Distributed Ledger
62
Data Pool
60
Marker
Self Organizing Storage
Mobile, Multi-channel Self-organizing Multiplexing Data Collector
Secure, Network-Sensitive Communication
from FIG.4
Data Pool
60
Camera
52
Sensor
Tag
Smartphone/ tablet
58
Swarm of Collectors
4202
Access Point
Internet
110
from FIG. 1
Multi-Sensory Interface
AR/VR Interface
Mapping/ Navigation
Wearable IoT Device

FIG. 3

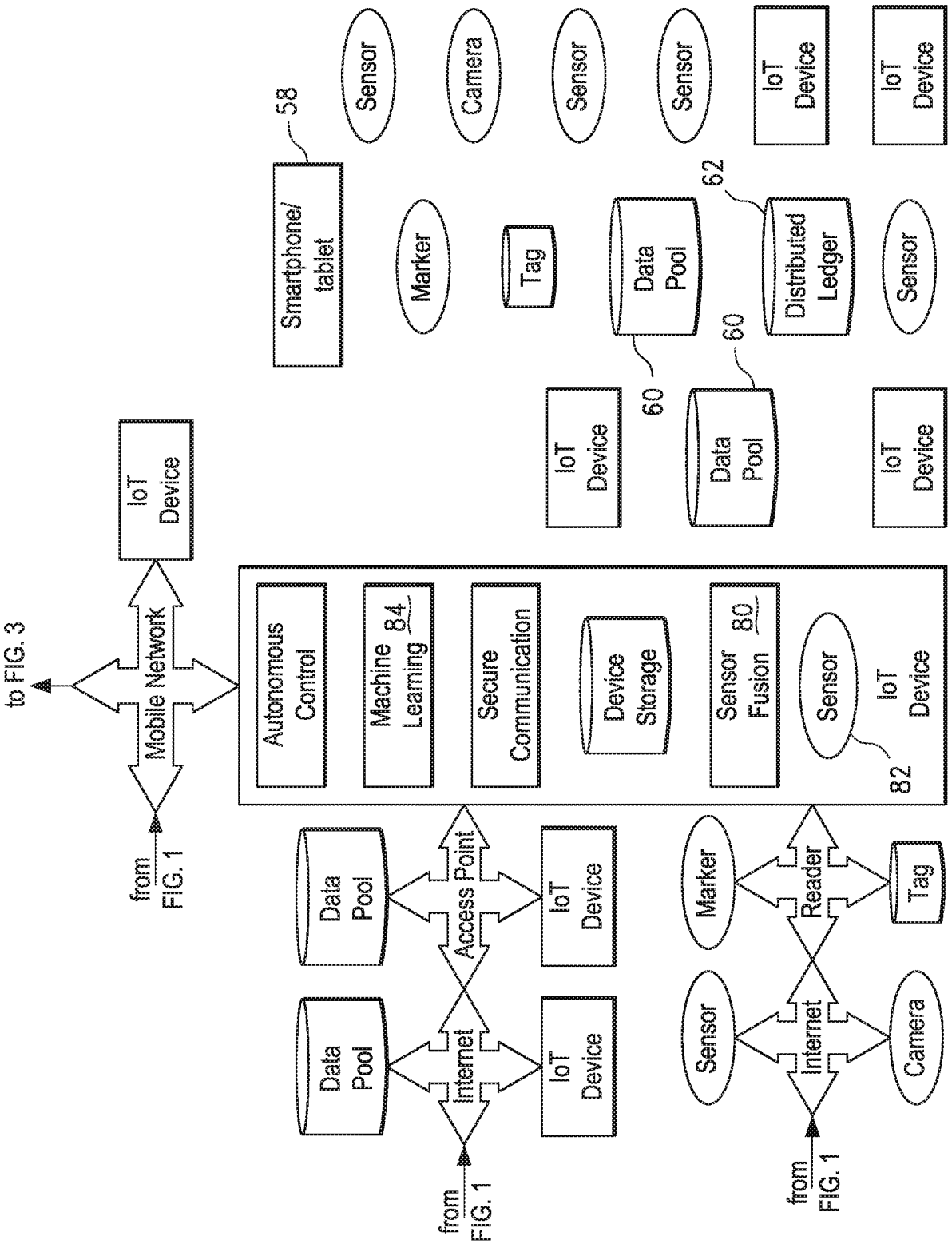

to FIG. 3
from FIG. 1
Mobile Network
IoT Device
Autonomous Control
Machine Learning 84
Secure Communication
Device Storage
Sensor Fusion 80
Sensor
IoT Device
82
58
Smartphone/ tablet
Sensor
Camera
Sensor
Sensor
IoT Device
IoT Device
Marker
Tag
Data Pool
60
62
Distributed Ledger
Sensor
IoT Device
Data Pool
60
IoT Device
Data Pool
Access Point
IoT Device
Data Pool
Internet
IoT Device
from FIG. 1
Marker
Reader
Tag
Sensor
Internet
Camera
from FIG. 1

FIG. 4

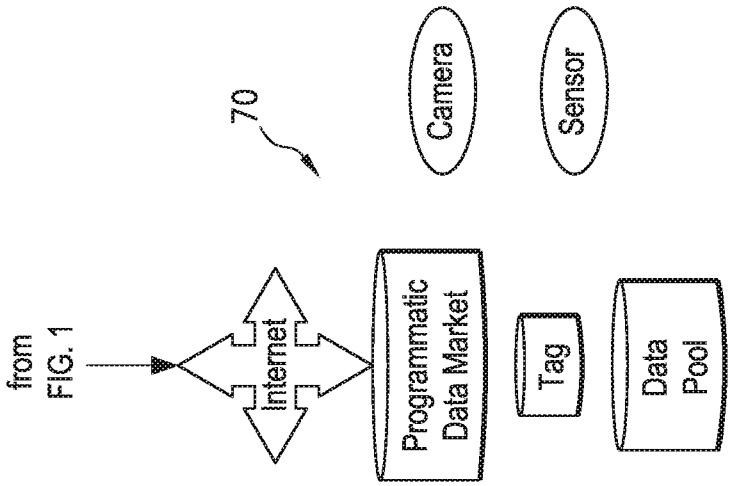

from FIG. 1
Internet
70
Programmatic Data Market
Camera
Sensor
Tag
Data Pool

FIG. 5

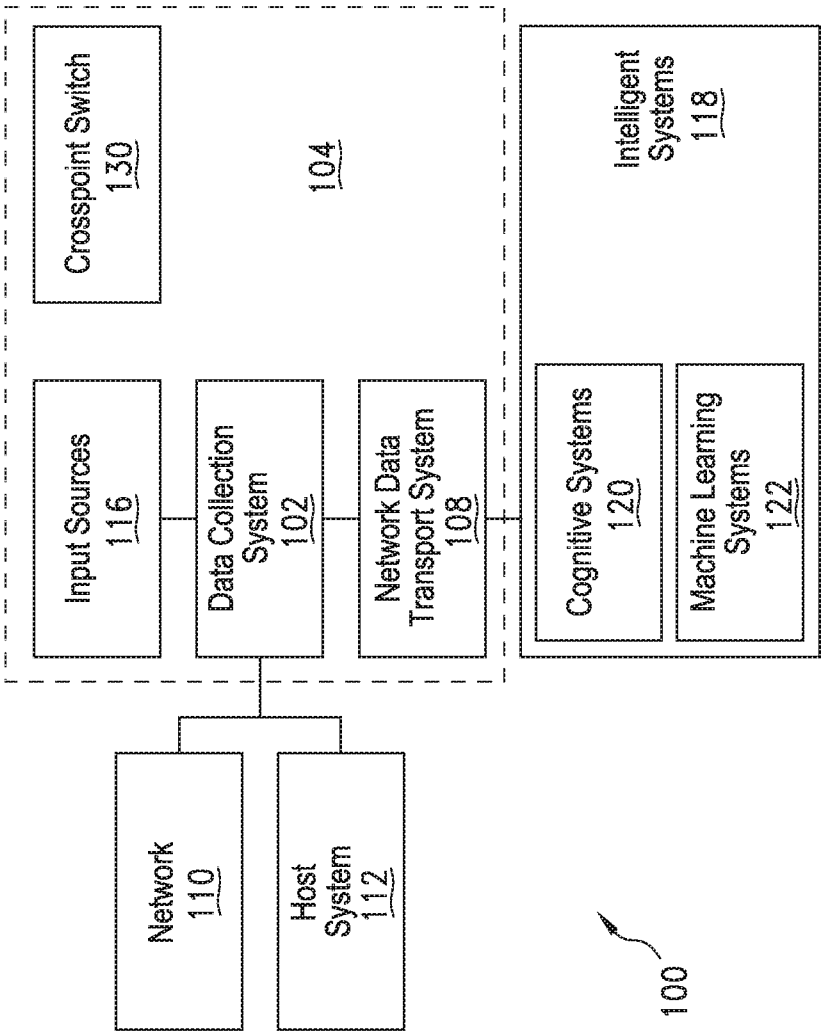
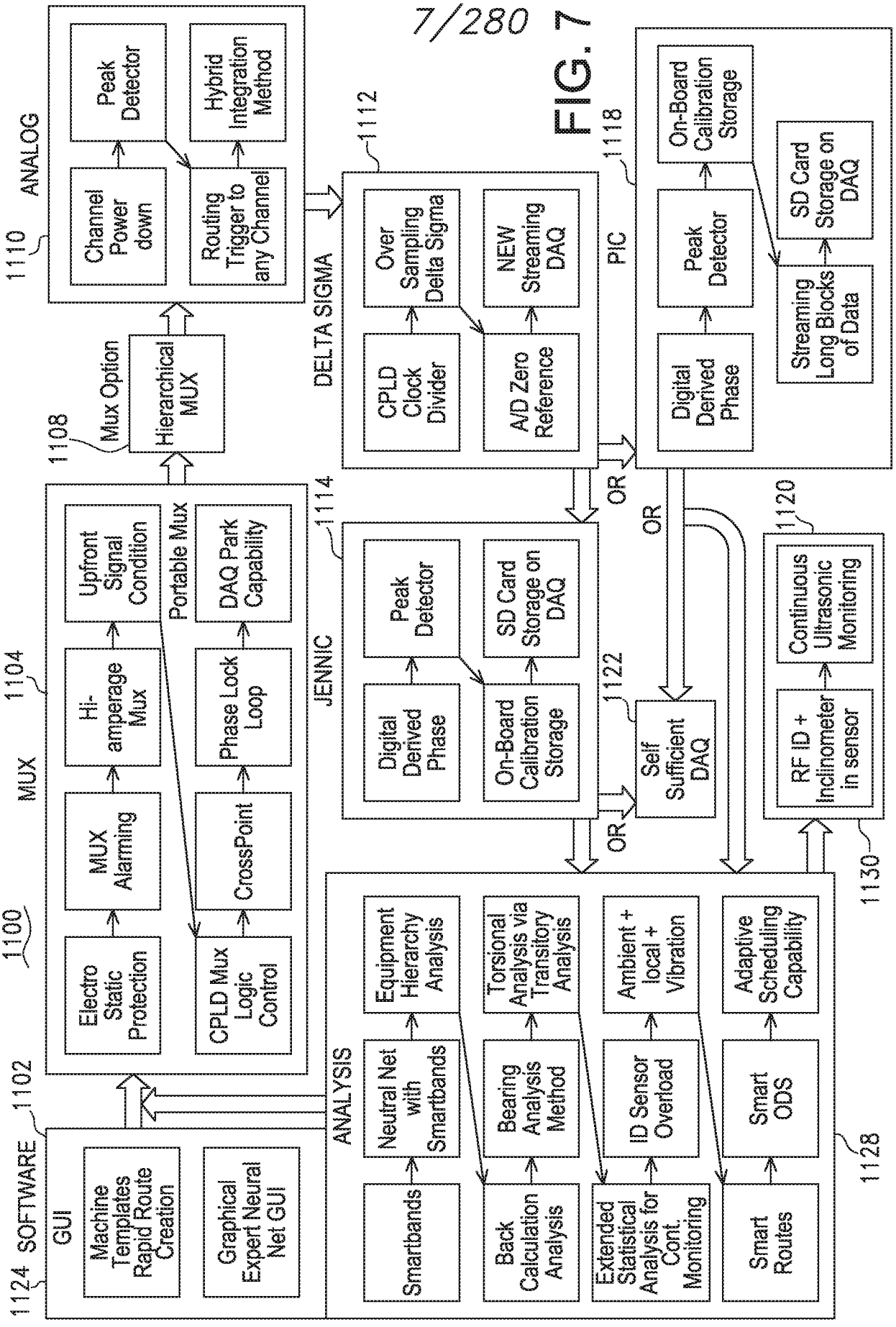

Crosspoint Switch
130
104
Intelligent
Systems
118
Input Sources
116
Data Collection
System
102
Network Data
Transport System
108
Cognitive Systems
120
Machine Learning
Systems
122
Network
110
Host
System
112
100

FIG. 6


7/280
FIG. 7
1124 SOFTWARE
GUI
Machine Templates Rapid Route Creation
Graphical Expert Neural Net GUI
1102
1100
MUX
Electro Static Protection
MUX Alarming
Hi-amperage Mux
1104
Upfront Signal Condition
Portable Mux
CPLD Mux Logic Control
CrossPoint
Phase Lock Loop
DAQ Park Capability
1108
Mux Option
Hierarchical MUX
1110 ANALOG
Channel Power down
Routing Trigger to any Channel
Peak Detector
Hybrid Integration Method
DELTA SIGMA
1112
CPLD Clock Divider
Over Sampling Delta Sigma
A/D Zero Reference
NEW Streaming DAQ
PIC
1118
Digital Derived Phase
Peak Detector
On-Board Calibration Storage
Streaming Long Blocks of Data
SD Card Storage on DAQ
JENNIC
1114
Digital Derived Phase
Peak Detector
On-Board Calibration Storage
SD Card Storage on DAQ
1122
Self Sufficient DAQ
OR
OR
OR
1120
RF ID + Inclinometer in sensor
Continuous Ultrasonic Monitoring
1130
ANALYSIS
Smartbands
Neutral Net with Smartbands
Equipment Hierarchy Analysis
Back Calculation Analysis
Bearing Analysis Method
Torsional Analysis via Transitory Analysis
Extended Statistical Analysis for Cont. Monitoring
ID Sensor Overload
Ambient + local + Vibration
Smart Routes
Smart ODS
Adaptive Scheduling Capability
1128

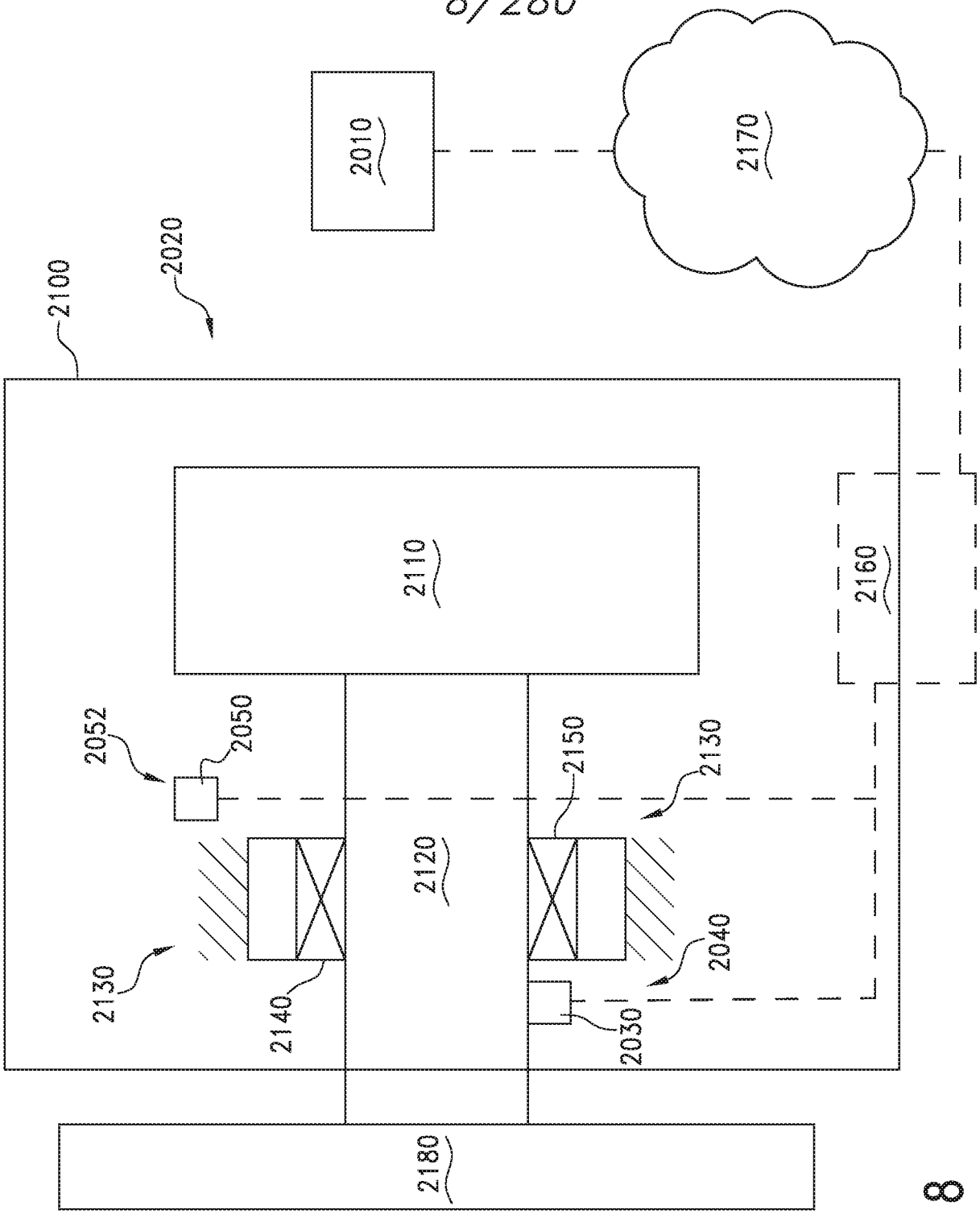

2010
2170
2020
2100
2110
2160
2052
2050
2150
2130
2120
2130
2140
2040
2030
2180

FIG. 8

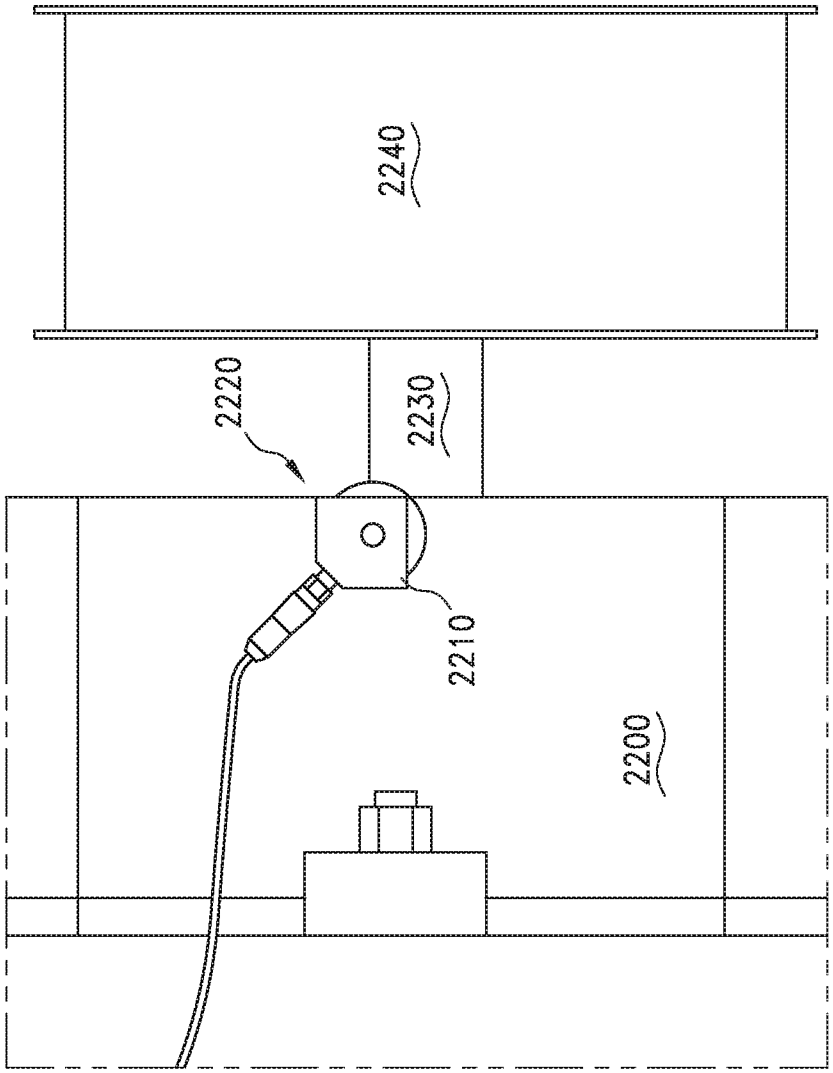


FIG. 9

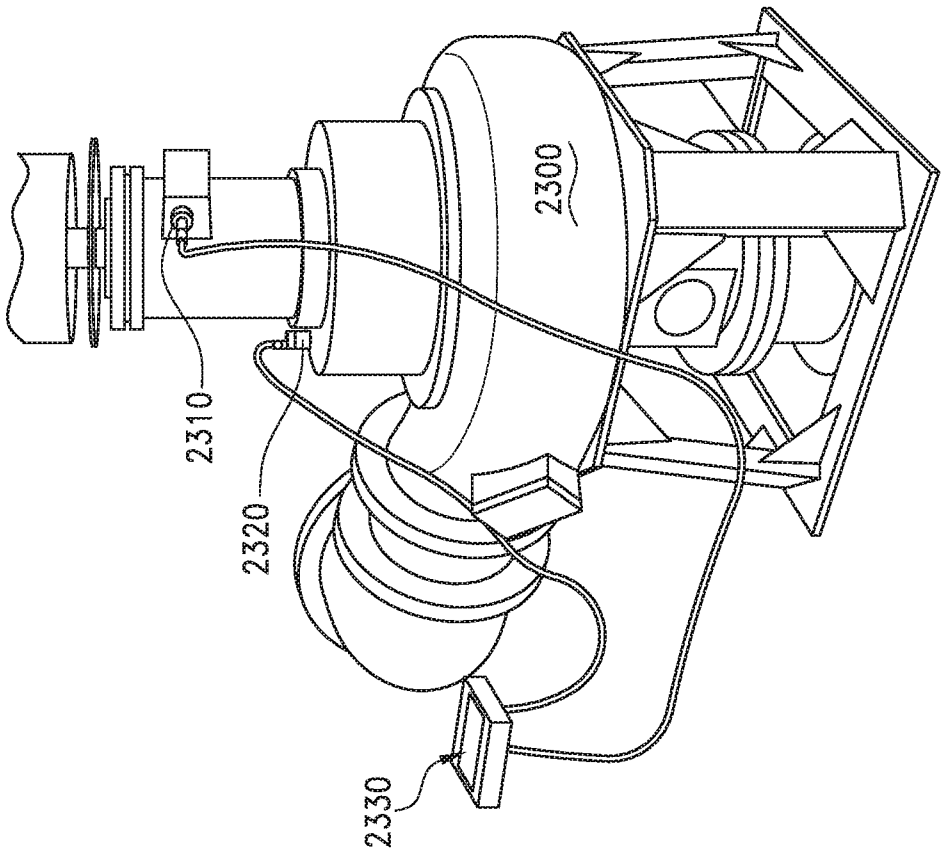


FIG. 10

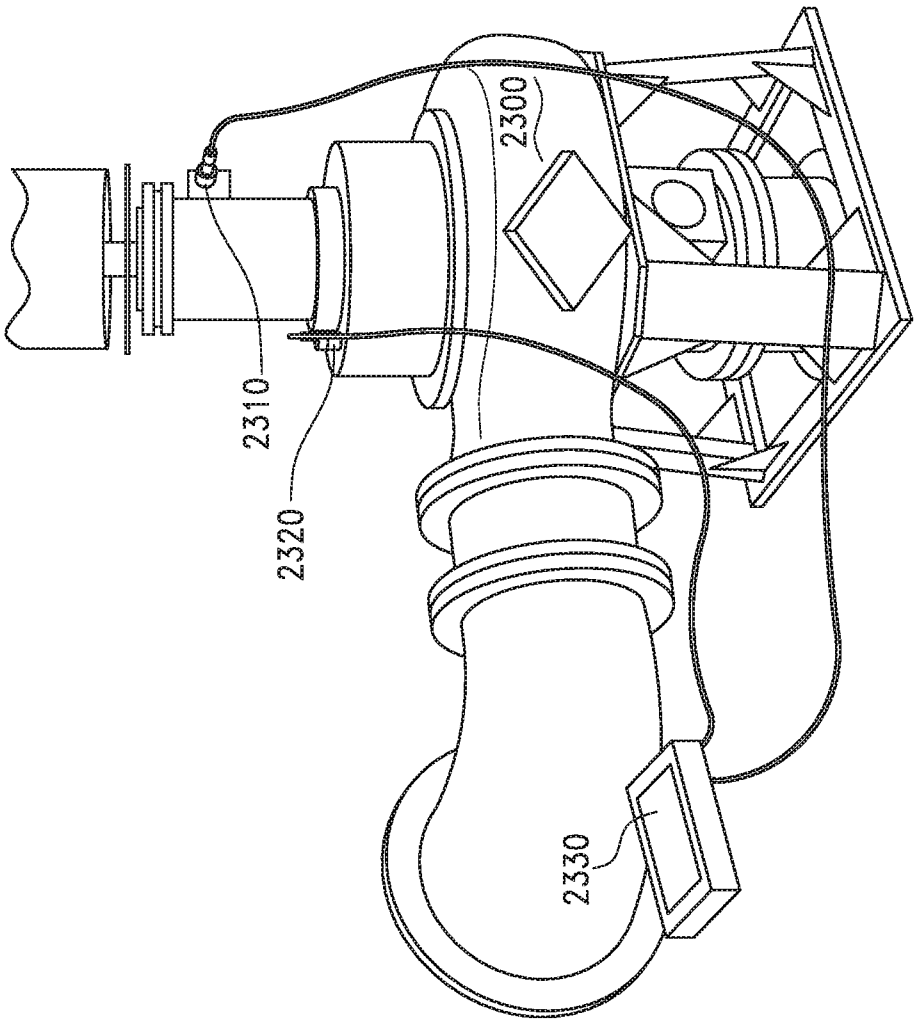
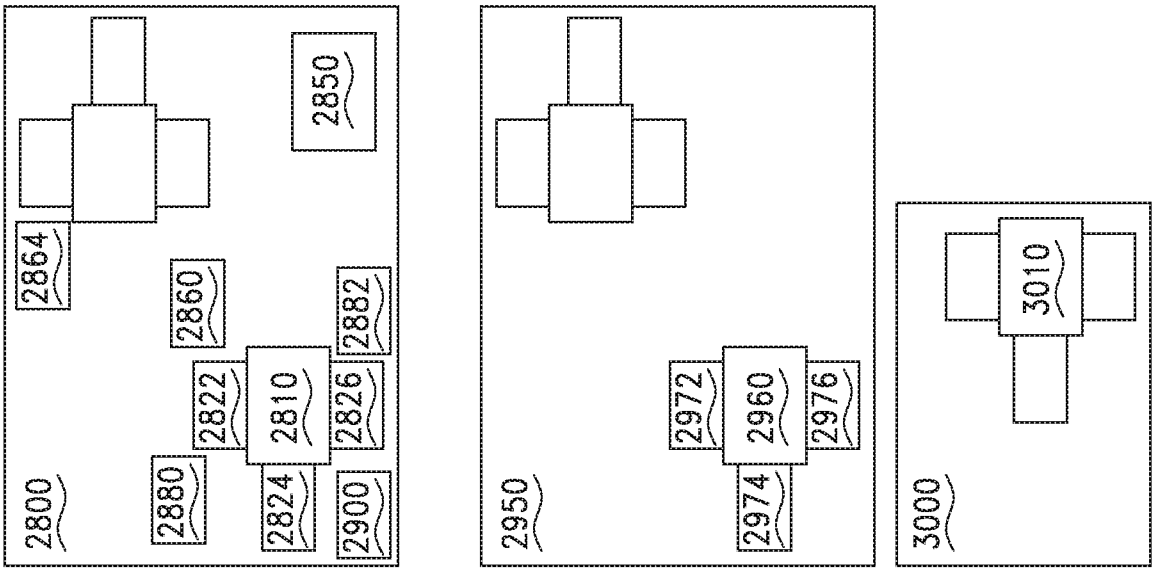


FIG. 11


2800
2850
2864
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2822
2810
2826
2882
2880
2824
2900
2950
2972
2960
2976
2974
3000
3010

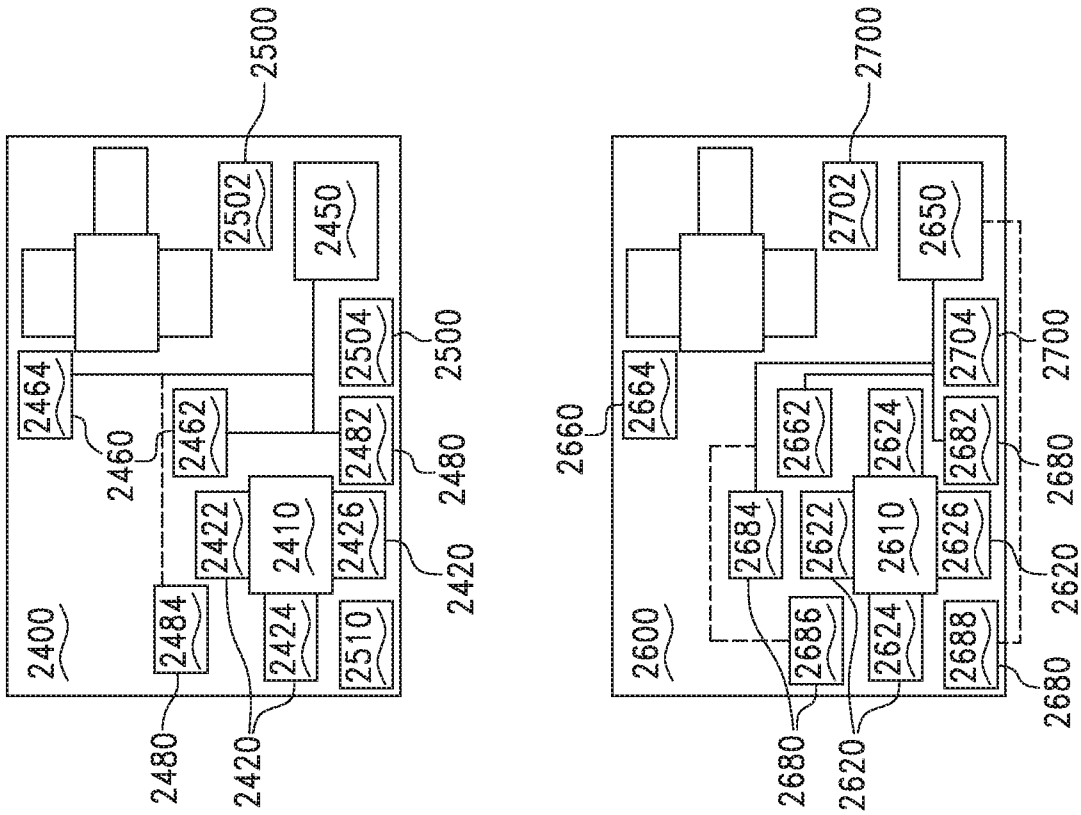
2400
2500
2502
2450
2464
2460
2462
2504
2482
2480
2422
2410
2426
2420
2484
2424
2510
2600
2700
2702
2650
2664
2660
2662
2624
2704
2682
2684
2622
2610
2626
2686
2624
2688
2680
2620

FIG. 12

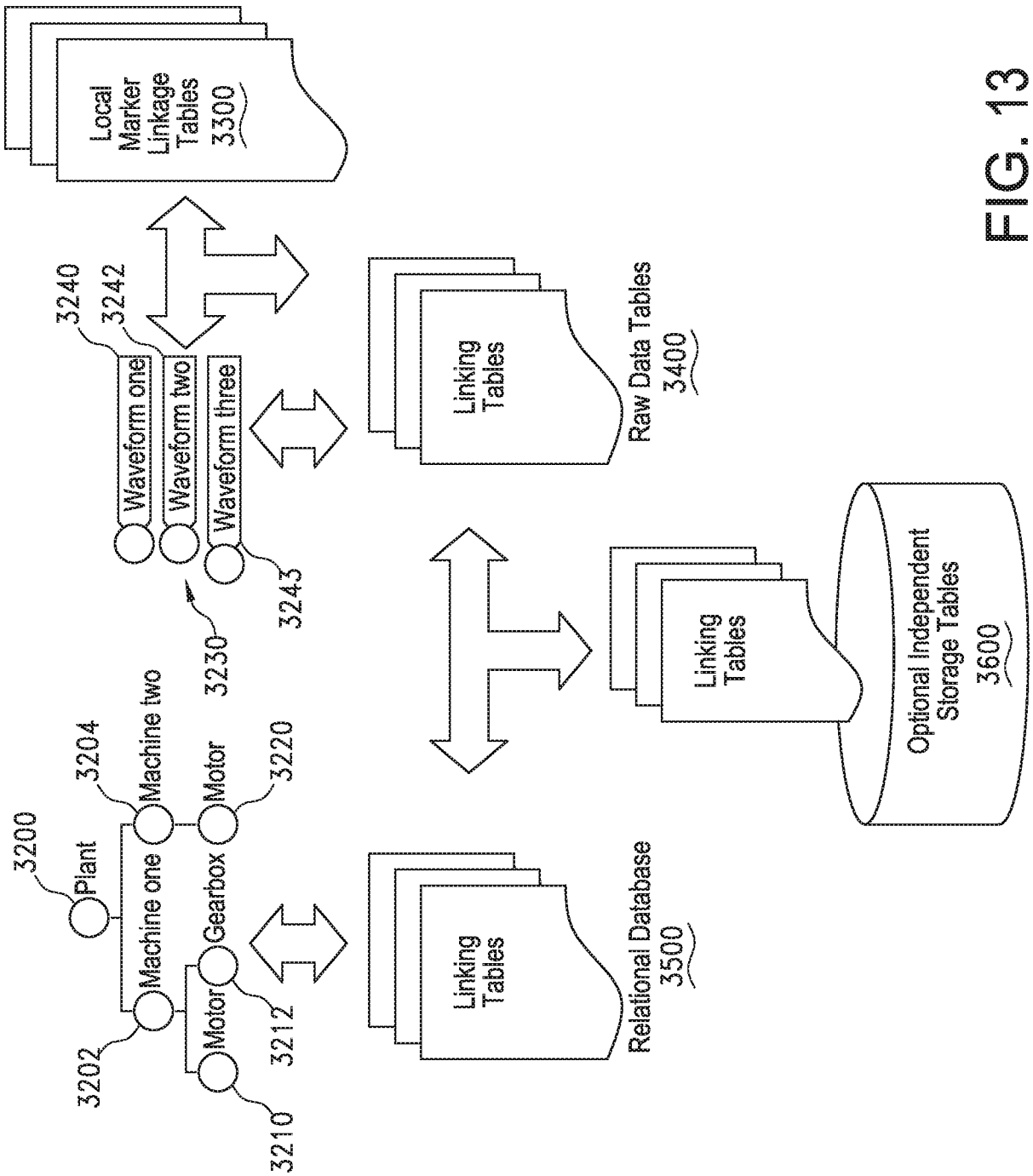
Local Marker Linkage Tables 3300
3240
3242
Waveform one
Waveform two
Waveform three
3243
3230
Linking Tables
Raw Data Tables 3400
Linking Tables
Optional Independent Storage Tables 3600
Linking Tables
Relational Database 3500
3200
Plant
3204
Machine two
Motor
3220
Machine one
Gearbox
Motor
3212
3202
Motor
3210

FIG. 13

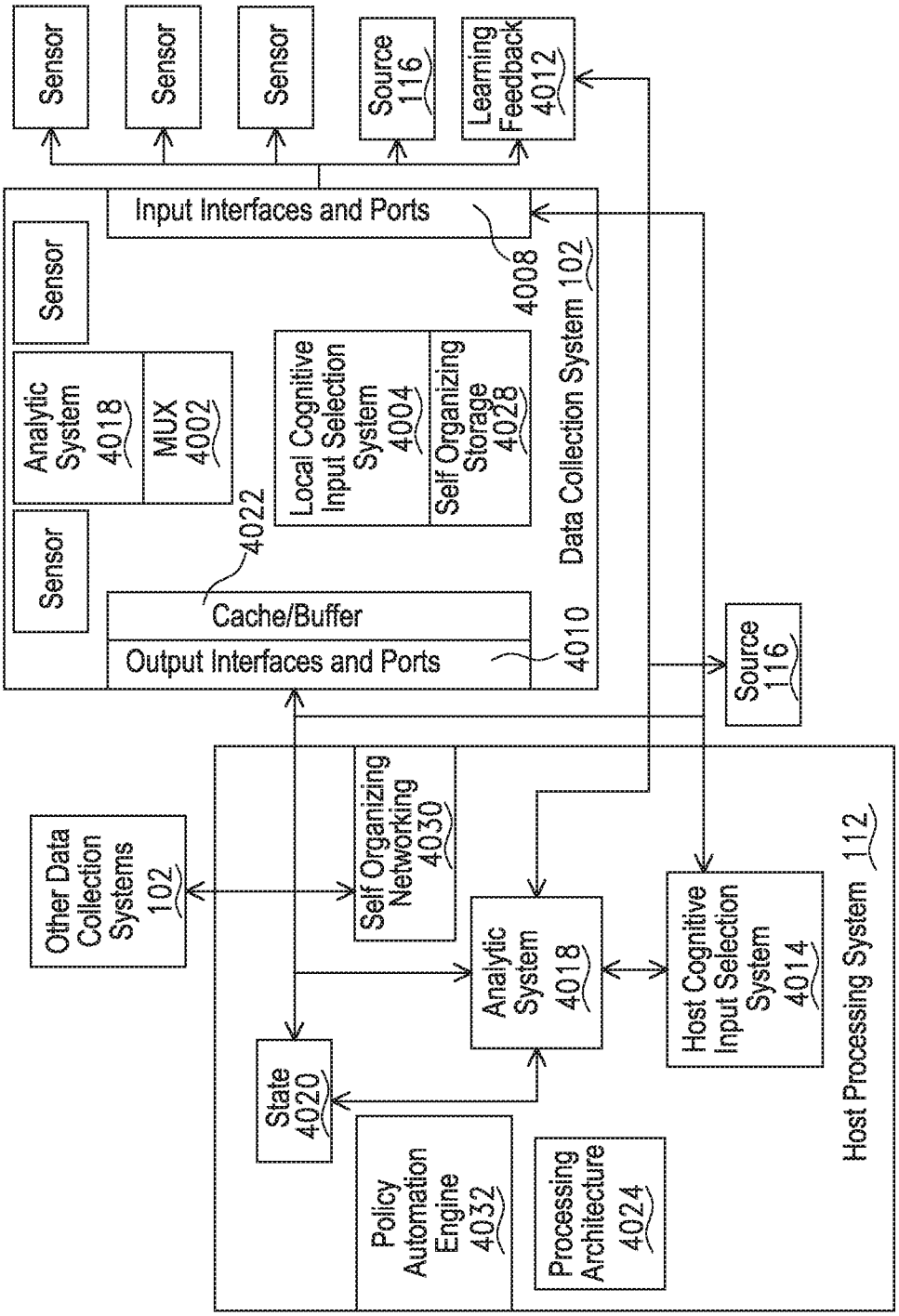
Sensor
Sensor
Sensor
Source 116
Learning Feedback 4012
Input Interfaces and Ports
4008
Sensor
Analytic System 4018
MUX 4002
Local Cognitive Input Selection System 4004
Self Organizing Storage 4028
Data Collection System 102
Sensor
4022
Cache/Buffer
Output Interfaces and Ports
4010
Source 116
Other Data Collection Systems 102
Self Organizing Networking 4030
Analytic System 4018
Host Cognitive Input Selection System 4014
State 4020
Policy Automation Engine 4032
Processing Architecture 4024
Host Processing System 112

FIG. 14

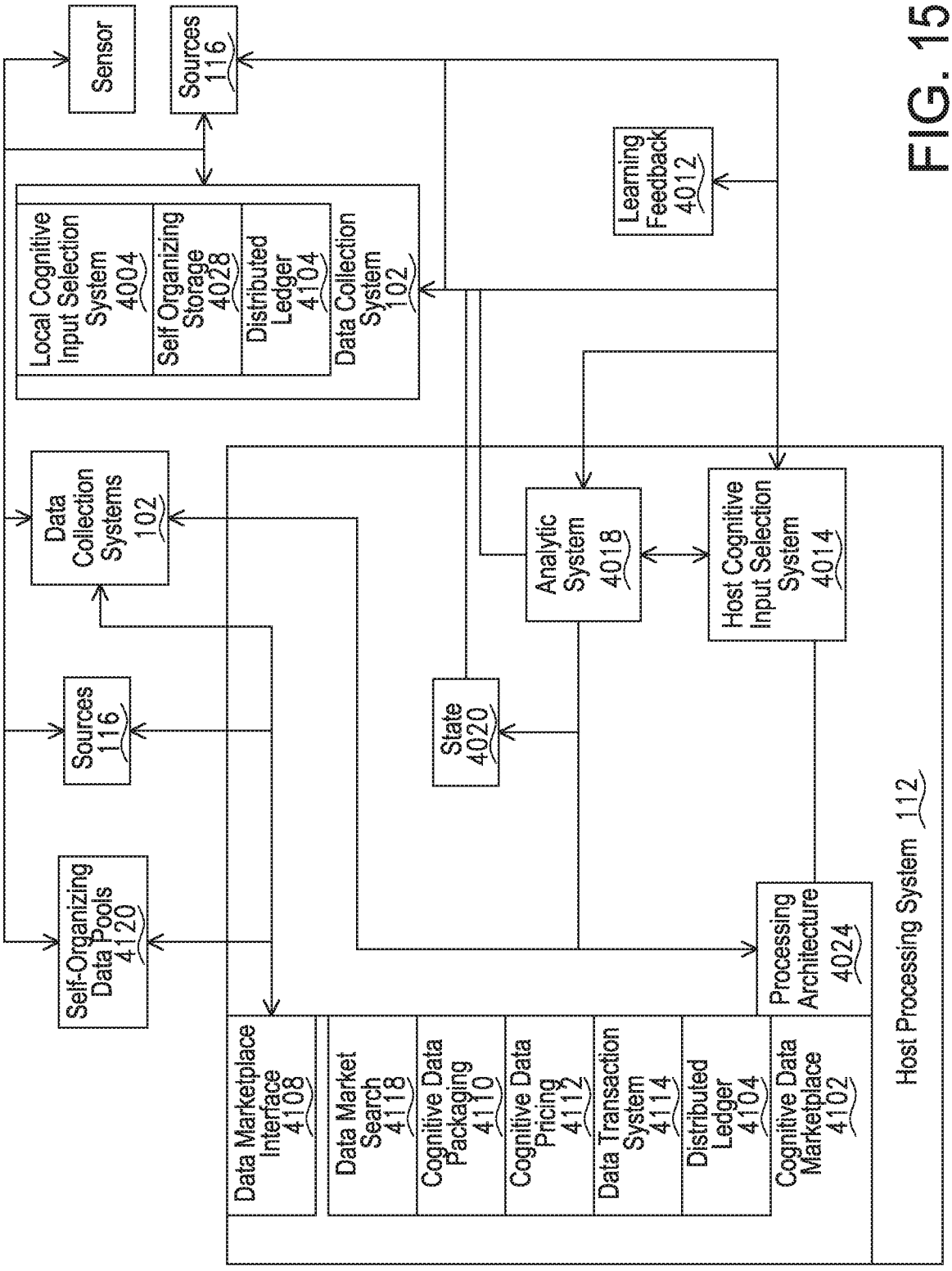
Sensor
Sources 116
Local Cognitive Input Selection System 4004
Self Organizing Storage 4028
Distributed Ledger 4104
Data Collection System 102
Learning Feedback 4012
Data Collection Systems 102
Analytic System 4018
Host Cognitive Input Selection System 4014
Sources 116
State 4020
Self-Organizing Data Pools 4120
Processing Architecture 4024
Data Marketplace Interface 4108
Data Market Search 4118
Cognitive Data Packaging 4110
Cognitive Data Pricing 4112
Data Transaction System 4114
Distributed Ledger 4104
Cognitive Data Marketplace 4102
Host Processing System 112

FIG. 15

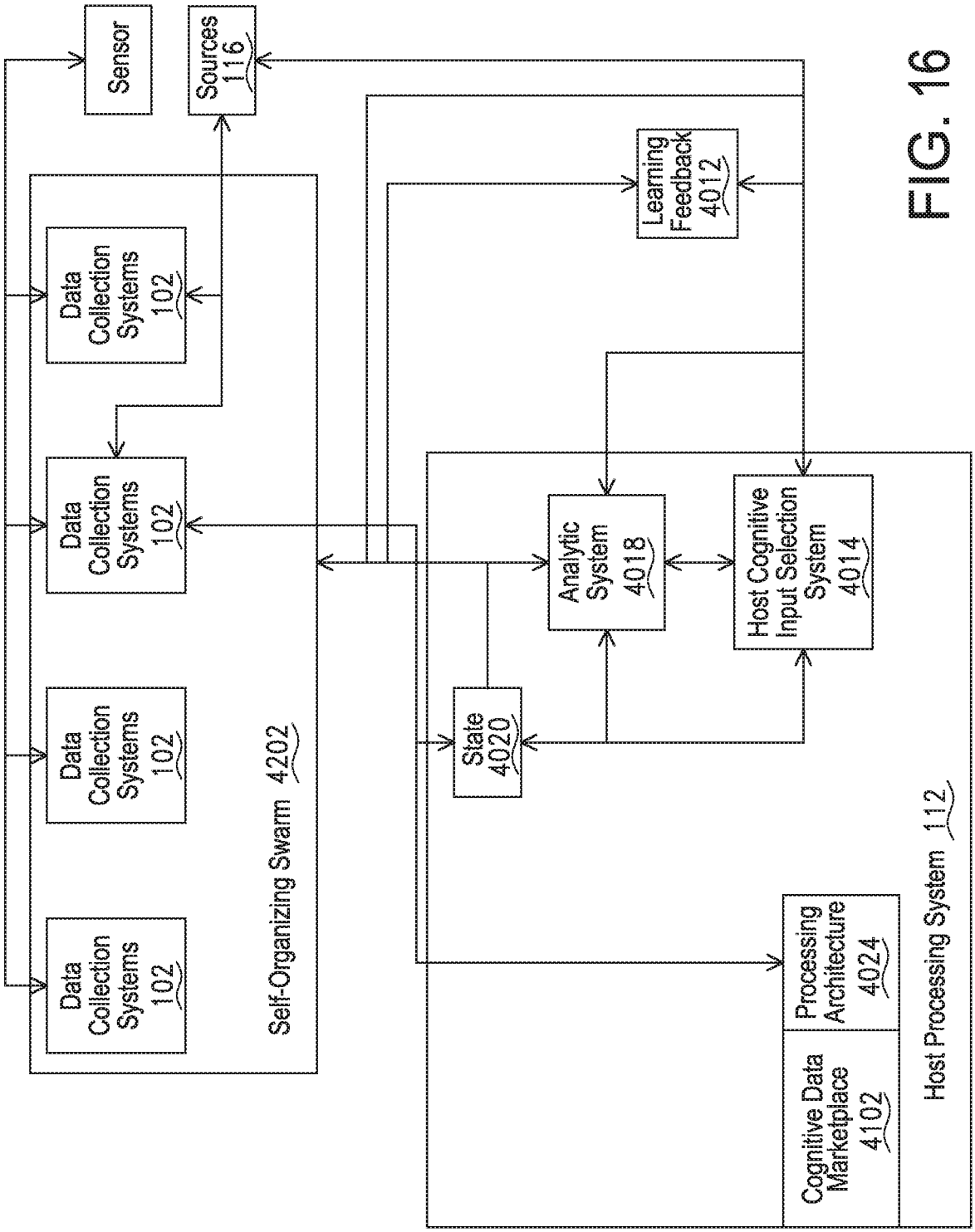
Sensor
Sources 116
Learning Feedback 4012
Data Collection Systems 102
Data Collection Systems 102
Data Collection Systems 102
Data Collection Systems 102
Analytic System 4018
Host Cognitive Input Selection System 4014
State 4020
Self-Organizing Swarm 4202
Processing Architecture 4024
Cognitive Data Marketplace 4102
Host Processing System 112

FIG. 16

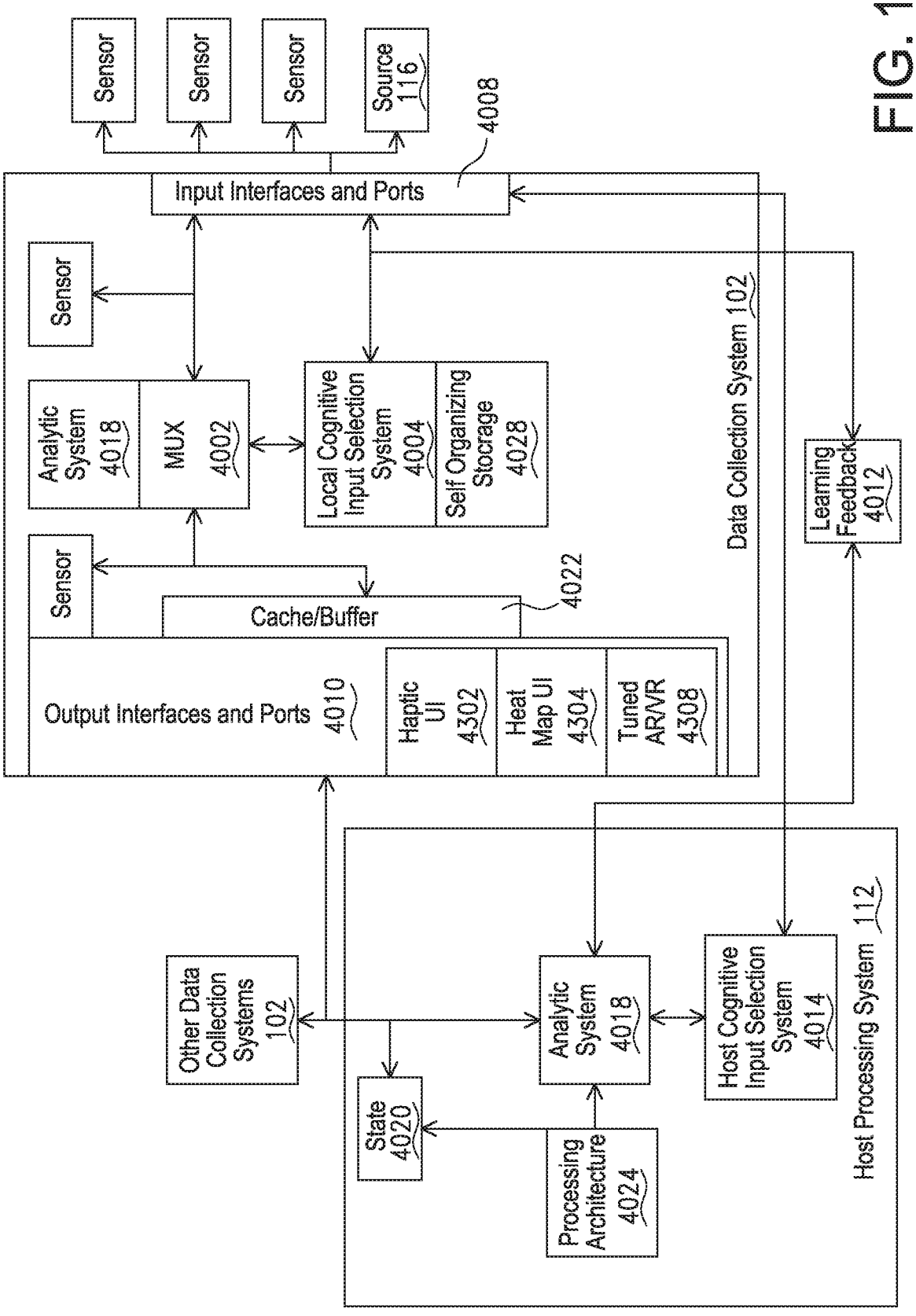
Sensor
Sensor
Sensor
Source 116
4008
Input Interfaces and Ports
Sensor
Analytic System 4018
MUX 4002
Local Cognitive Input Selection System 4004
Self Organizing Stocrage 4028
Data Collection System 102
Learning Feedback 4012
Sensor
Cache/Buffer
4022
Output Interfaces and Ports 4010
Haptic UI 4302
Heat Map UI 4304
Tuned AR/VR 4308
Other Data Collection Systems 102
Analytic System 4018
Host Cognitive Input Selection System 4014
State 4020
Processing Architecture 4024
Host Processing System 112

FIG. 17

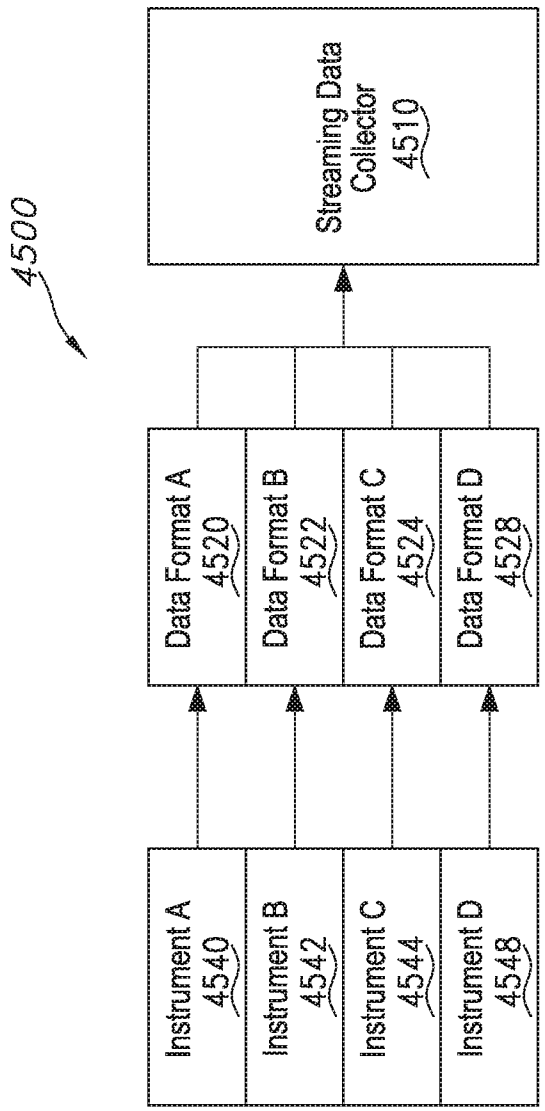
4500
Streaming Data Collector 4510
Data Format A 4520
Data Format B 4522
Data Format C 4524
Data Format D 4528
Instrument A 4540
Instrument B 4542
Instrument C 4544
Instrument D 4548

FIG. 18

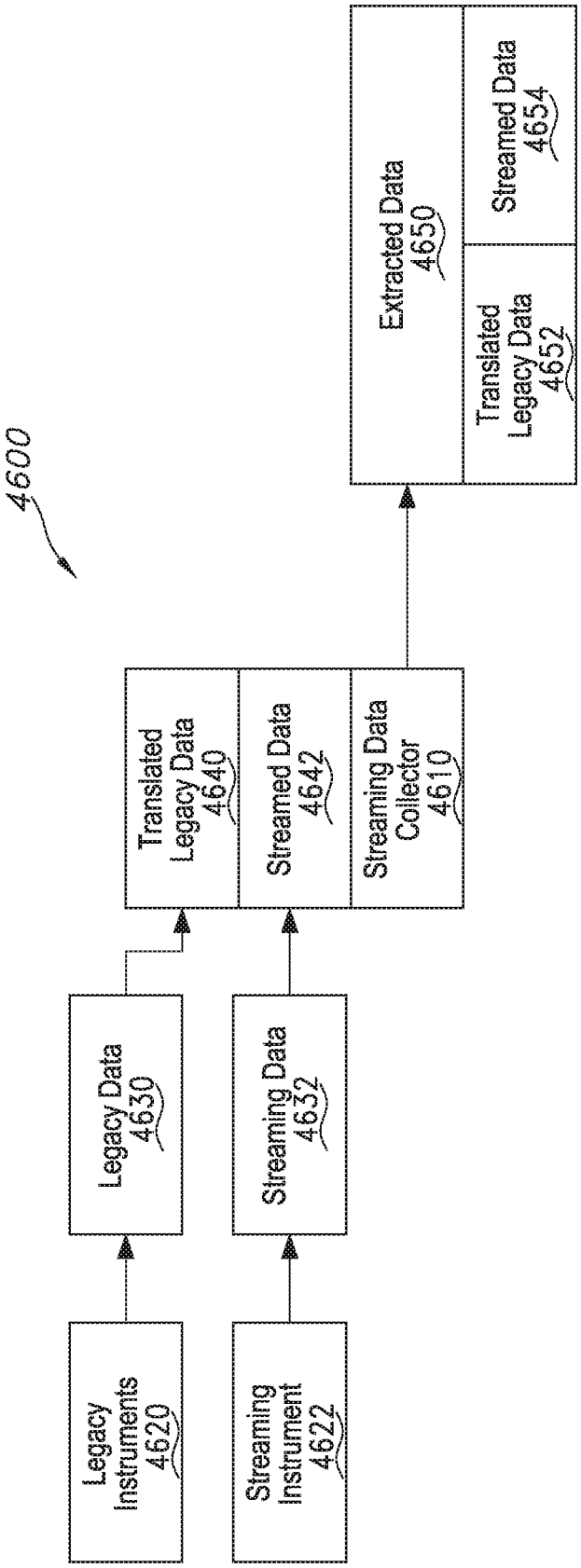
4600
Legacy Instruments 4620
Streaming Instrument 4622
Legacy Data 4630
Streaming Data 4632
Translated Legacy Data 4640
Streamed Data 4642
Streaming Data Collector 4610
Extracted Data 4650
Translated Legacy Data 4652
Streamed Data 4654

FIG. 19

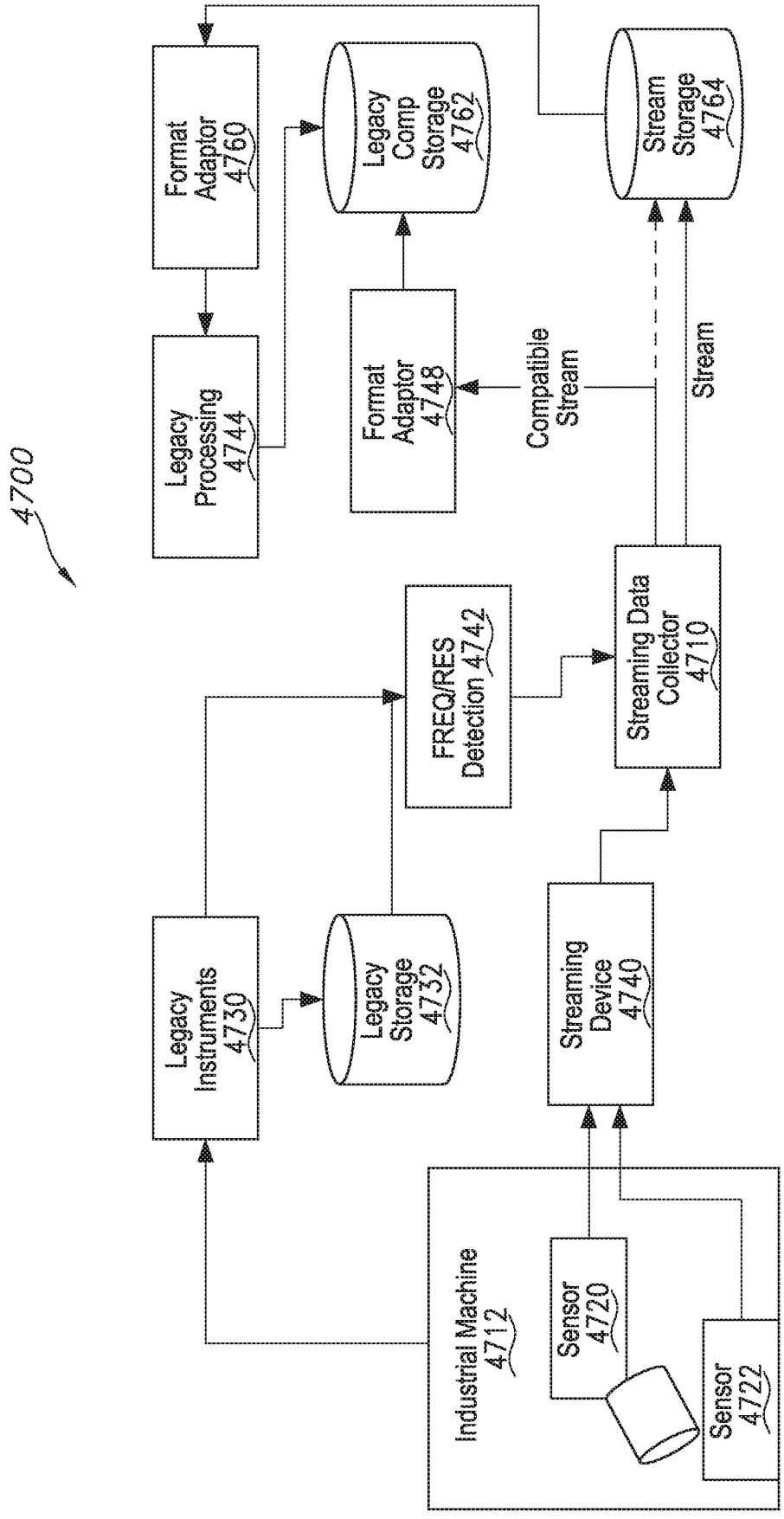
4700
Format Adaptor 4760
Legacy Comp Storage 4762
Stream Storage 4764
Legacy Processing 4744
Format Adaptor 4748
Compatible Stream
Stream
FREQ/RES Detection 4742
Streaming Data Collector 4710
Legacy Instruments 4730
Legacy Storage 4732
Streaming Device 4740
Industrial Machine 4712
Sensor 4720
Sensor 4722

FIG. 20

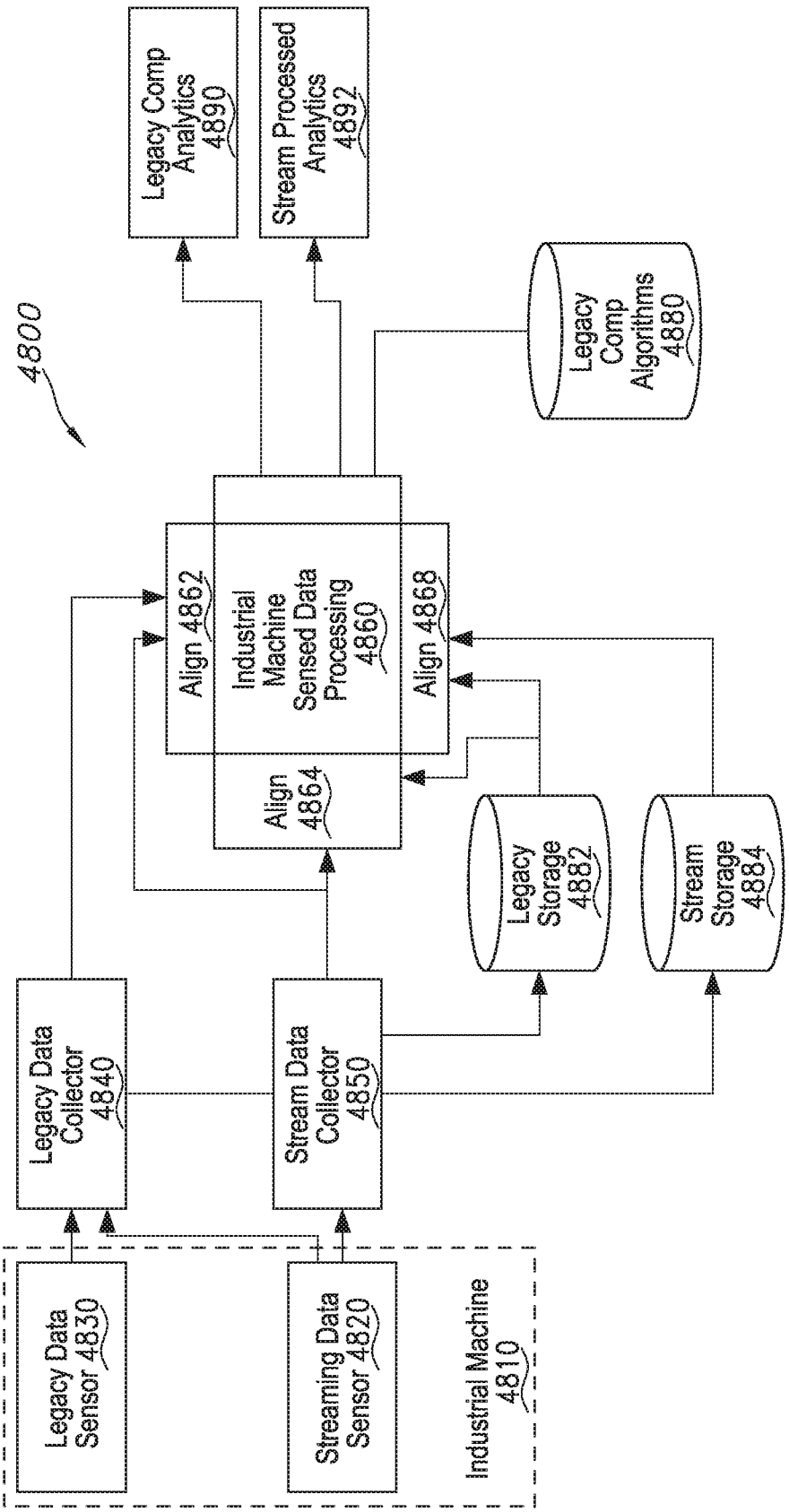
4800
Legacy Comp Analytics 4890
Stream Processed Analytics 4892
Legacy Comp Algorithms 4880
Align 4862
Industrial Machine Sensed Data Processing 4860
Align 4868
Align 4864
Legacy Storage 4882
Stream Storage 4884
Legacy Data Collector 4840
Stream Data Collector 4850
Legacy Data Sensor 4830
Streaming Data Sensor 4820
Industrial Machine 4810

FIG. 21

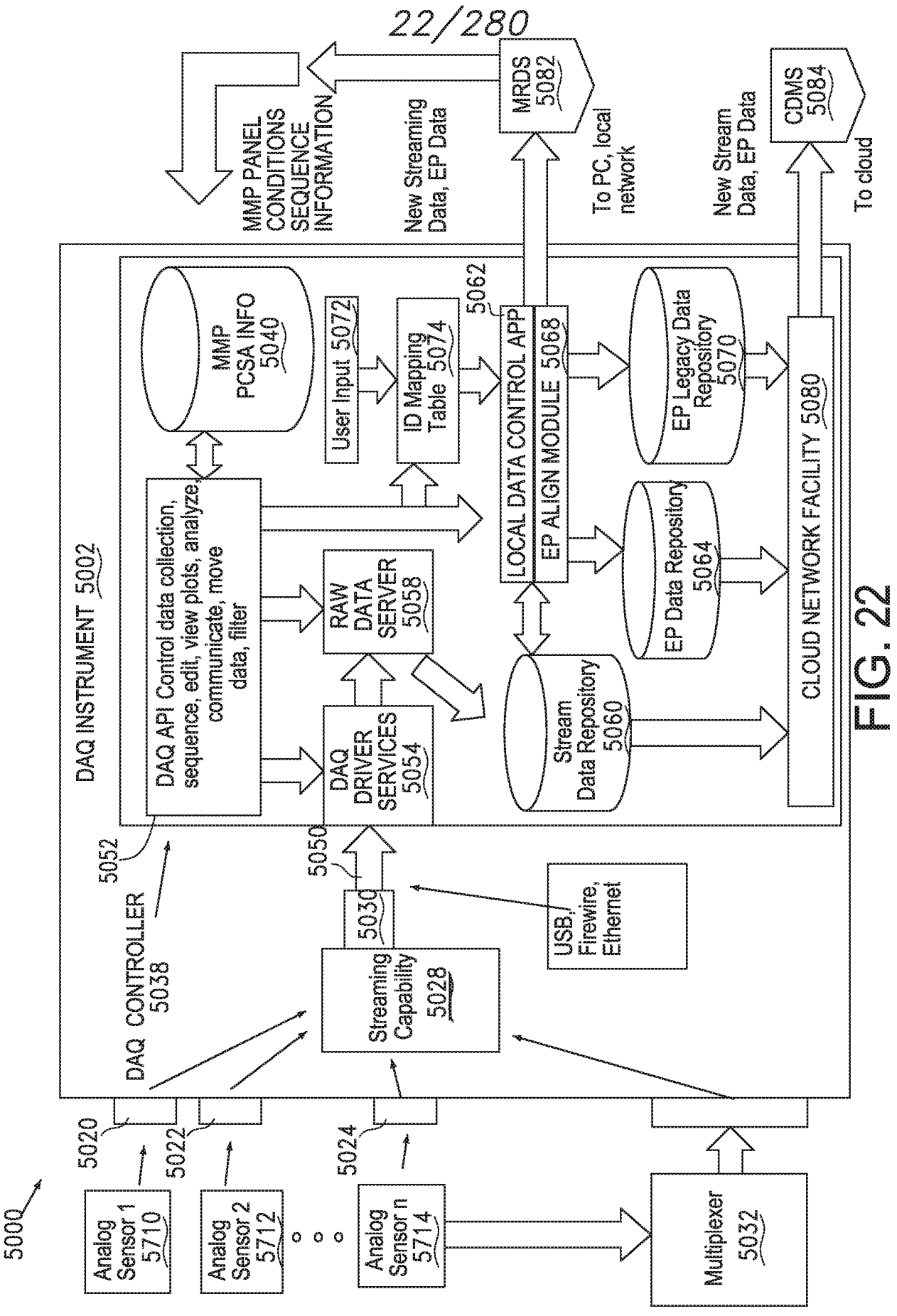
5000
Analog Sensor 1 5710
Analog Sensor 2 5712
Analog Sensor n 5714
5020
5022
5024
DAQ INSTRUMENT 5002
DAQ CONTROLLER 5038
5052
DAQ API Control data collection, sequence, edit, view plots, analyze, communicate, move data, filter
MMP PCSA INFO 5040
User Input 5072
ID Mapping Table 5074
5062
LOCAL DATA CONTROL APP
EP ALIGN MODULE 5068
RAW DATA SERVER 5058
DAQ DRIVER SERVICES 5054
5050
5030
Streaming Capability 5028
USB, Firewire, Ethernet
Stream Data Repository 5060
EP Data Repository 5064
EP Legacy Data Repository 5070
CLOUD NETWORK FACILITY 5080
Multiplexer 5032
MMP PANEL CONDITIONS SEQUENCE INFORMATION
New Streaming Data, EP Data
MRDS 5082
To PC, local network
New Stream Data, EP Data
CDMS 5084
To cloud

FIG. 22

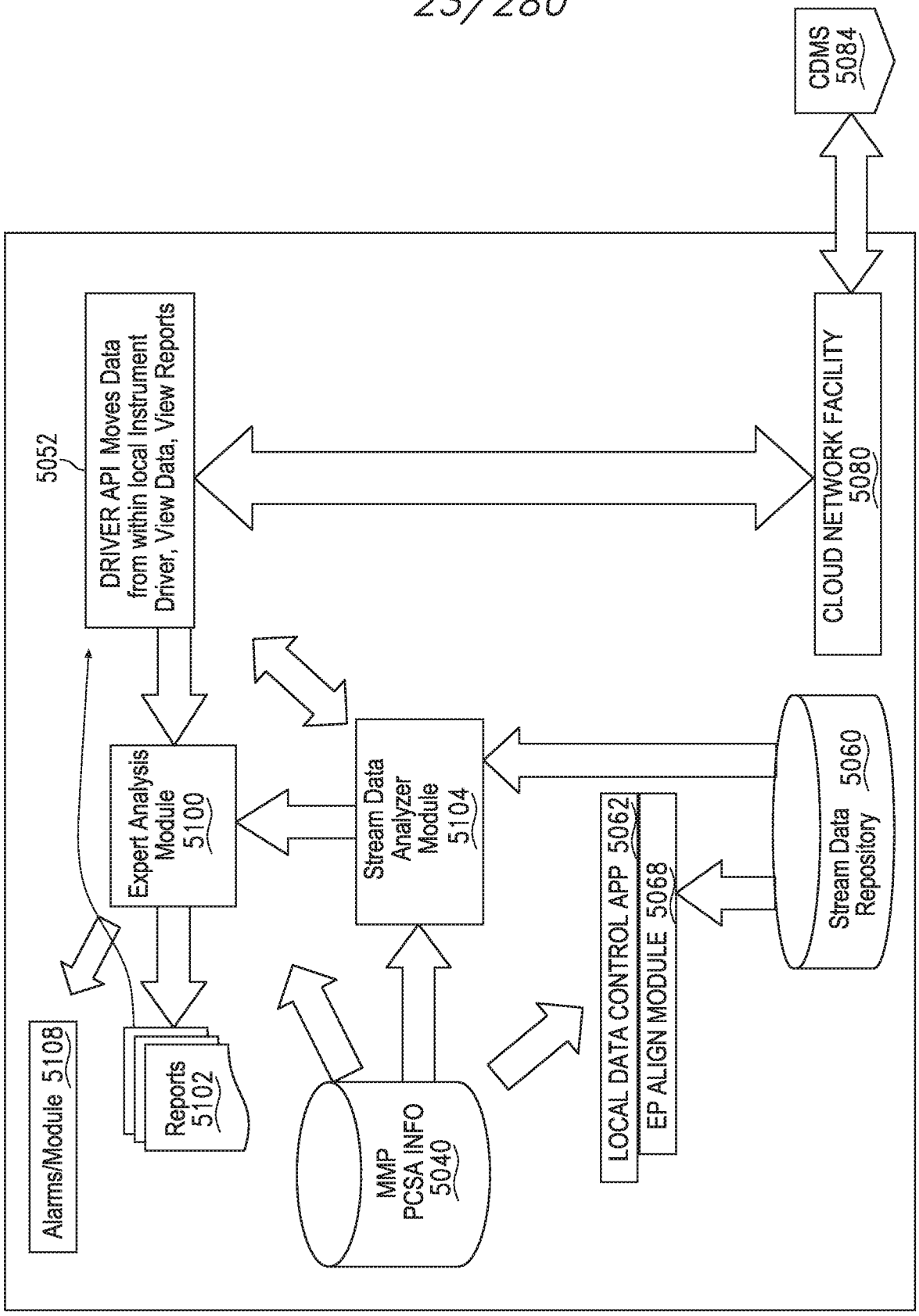
CDMS 5084
5052
DRIVER API Moves Data from within local Instrument Driver, View Data, View Reports
CLOUD NETWORK FACILITY 5080
Expert Analysis Module 5100
Stream Data Analyzer Module 5104
Stream Data Repository 5060
LOCAL DATA CONTROL APP 5062
EP ALIGN MODULE 5068
Alarms/Module 5108
Reports 5102
MMP PCSA INFO 5040

FIG. 23

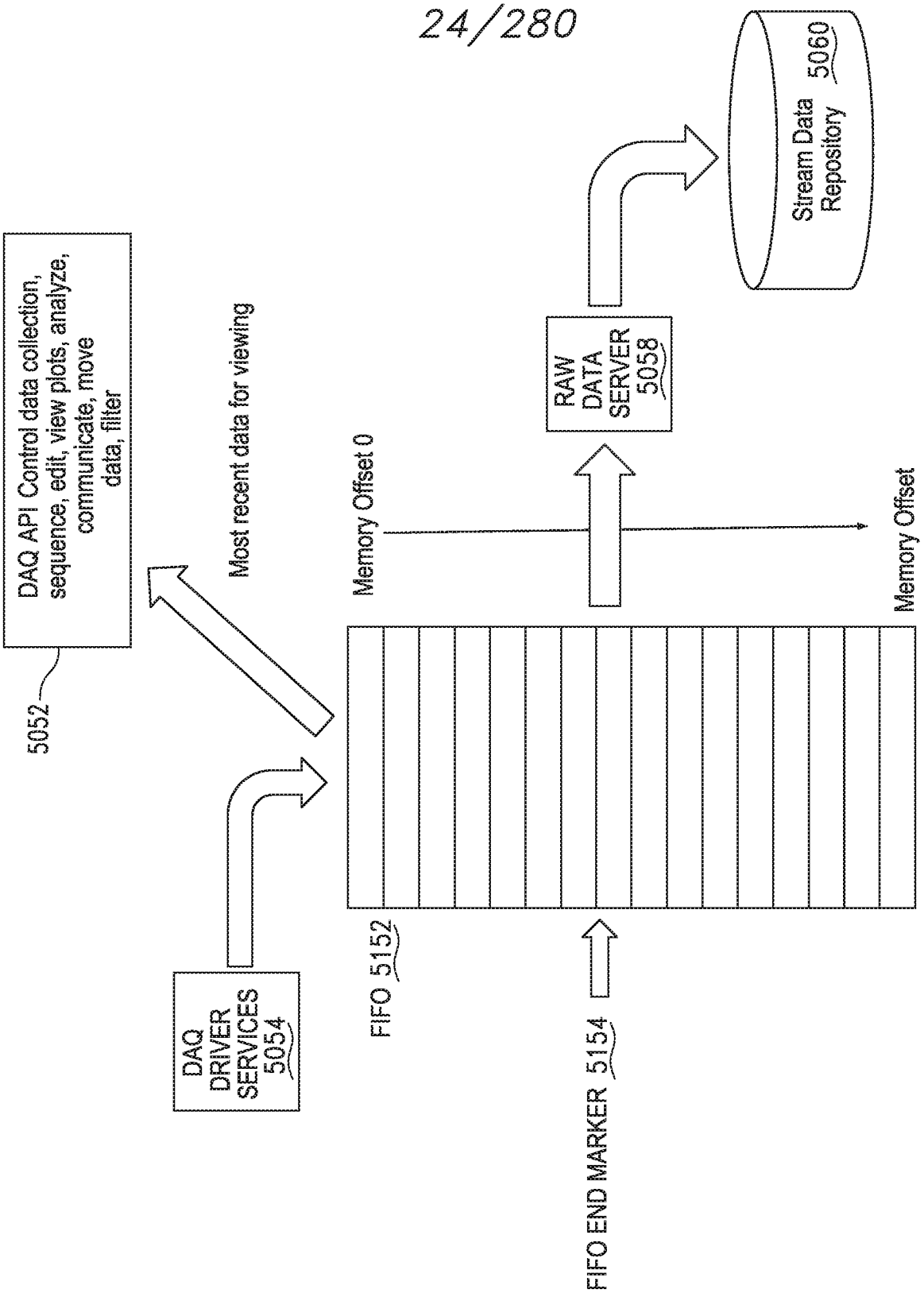
DAQ API Control data collection, sequence, edit, view plots, analyze, communicate, move data, filter
5052
Most recent data for viewing
Memory Offset 0
Memory Offset
RAW DATA SERVER 5058
Stream Data Repository 5060
DAQ DRIVER SERVICES 5054
FIFO 5152
FIFO END MARKER 5154

FIG. 24

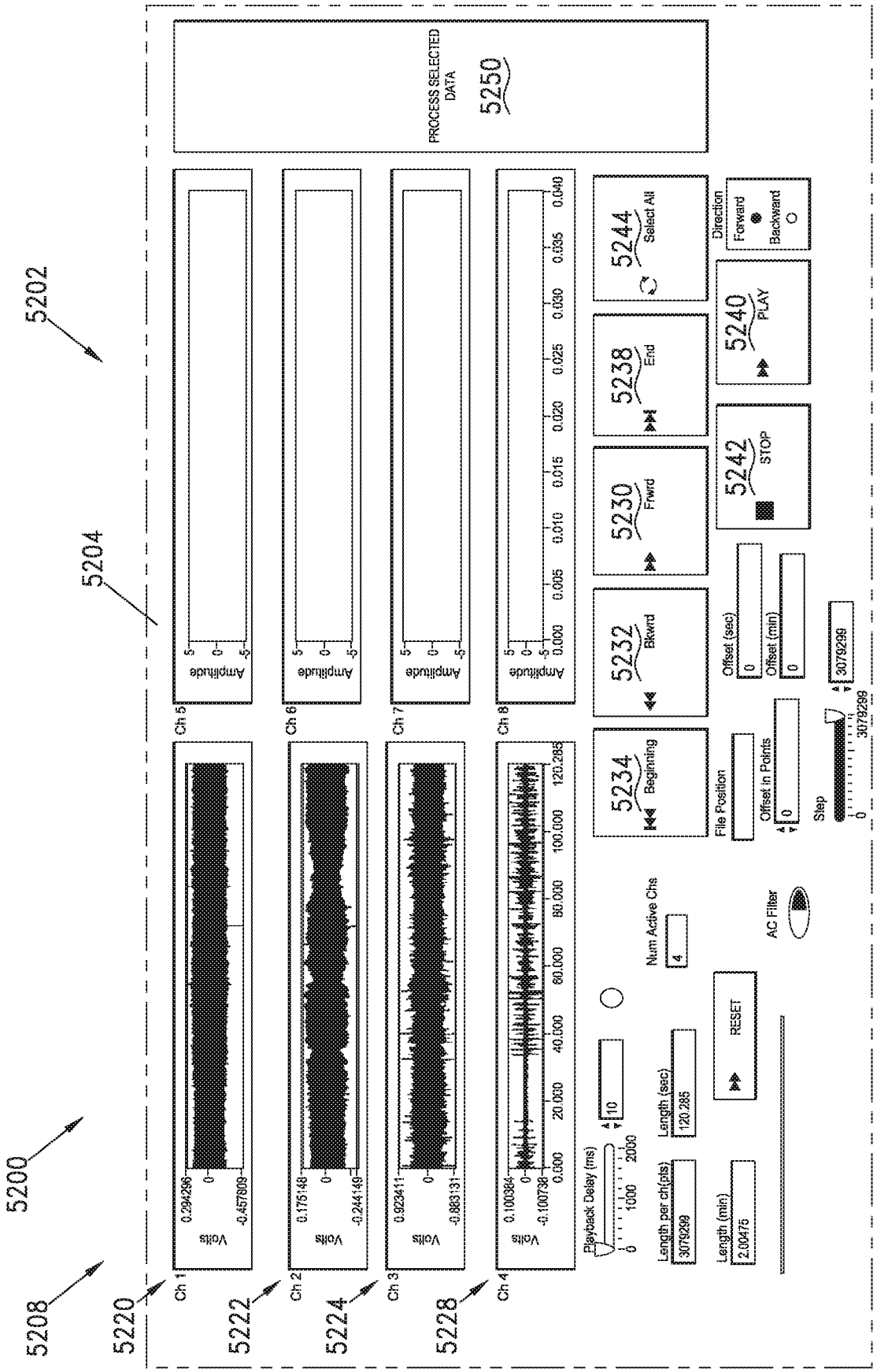
5200
5202
5204
5208
5220
5222
5224
5228
PROCESS SELECTED DATA
5250
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
Ch 8
Amplitude
Volts
5234 Beginning
5232 Bkwrd
5230 Frwrd
5238 End
5242 STOP
5240 PLAY
5244 Select All
Direction
Forward
Backward
File Position
Offset (sec)
Offset (min)
Offset in Points
Step
Playback Delay (ms)
Num Active Chs
Length (sec)
Length per ch(pts)
Length (min)
RESET
AC Filter

FIG. 25

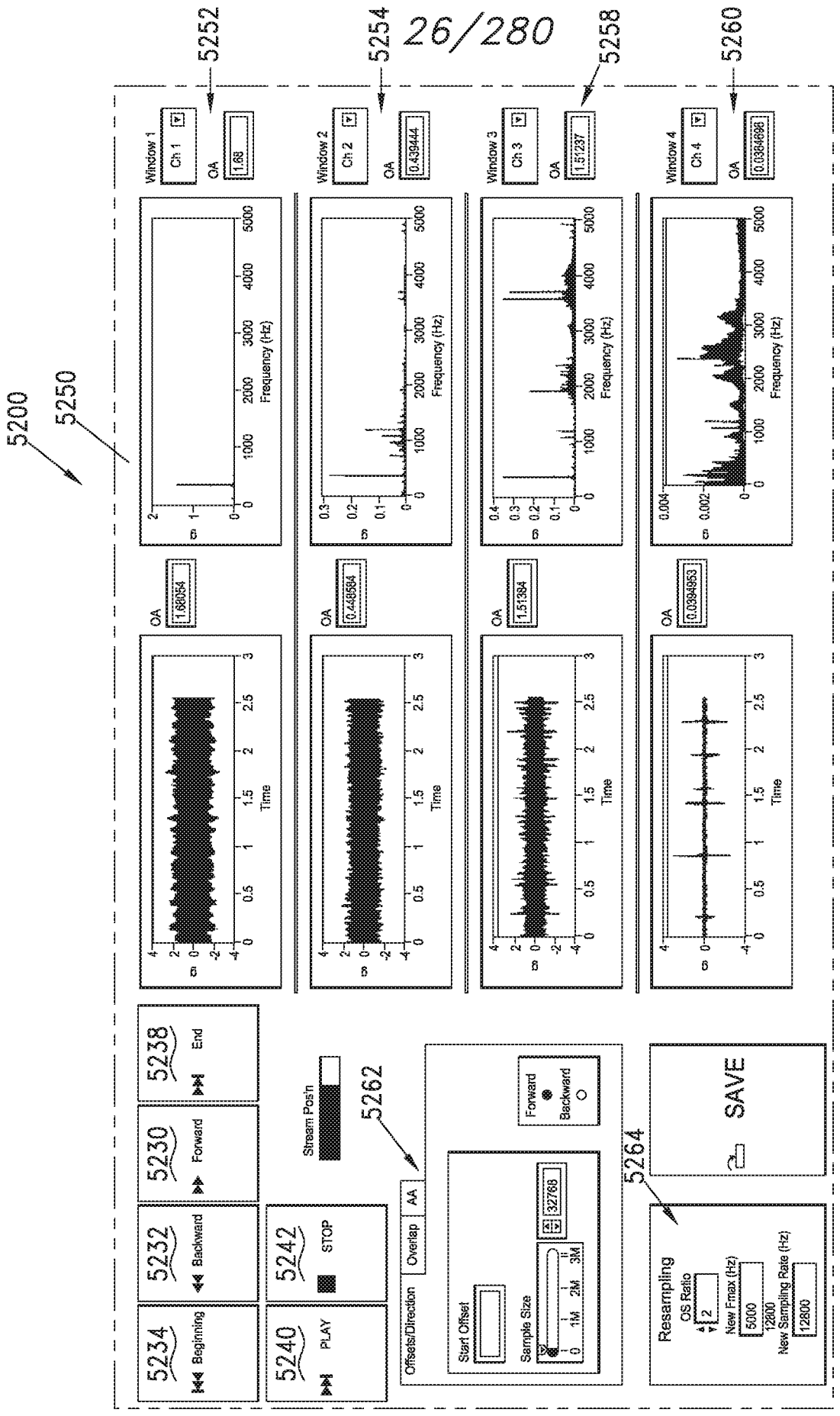
5200
5250
5252
5254
5258
5260
5262
5264
Window 1
Ch 1
OA
1.68
Window 2
Ch 2
0.439444
Window 3
Ch 3
1.51237
Window 4
Ch 4
0.0364696
1.68054
0.448564
1.51384
0.0394953
Frequency (Hz)
Time
5234 Beginning
5232 Backward
5240 PLAY
5242 STOP
5230 Forward
5238 End
Stream Pos'n
Offsets/Direction
Overlap
AA
Start Offset
Sample Size
32768
Forward
Backward
Resampling
OS Ratio
2
New Fmax (Hz)
5000
12800
New Sampling Rate (Hz)
12800
SAVE

FIG. 26

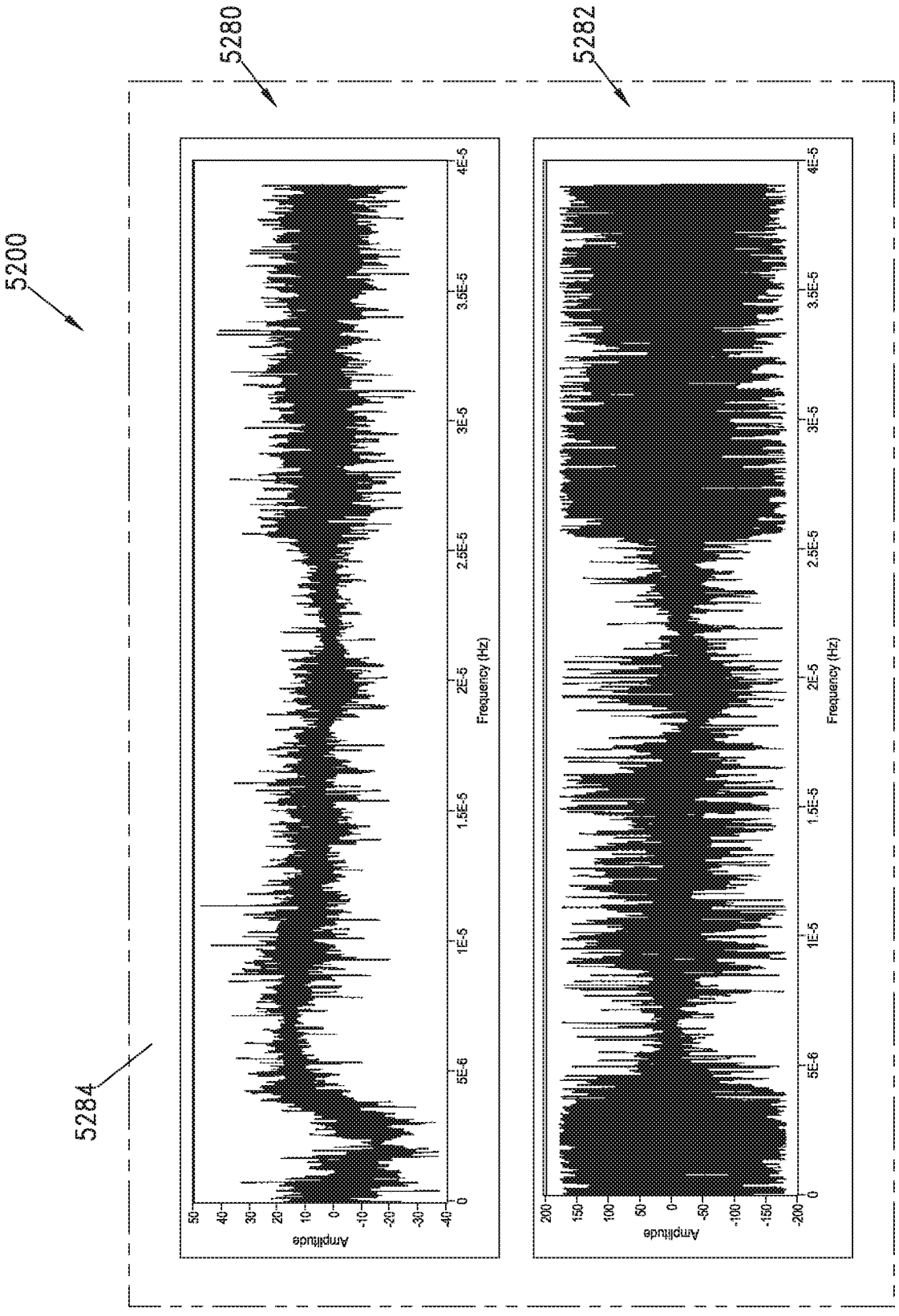
5200
5280
5282
5284
Amplitude
Frequency (Hz)
50
40
30
20
10
0
-10
-20
-30
-40
5E-6
1E-5
1.5E-5
2E-5
2.5E-5
3E-5
3.5E-5
4E-5
200
150
100
50
0
-50
-100
-150
-200

FIG. 27

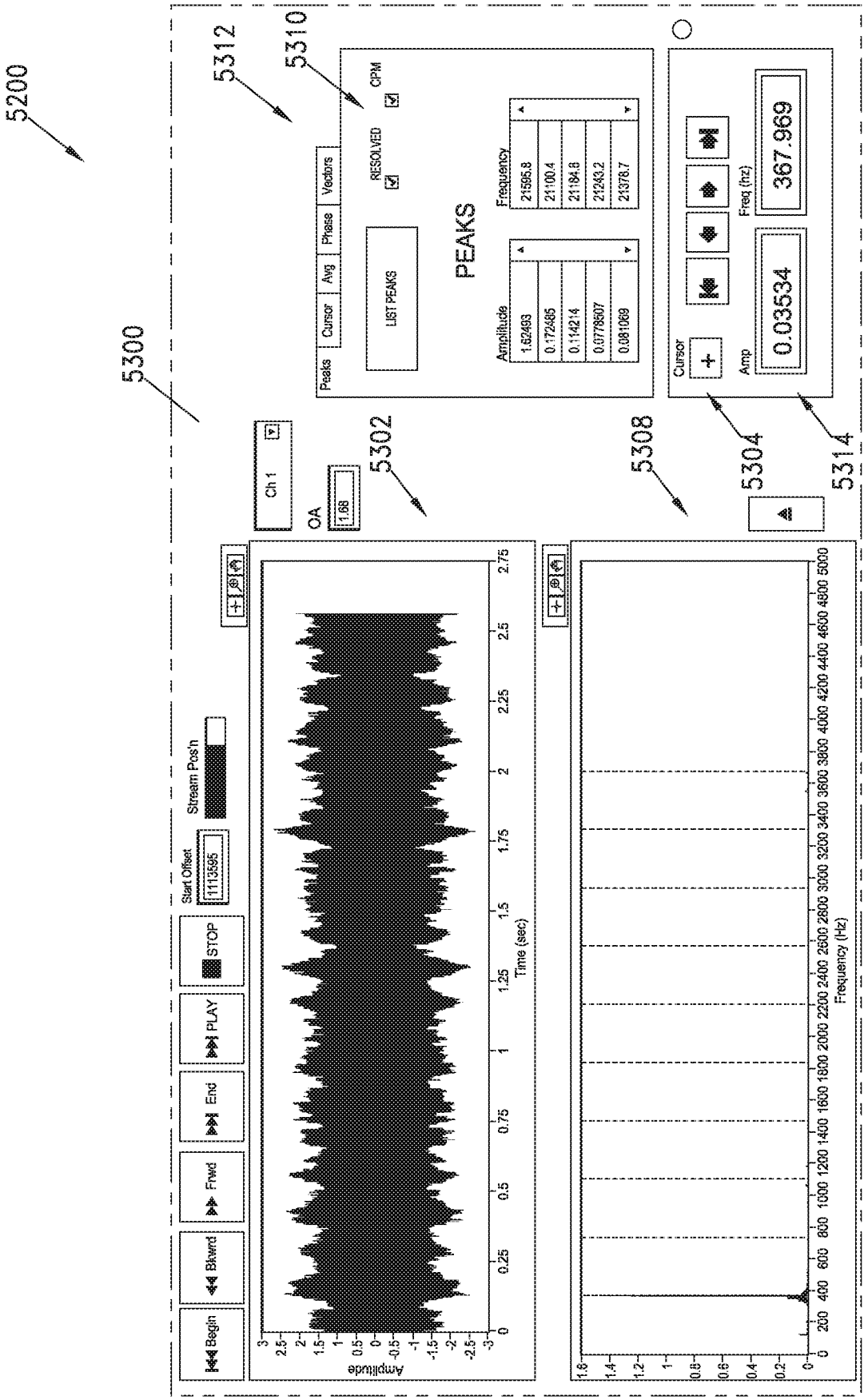
5200
5300
5310
5312
5302
5304
5308
5314
Peaks
Cursor
Avg
Phase
Vectors
LIST PEAKS
PEAKS
RESOLVED
CPM
Amplitude
Frequency
1.62493
0.172485
0.114214
0.0778507
0.0810069
21595.8
21100.4
21184.8
21243.2
21378.7
Cursor
Amp
Freq (hz)
0.03534
367.969
Ch 1
OA
1.68
Start Offset
11113595
Stream Pos'n
Begin
Bkwrd
Fwd
End
PLAY
STOP
Amplitude
Time (sec)
Frequency (Hz)

FIG. 28

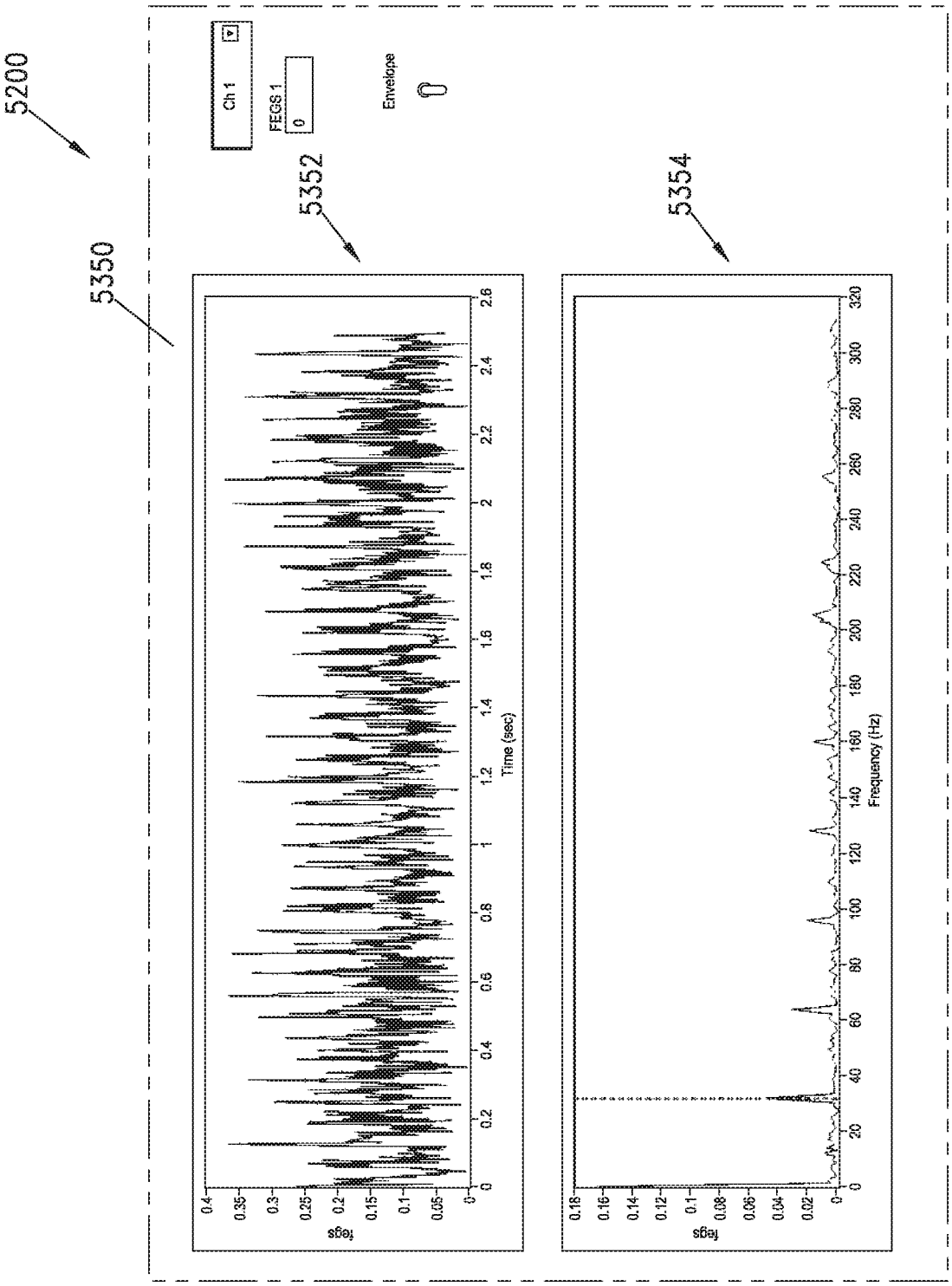
5200
5350
5352
5354
Ch 1
FEGS 1
0
Envelope
0
fegs
Time (sec)
Frequency (Hz)

FIG. 29

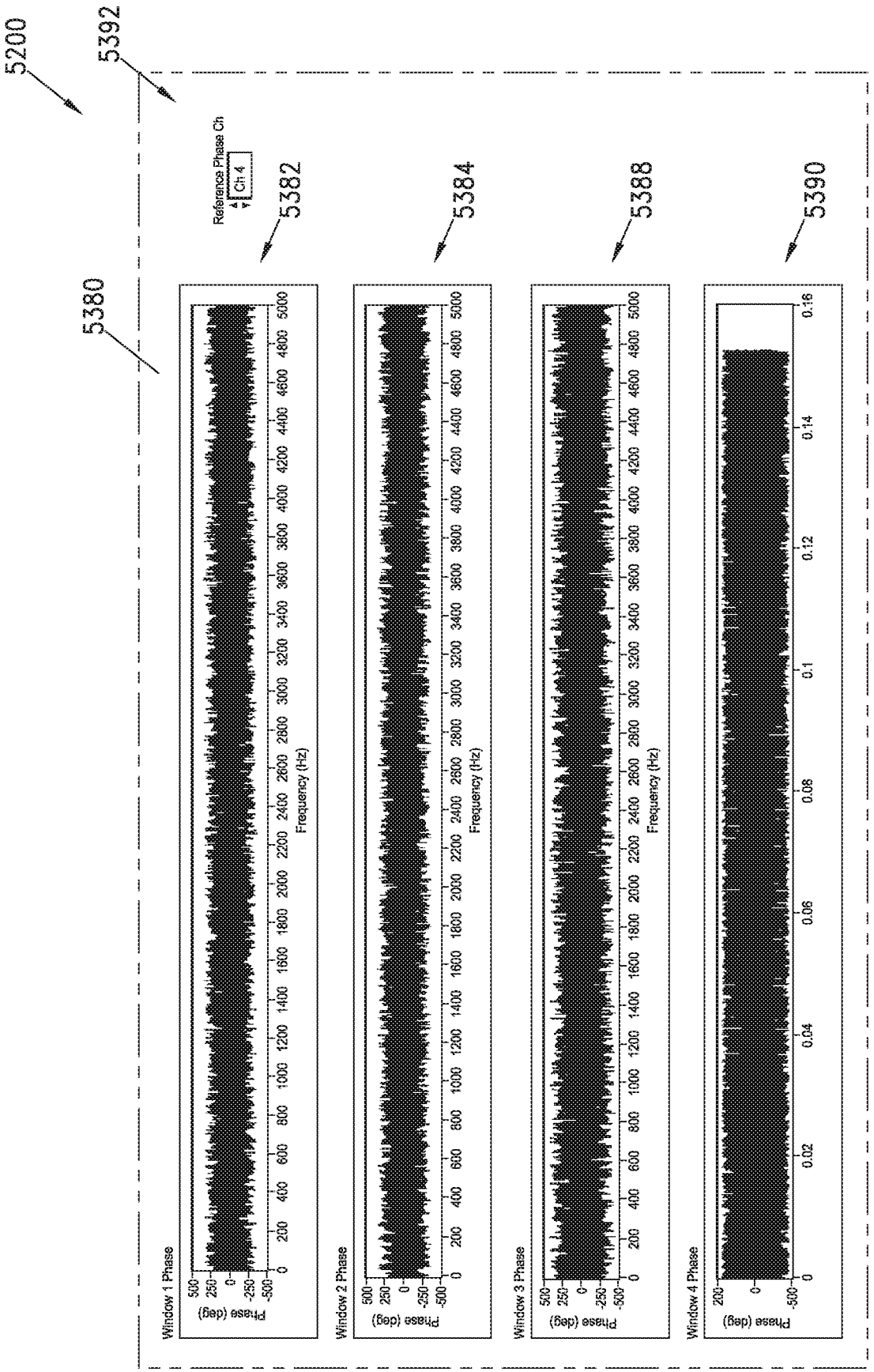
5200
5392
5380
5382
5384
5388
5390
Reference Phase Ch
Ch 4
Window 1 Phase
Window 2 Phase
Window 3 Phase
Window 4 Phase
Phase (deg)
Frequency (Hz)

FIG. 30

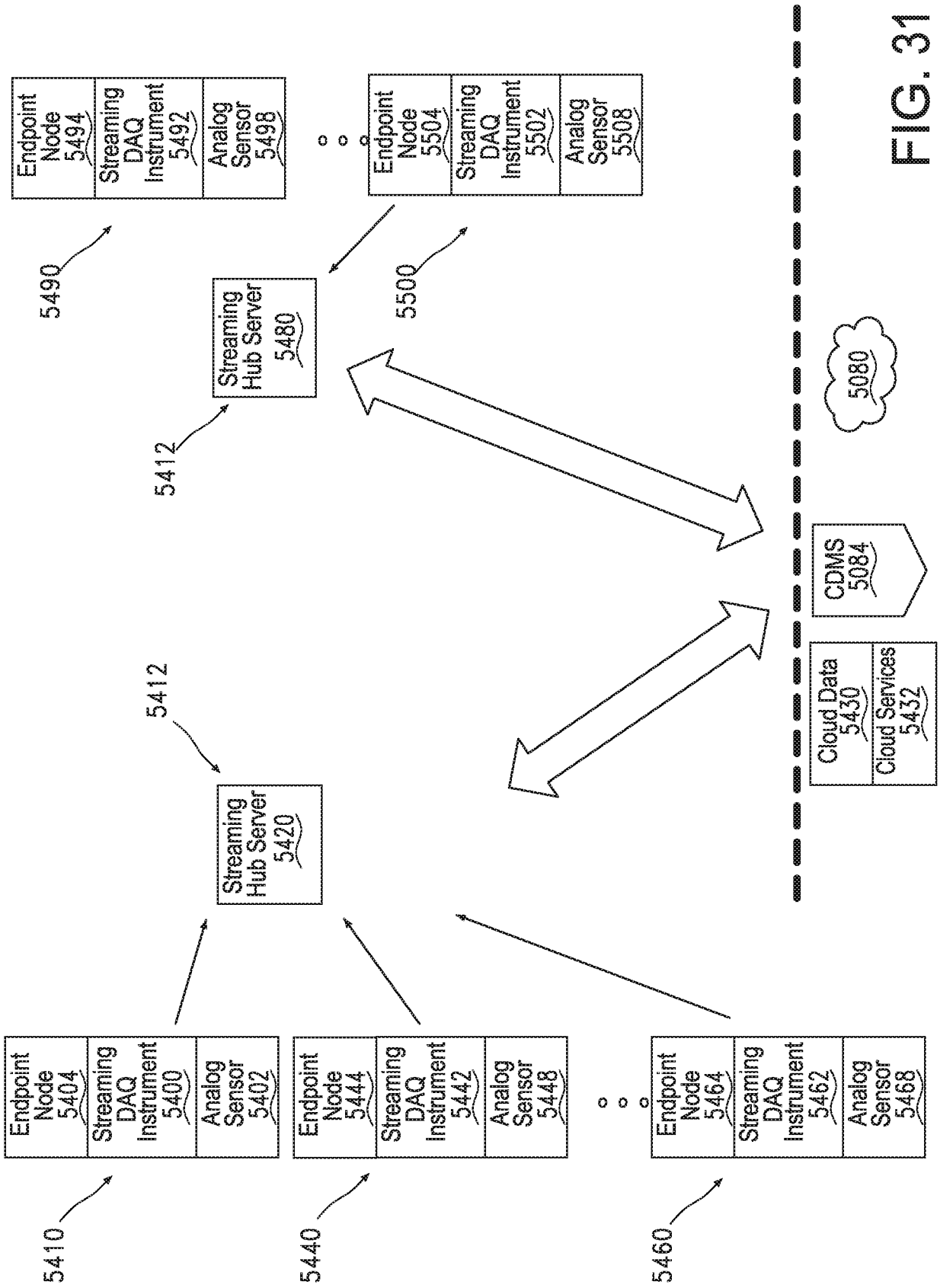
Endpoint Node 5494
Streaming DAQ Instrument 5492
Analog Sensor 5498
Endpoint Node 5504
Streaming DAQ Instrument 5502
Analog Sensor 5508
5490
5500
Streaming Hub Server 5480
5412
5080
CDMS 5084
Cloud Data 5430
Cloud Services 5432
5412
Streaming Hub Server 5420
Endpoint Node 5404
Streaming DAQ Instrument 5400
Analog Sensor 5402
Endpoint Node 5444
Streaming DAQ Instrument 5442
Analog Sensor 5448
Endpoint Node 5464
Streaming DAQ Instrument 5462
Analog Sensor 5468
5410
5440
5460

FIG. 31

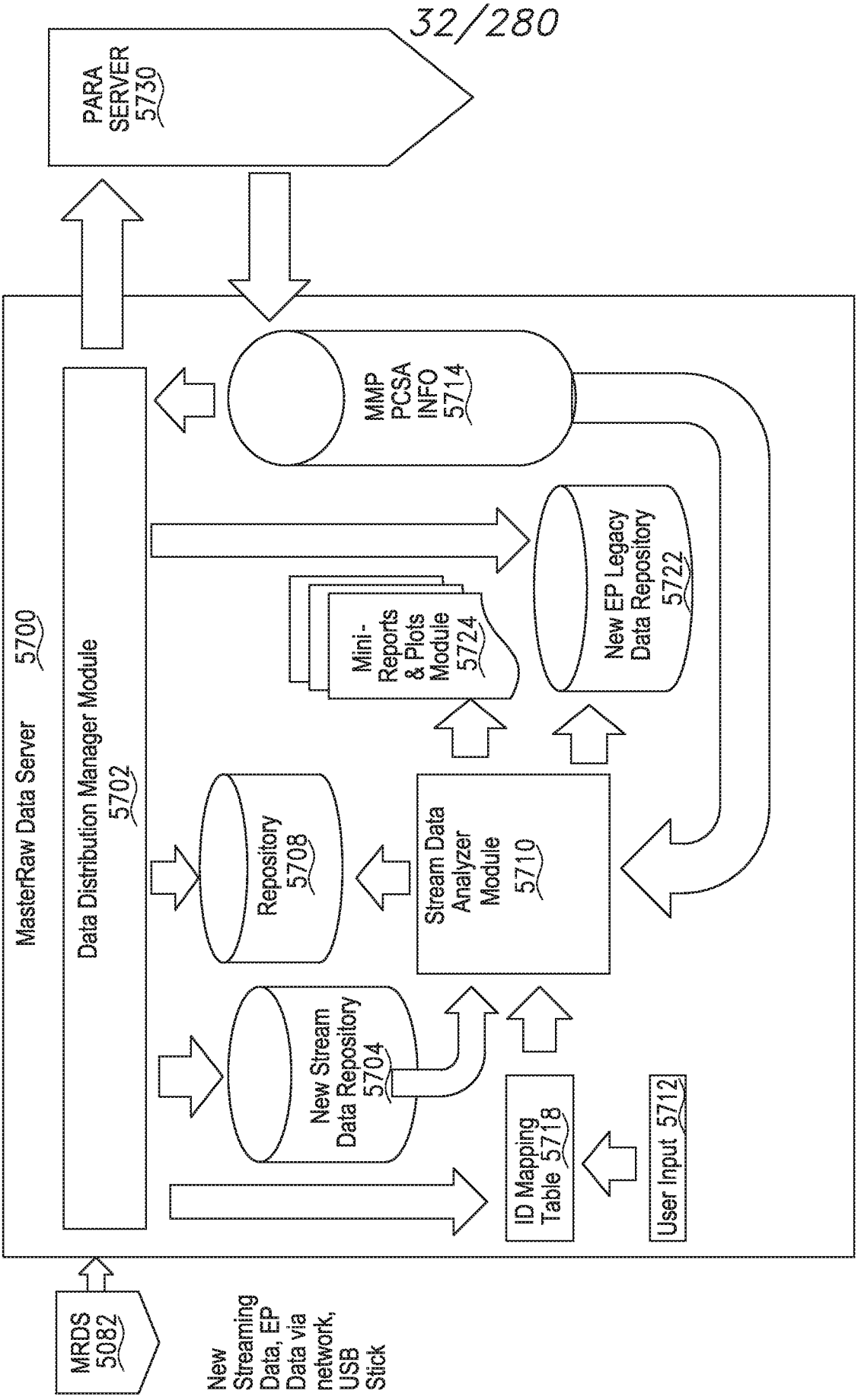
PARA SERVER 5730
MasterRaw Data Server 5700
Data Distribution Manager Module 5702
MMP PCSA INFO 5714
New EP Legacy Data Repository 5722
Mini-Reports & Plots Module 5724
Repository 5708
Stream Data Analyzer Module 5710
New Stream Data Repository 5704
ID Mapping Table 5718
User Input 5712
MRDS 5082
New Streaming Data, EP Data via network, USB Stick

FIG. 32

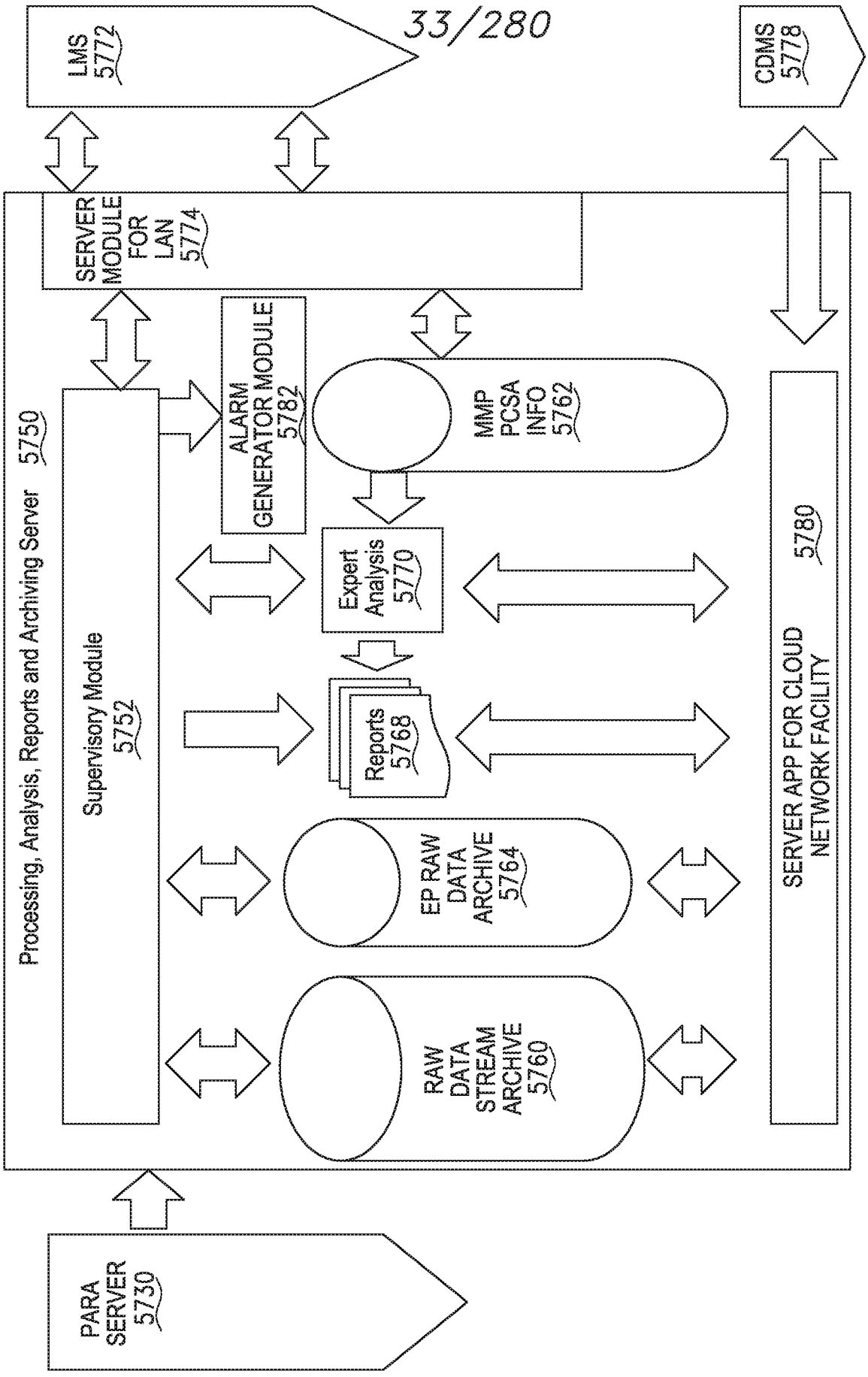
LMS 5772
CDMS 5778
SERVER MODULE FOR LAN 5774
Processing, Analysis, Reports and Archiving Server 5750
Supervisory Module 5752
ALARM GENERATOR MODULE 5782
MMP PCSA INFO 5762
Expert Analysis 5770
Reports 5768
EP RAW DATA ARCHIVE 5764
RAW DATA STREAM ARCHIVE 5760
SERVER APP FOR CLOUD NETWORK FACILITY 5780
PARA SERVER 5730

FIG. 33

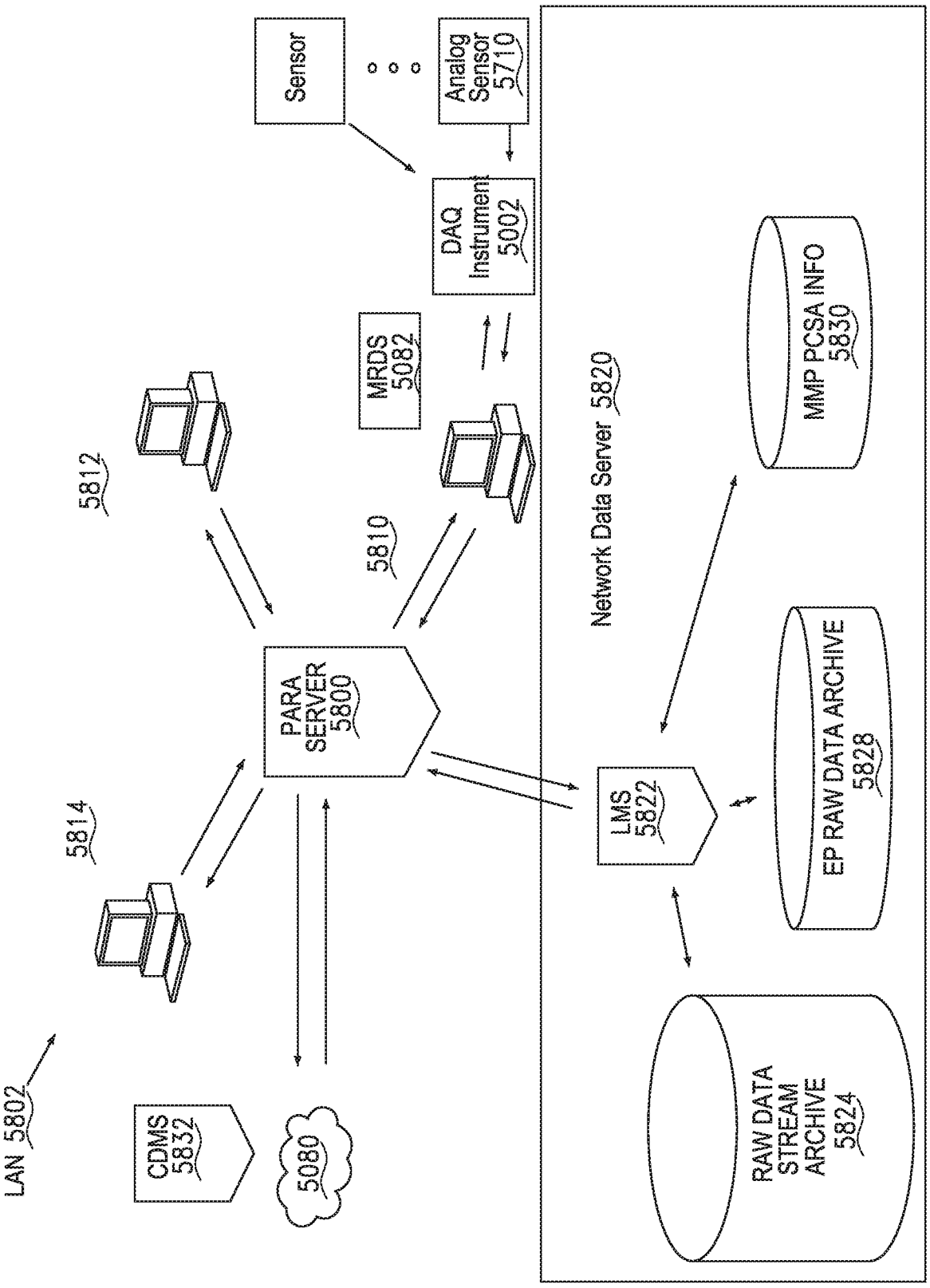
Sensor
Analog Sensor 5710
DAQ Instrument 5002
MRDS 5082
5812
5810
5814
PARA SERVER 5800
Network Data Server 5820
MMP PCSA INFO 5830
LMS 5822
EP RAW DATA ARCHIVE 5828
RAW DATA STREAM ARCHIVE 5824
LAN 5802
CDMS 5832
5080

FIG. 34

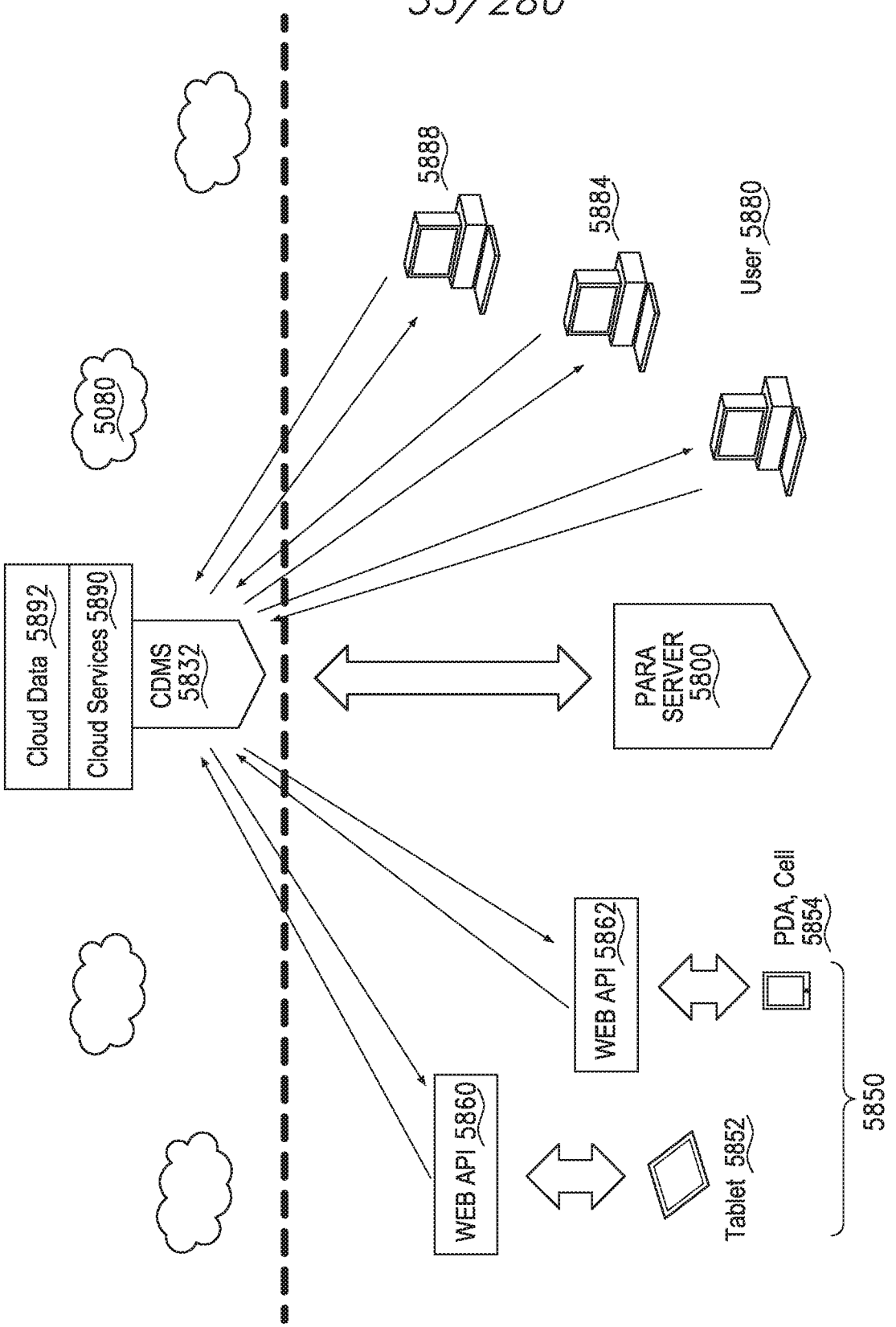
5888
5884
User 5880
5080
Cloud Data 5892
Cloud Services 5890
CDMS 5832
PARA SERVER 5800
WEB API 5862
PDA, Cell 5854
WEB API 5860
Tablet 5852
5850

FIG. 35

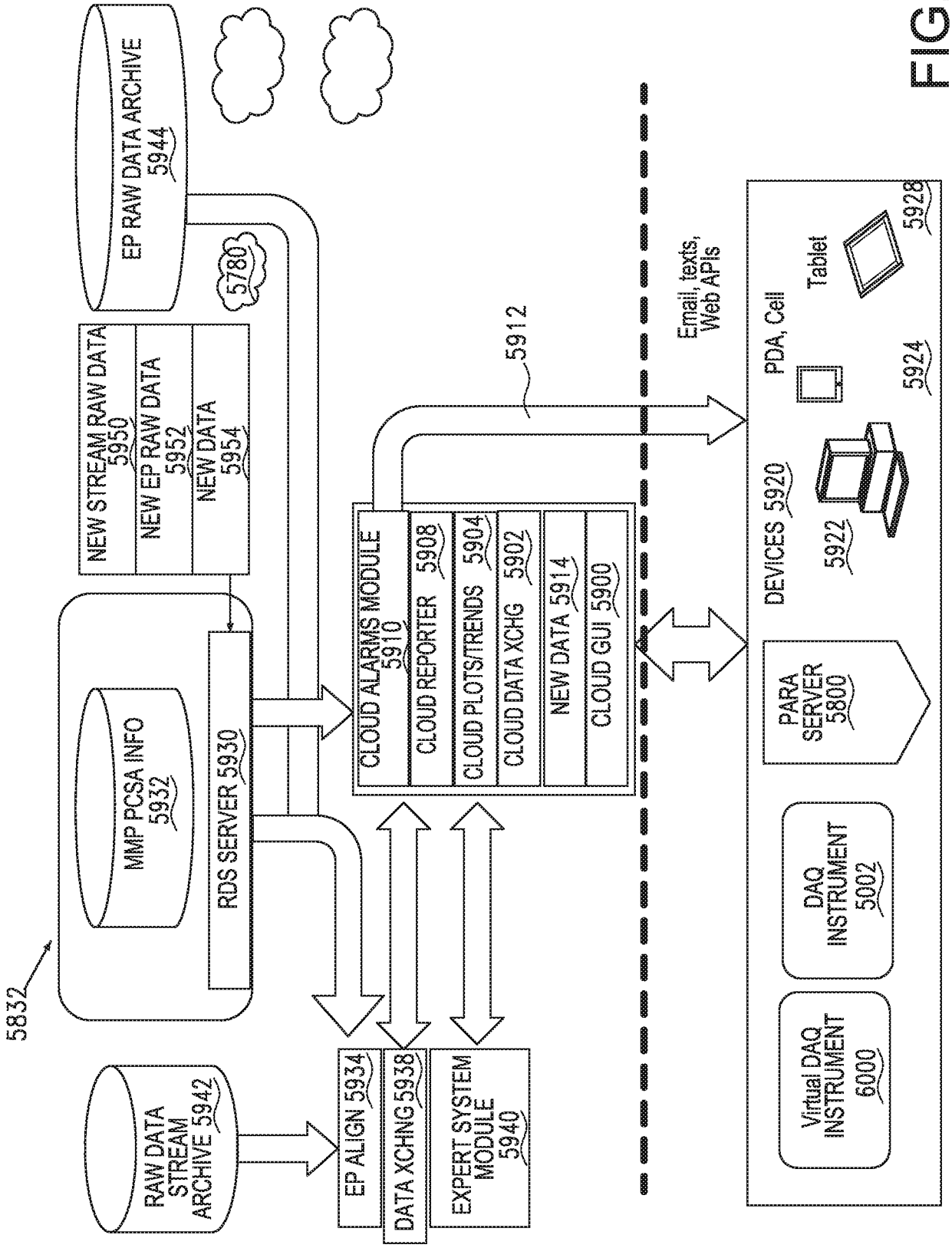
EP RAW DATA ARCHIVE 5944
5780
NEW STREAM RAW DATA 5950
NEW EP RAW DATA 5952
NEW DATA 5954
5912
Email, texts, Web APIs
PDA, Cell
Tablet
5928
5924
DEVICES 5920
5922
CLOUD ALARMS MODULE 5910
CLOUD REPORTER 5908
CLOUD PLOTS/TRENDS 5904
CLOUD DATA XCHG 5902
NEW DATA 5914
CLOUD GUI 5900
MMP PCSA INFO 5932
RDS SERVER 5930
5832
PARA SERVER 5800
DAQ INSTRUMENT 5002
Virtual DAQ INSTRUMENT 6000
RAW DATA STREAM ARCHIVE 5942
EP ALIGN 5934
DATA XCHNG 5938
EXPERT SYSTEM MODULE 5940

FIG. 36

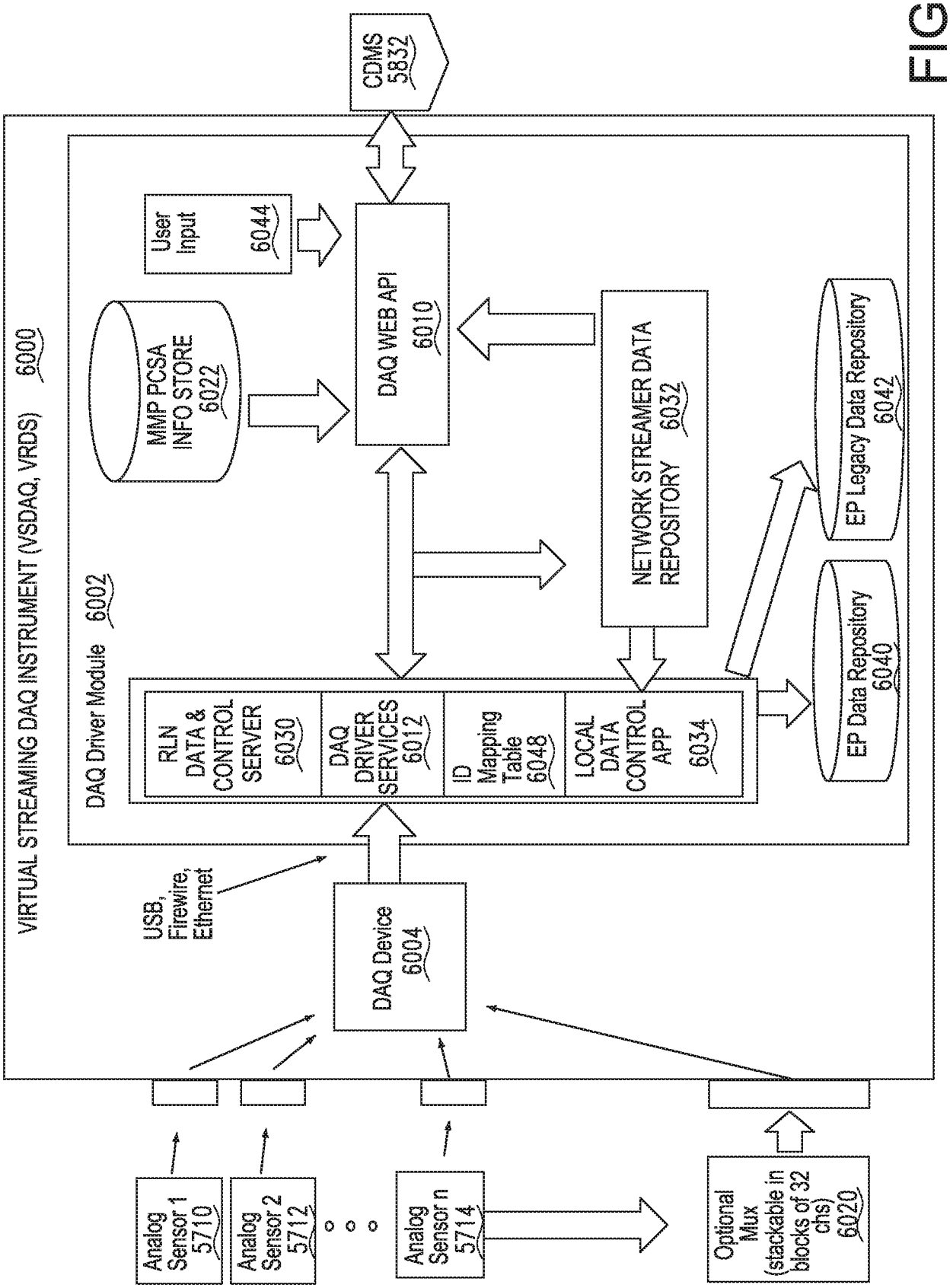
VIRTUAL STREAMING DAQ INSTRUMENT (VSDAQ, VRDS) 6000
DAQ Driver Module 6002
RLN DATA & CONTROL SERVER 6030
DAQ DRIVER SERVICES 6012
ID Mapping Table 6048
LOCAL DATA CONTROL APP 6034
DAQ WEB API 6010
MMP PCSA INFO STORE 6022
User Input 6044
CDMS 5832
NETWORK STREAMER DATA REPOSITORY 6032
EP Legacy Data Repository 6042
EP Data Repository 6040
DAQ Device 6004
USB, Firewire, Ethernet
Analog Sensor 1 5710
Analog Sensor 2 5712
Analog Sensor n 5714
Optional Mux (stackable in blocks of 32 chs) 6020

FIG. 37

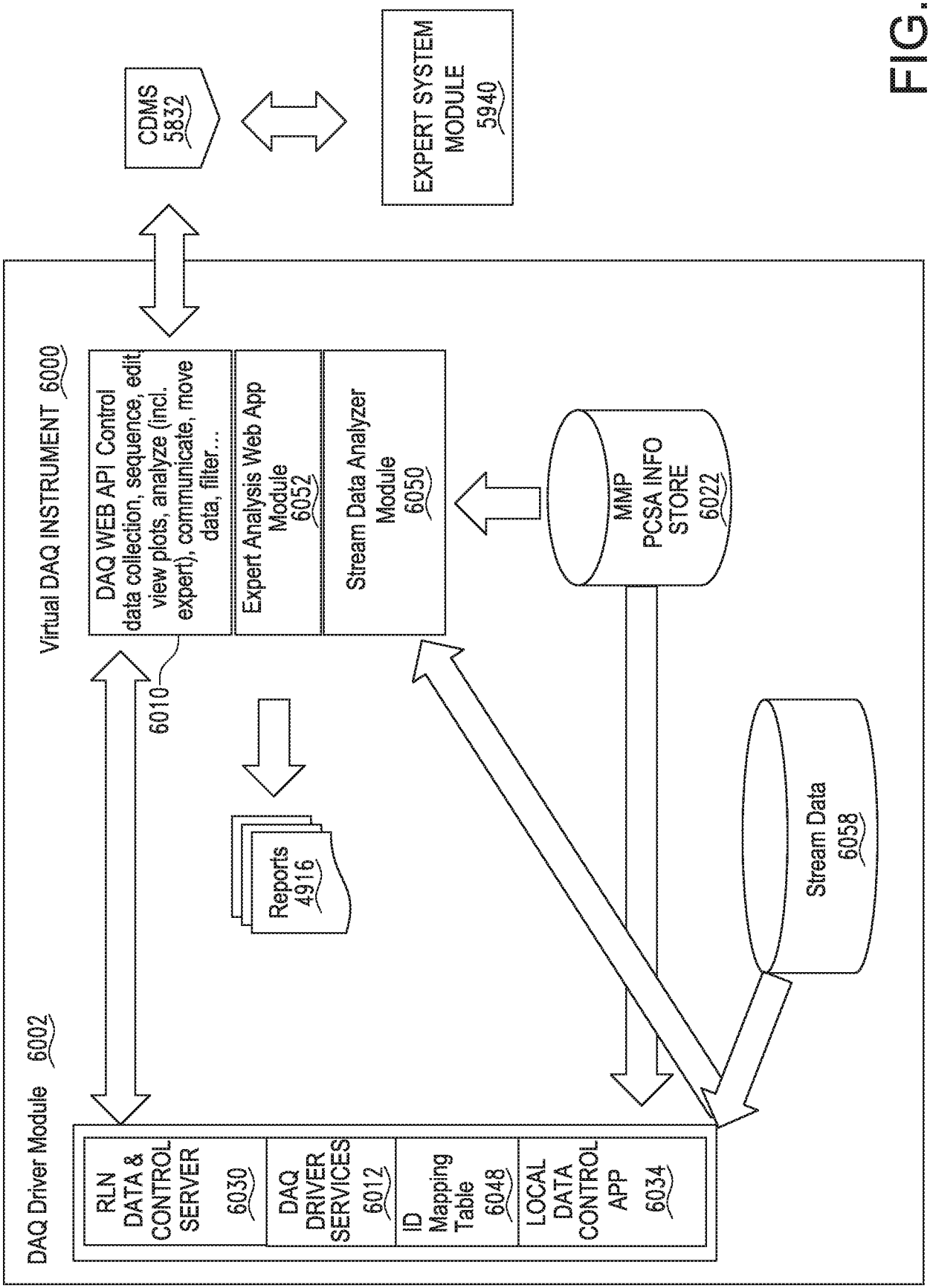
CDMS
5832
EXPERT SYSTEM MODULE
5940
Virtual DAQ INSTRUMENT 6000
DAQ WEB API Control
data collection, sequence, edit
view plots, analyze (incl.
expert), communicate, move
data, filter…
Expert Analysis Web App
Module
6052
Stream Data Analyzer
Module
6050
MMP
PCSA INFO
STORE
6022
6010
Reports
4916
Stream Data
6058
DAQ Driver Module 6002
RLN
DATA &
CONTROL
SERVER
6030
DAQ
DRIVER
SERVICES
6012
ID
Mapping
Table
6048
LOCAL
DATA
CONTROL
APP
6034

FIG. 38

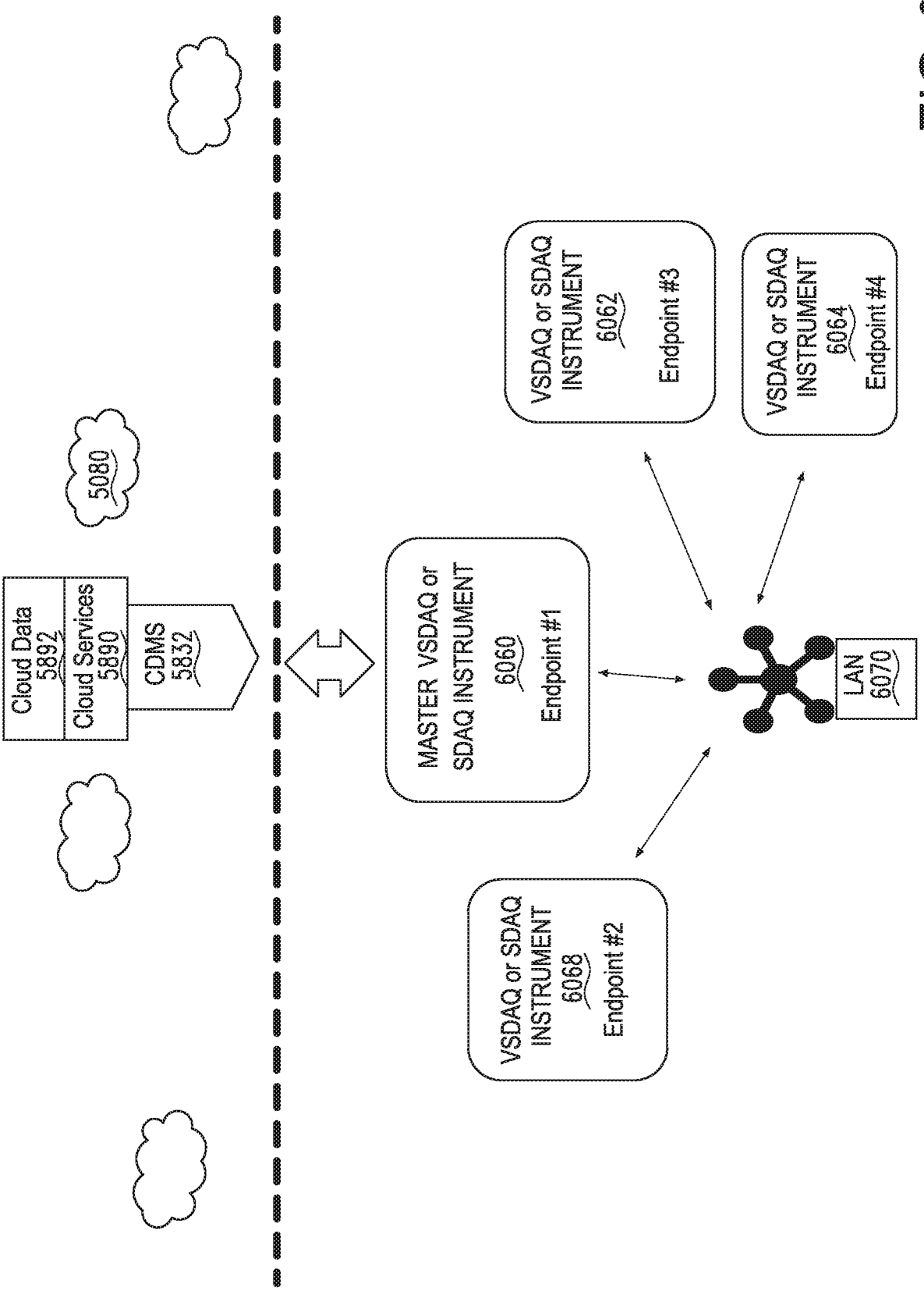
Cloud Data
5892
Cloud Services
5890
CDMS
5832
5080
MASTER VSDAQ or
SDAQ INSTRUMENT
6060
Endpoint #1
VSDAQ or SDAQ
INSTRUMENT
6062
Endpoint #3
VSDAQ or SDAQ
INSTRUMENT
6064
Endpoint #4
VSDAQ or SDAQ
INSTRUMENT
6068
Endpoint #2
LAN
6070

FIG. 39

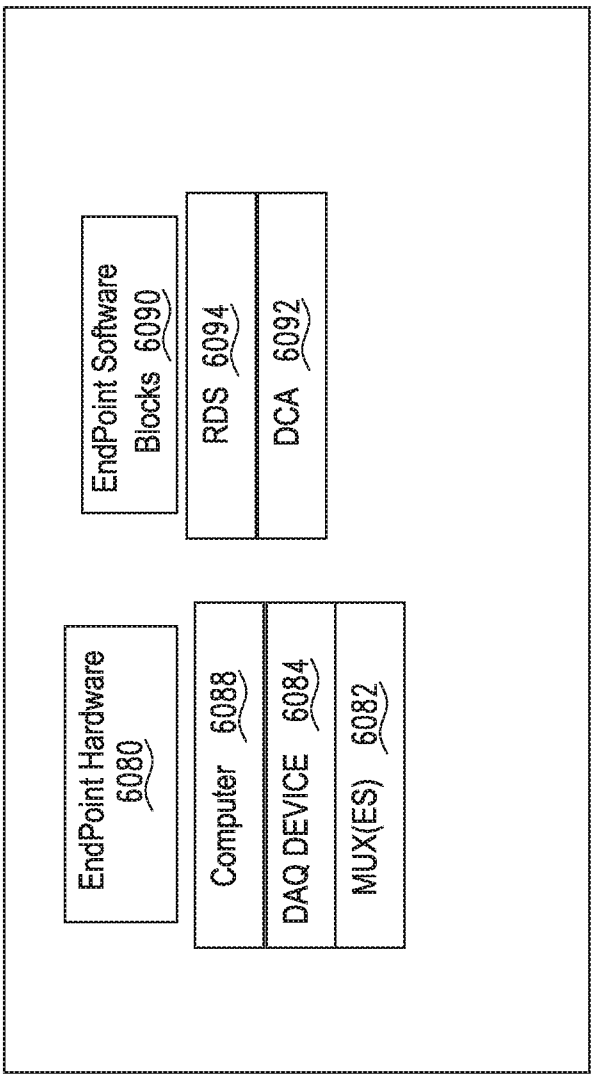
EndPoint Hardware 6080
Computer 6088
DAQ DEVICE 6084
MUX(ES) 6082
EndPoint Software Blocks 6090
RDS 6094
DCA 6092

FIG. 40

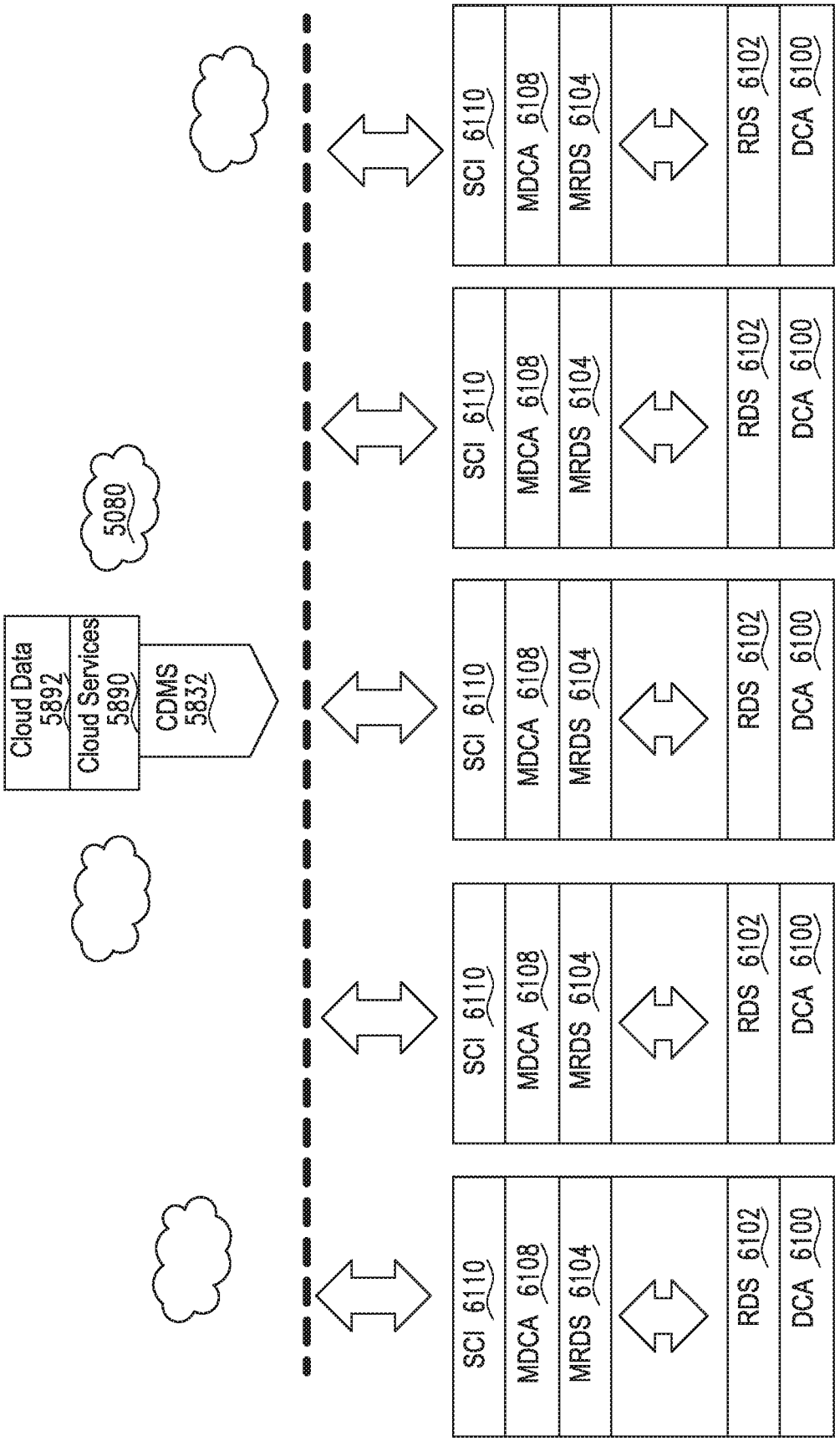
Cloud Data 5892
Cloud Services 5890
CDMS 5832
5080
SCI 6110
MDCA 6108
MRDS 6104
RDS 6102
DCA 6100

FIG. 41

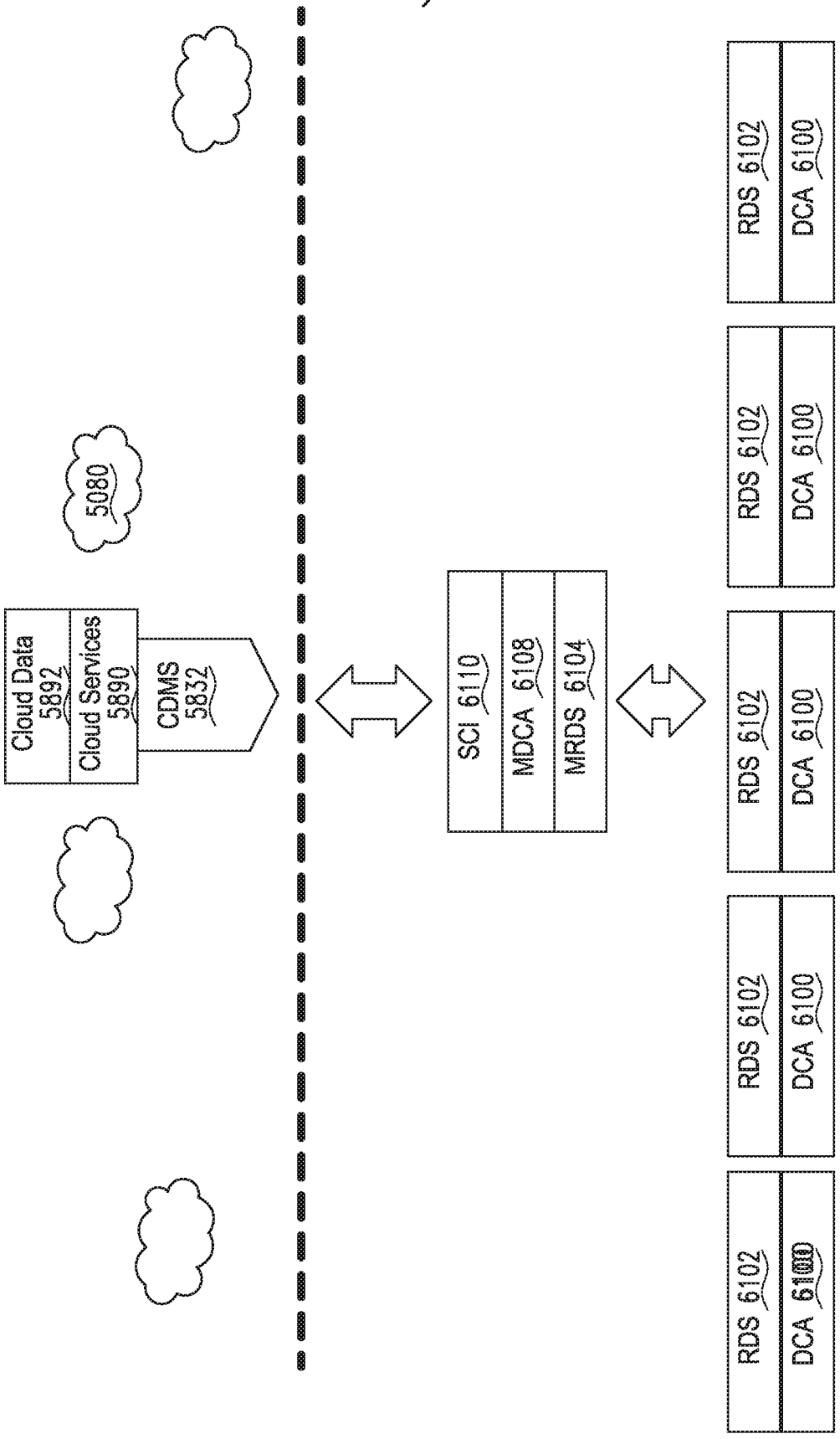
Cloud Data 5892
Cloud Services 5890
CDMS 5832
5080
SCI 6110
MDCA 6108
MRDS 6104
RDS 6102
DCA 6100
RDS 6102
DCA 6100
RDS 6102
DCA 6100
RDS 6102
DCA 6100
RDS 6102
DCA 6100

FIG. 42

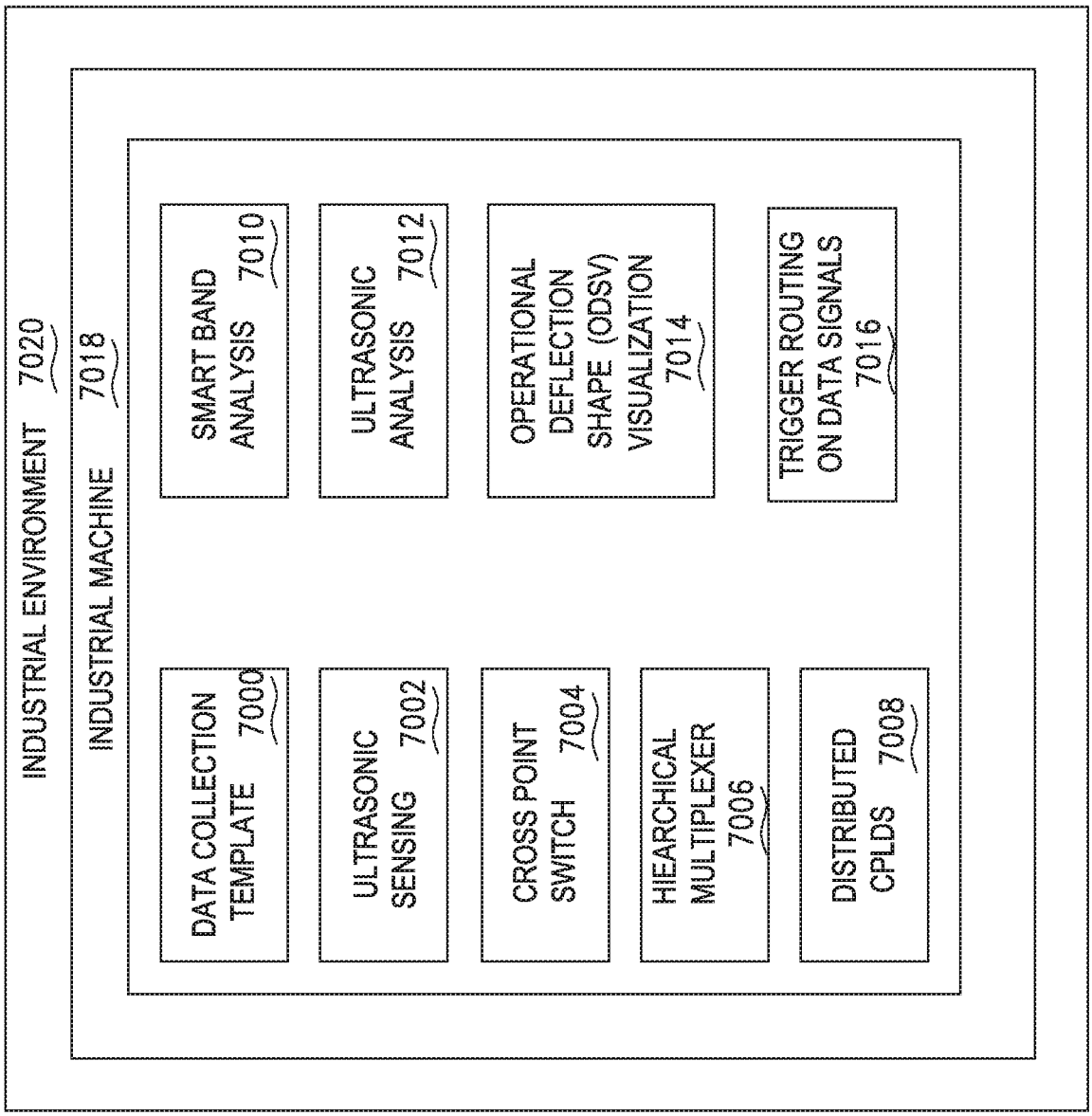
INDUSTRIAL ENVIRONMENT 7020
INDUSTRIAL MACHINE 7018
DATA COLLECTION TEMPLATE 7000
ULTRASONIC SENSING 7002
CROSS POINT SWITCH 7004
HIEARCHICAL MULTIPLEXER 7006
DISTRIBUTED CPLDS 7008
SMART BAND ANALYSIS 7010
ULTRASONIC ANALYSIS 7012
OPERATIONAL DEFLECTION SHAPE (ODSV) VISUALIZATION 7014
TRIGGER ROUTING ON DATA SIGNALS 7016

FIG. 43

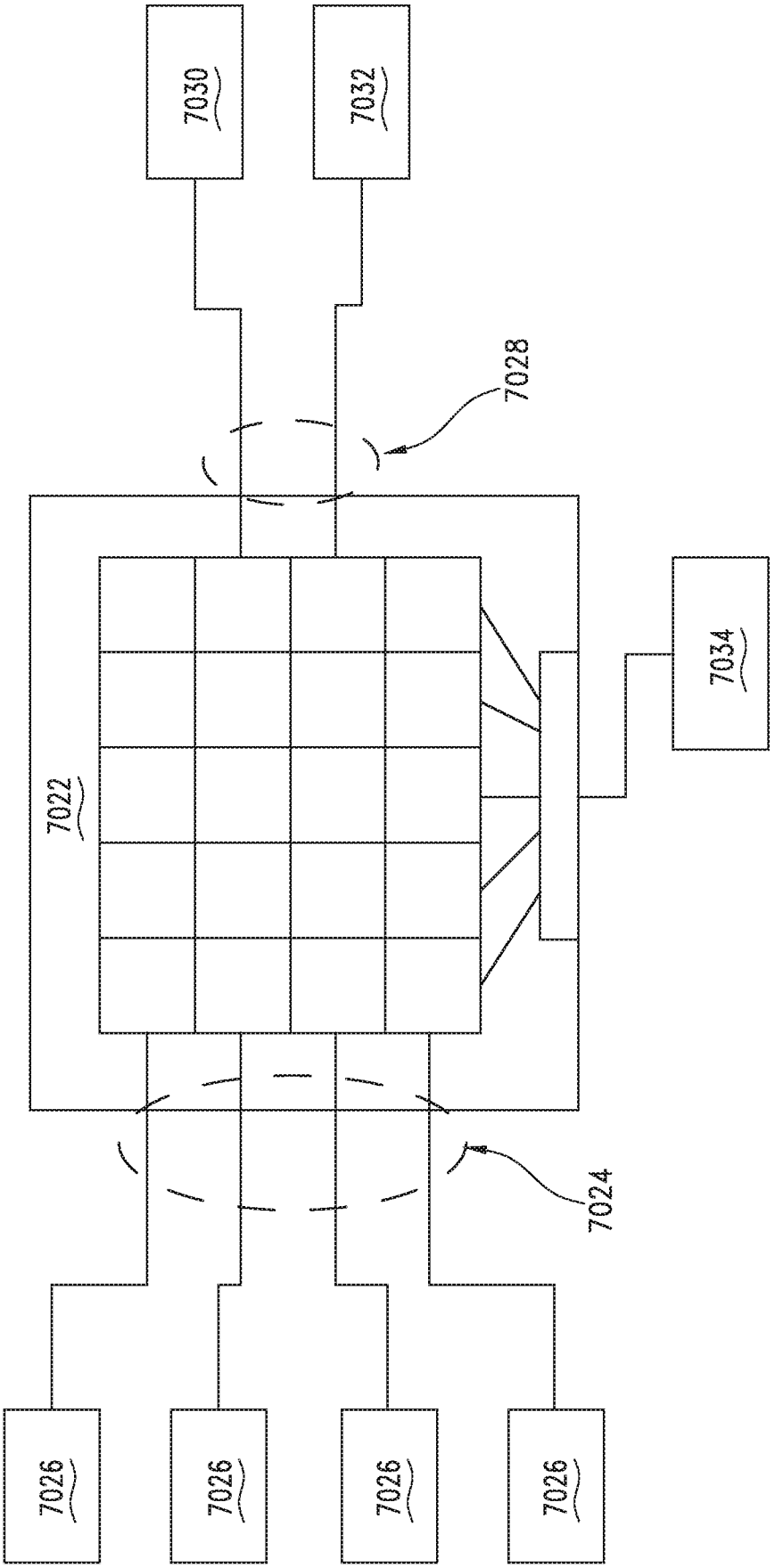

FIG. 44

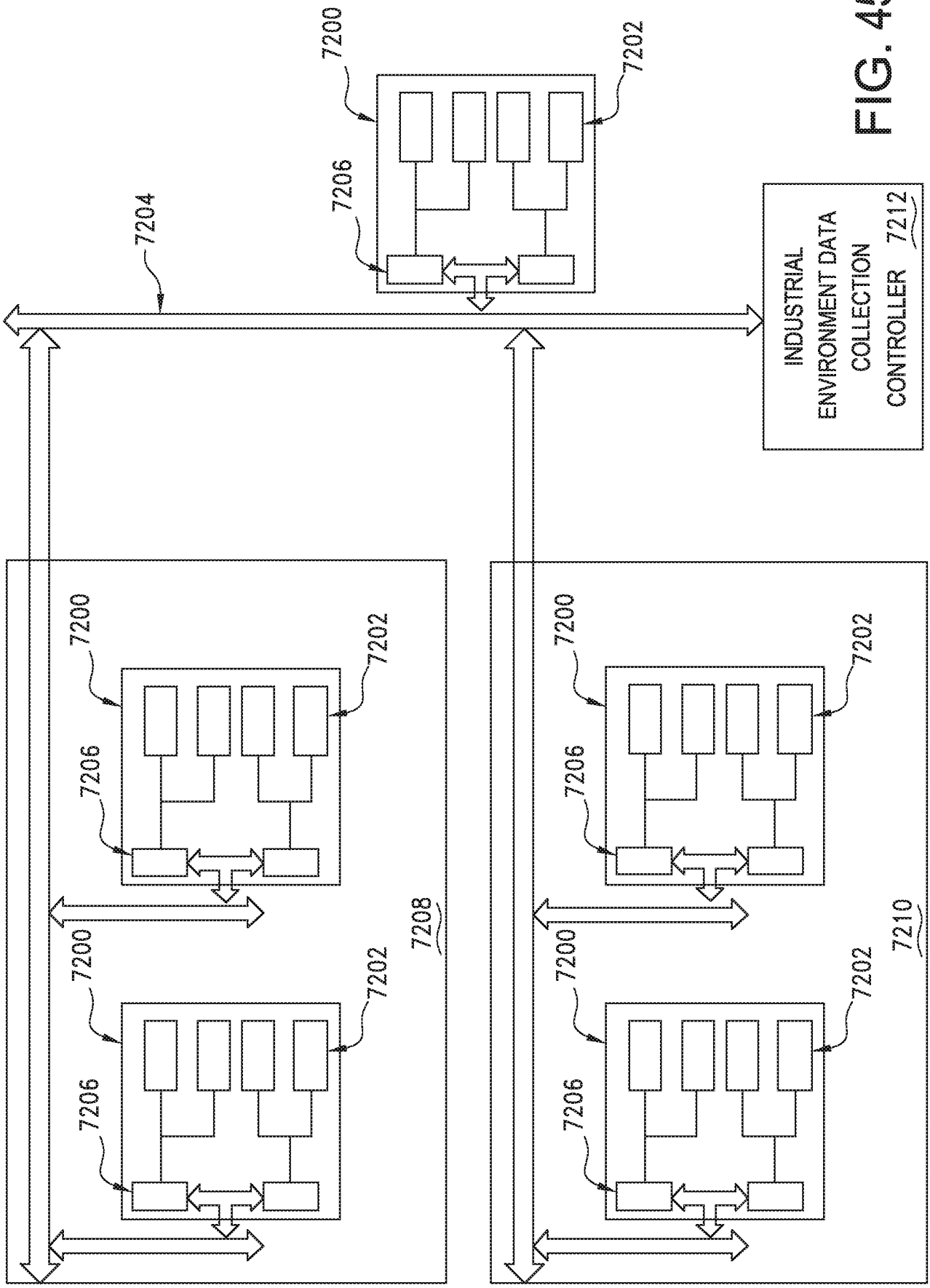
7200
7202
7206
7204
INDUSTRIAL ENVIRONMENT DATA COLLECTION CONTROLLER 7212
7208
7210

FIG. 45

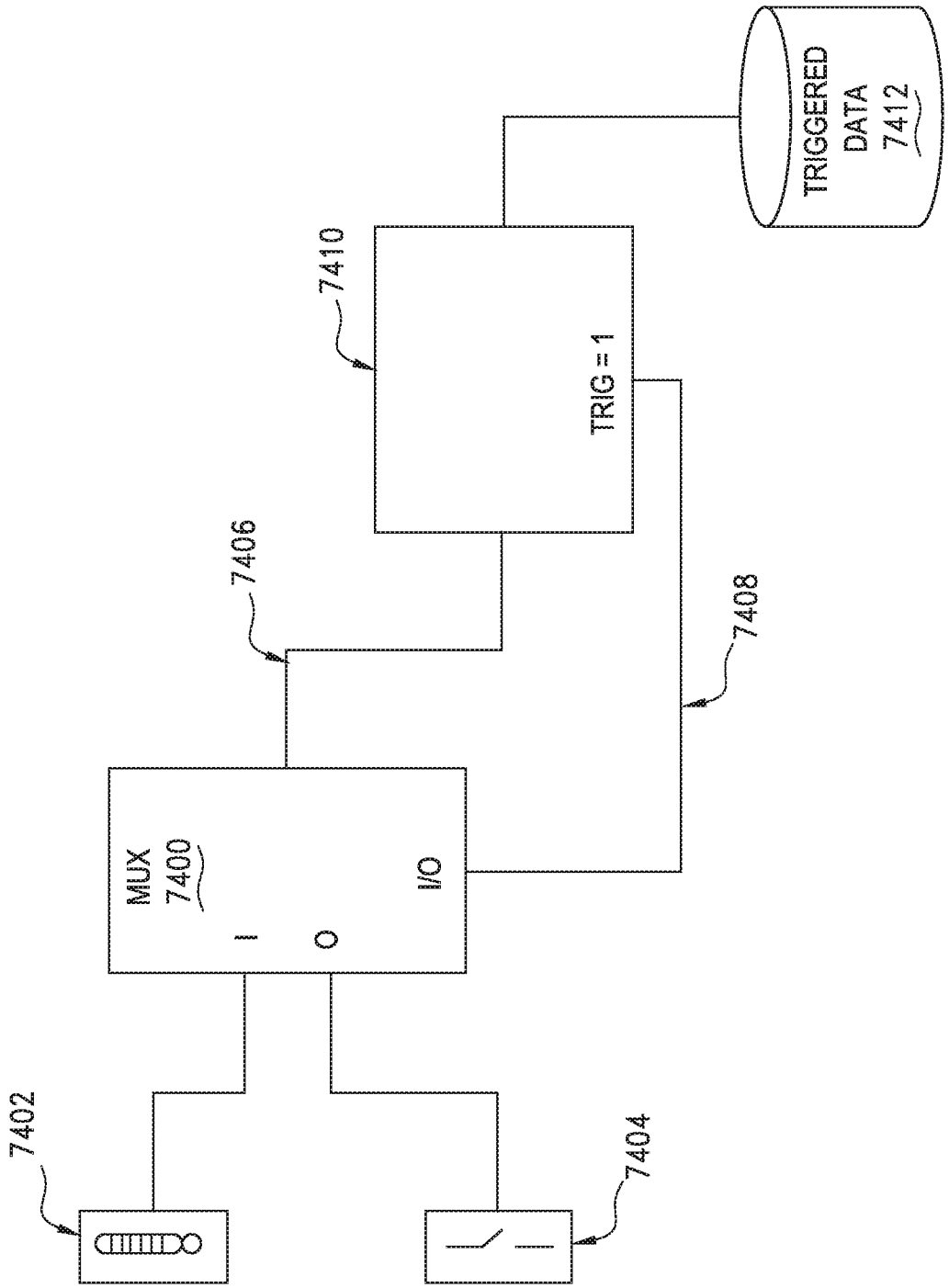
TRIGGERED DATA 7412
7410
TRIG = 1
7406
7408
MUX 7400
I/O
I
O
7402
7404

FIG. 46

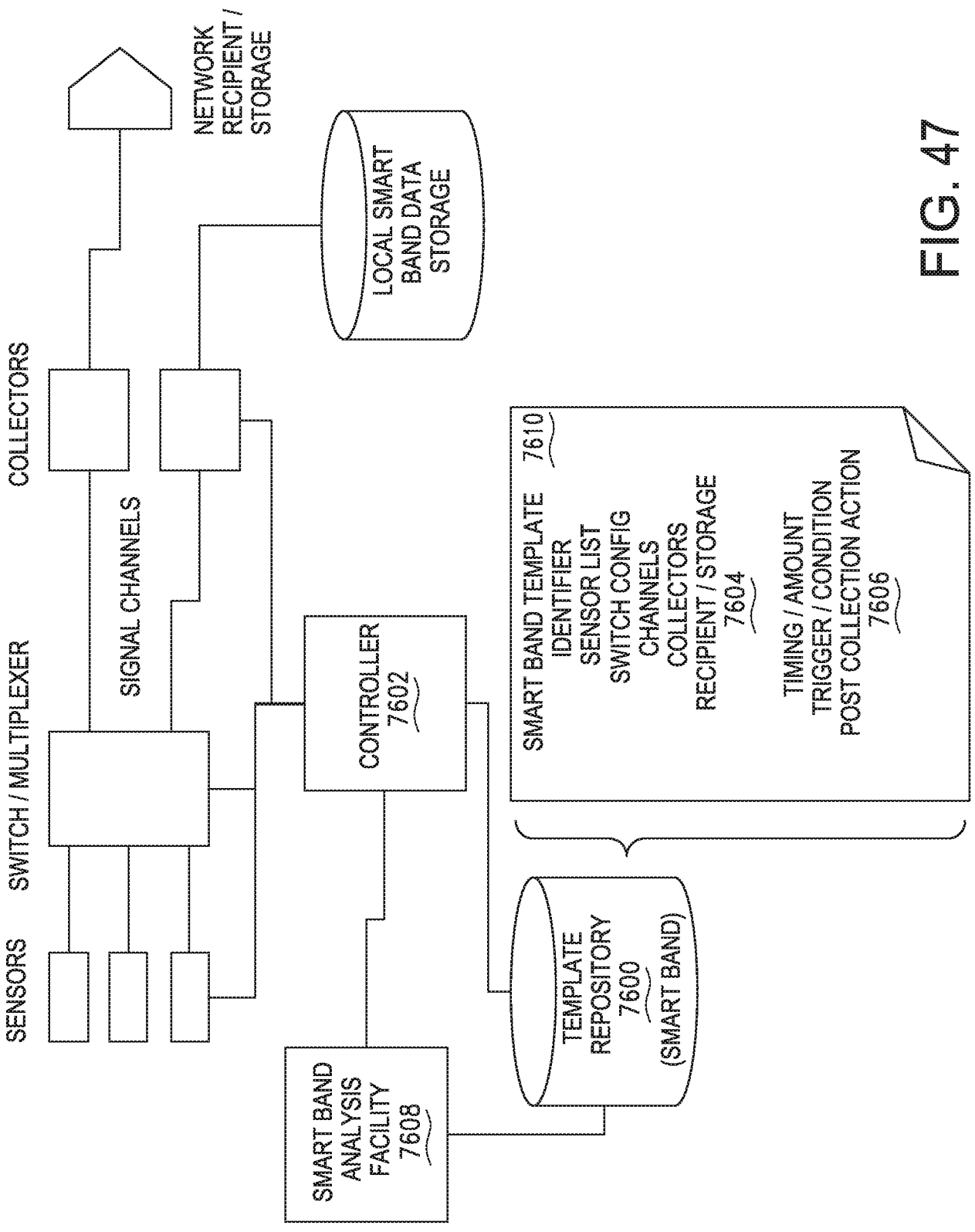
NETWORK RECIPIENT / STORAGE
LOCAL SMART BAND DATA STORAGE
COLLECTORS
SIGNAL CHANNELS
SWITCH / MULTIPLEXER
SENSORS
CONTROLLER 7602
SMART BAND TEMPLATE 7610
IDENTIFIER
SENSOR LIST
SWITCH CONFIG
CHANNELS
COLLECTORS
RECIPIENT / STORAGE 7604
TIMING / AMOUNT
TRIGGER / CONDITION
POST COLLECTION ACTION 7606
TEMPLATE REPOSITORY 7600 (SMART BAND)
SMART BAND ANALYSIS FACILITY 7608

FIG. 47

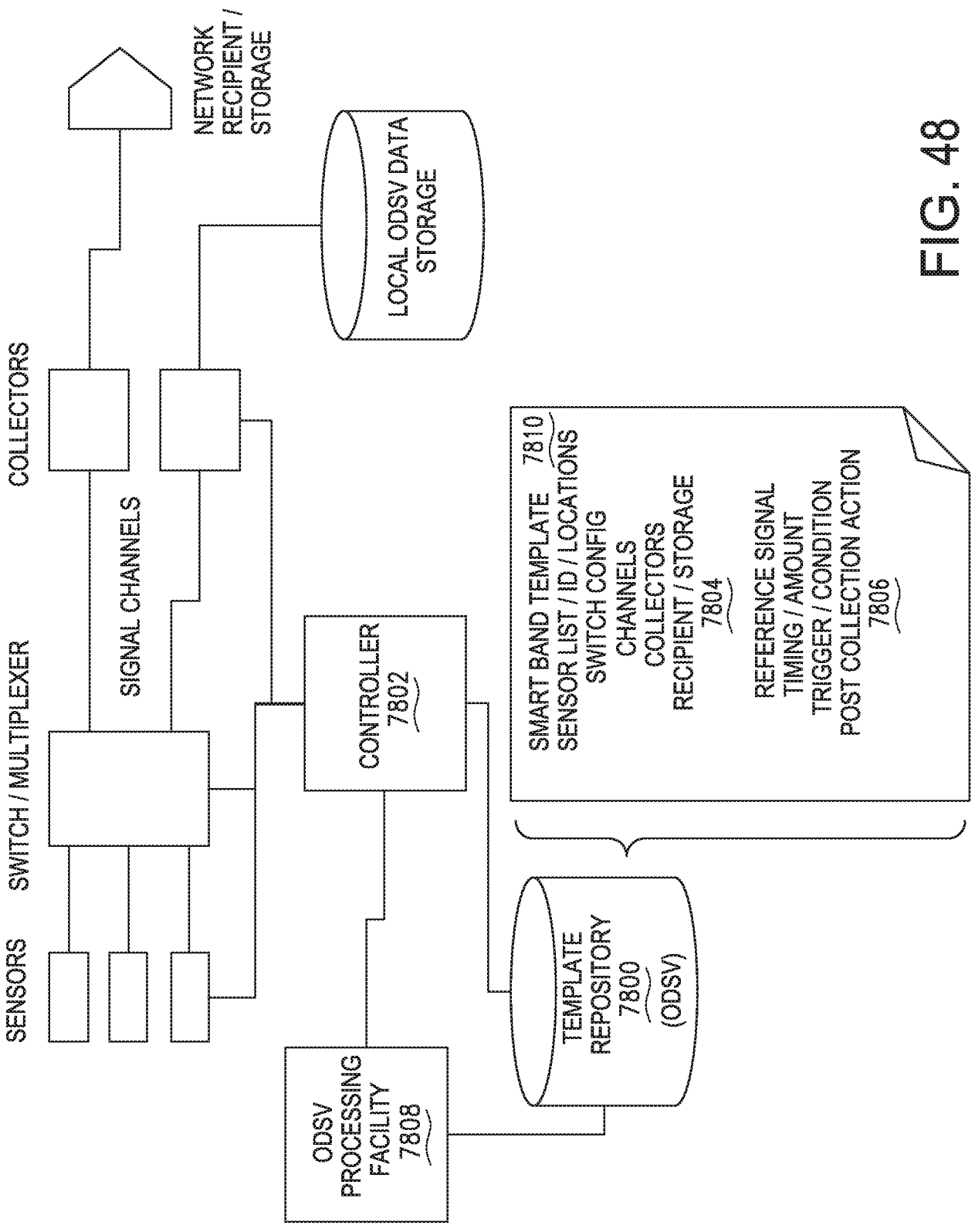
NETWORK RECIPIENT / STORAGE
LOCAL ODSV DATA STORAGE
COLLECTORS
SIGNAL CHANNELS
SWITCH / MULTIPLEXER
SENSORS
CONTROLLER 7802
SMART BAND TEMPLATE 7810
SENSOR LIST / ID / LOCATIONS
SWITCH CONFIG
CHANNELS
COLLECTORS
RECIPIENT / STORAGE 7804
REFERENCE SIGNAL
TIMING / AMOUNT
TRIGGER / CONDITION
POST COLLECTION ACTION 7806
TEMPLATE REPOSITORY 7800 (ODSV)
ODSV PROCESSING FACILITY 7808

FIG. 48

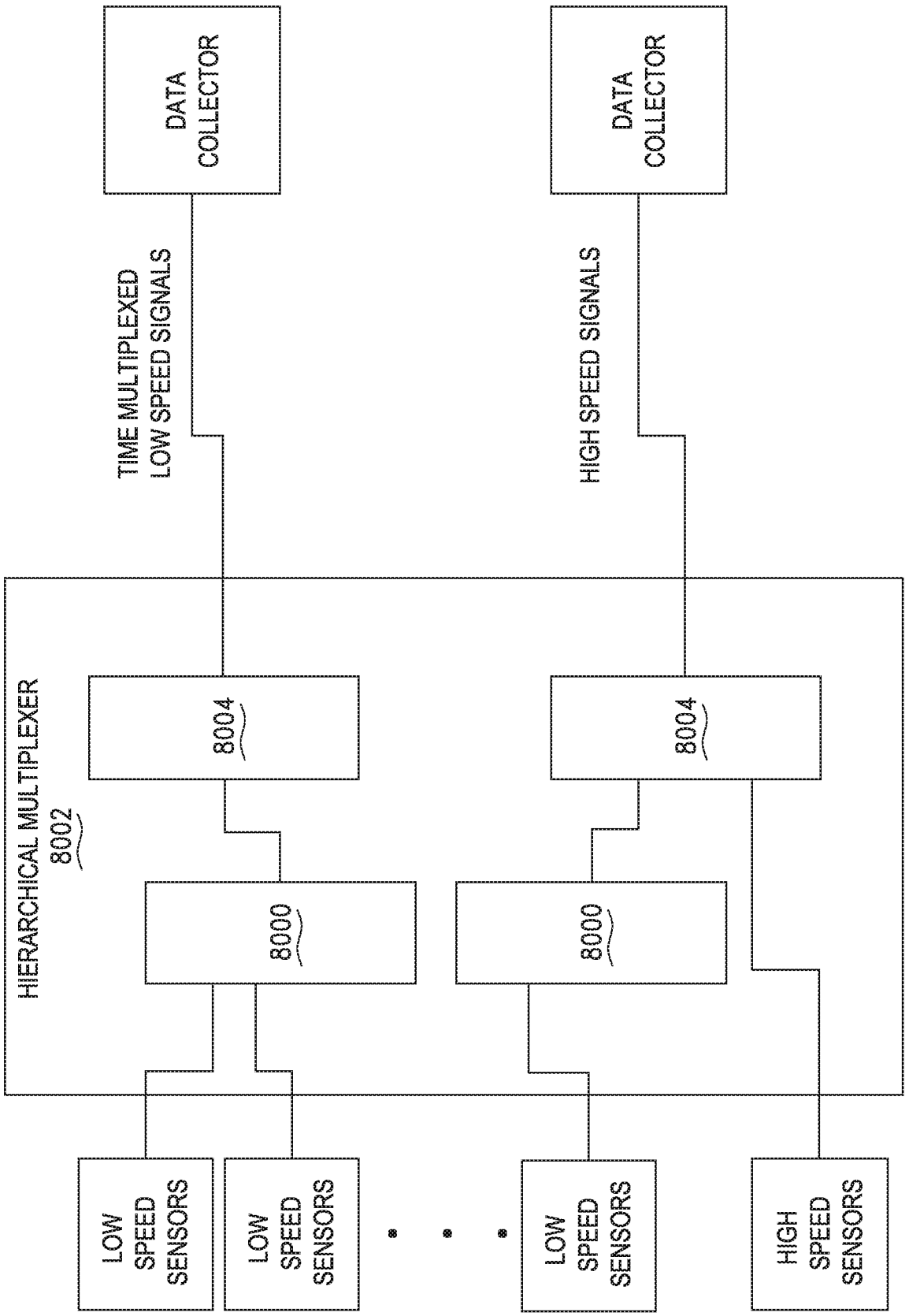
DATA COLLECTOR
DATA COLLECTOR
TIME MULTIPLEXED LOW SPEED SIGNALS
HIGH SPEED SIGNALS
HIERARCHICAL MULTIPLEXER
8002
8004
8004
8000
8000
LOW SPEED SENSORS
LOW SPEED SENSORS
LOW SPEED SENSORS
HIGH SPEED SENSORS

FIG. 49

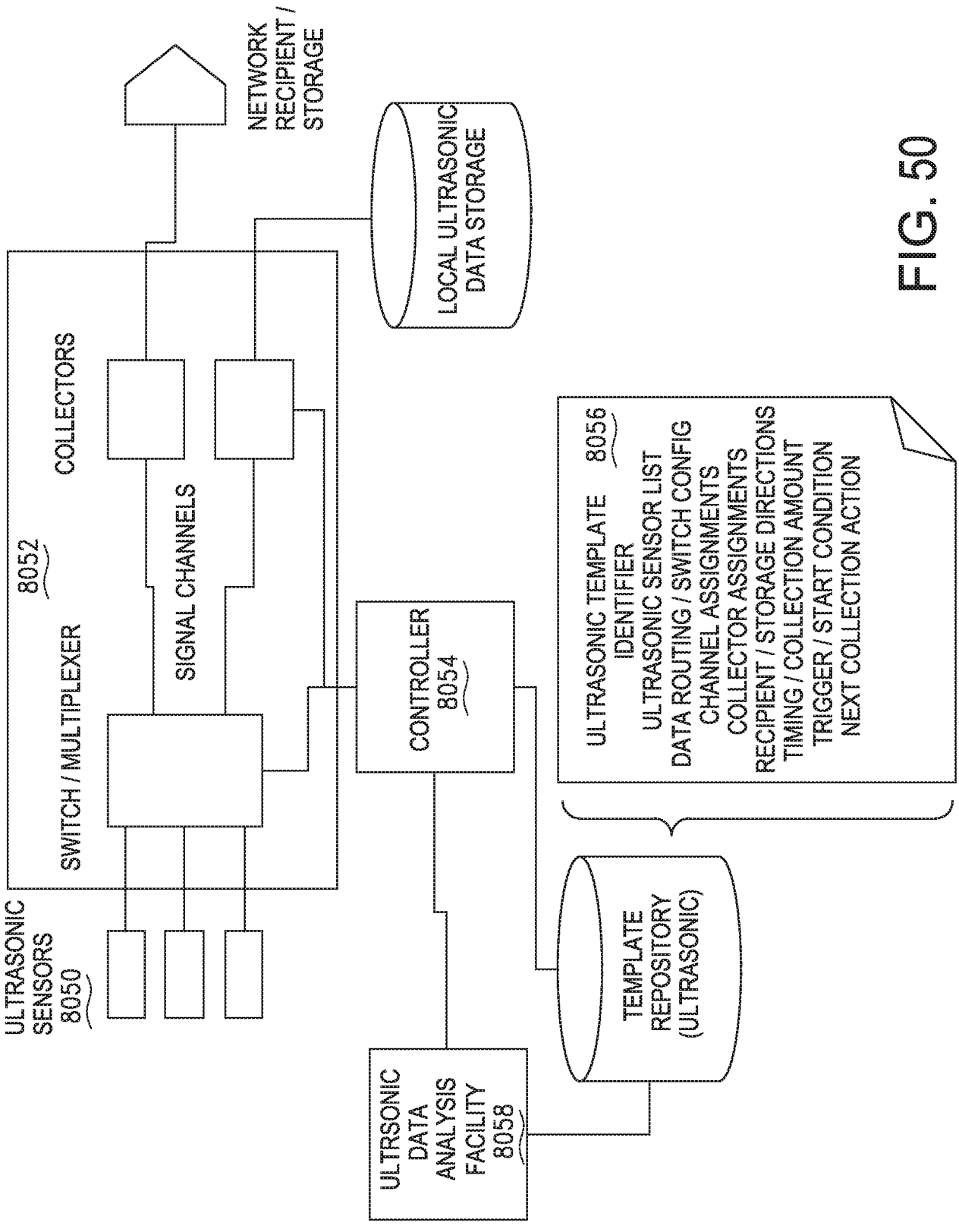
NETWORK RECIPIENT / STORAGE
LOCAL ULTRASONIC DATA STORAGE
8052
SWITCH / MULTIPLEXER
COLLECTORS
SIGNAL CHANNELS
CONTROLLER 8054
ULTRASONIC SENSORS 8050
ULTRASONIC TEMPLATE 8056
IDENTIFIER
ULTRASONIC SENSOR LIST
DATA ROUTING / SWITCH CONFIG
CHANNEL ASSIGNMENTS
COLLECTOR ASSIGNMENTS
RECIPIENT / STORAGE DIRECTIONS
TIMING / COLLECTION AMOUNT
TRIGGER / START CONDITION
NEXT COLLECTION ACTION
TEMPLATE REPOSITORY (ULTRASONIC)
ULTRSONIC DATA ANALYSIS FACILITY 8058

FIG. 50

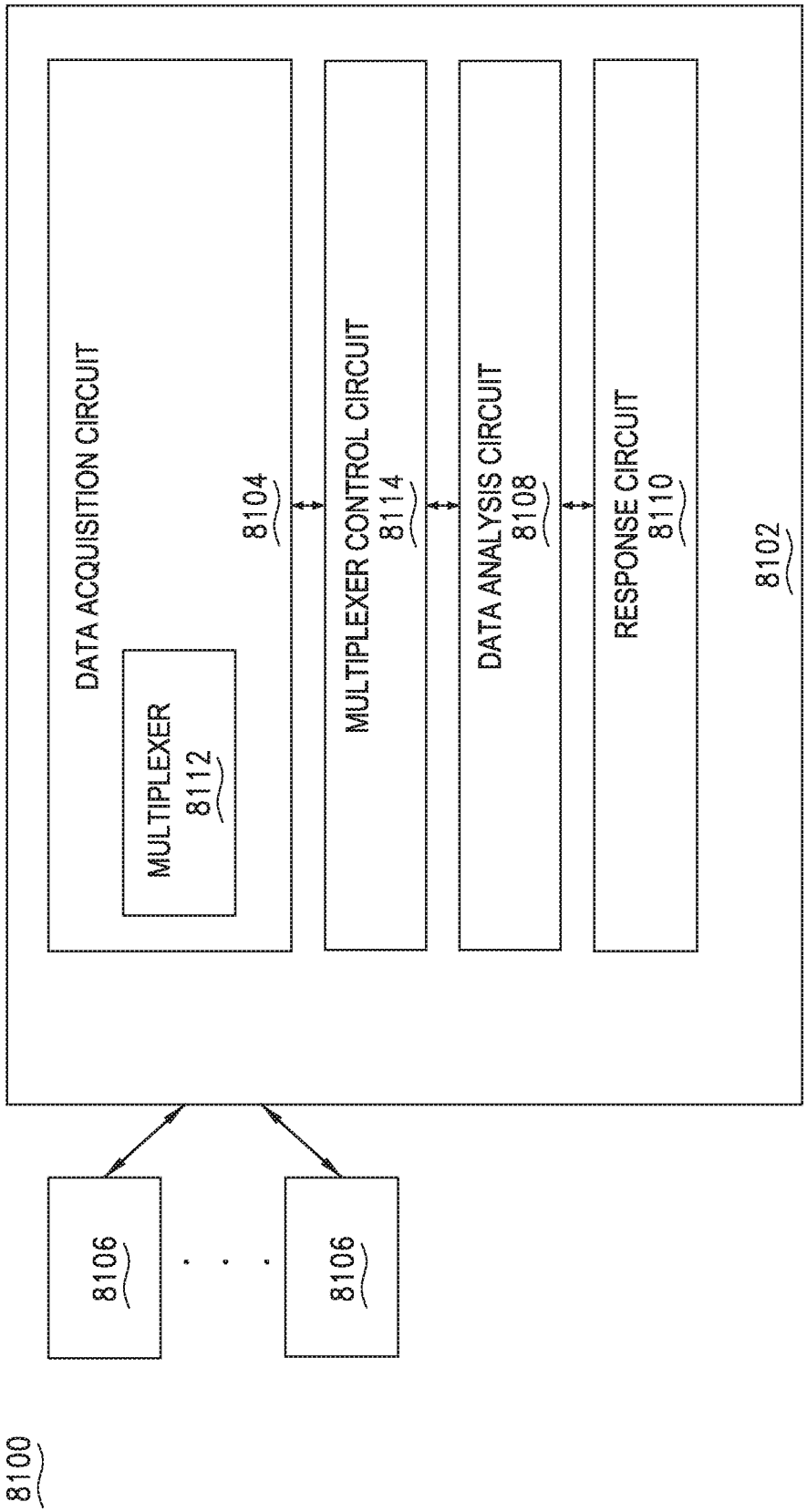
8100
8102
DATA ACQUISITION CIRCUIT
MULTIPLEXER
8112
8104
MULTIPLEXER CONTROL CIRCUIT
8114
DATA ANALYSIS CIRCUIT
8108
RESPONSE CIRCUIT
8110
8106
8106

FIG. 51

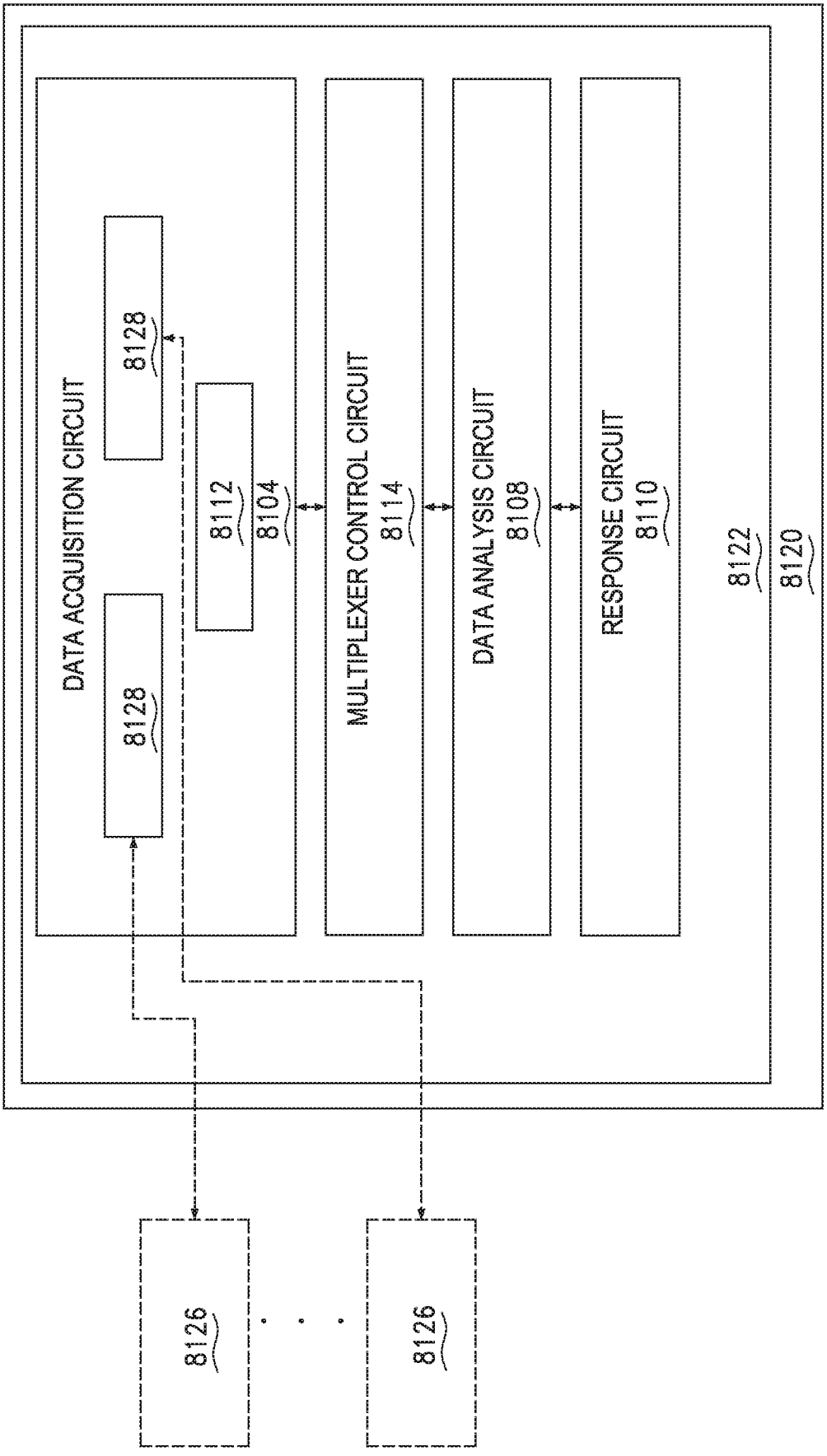
DATA ACQUISITION CIRCUIT
8128
8112
8104
8128
MULTIPLEXER CONTROL CIRCUIT
8114
DATA ANALYSIS CIRCUIT
8108
RESPONSE CIRCUIT
8110
8122
8120
8126
8126

FIG. 52

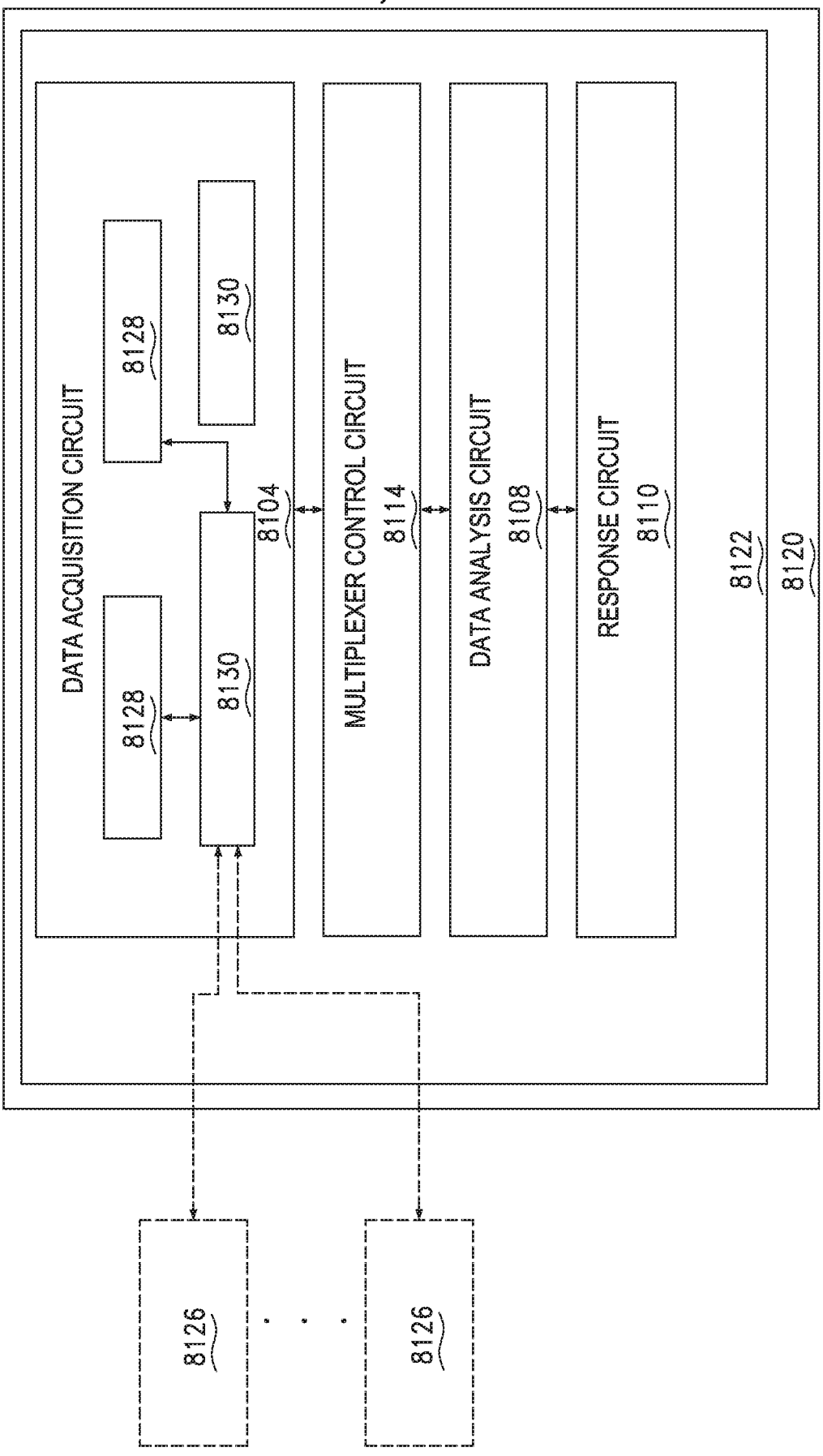
DATA ACQUISITION CIRCUIT
8128
8130
8104
8128
8130
MULTIPLEXER CONTROL CIRCUIT
8114
DATA ANALYSIS CIRCUIT
8108
RESPONSE CIRCUIT
8110
8122
8120
8126
8126

FIG. 53

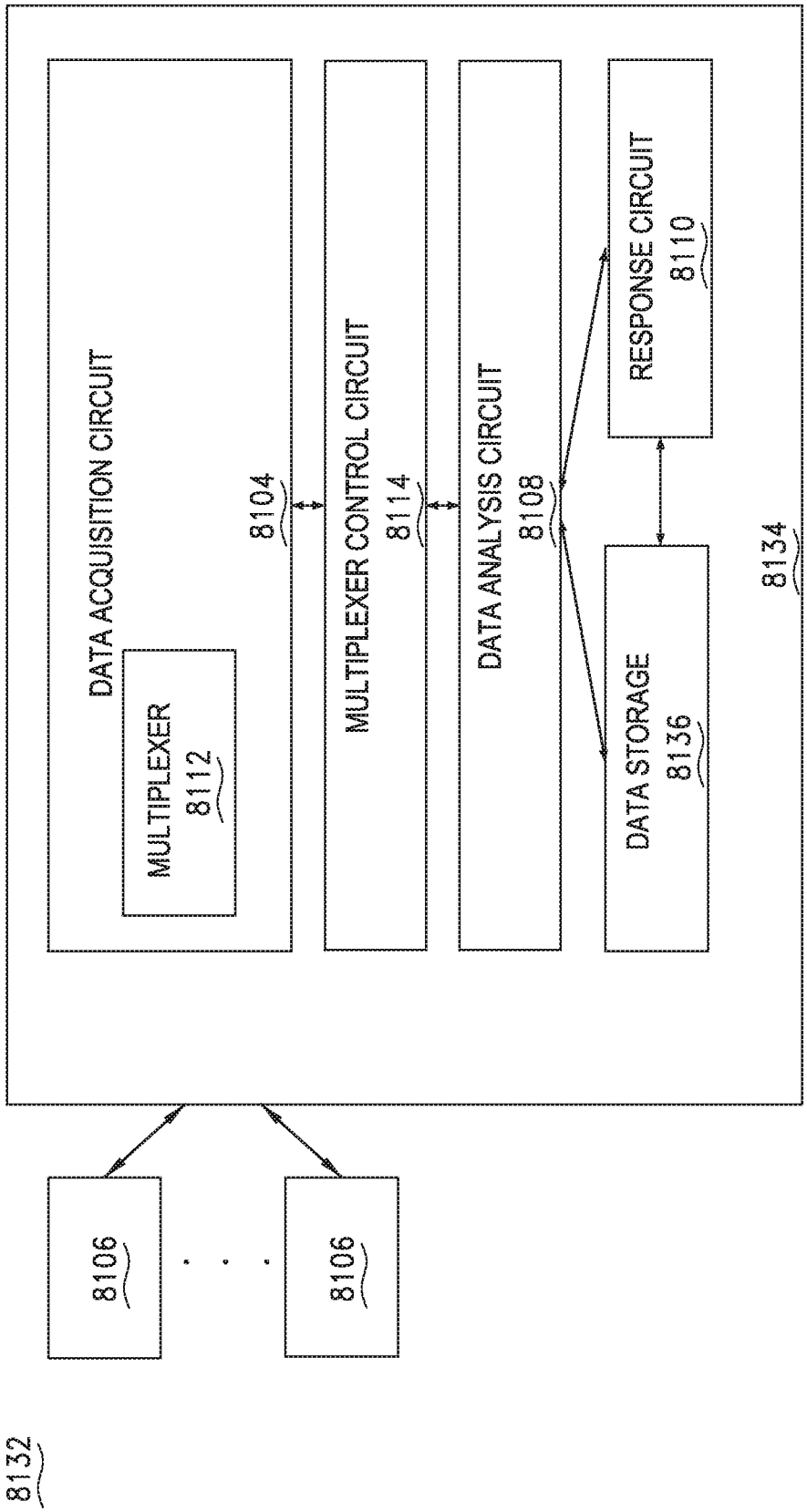
8132
8106
8106
8134
DATA ACQUISITION CIRCUIT
MULTIPLEXER
8112
8104
MULTIPLEXER CONTROL CIRCUIT
8114
DATA ANALYSIS CIRCUIT
8108
RESPONSE CIRCUIT
8110
DATA STORAGE
8136

FIG. 54

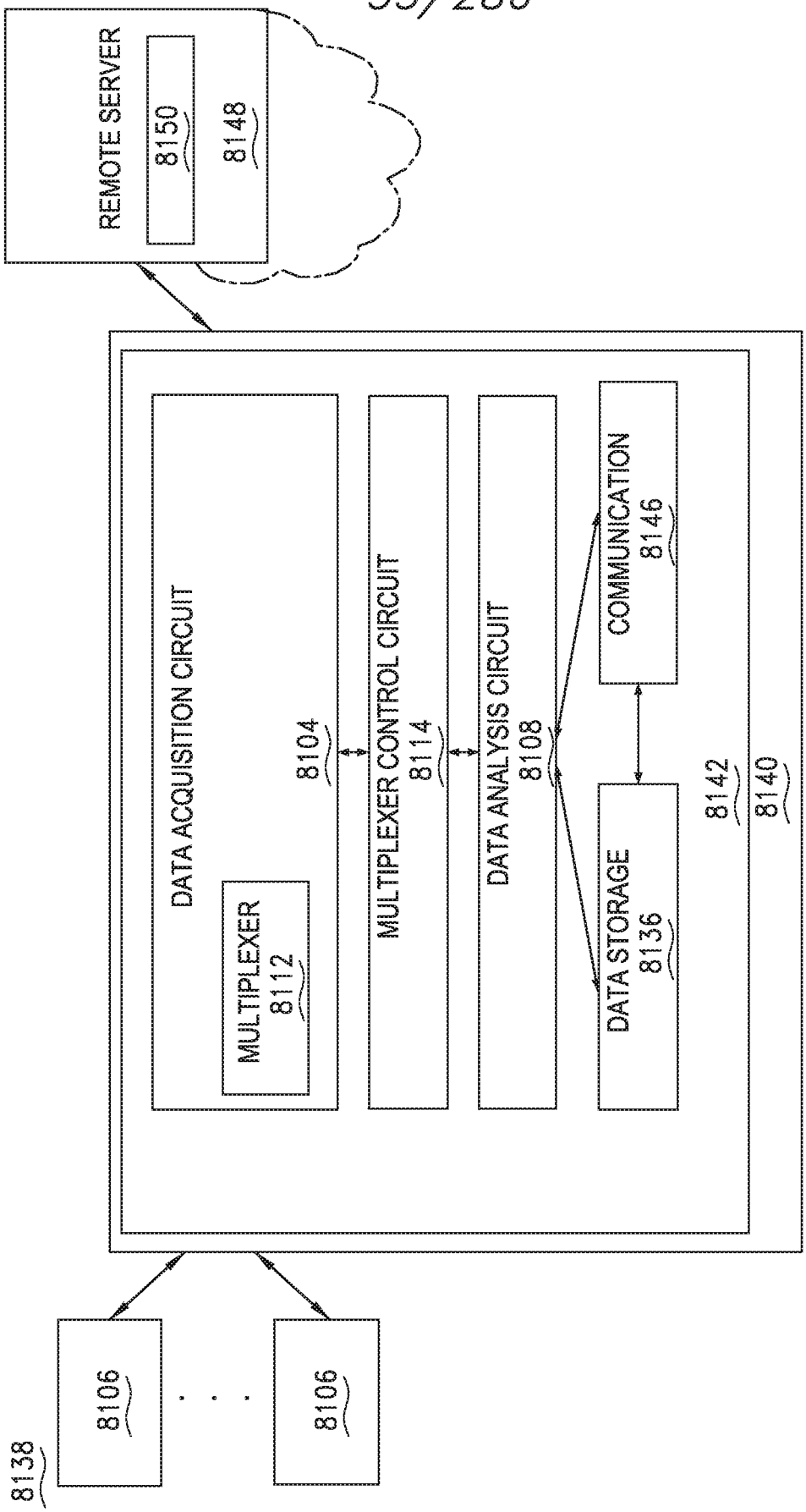
REMOTE SERVER
8150
8148
DATA ACQUISITION CIRCUIT
MULTIPLEXER
8112
8104
MULTIPLEXER CONTROL CIRCUIT
8114
DATA ANALYSIS CIRCUIT
8108
COMMUNICATION
8146
DATA STORAGE
8136
8142
8140
8106
8106
8138

FIG. 55

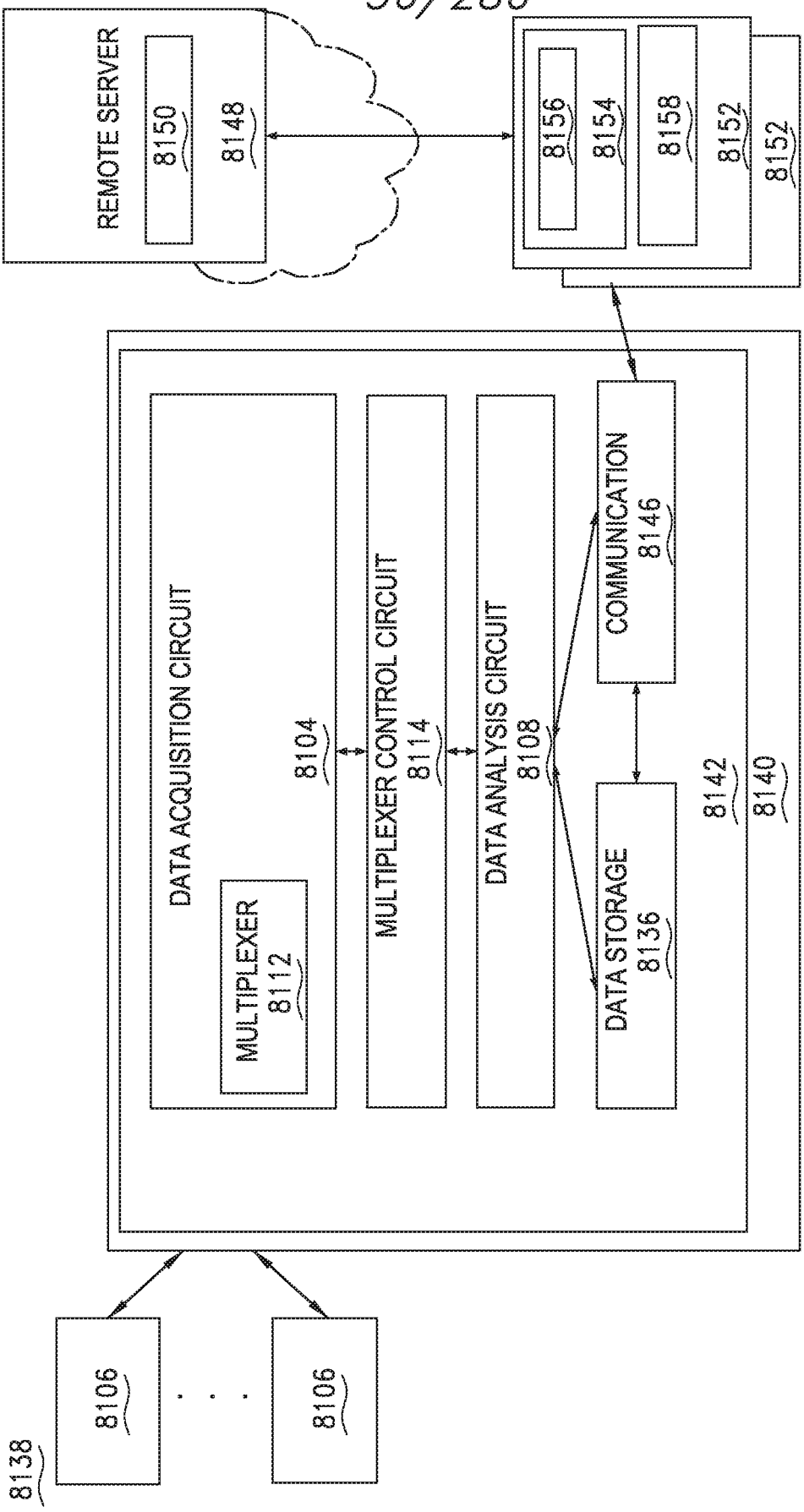
REMOTE SERVER
8150
8148
8156
8154
8158
8152
8152
8140
8142
DATA ACQUISITION CIRCUIT
MULTIPLEXER
8112
8104
MULTIPLEXER CONTROL CIRCUIT
8114
DATA ANALYSIS CIRCUIT
8108
COMMUNICATION
8146
DATA STORAGE
8136
8138
8106
8106

FIG. 56

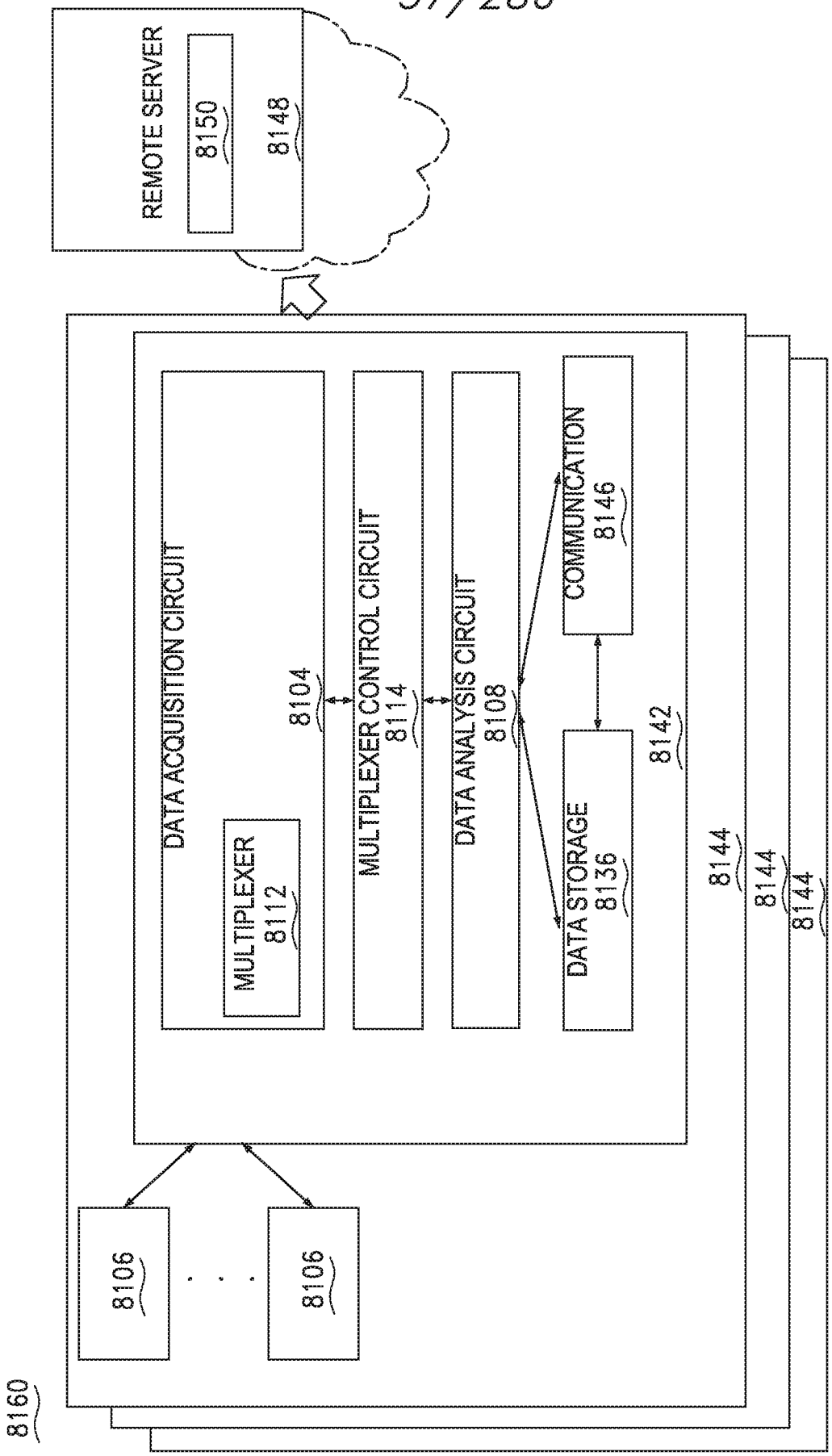
REMOTE SERVER
8150
8148
8160
8144
8144
8144
8142
DATA ACQUISITION CIRCUIT
MULTIPLEXER
8112
8104
MULTIPLEXER CONTROL CIRCUIT
8114
DATA ANALYSIS CIRCUIT
8108
COMMUNICATION
8146
DATA STORAGE
8136
8106
8106

FIG. 57

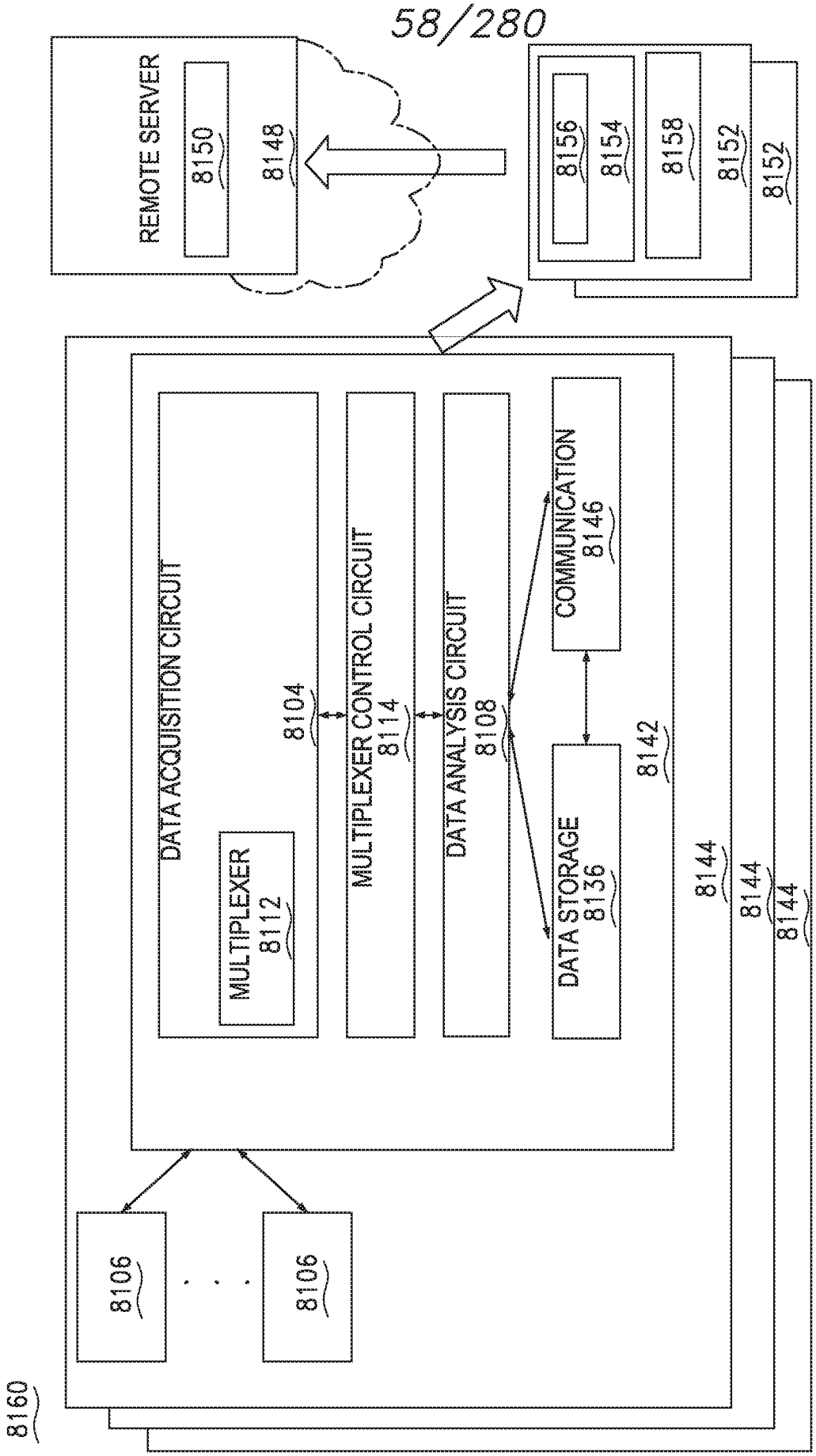
REMOTE SERVER
8150
8148
8156
8154
8158
8152
8152
8160
8106
8106
DATA ACQUISITION CIRCUIT
MULTIPLEXER
8112
8104
MULTIPLEXER CONTROL CIRCUIT
8114
DATA ANALYSIS CIRCUIT
8108
COMMUNICATION
8146
DATA STORAGE
8136
8142
8144
8144
8144

FIG. 58

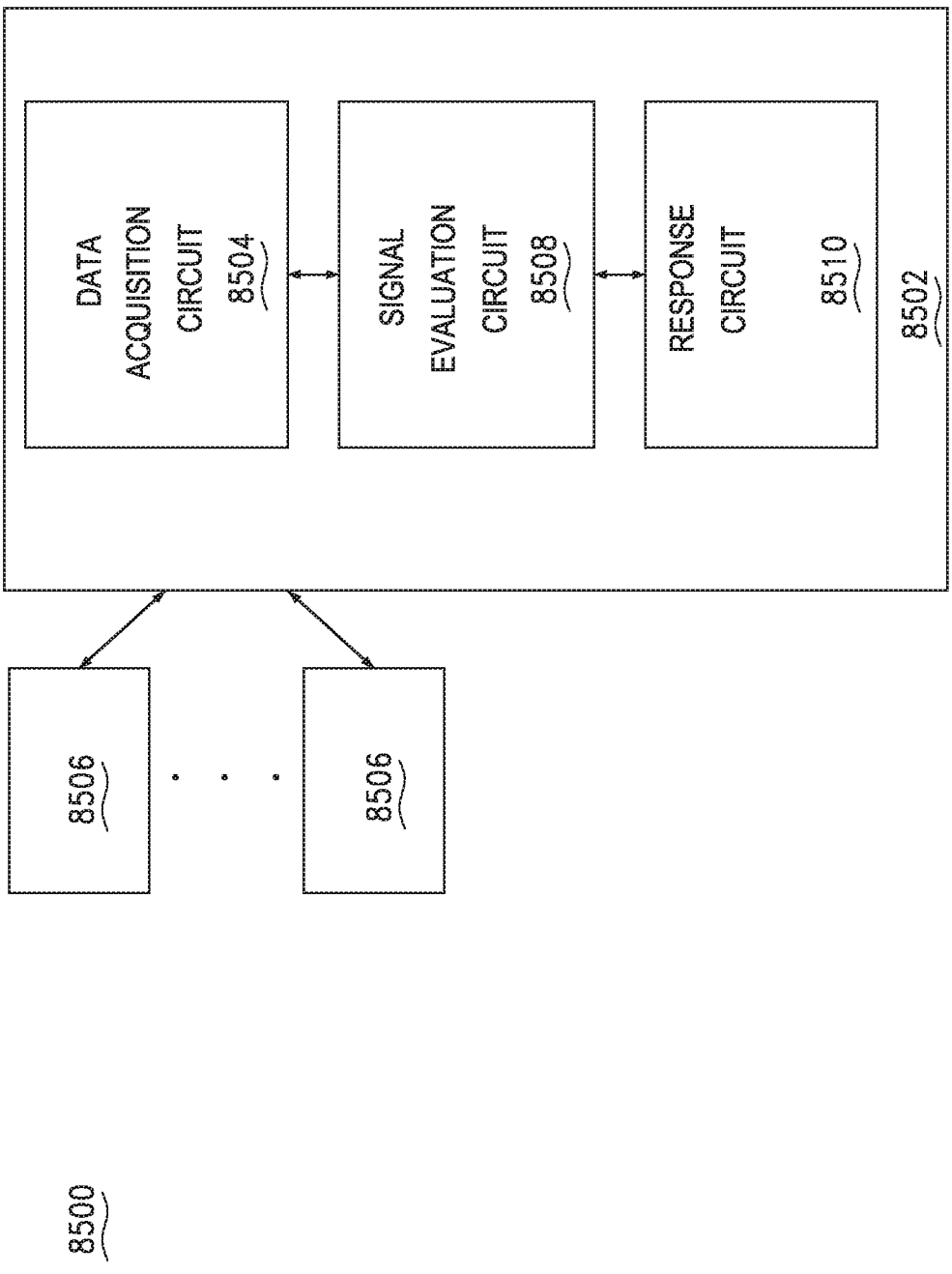
DATA ACQUISITION CIRCUIT 8504
SIGNAL EVALUATION CIRCUIT 8508
RESPONSE CIRCUIT 8510
8502
8506
8506
8500

FIG. 59

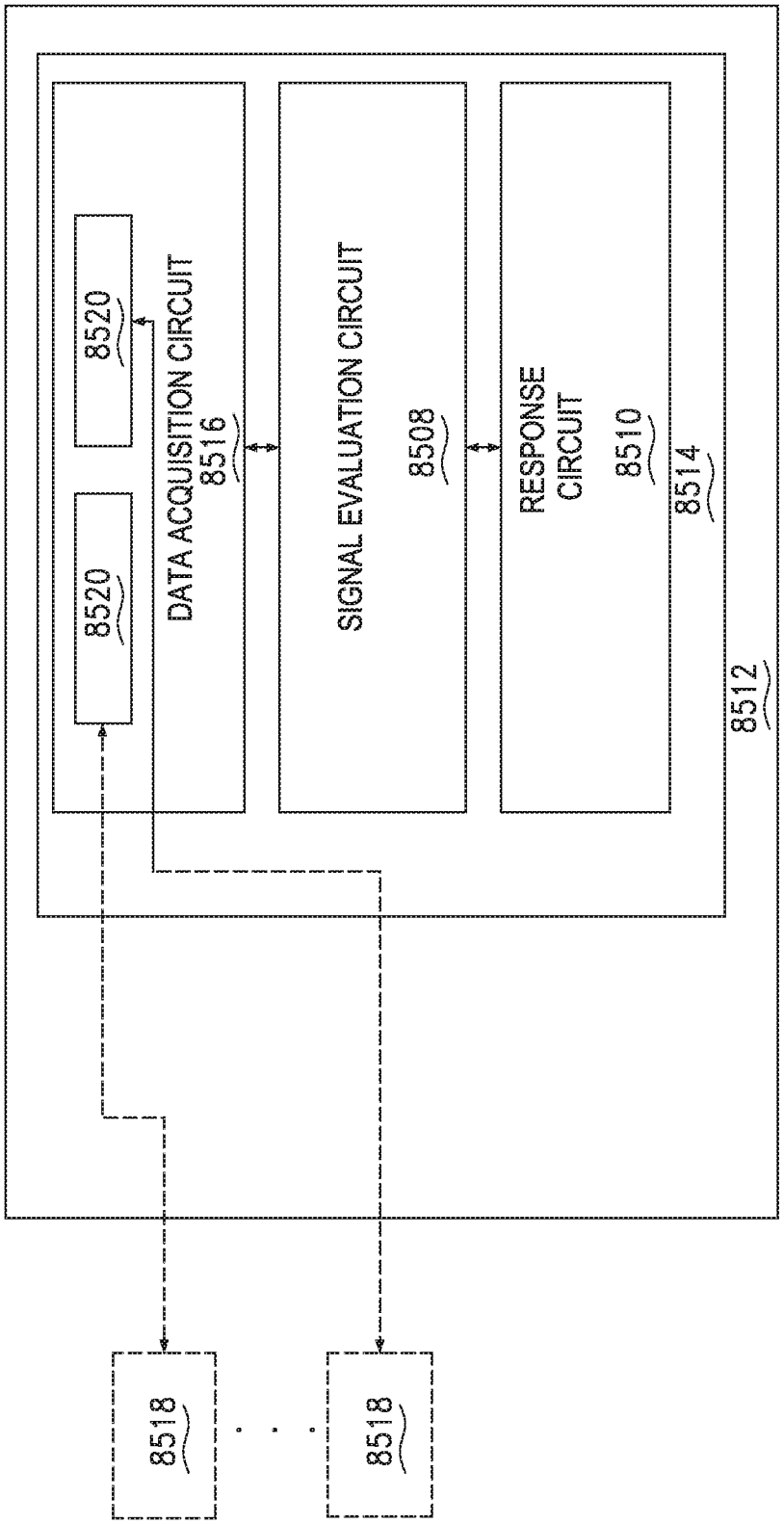
8520
8520
DATA ACQUISITION CIRCUIT
8516
SIGNAL EVALUATION CIRCUIT
8508
RESPONSE CIRCUIT
8510
8514
8512
8518
8518

FIG. 60

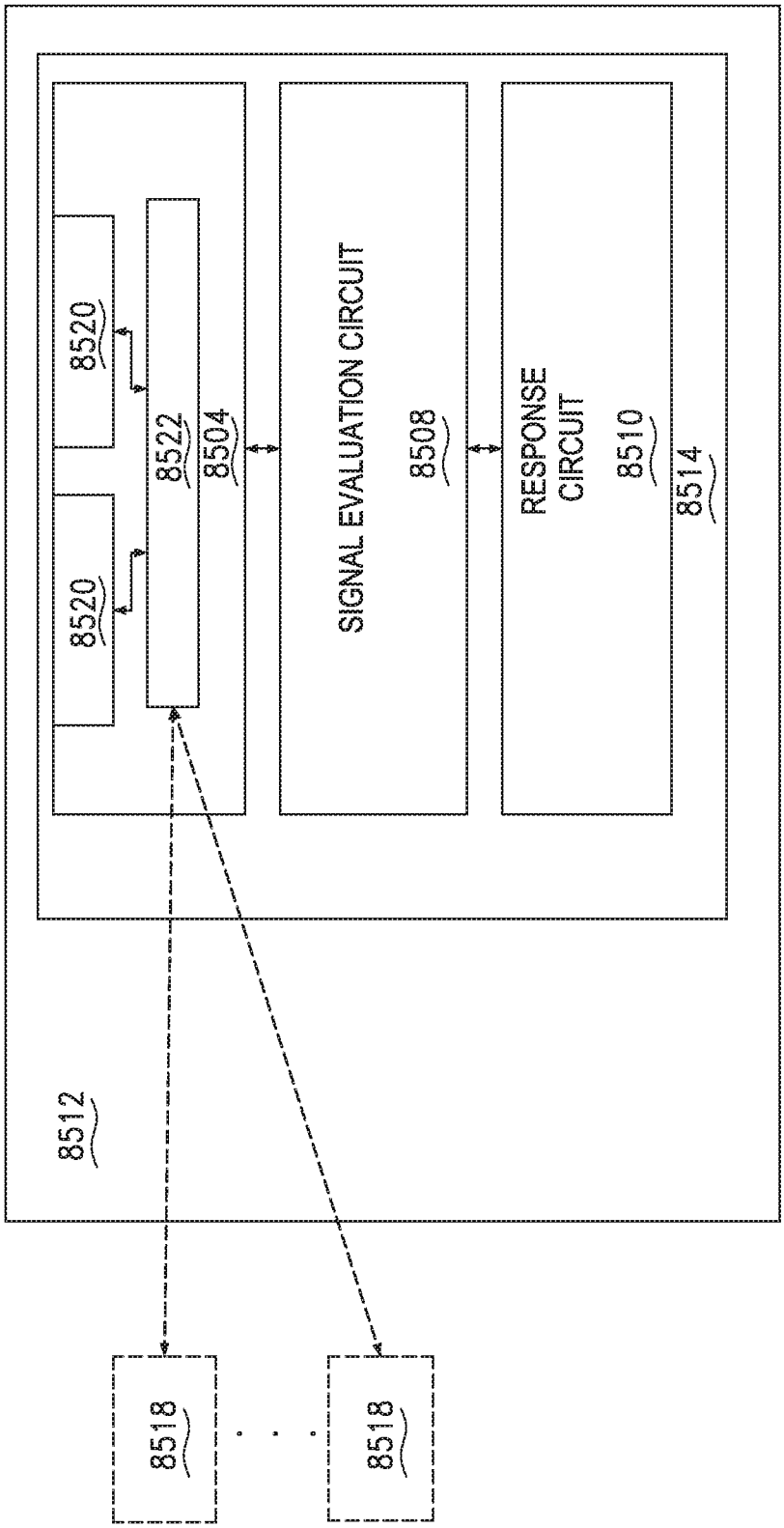
8520
8520
8522
8504
SIGNAL EVALUATION CIRCUIT
8508
RESPONSE CIRCUIT
8510
8514
8512
8518
8518

FIG. 61

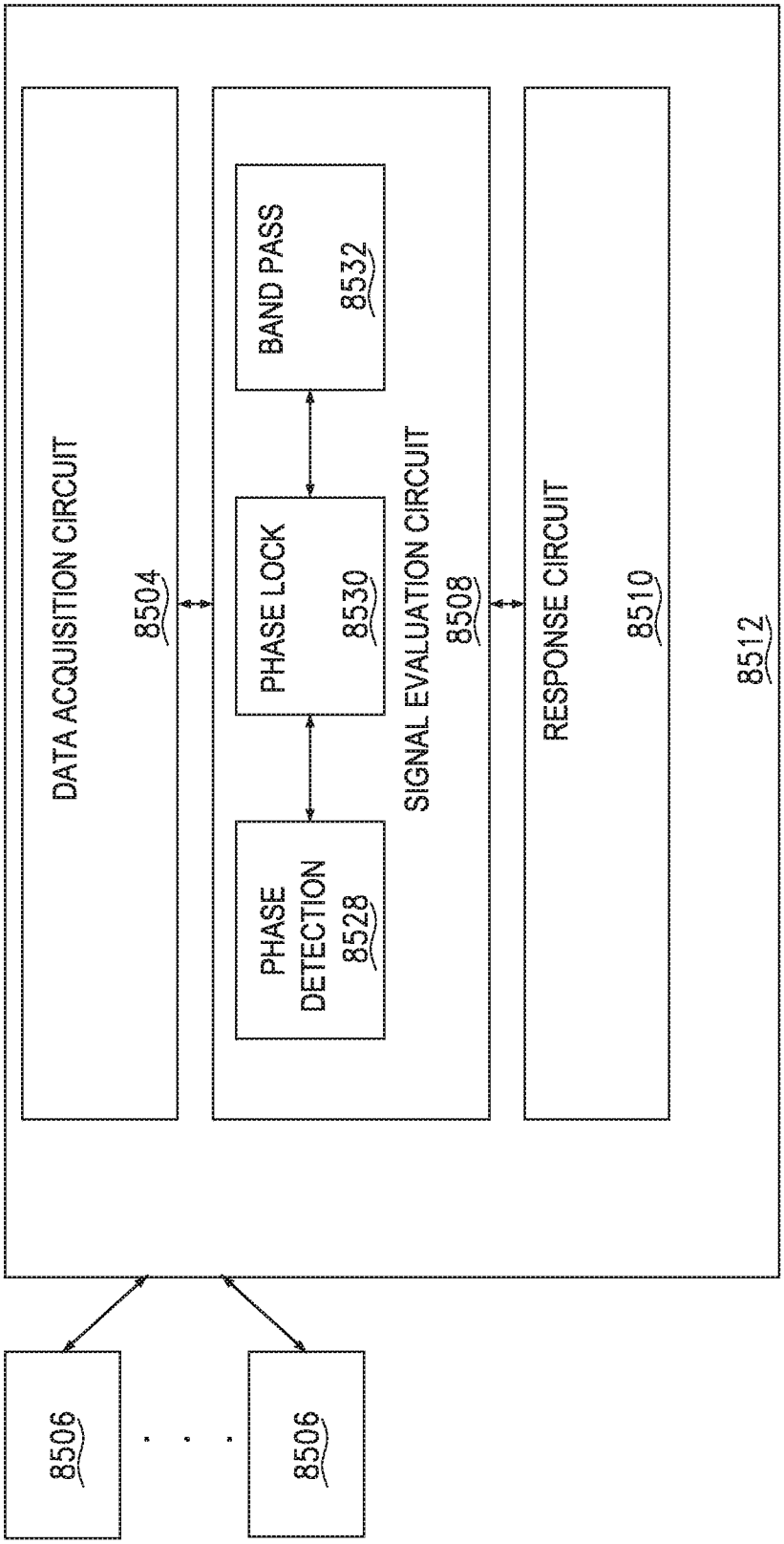
DATA ACQUISITION CIRCUIT
8504
SIGNAL EVALUATION CIRCUIT
8508
BAND PASS
8532
PHASE LOCK
8530
PHASE DETECTION
8528
RESPONSE CIRCUIT
8510
8512
8506
8506

FIG. 62

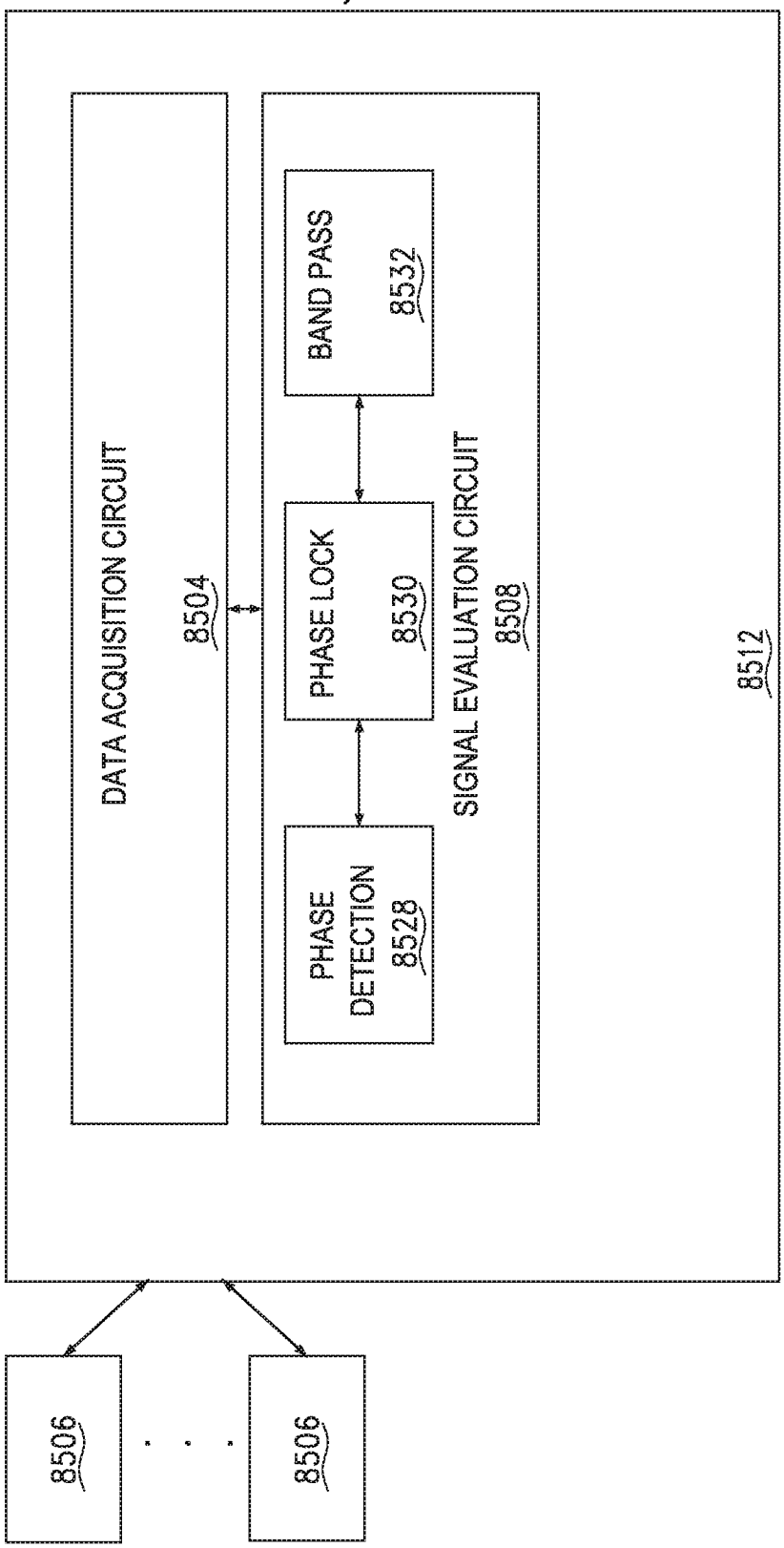
DATA ACQUISITION CIRCUIT
8504
SIGNAL EVALUATION CIRCUIT
8508
BAND PASS
8532
PHASE LOCK
8530
PHASE DETECTION
8528
8512
8506
8506

FIG. 63

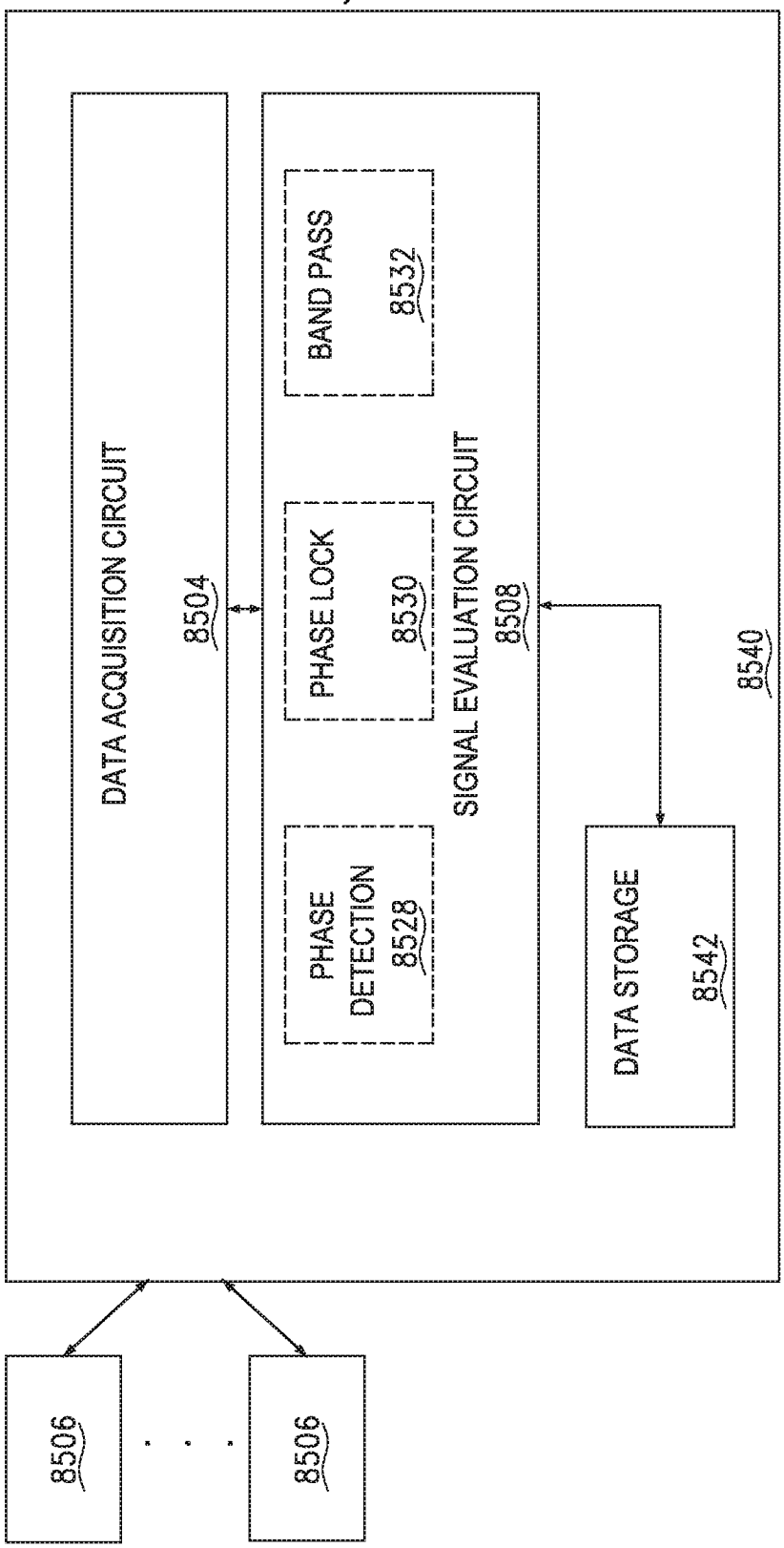
DATA ACQUISITION CIRCUIT
8504
SIGNAL EVALUATION CIRCUIT
8508
BAND PASS
8532
PHASE LOCK
8530
PHASE DETECTION
8528
DATA STORAGE
8542
8540
8506
8506

FIG. 64

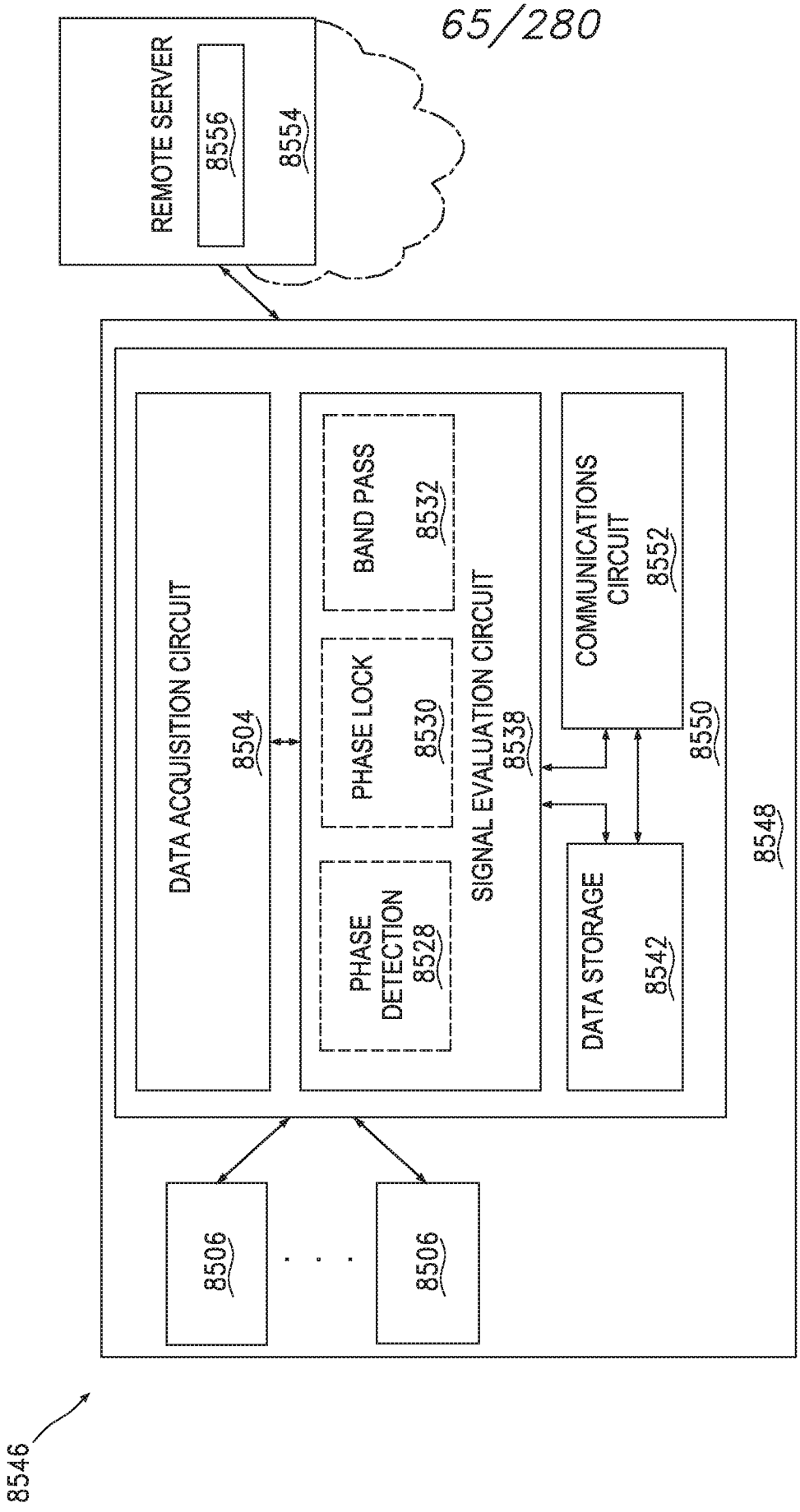
REMOTE SERVER
8556
8554
DATA ACQUISITION CIRCUIT
8504
SIGNAL EVALUATION CIRCUIT
8538
BAND PASS
8532
PHASE LOCK
8530
PHASE DETECTION
8528
COMMUNICATIONS CIRCUIT
8552
DATA STORAGE
8542
8550
8548
8506
8506
8546

FIG. 65

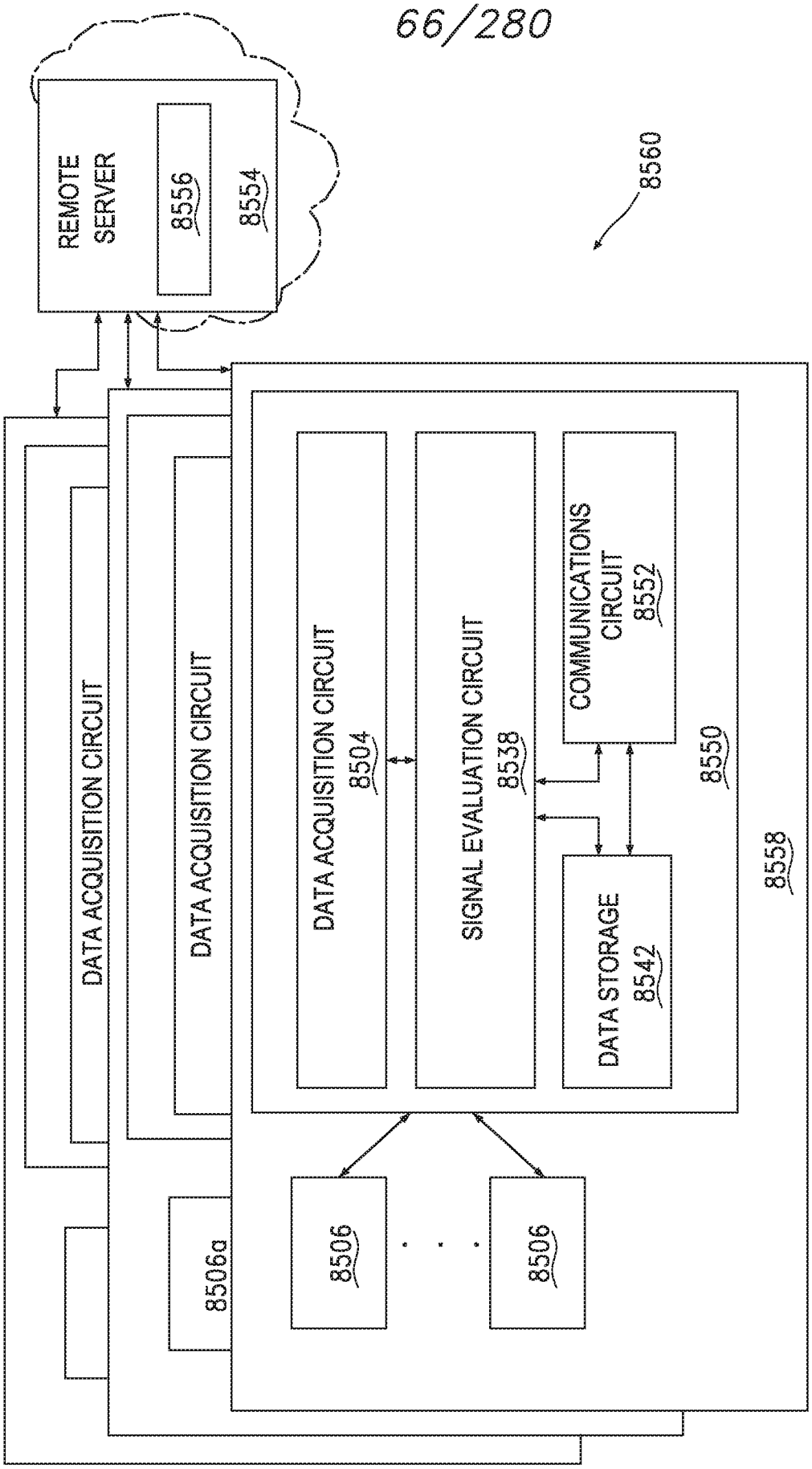
REMOTE SERVER
8556
8554
8560
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT
8504
SIGNAL EVALUATION CIRCUIT
8538
COMMUNICATIONS CIRCUIT
8552
DATA STORAGE
8542
8550
8558
8506a
8506
8506

FIG. 66

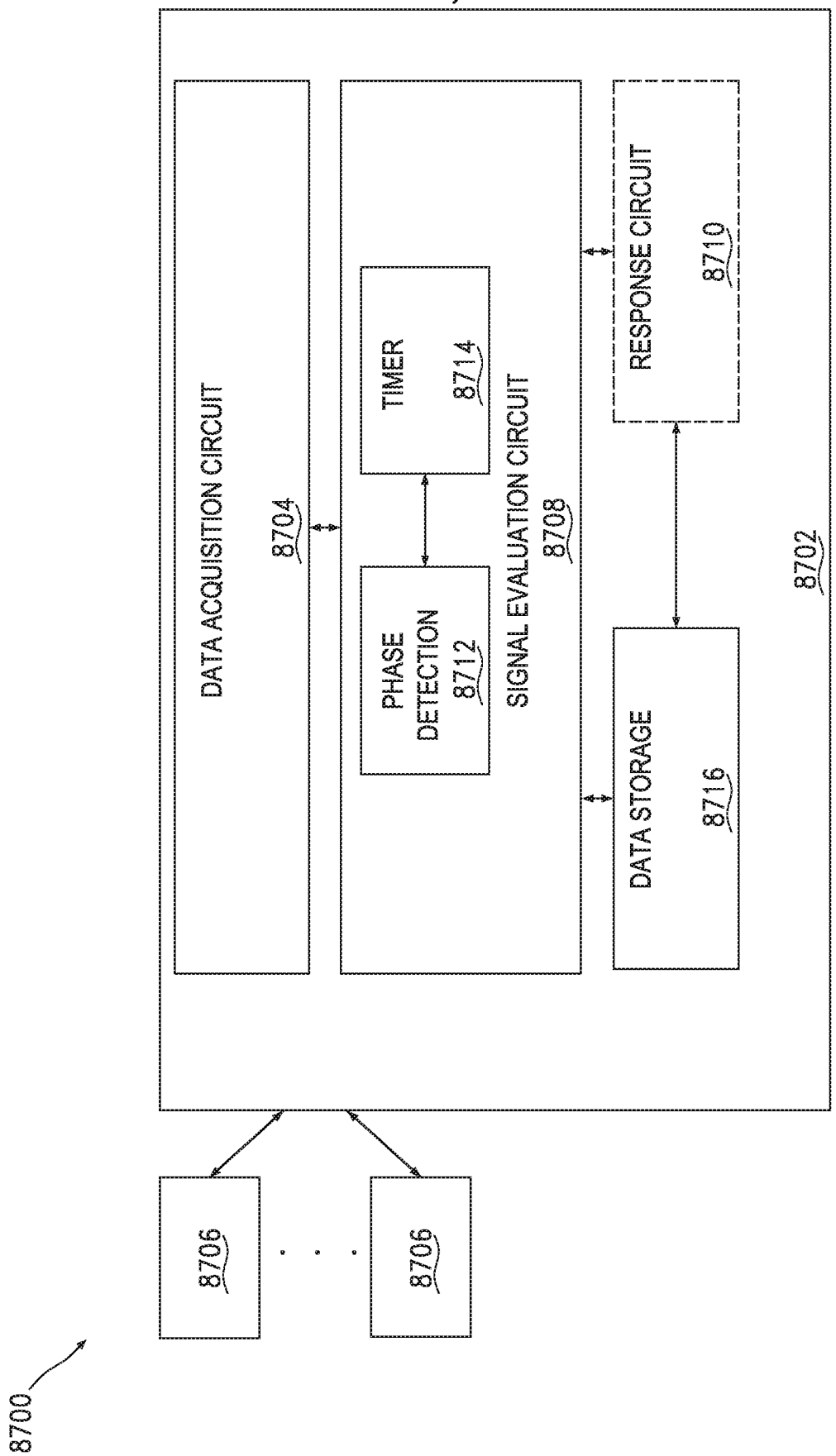
8700
8706
8706
8702
DATA ACQUISITION CIRCUIT
8704
SIGNAL EVALUATION CIRCUIT
8708
TIMER
8714
PHASE DETECTION
8712
RESPONSE CIRCUIT
8710
DATA STORAGE
8716

FIG. 67

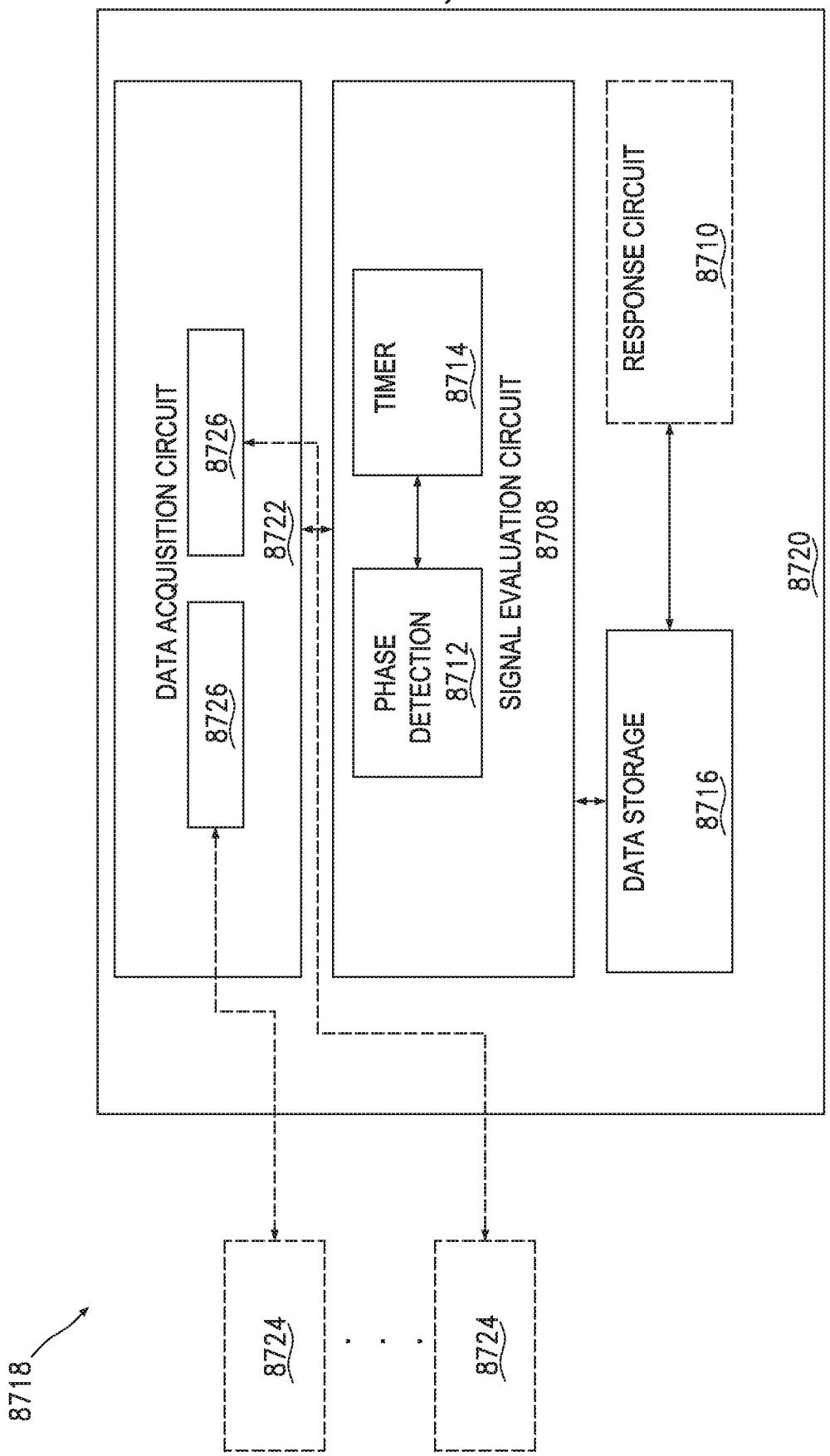
8718
8724
8724
8720
DATA ACQUISITION CIRCUIT
8726
8726
8722
SIGNAL EVALUATION CIRCUIT
8708
PHASE DETECTION
8712
TIMER
8714
RESPONSE CIRCUIT
8710
DATA STORAGE
8716

FIG. 68

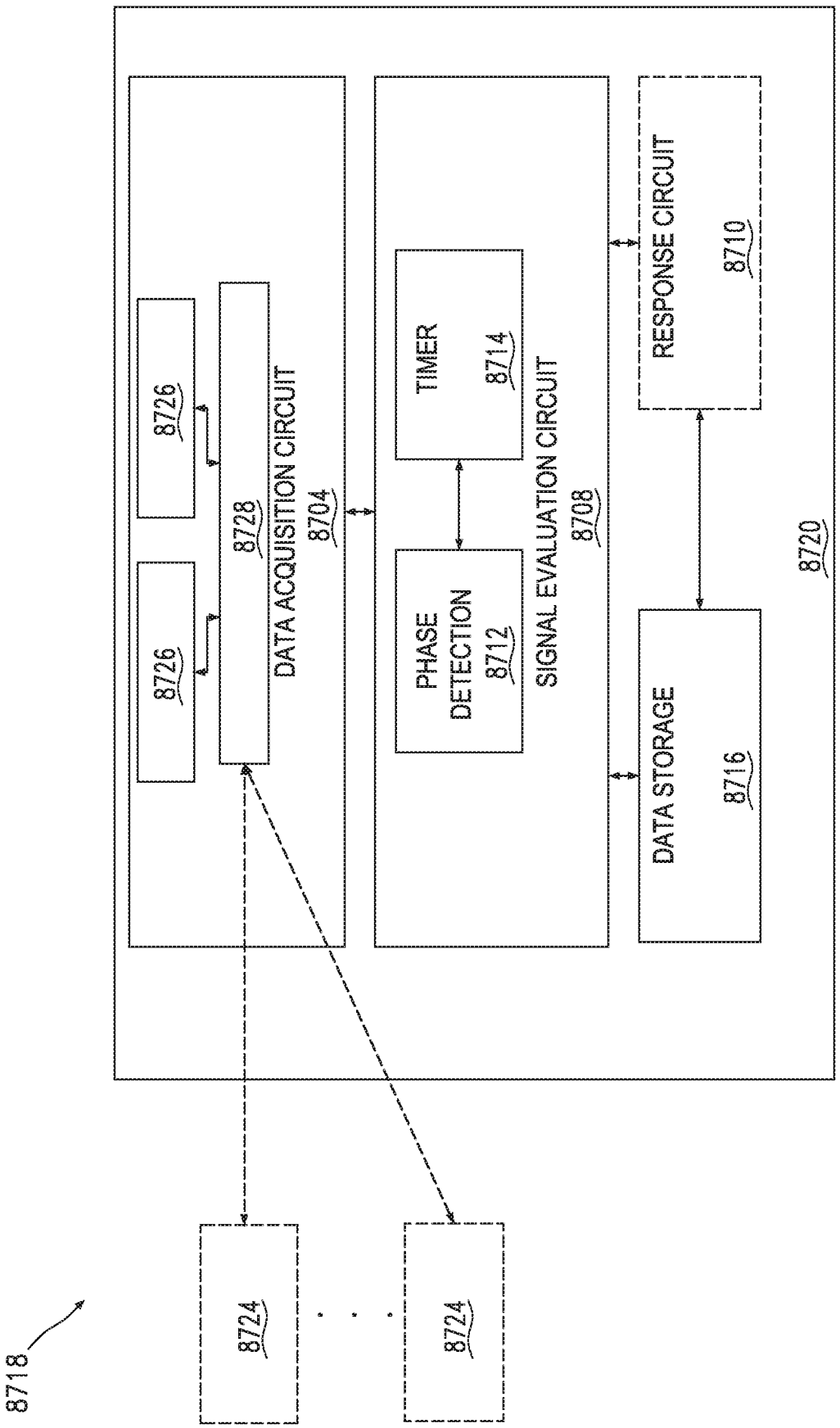
8720
8726
8726
8728
DATA ACQUISITION CIRCUIT
8704
TIMER
8714
PHASE DETECTION
8712
SIGNAL EVALUATION CIRCUIT
8708
RESPONSE CIRCUIT
8710
DATA STORAGE
8716
8724
8724
8718

FIG. 69

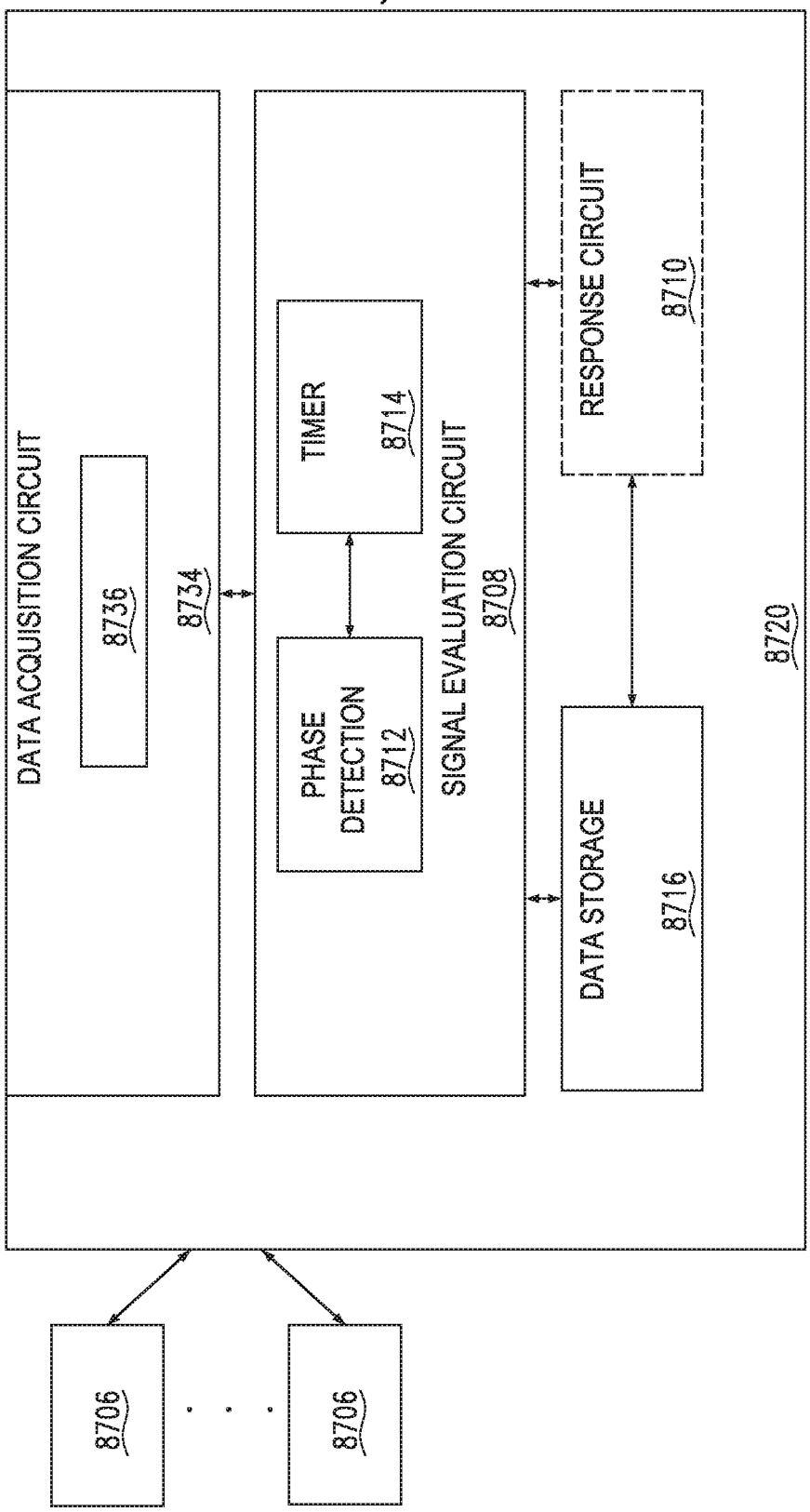
DATA ACQUISITION CIRCUIT
8736
8734
SIGNAL EVALUATION CIRCUIT
8708
TIMER
8714
PHASE DETECTION
8712
RESPONSE CIRCUIT
8710
DATA STORAGE
8716
8720
8706
8706

FIG. 70

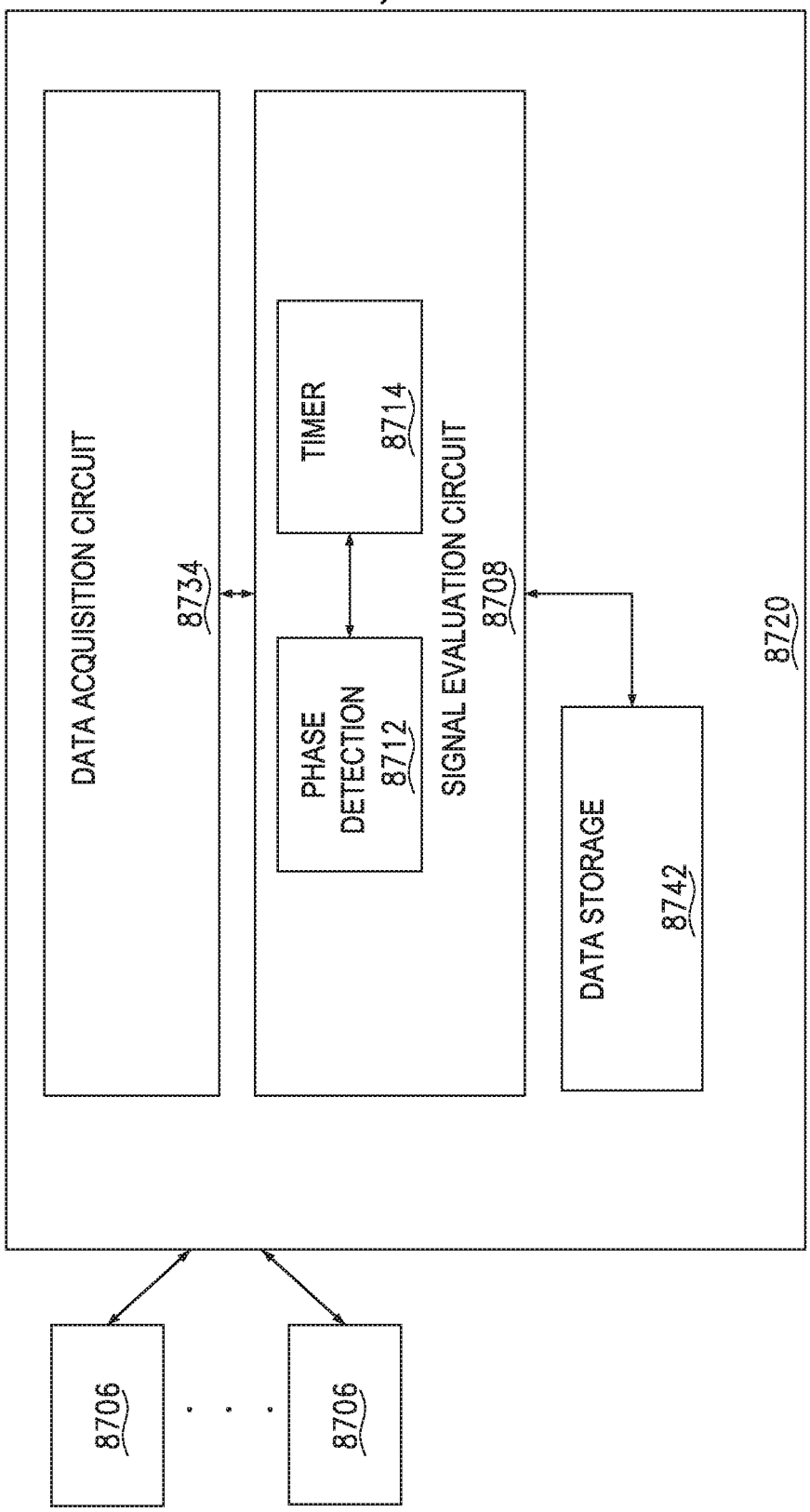
DATA ACQUISITION CIRCUIT
8734
SIGNAL EVALUATION CIRCUIT
8708
TIMER
8714
PHASE DETECTION
8712
DATA STORAGE
8742
8720
8706
8706

FIG. 71

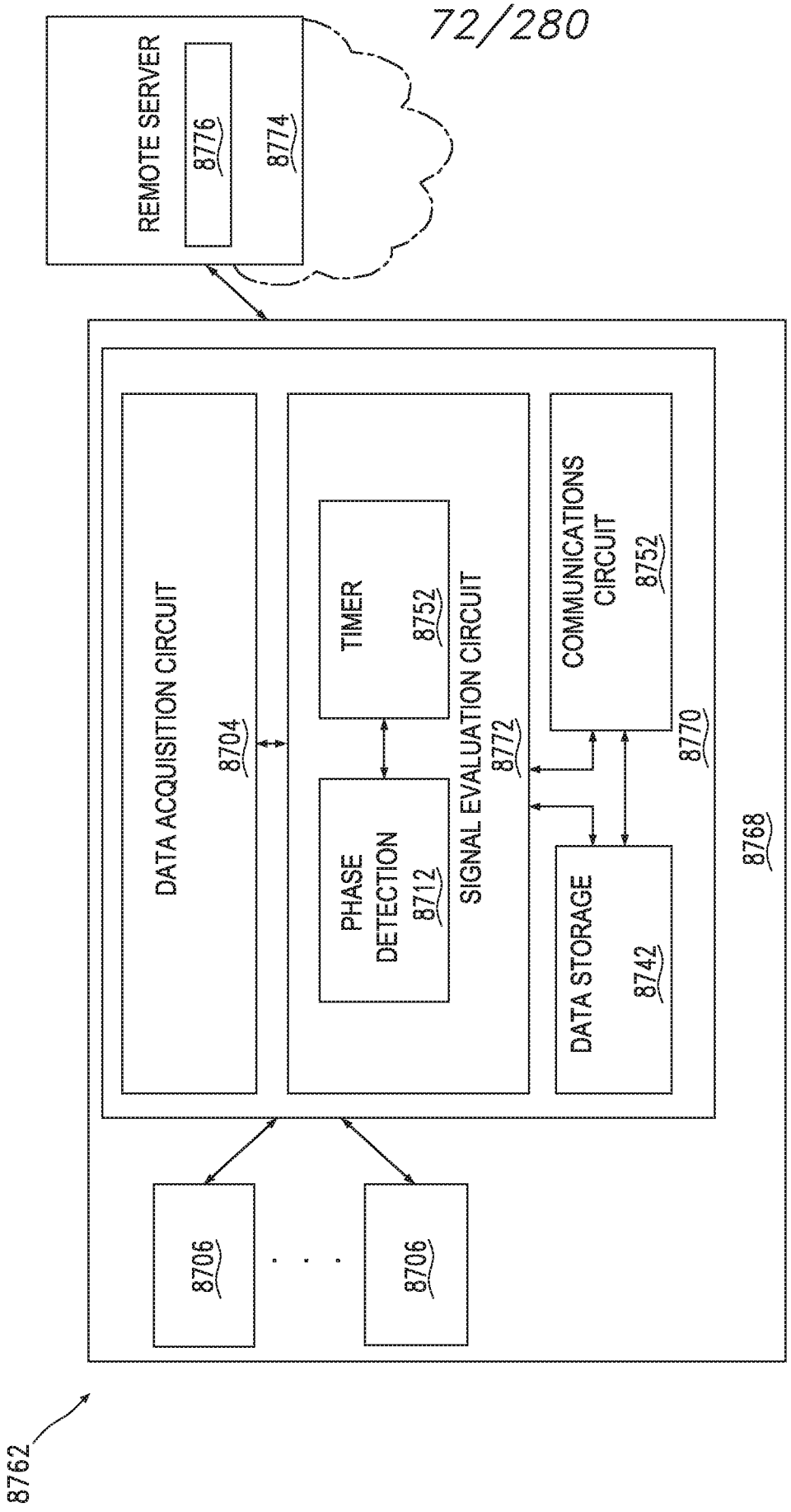
72/280
REMOTE SERVER
8776
8774
DATA ACQUISITION CIRCUIT
8704
SIGNAL EVALUATION CIRCUIT
8772
TIMER
8752
PHASE DETECTION
8712
COMMUNICATIONS CIRCUIT
8752
8770
DATA STORAGE
8742
8768
8706
8706
8762

FIG. 72

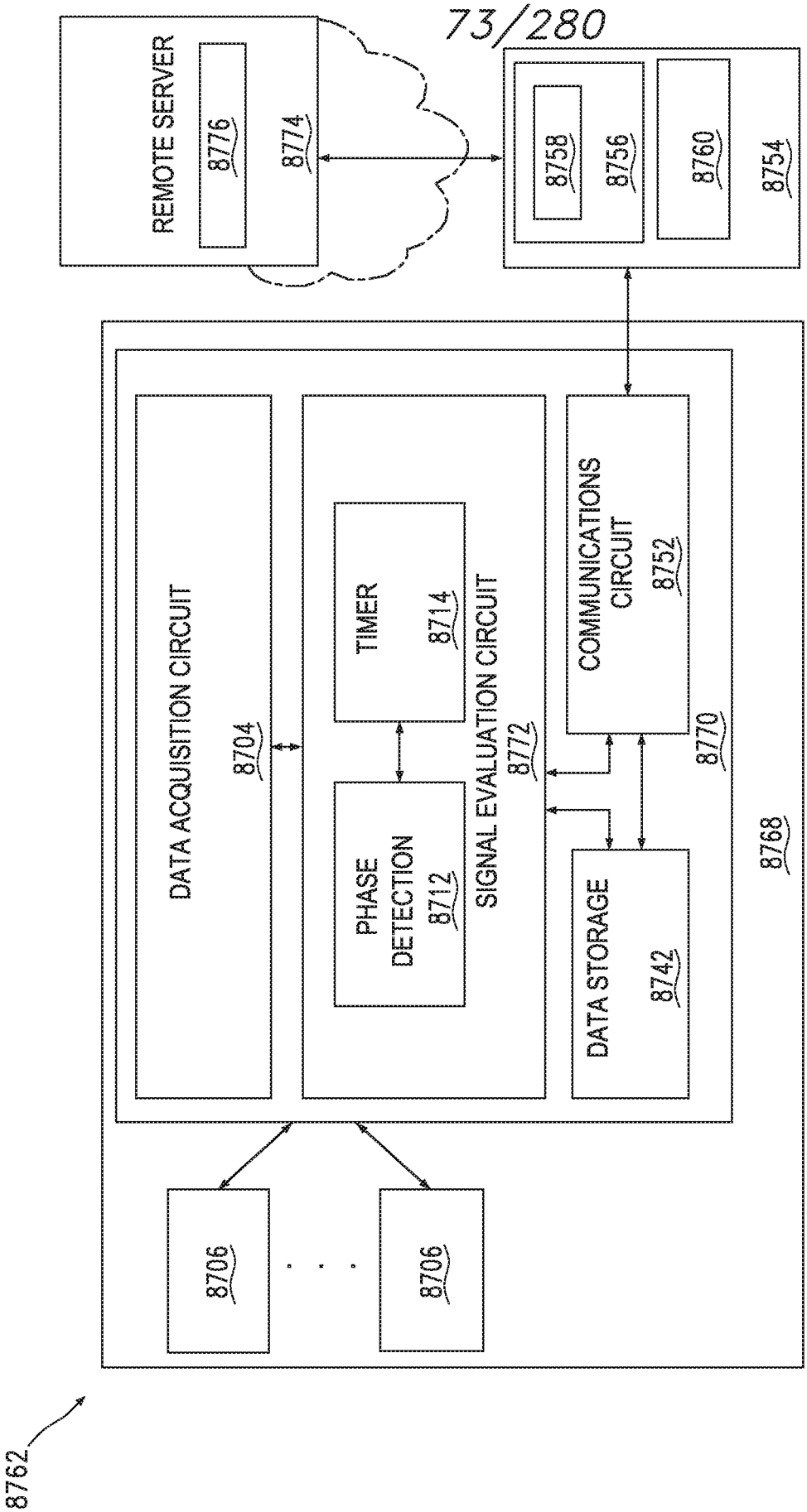
73/280
REMOTE SERVER
8776
8774
8758
8756
8760
8754
DATA ACQUISITION CIRCUIT
8704
TIMER
8714
PHASE DETECTION
8712
SIGNAL EVALUATION CIRCUIT
8772
COMMUNICATIONS CIRCUIT
8752
8770
DATA STORAGE
8742
8768
8706
8706
8762

FIG. 73

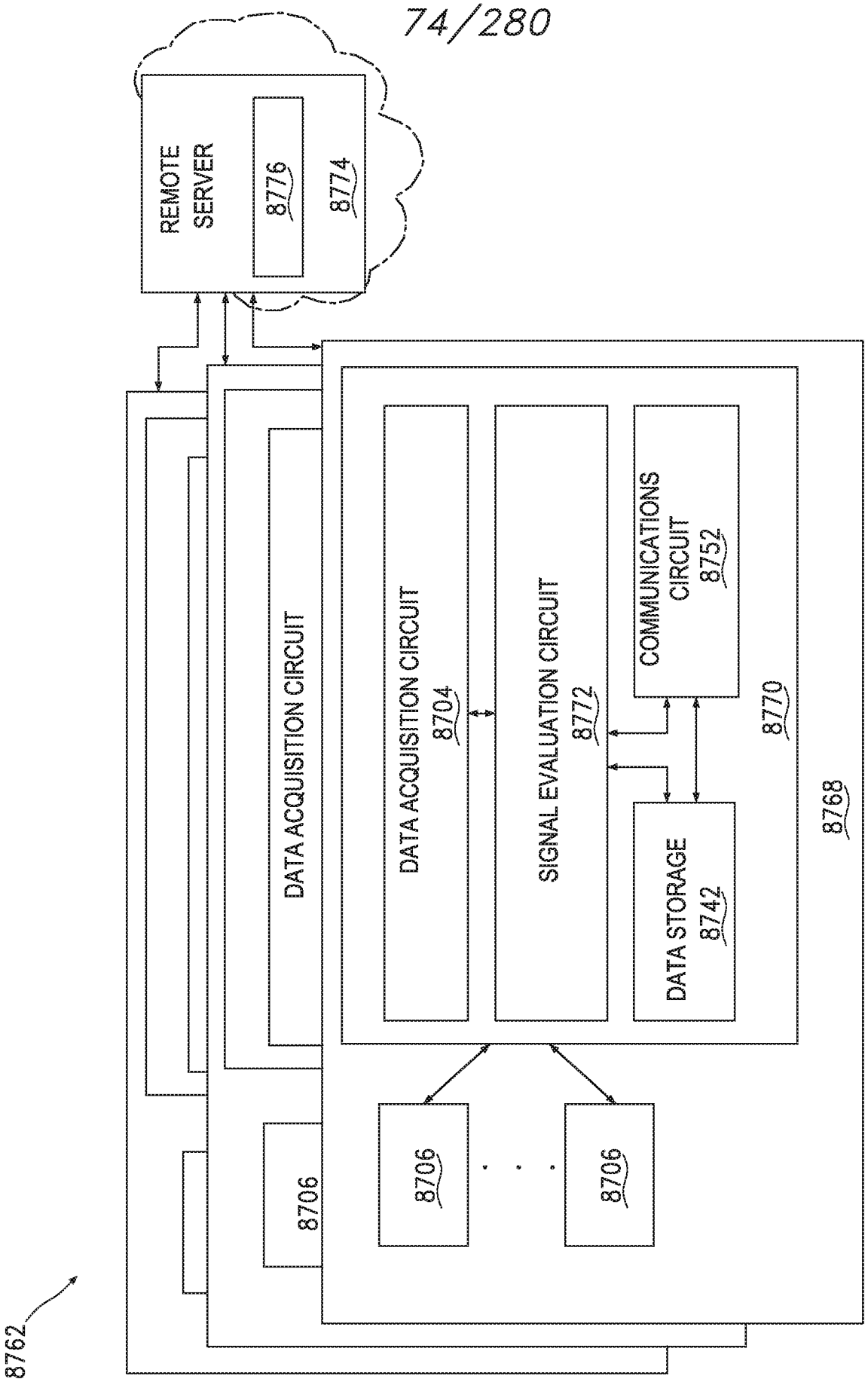
REMOTE SERVER
8776
8774
8762
8768
8770
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT 8704
SIGNAL EVALUATION CIRCUIT 8772
COMMUNICATIONS CIRCUIT 8752
DATA STORAGE 8742
8706
8706
8706

FIG. 74

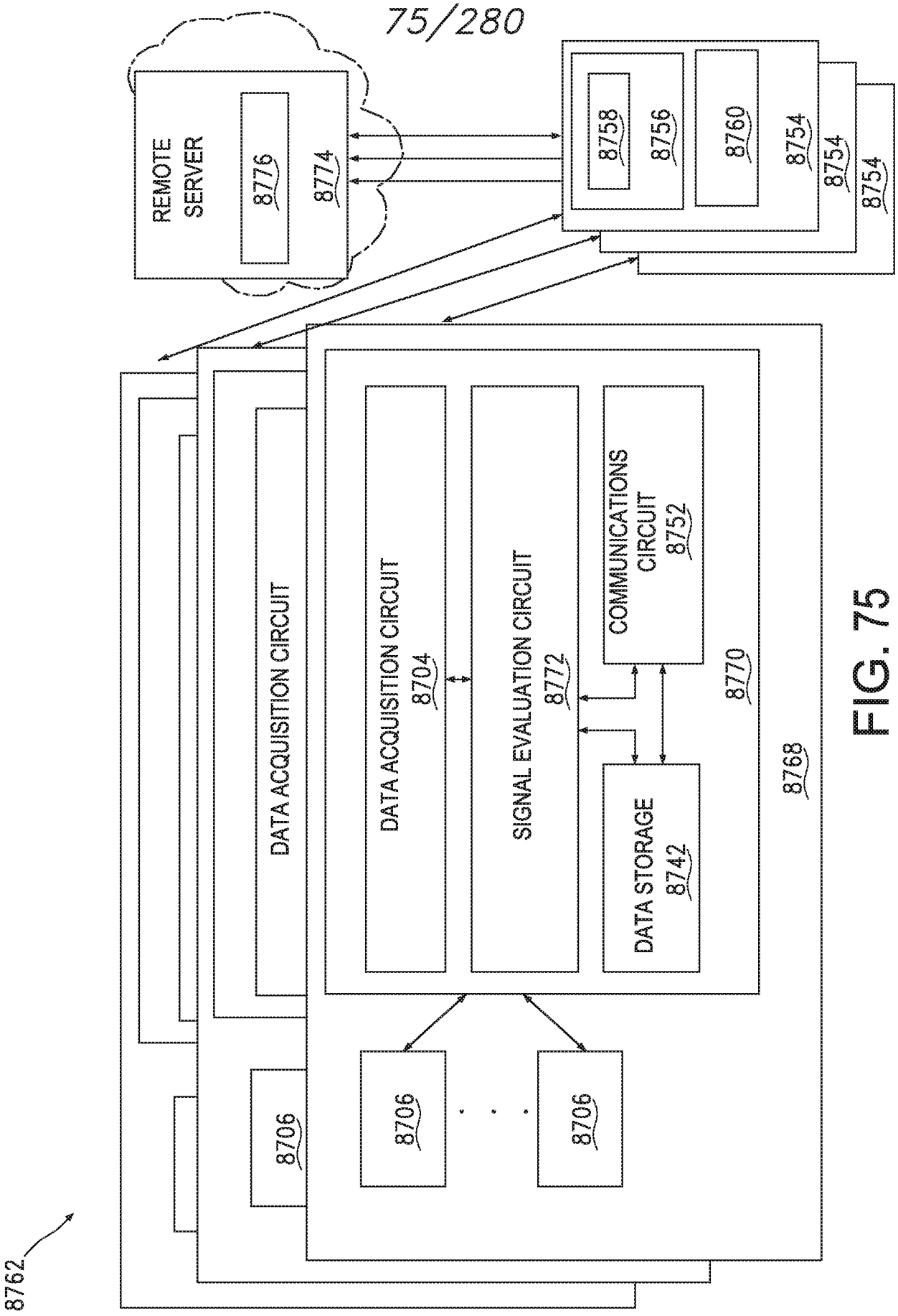
REMOTE SERVER
8776
8774
8758
8756
8760
8754
8754
8754
8762
8706
8706
8706
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT 8704
SIGNAL EVALUATION CIRCUIT 8772
COMMUNICATIONS CIRCUIT 8752
DATA STORAGE 8742
8770
8768

FIG. 75

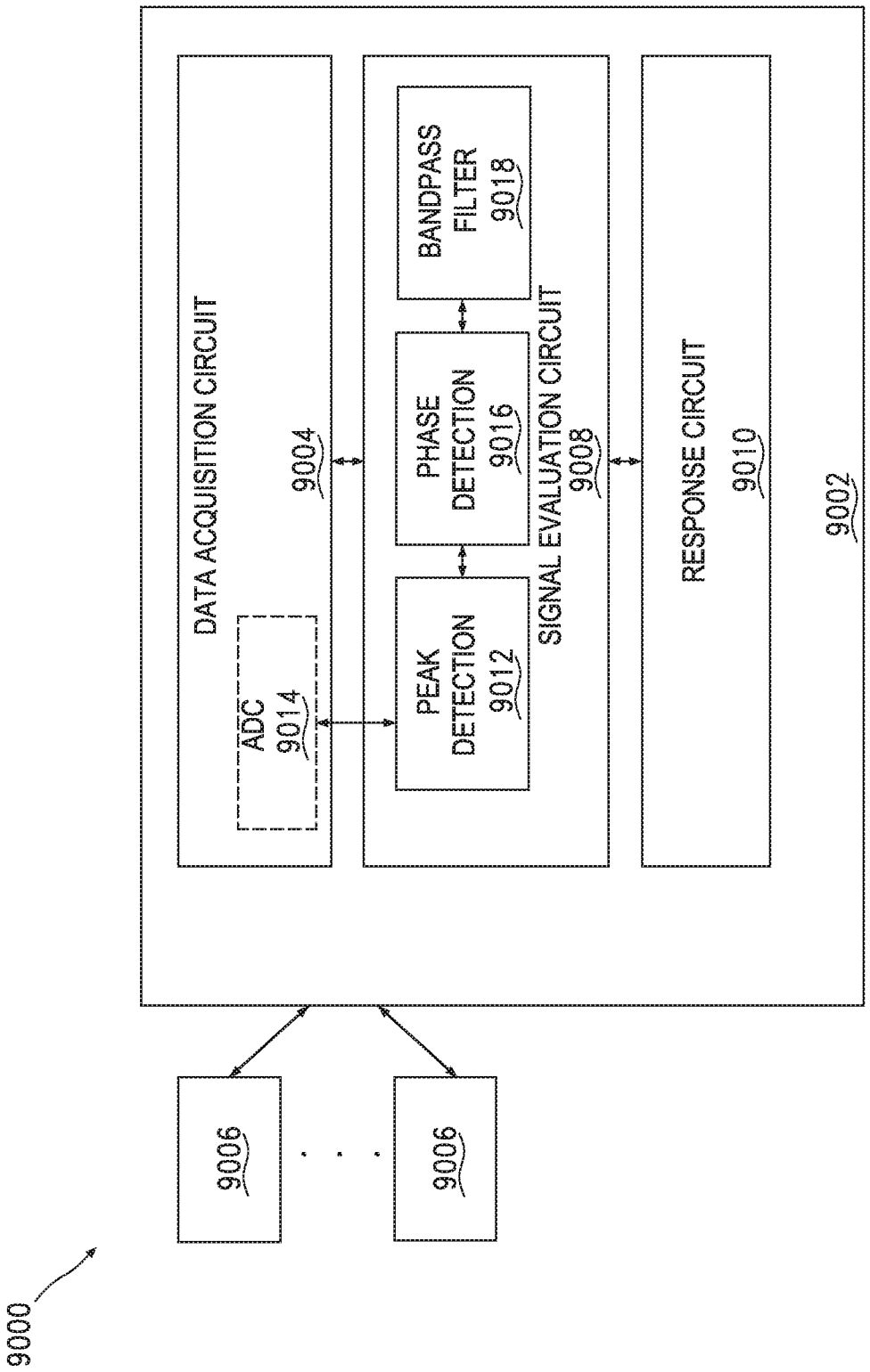
9000
9006
9006
9002
DATA ACQUISITION CIRCUIT
9004
ADC
9014
SIGNAL EVALUATION CIRCUIT
9008
PEAK DETECTION
9012
PHASE DETECTION
9016
BANDPASS FILTER
9018
RESPONSE CIRCUIT
9010

FIG. 76

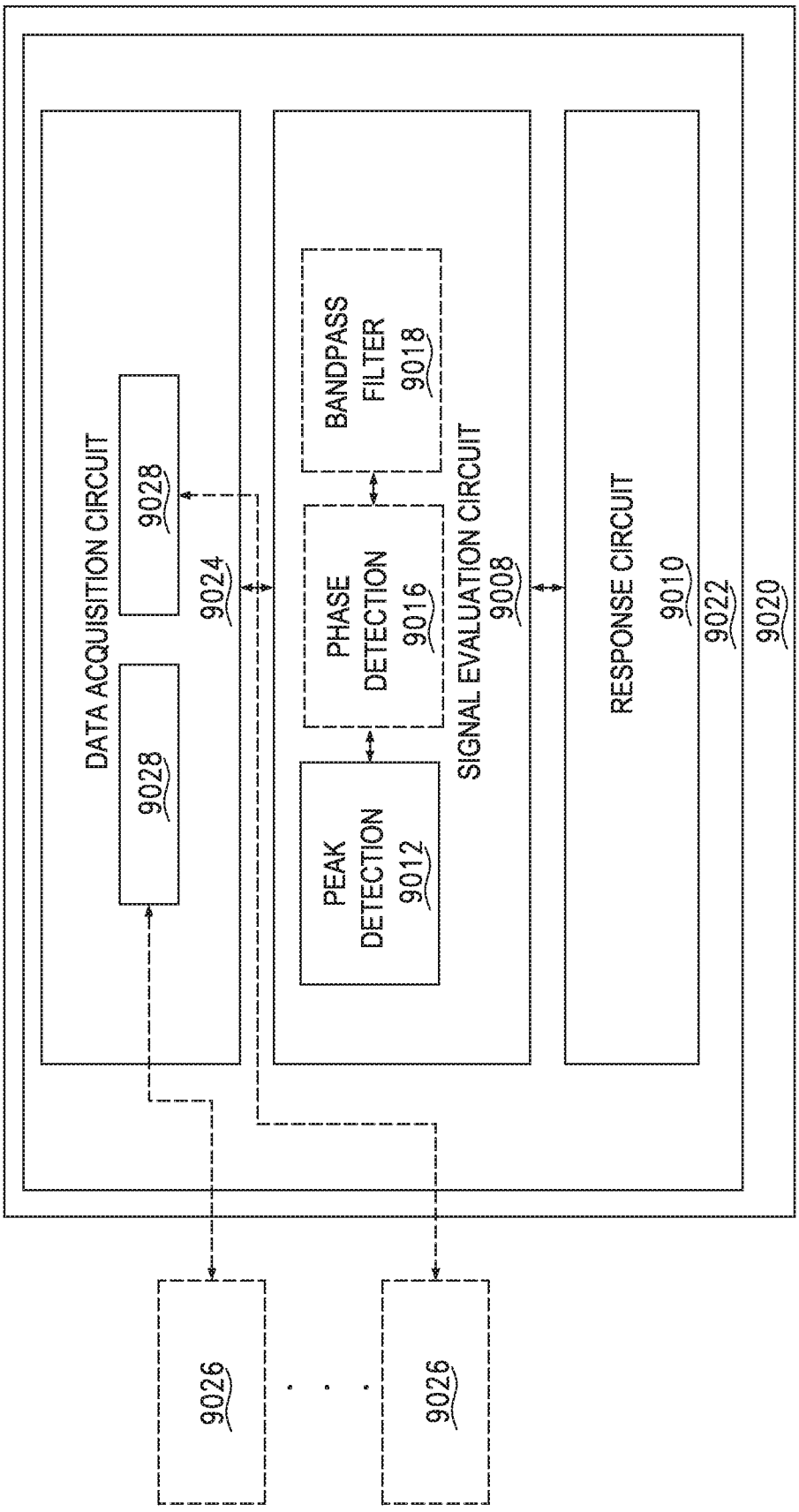
DATA ACQUISITION CIRCUIT
9028
9028
9024
SIGNAL EVALUATION CIRCUIT
9008
BANDPASS FILTER 9018
PHASE DETECTION 9016
PEAK DETECTION 9012
RESPONSE CIRCUIT
9010
9022
9020
9026
9026

FIG. 77

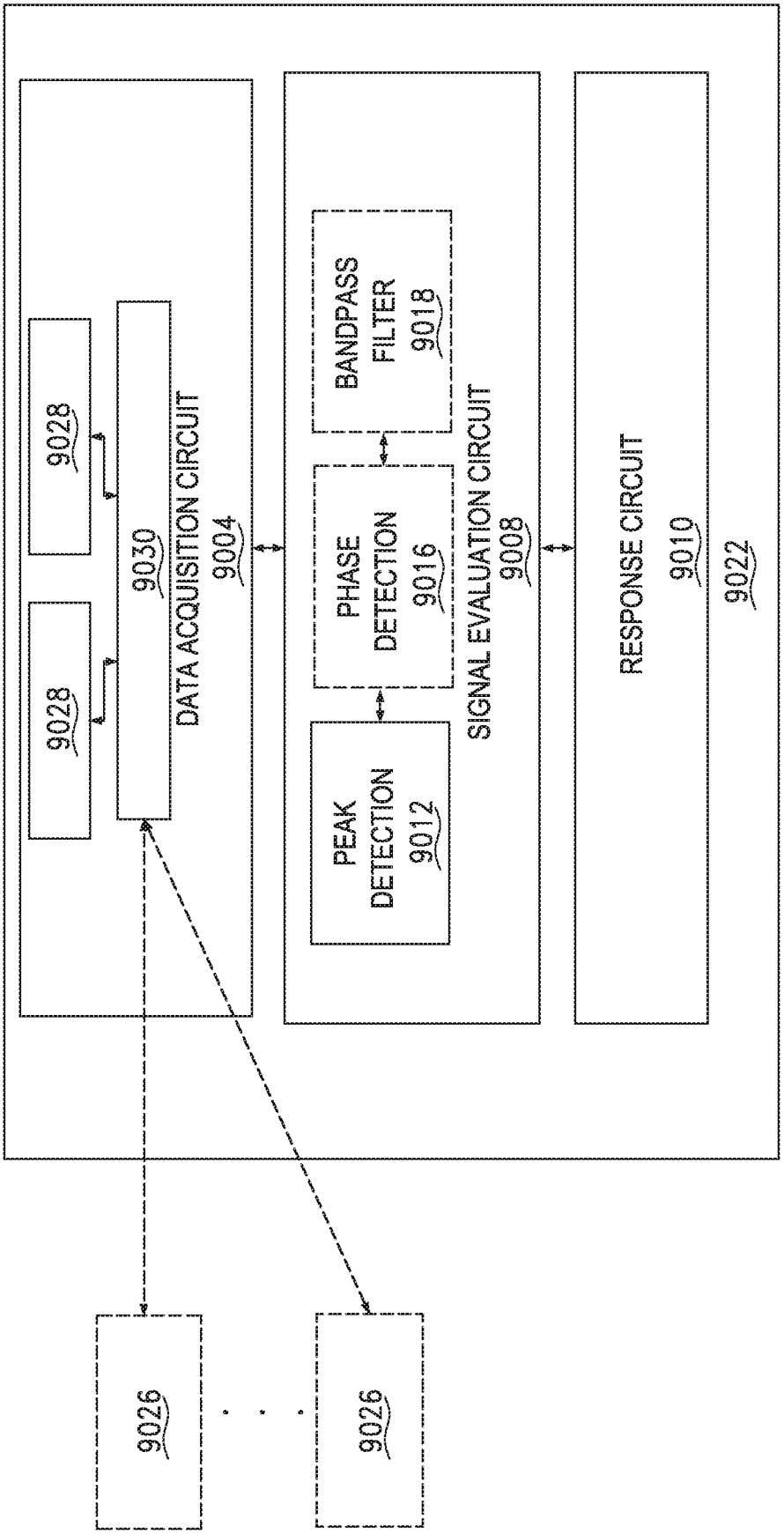
9028
9028
9030
DATA ACQUISITION CIRCUIT
9004
PEAK DETECTION 9012
PHASE DETECTION 9016
BANDPASS FILTER 9018
SIGNAL EVALUATION CIRCUIT
9008
RESPONSE CIRCUIT
9010
9022
9026
9026

FIG. 78

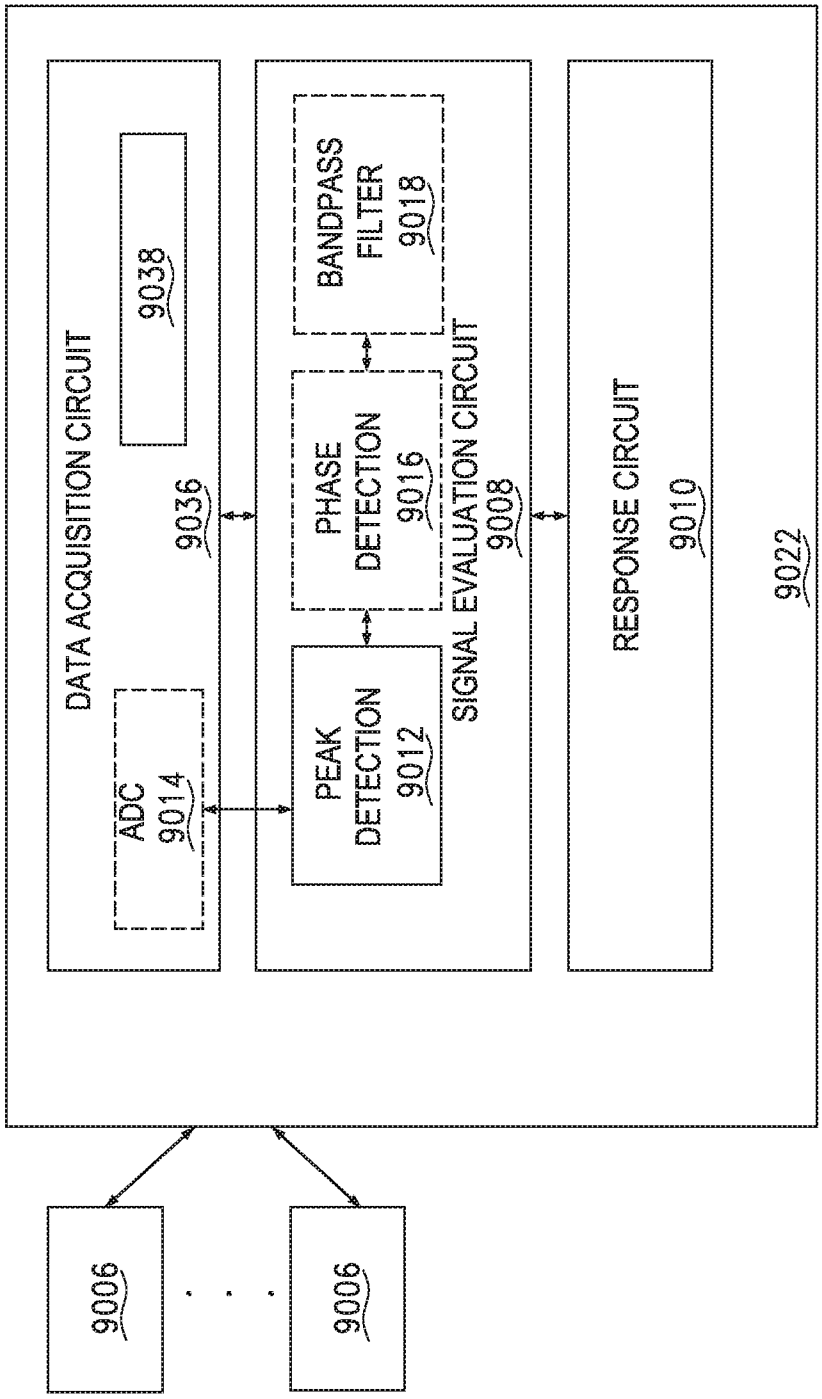
9022
DATA ACQUISITION CIRCUIT
9036
ADC
9014
9038
SIGNAL EVALUATION CIRCUIT
9008
PEAK DETECTION
9012
PHASE DETECTION
9016
BANDPASS FILTER
9018
RESPONSE CIRCUIT
9010
9006
9006

FIG. 79

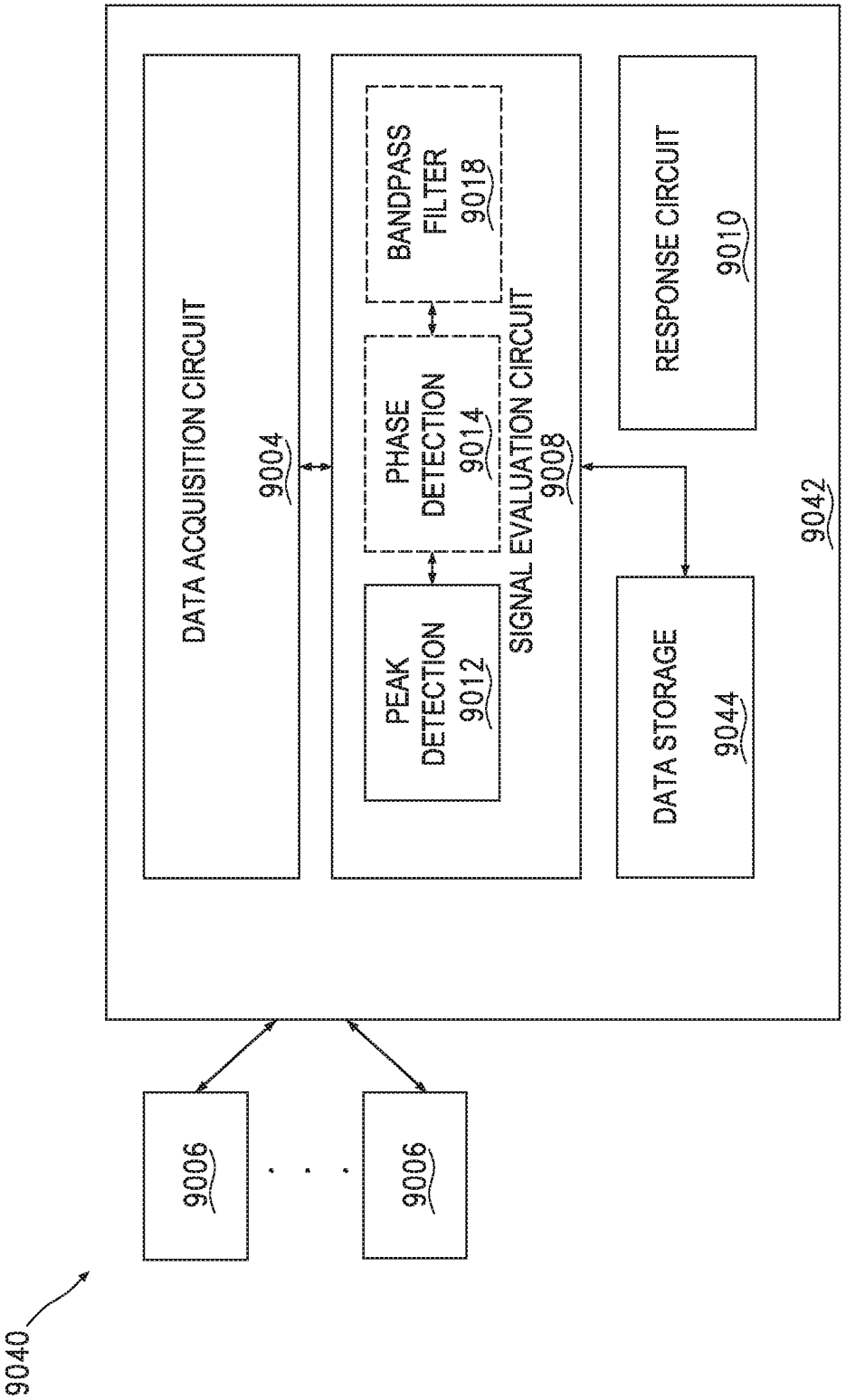
9040
9006
9006
9042
DATA ACQUISITION CIRCUIT
9004
SIGNAL EVALUATION CIRCUIT
9008
PEAK DETECTION 9012
PHASE DETECTION 9014
BANDPASS FILTER 9018
RESPONSE CIRCUIT 9010
DATA STORAGE 9044

FIG. 80

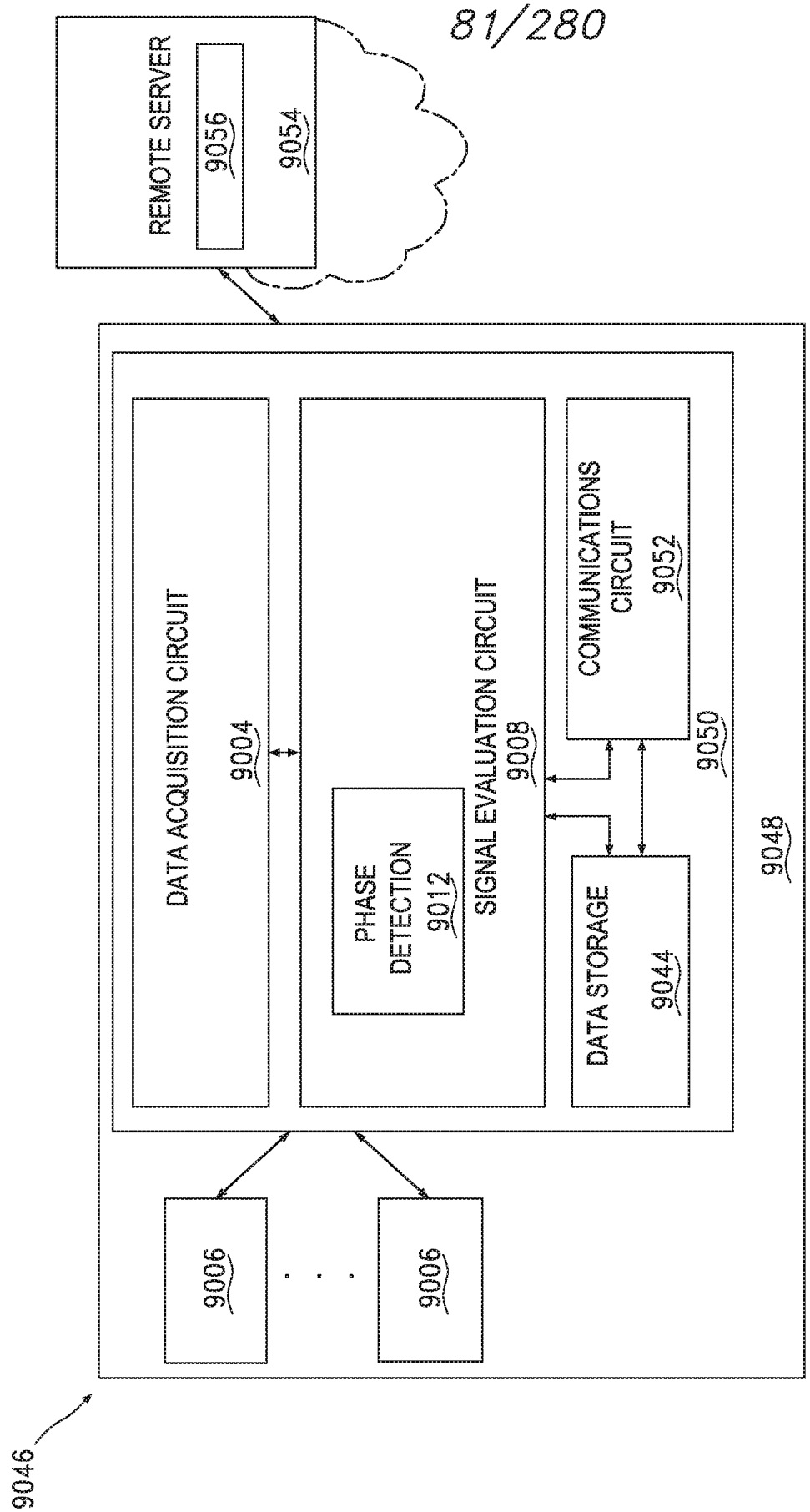
REMOTE SERVER
9056
9054
DATA ACQUISITION CIRCUIT
9004
SIGNAL EVALUATION CIRCUIT
9008
PHASE DETECTION
9012
COMMUNICATIONS CIRCUIT
9052
DATA STORAGE
9044
9050
9048
9006
9006
9046

FIG. 81

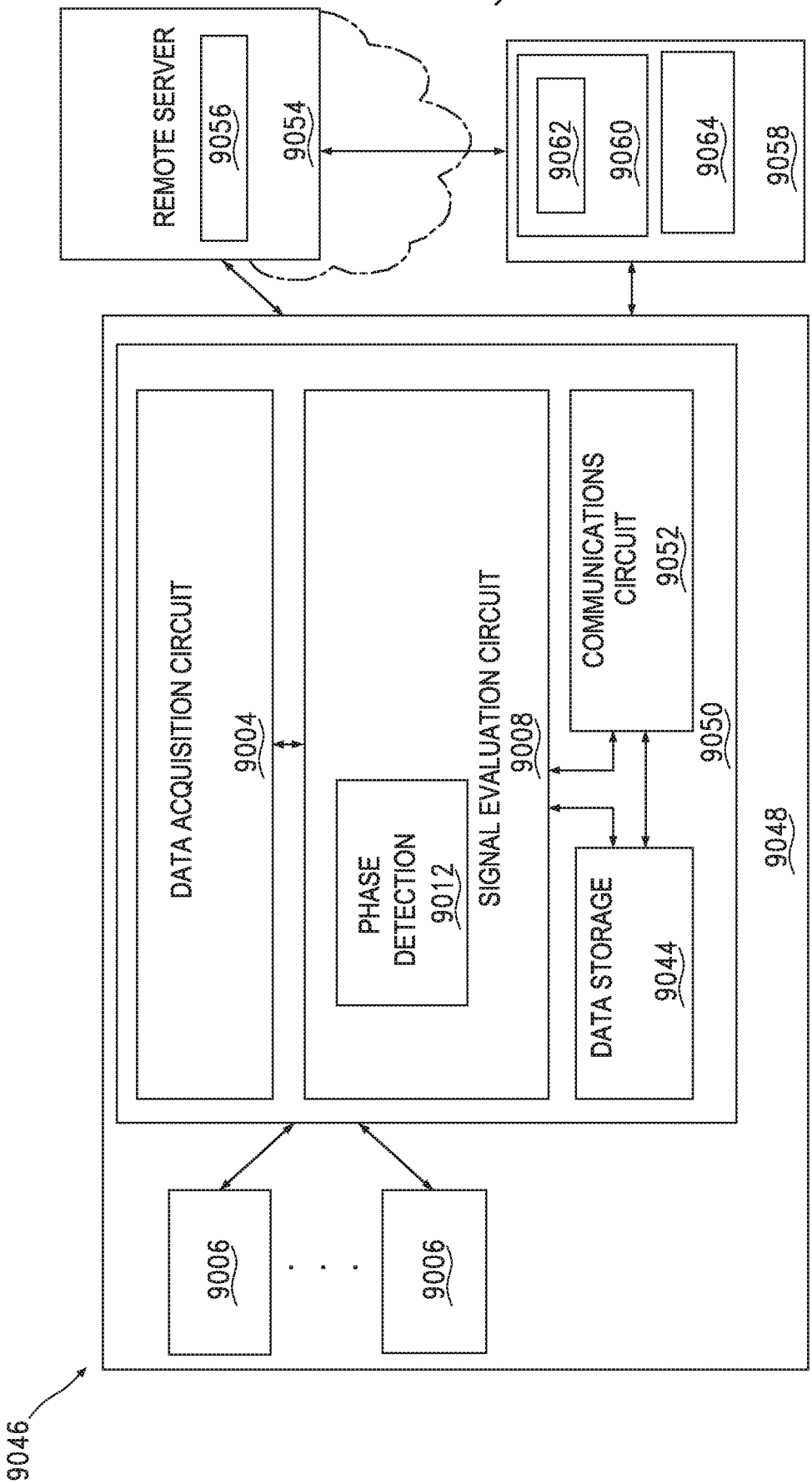
REMOTE SERVER
9056
9054
9062
9060
9064
9058
DATA ACQUISITION CIRCUIT
9004
PHASE DETECTION
9012
SIGNAL EVALUATION CIRCUIT
9008
COMMUNICATIONS CIRCUIT
9052
9050
DATA STORAGE
9044
9048
9006
9006
9046

FIG. 82

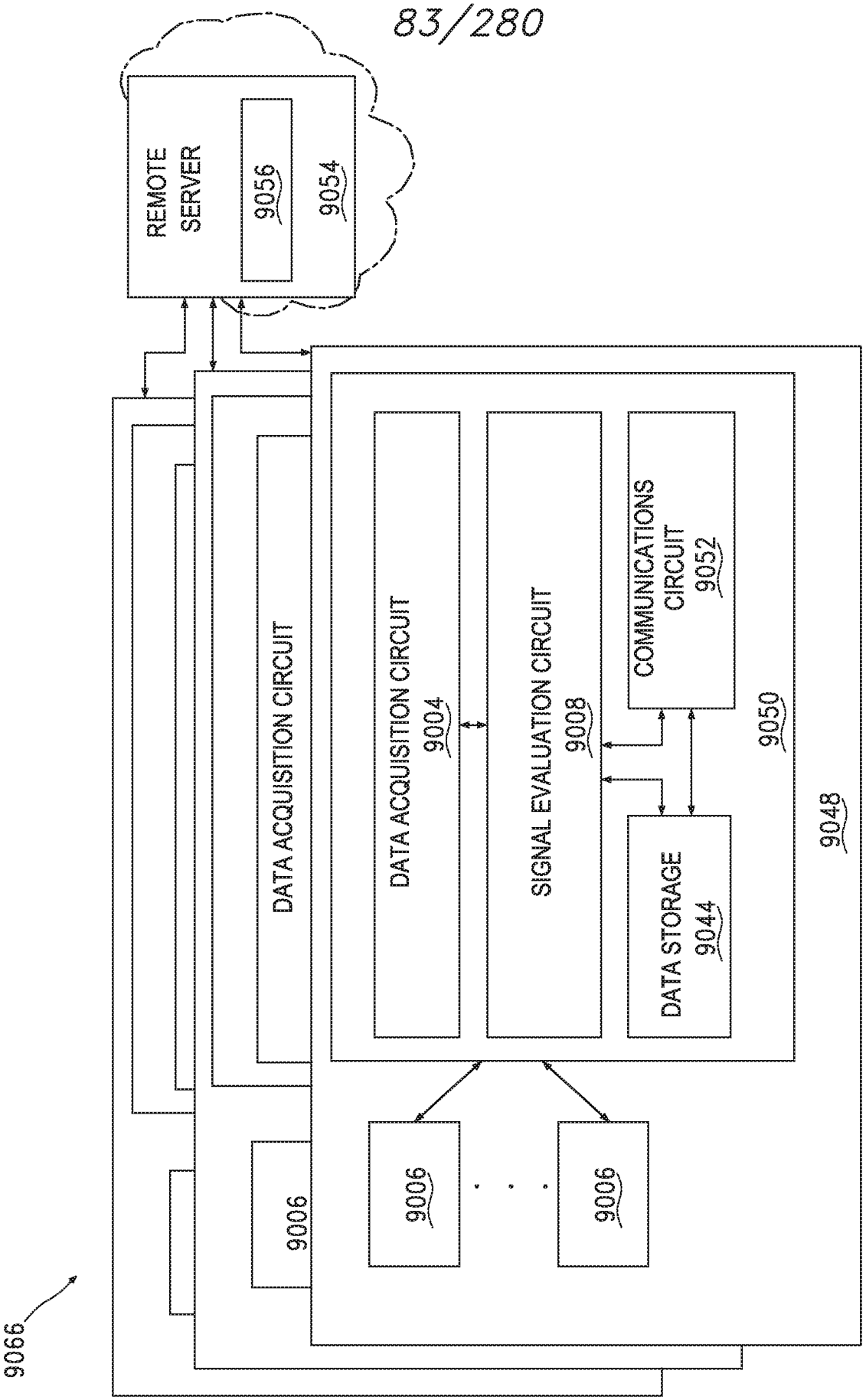
REMOTE SERVER
9056
9054
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT 9004
SIGNAL EVALUATION CIRCUIT 9008
COMMUNICATIONS CIRCUIT 9052
DATA STORAGE 9044
9050
9048
9006
9006
9006
9066

FIG. 83

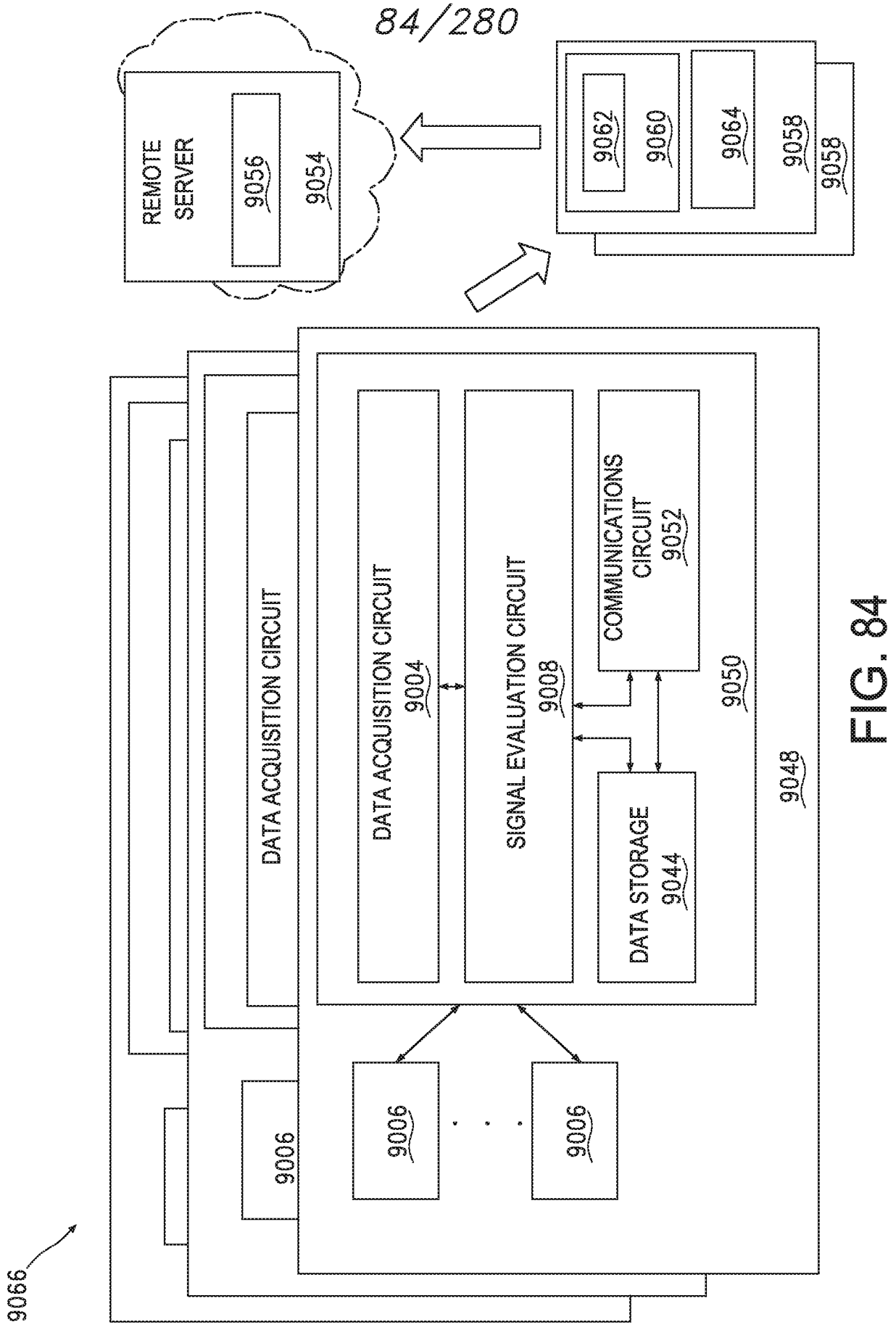
84/280
REMOTE SERVER
9056
9054
9062
9060
9064
9058
9058
9066
9048
9050
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT 9004
SIGNAL EVALUATION CIRCUIT 9008
COMMUNICATIONS CIRCUIT 9052
DATA STORAGE 9044
9006
9006
9006

FIG. 84

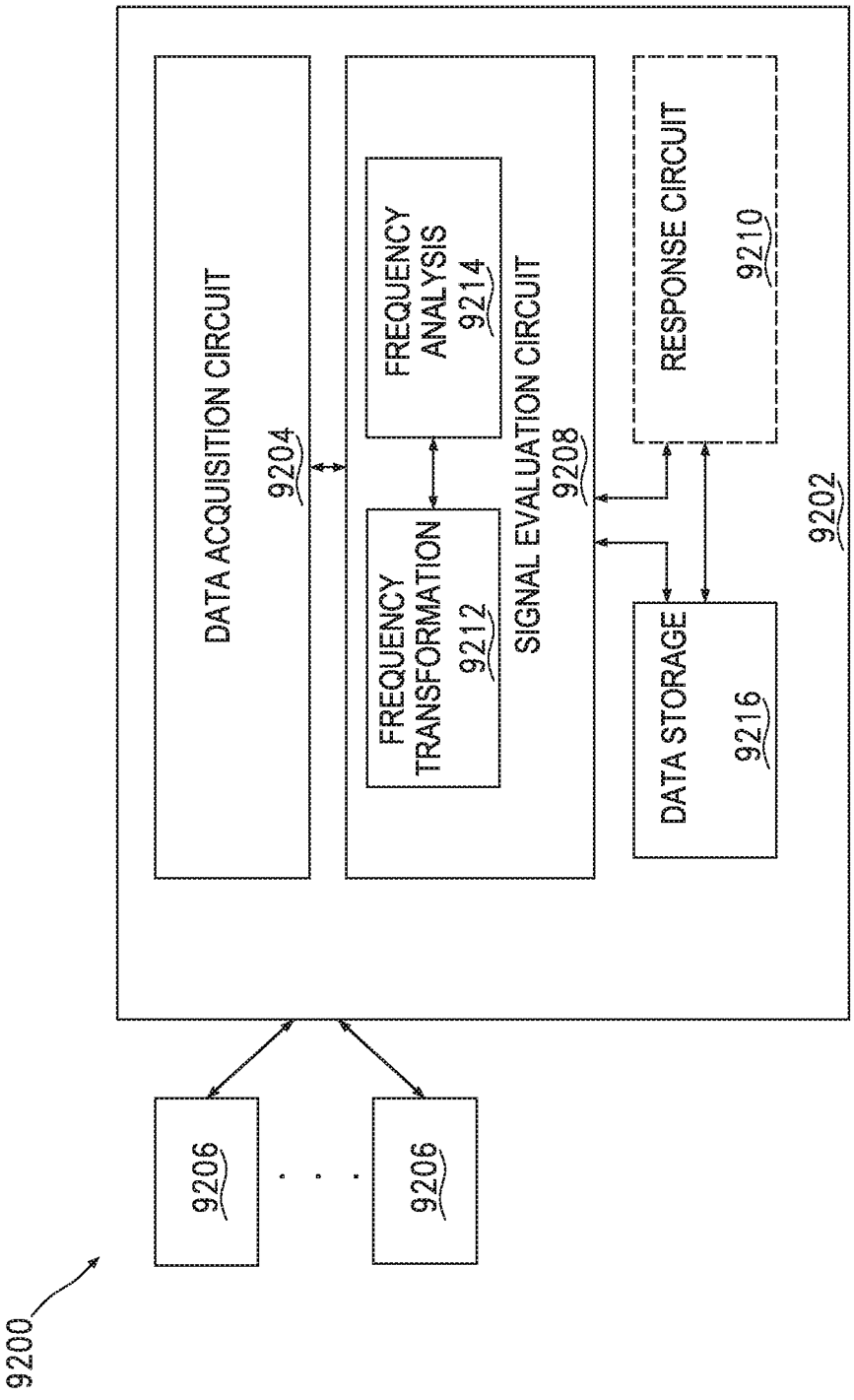
9200
9206
9206
9202
DATA ACQUISITION CIRCUIT
9204
SIGNAL EVALUATION CIRCUIT
9208
FREQUENCY TRANSFORMATION
9212
FREQUENCY ANALYSIS
9214
RESPONSE CIRCUIT
9210
DATA STORAGE
9216

FIG. 85

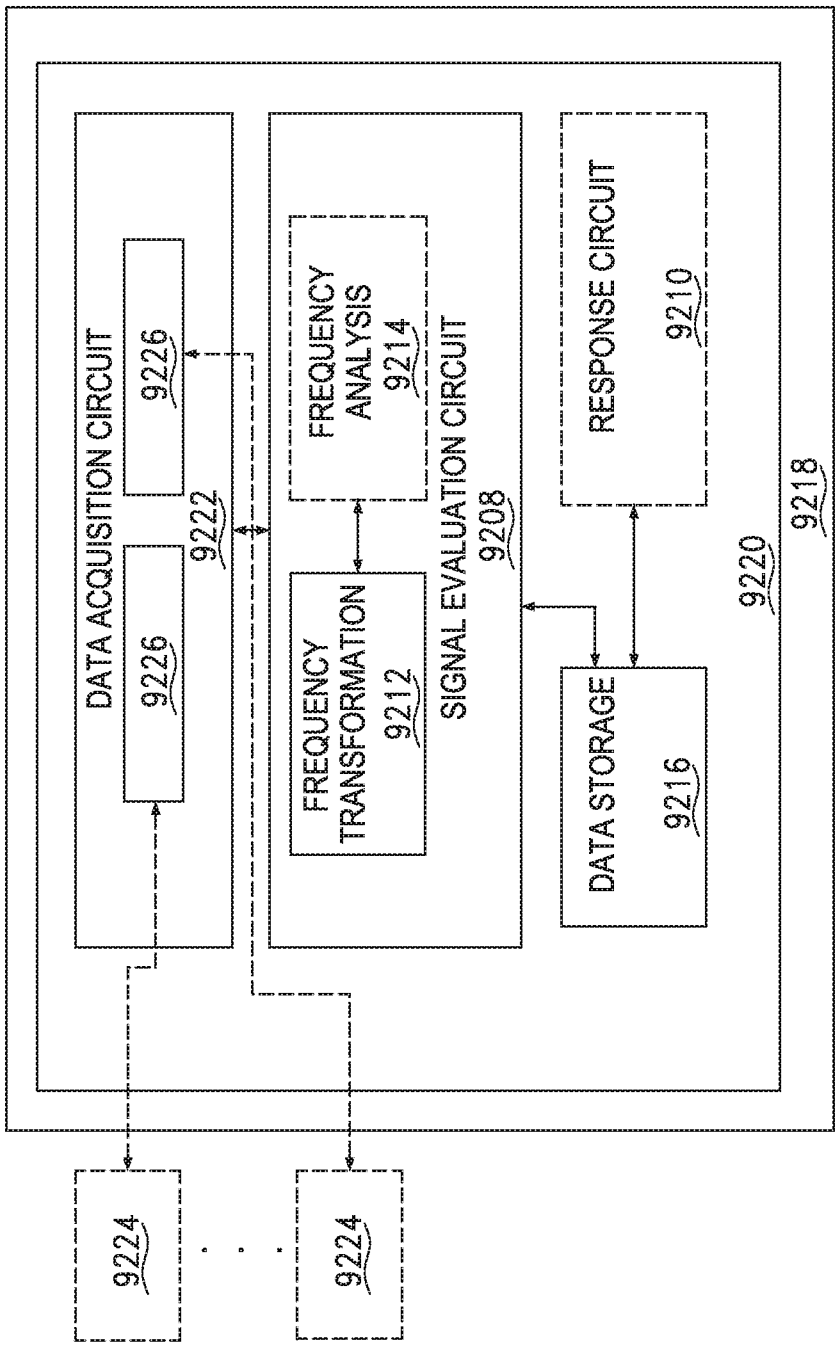
9218
9220
DATA ACQUISITION CIRCUIT
9226
9226
9222
SIGNAL EVALUATION CIRCUIT
9208
FREQUENCY TRANSFORMATION
9212
FREQUENCY ANALYSIS
9214
RESPONSE CIRCUIT
9210
DATA STORAGE
9216
9224
9224

FIG. 86

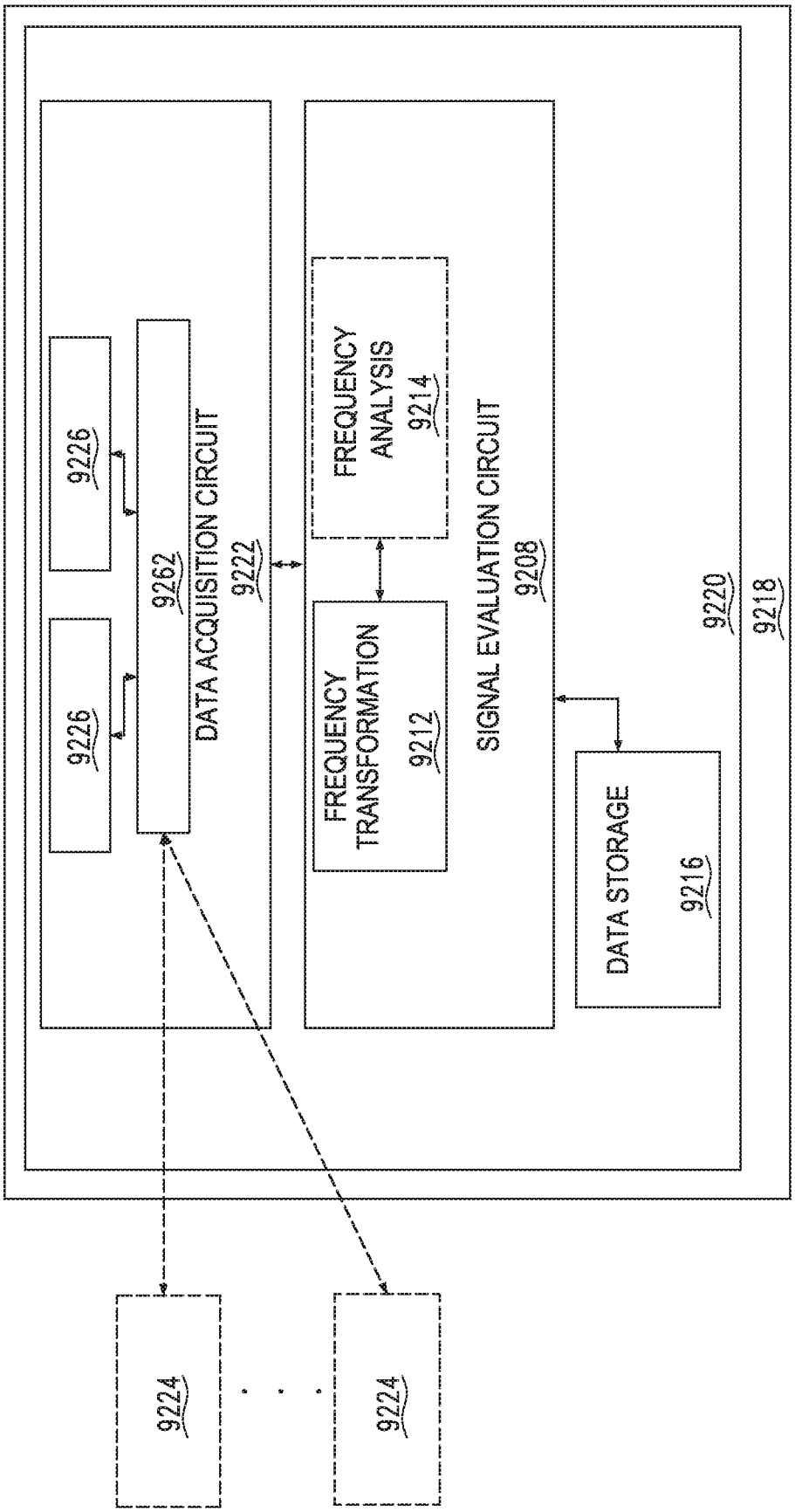
9218
9220
9208
SIGNAL EVALUATION CIRCUIT
FREQUENCY ANALYSIS 9214
FREQUENCY TRANSFORMATION 9212
DATA STORAGE 9216
9222
DATA ACQUISITION CIRCUIT
9262
9226
9226
9224
9224

FIG. 87

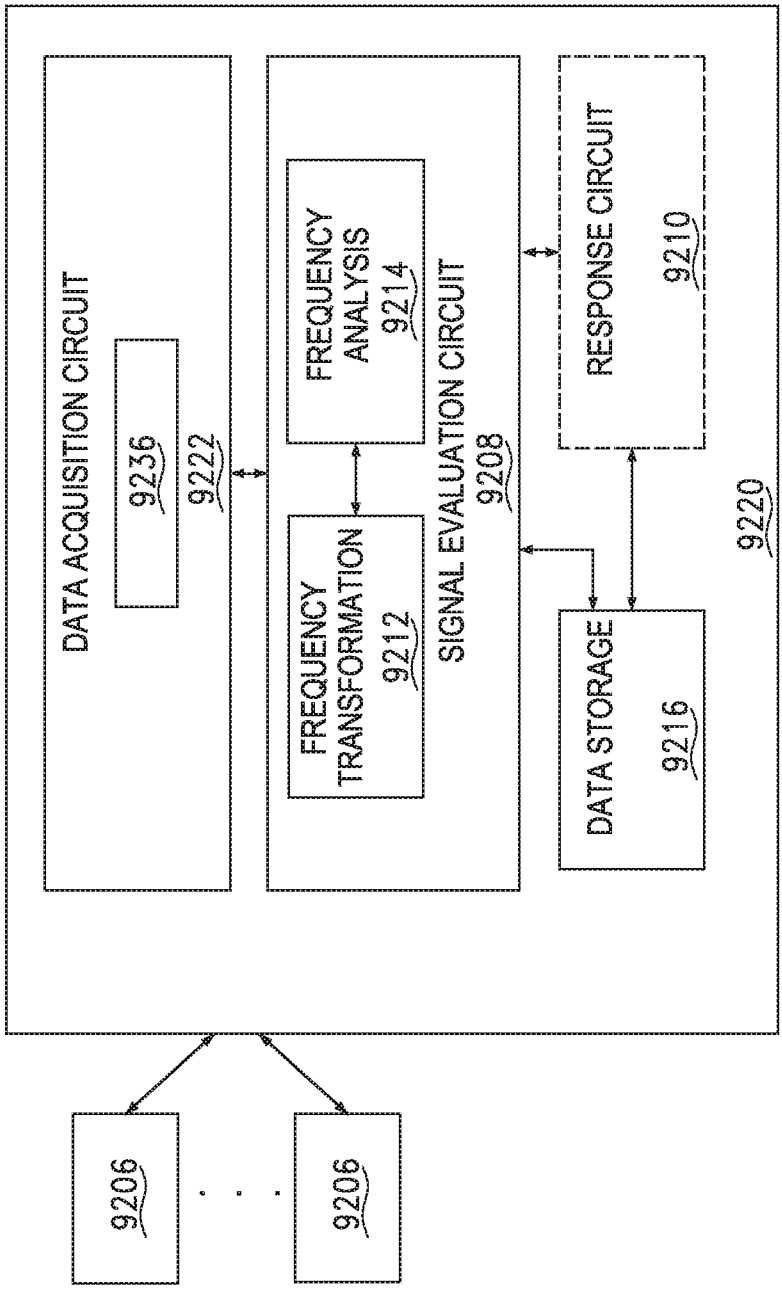
DATA ACQUISITION CIRCUIT
9236
9222
FREQUENCY ANALYSIS
9214
FREQUENCY TRANSFORMATION
9212
SIGNAL EVALUATION CIRCUIT
9208
RESPONSE CIRCUIT
9210
DATA STORAGE
9216
9220
9206
9206

FIG. 88

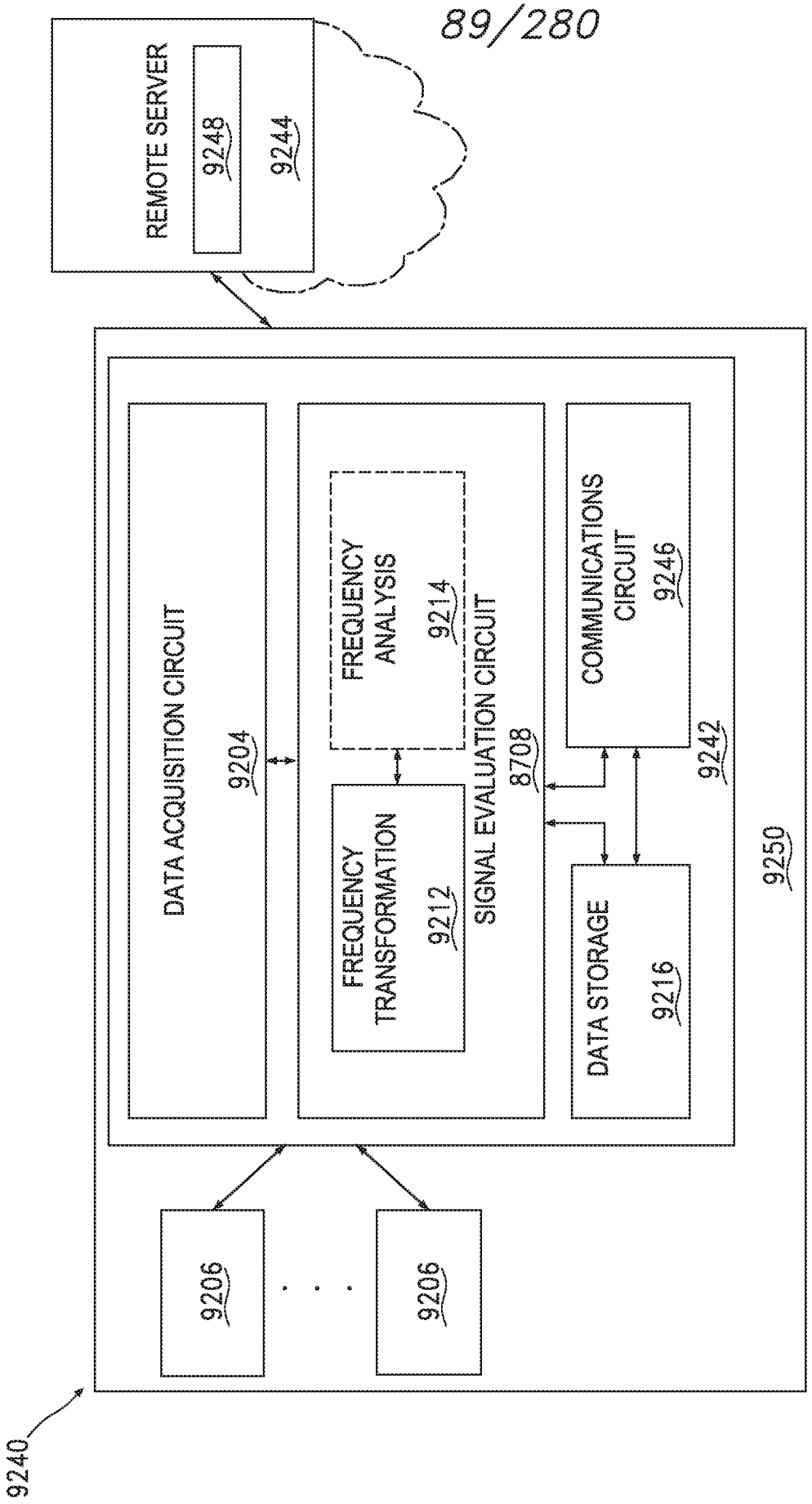
REMOTE SERVER
9248
9244
DATA ACQUISITION CIRCUIT
9204
FREQUENCY ANALYSIS
9214
FREQUENCY TRANSFORMATION
9212
SIGNAL EVALUATION CIRCUIT
8708
COMMUNICATIONS CIRCUIT
9246
DATA STORAGE
9216
9242
9250
9206
9206
9240

FIG. 89

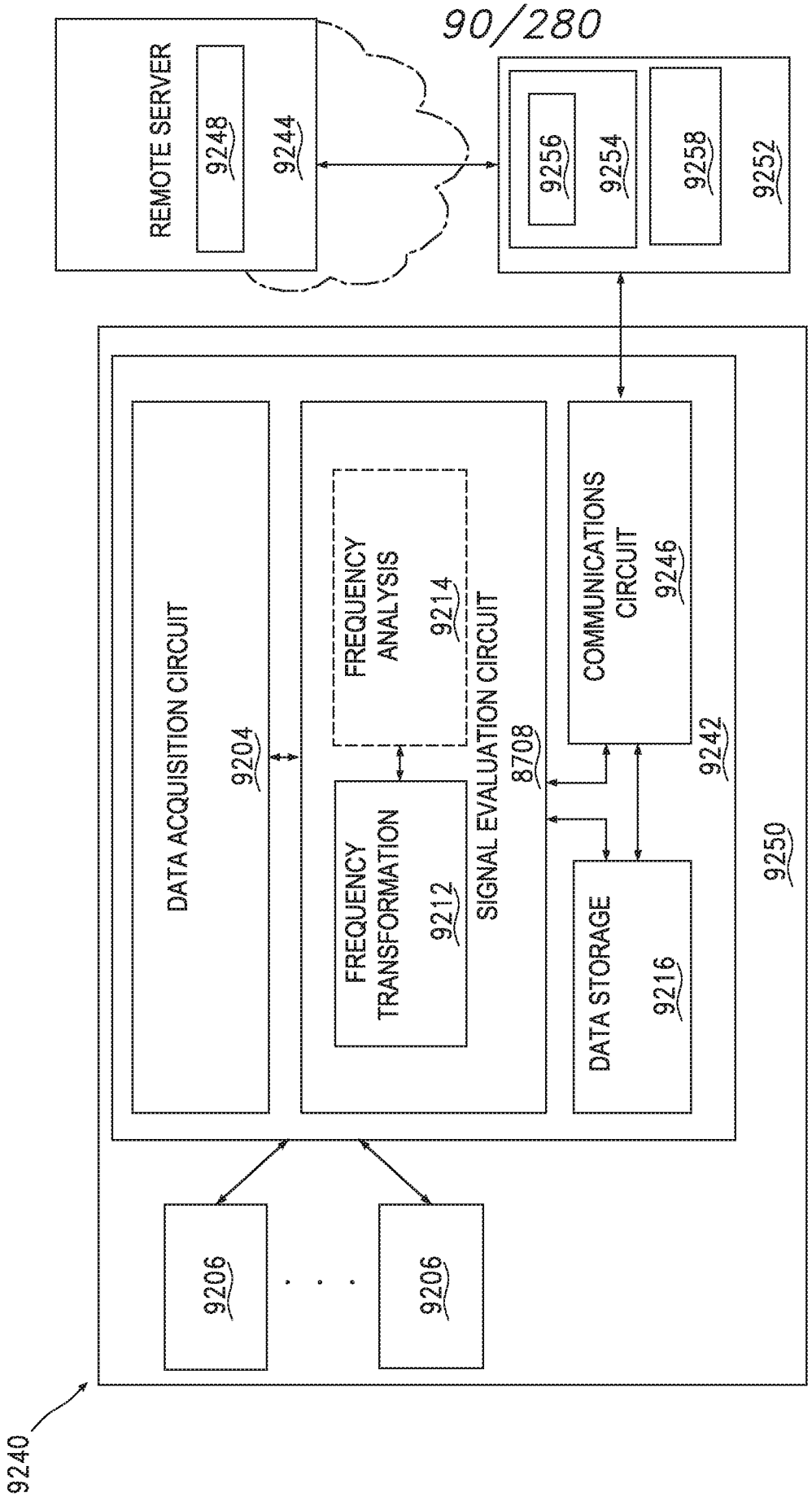
90/280
REMOTE SERVER
9248
9244
9256
9254
9258
9252
DATA ACQUISITION CIRCUIT
9204
FREQUENCY ANALYSIS
9214
FREQUENCY TRANSFORMATION
9212
SIGNAL EVALUATION CIRCUIT
8708
COMMUNICATIONS CIRCUIT
9246
DATA STORAGE
9216
9242
9250
9206
9206
9240

FIG. 90

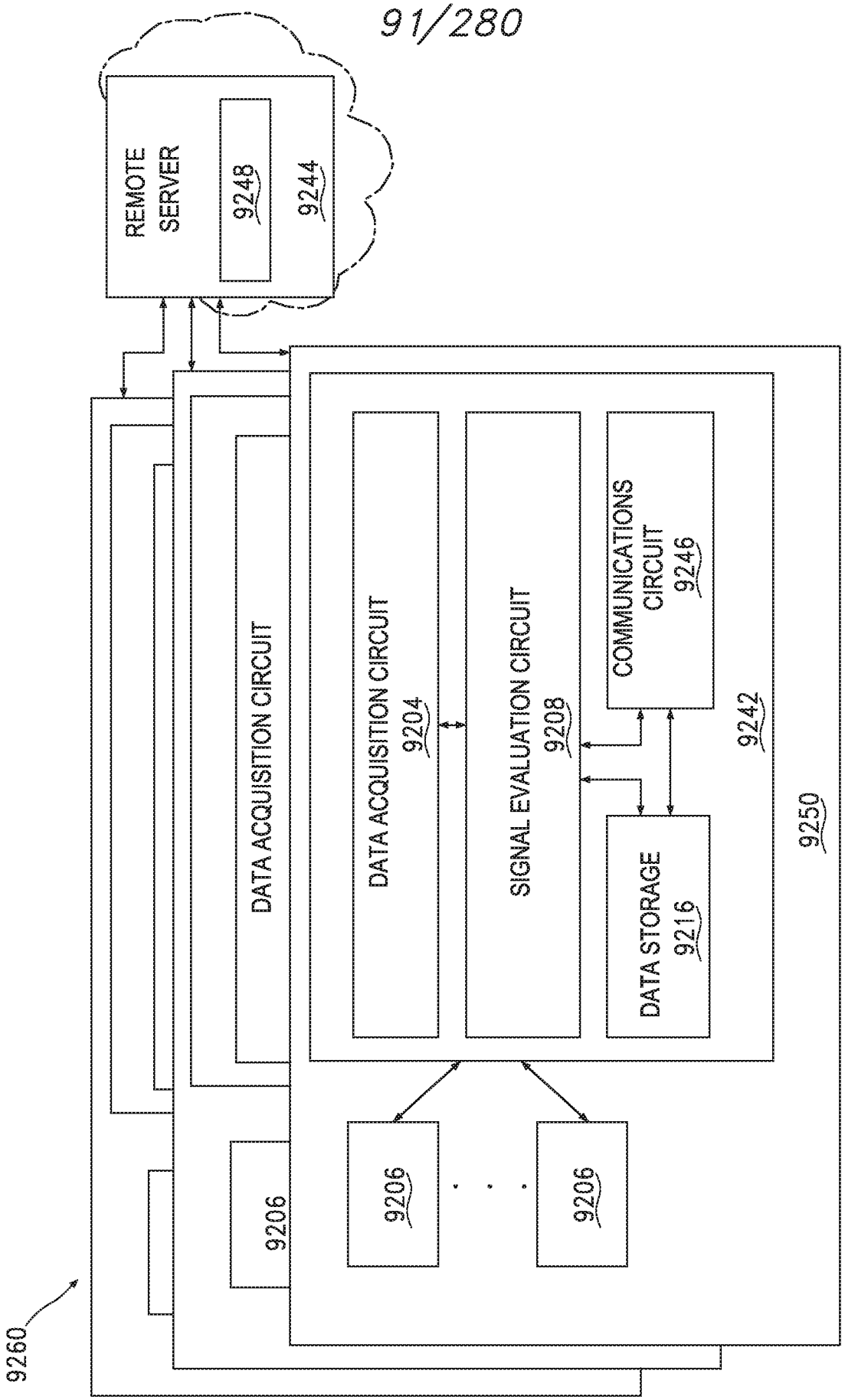
REMOTE SERVER
9248
9244
9260
9250
9242
DATA ACQUISITION CIRCUIT
9204
SIGNAL EVALUATION CIRCUIT
9208
COMMUNICATIONS CIRCUIT
9246
DATA STORAGE
9216
9206
9206
9206

FIG. 91

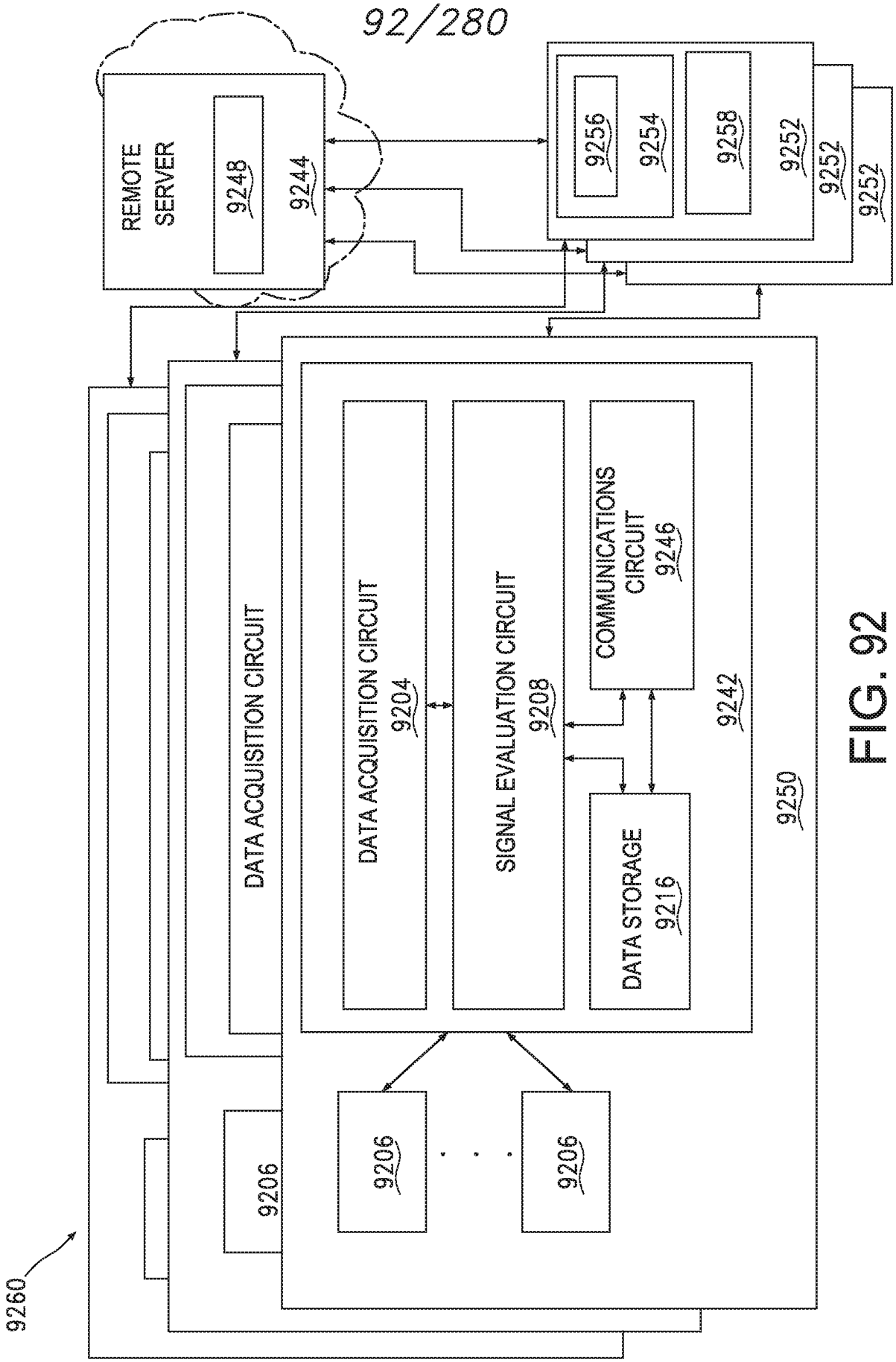
92/280
REMOTE SERVER
9248
9244
9256
9254
9258
9252
9252
9252
9260
9250
9242
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT 9204
SIGNAL EVALUATION CIRCUIT 9208
COMMUNICATIONS CIRCUIT 9246
DATA STORAGE 9216
9206
9206
9206

FIG. 92

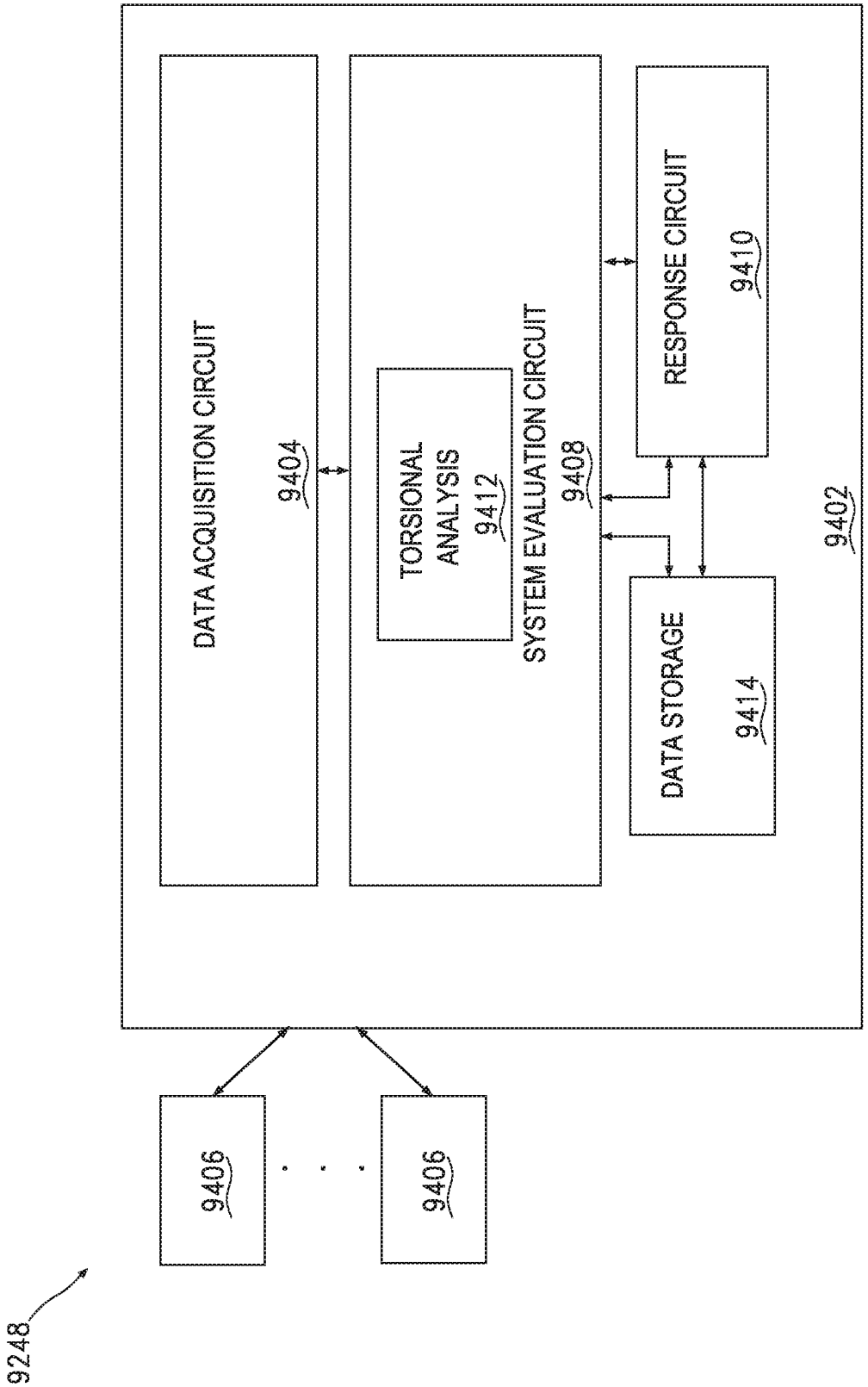
9248
9406
9406
9402
DATA ACQUISITION CIRCUIT
9404
SYSTEM EVALUATION CIRCUIT
9408
TORSIONAL ANALYSIS
9412
RESPONSE CIRCUIT
9410
DATA STORAGE
9414

FIG. 93

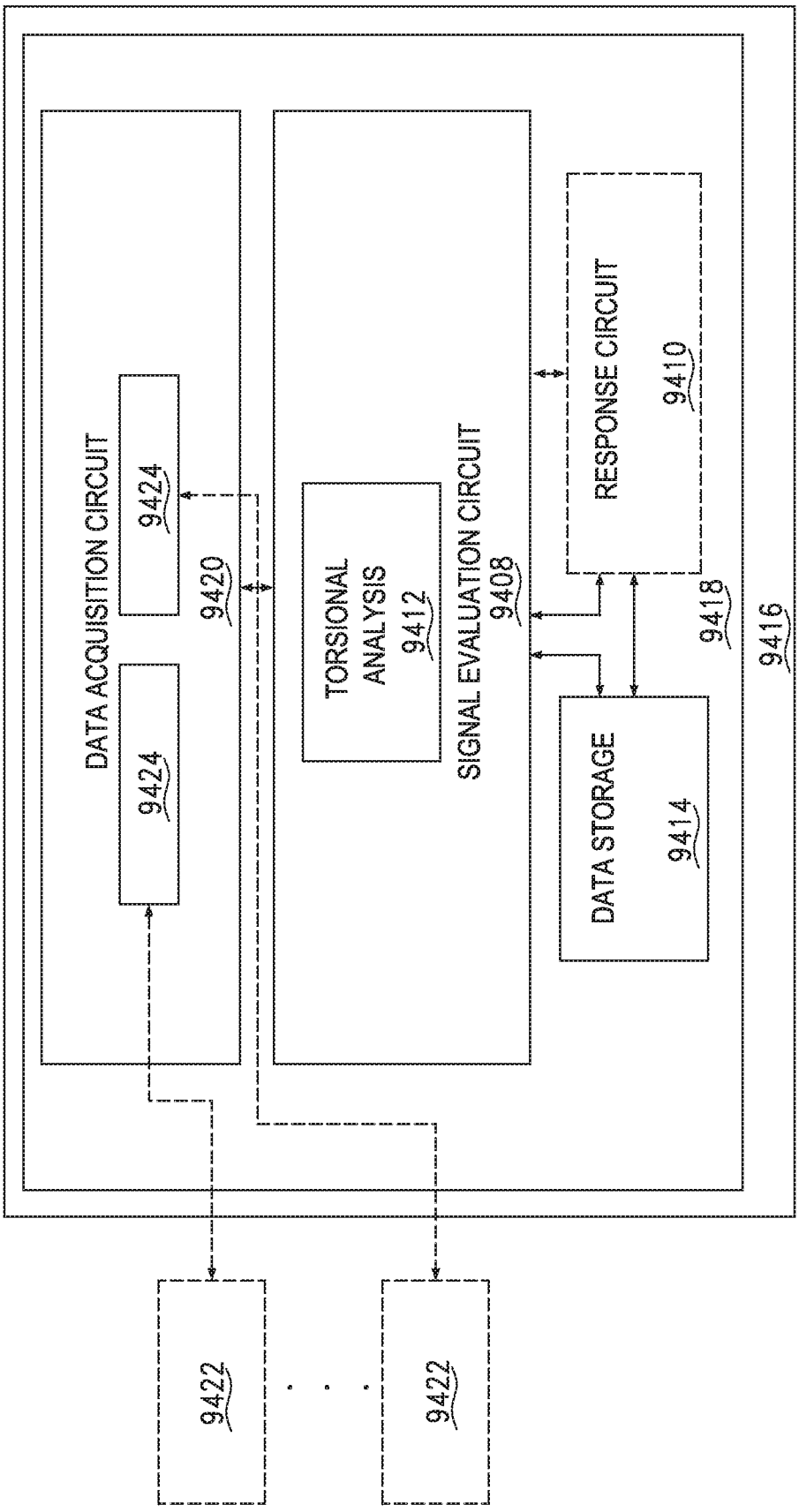
DATA ACQUISITION CIRCUIT
9424
9424
9420
TORSIONAL ANALYSIS
9412
SIGNAL EVALUATION CIRCUIT
9408
RESPONSE CIRCUIT
9410
9418
DATA STORAGE
9414
9416
9422
9422

FIG. 94

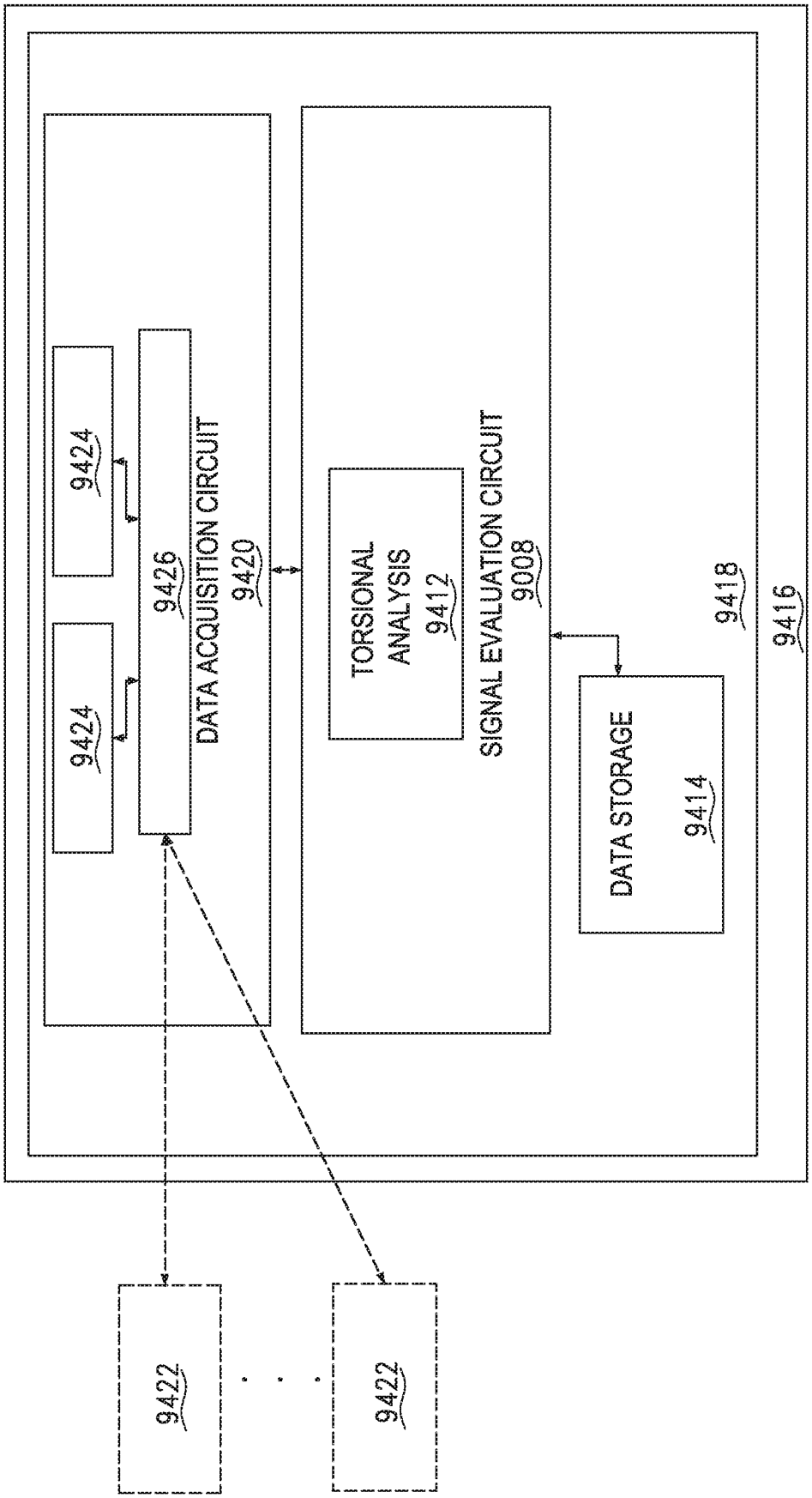
9424
9424
9426
DATA ACQUISITION CIRCUIT
9420
TORSIONAL ANALYSIS
9412
SIGNAL EVALUATION CIRCUIT
9008
DATA STORAGE
9414
9418
9416
9422
9422

FIG. 95

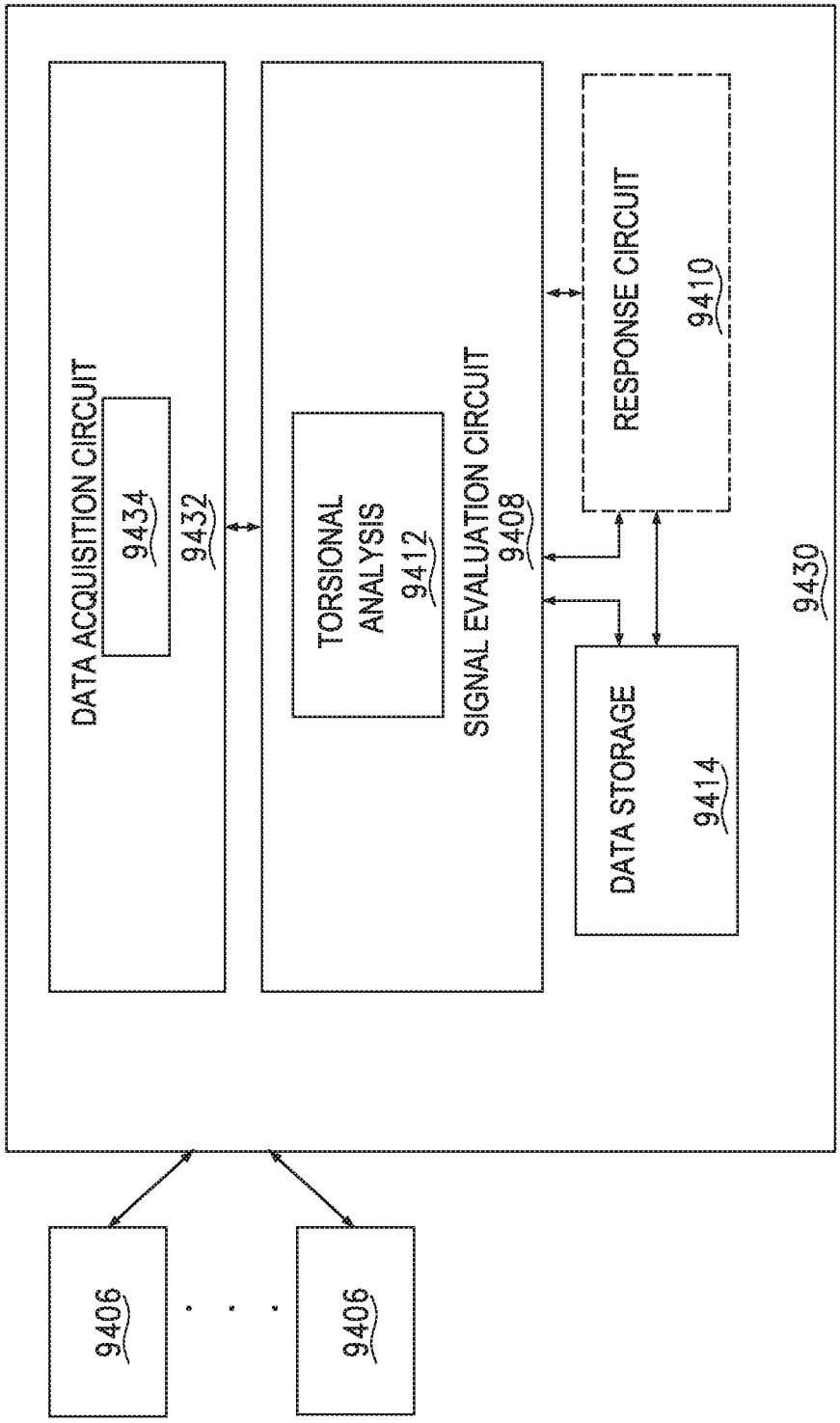
DATA ACQUISITION CIRCUIT
9434
9432
TORSIONAL ANALYSIS
9412
SIGNAL EVALUATION CIRCUIT
9408
RESPONSE CIRCUIT
9410
DATA STORAGE
9414
9430
9406
9406

FIG. 96

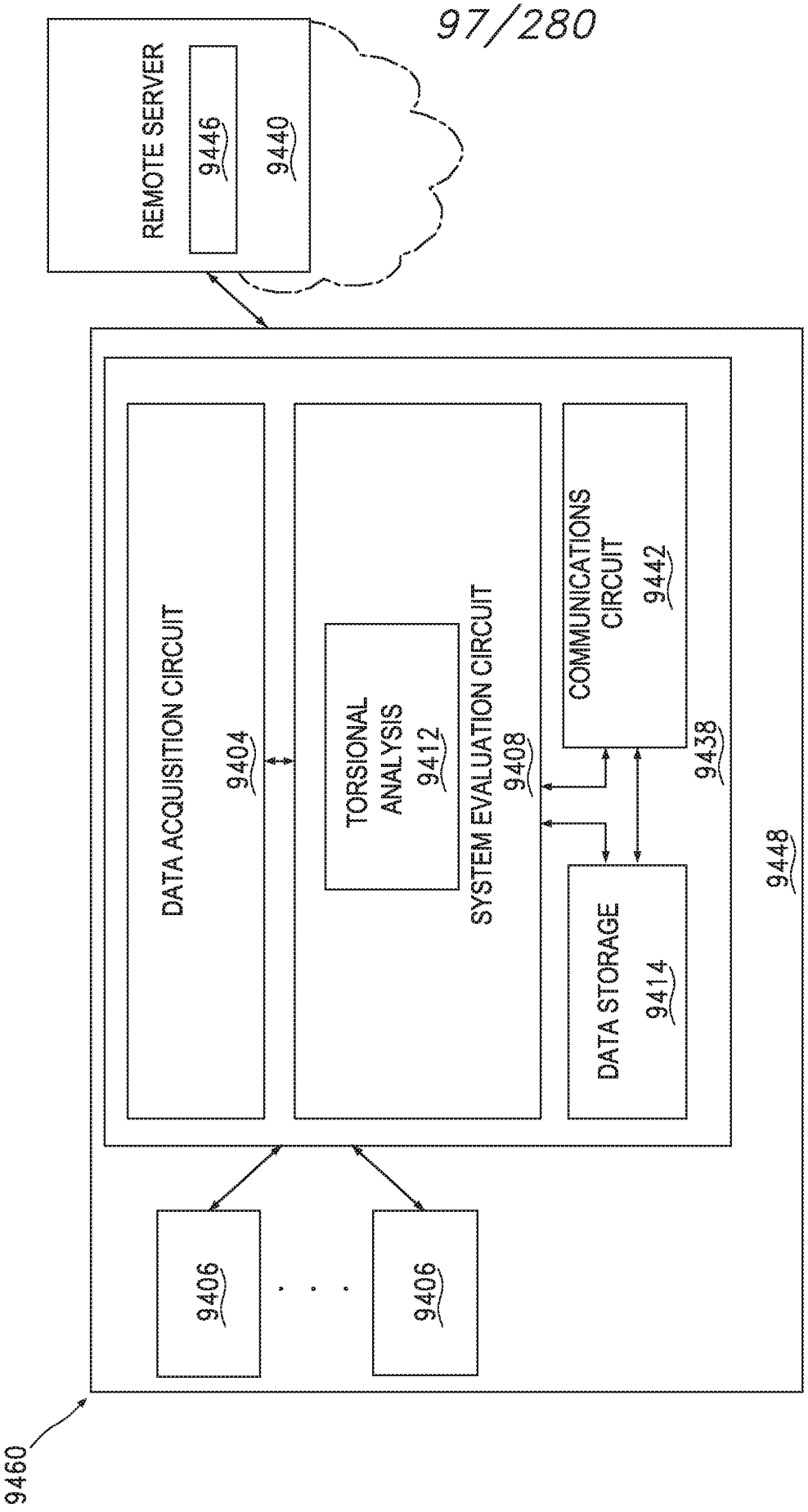
REMOTE SERVER
9446
9440
DATA ACQUISITION CIRCUIT
9404
TORSIONAL ANALYSIS
9412
SYSTEM EVALUATION CIRCUIT
9408
COMMUNICATIONS CIRCUIT
9442
9438
DATA STORAGE
9414
9448
9406
9406
9460

FIG. 97

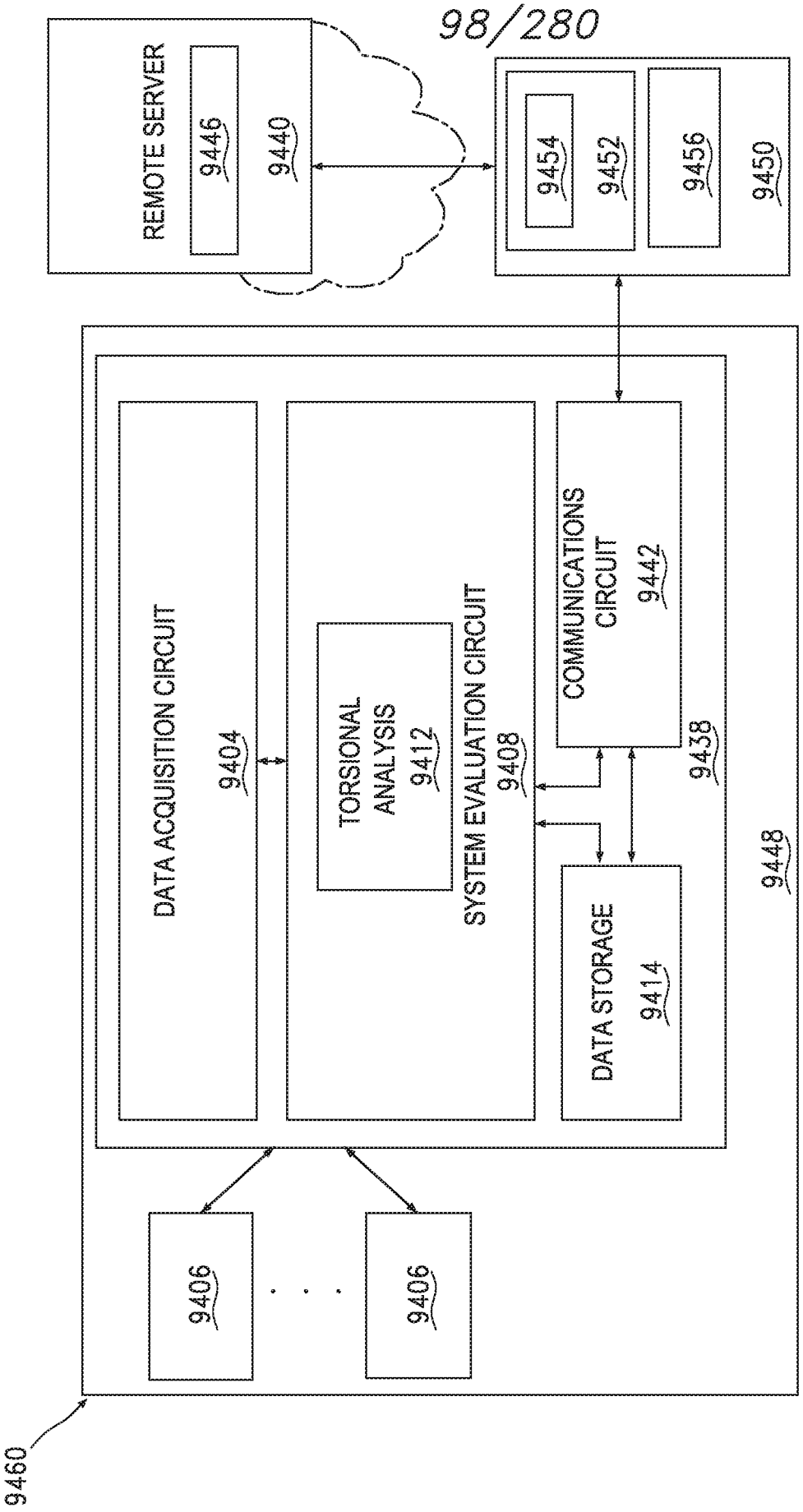
98/280
REMOTE SERVER
9446
9440
9454
9452
9456
9450
DATA ACQUISITION CIRCUIT
9404
TORSIONAL ANALYSIS
9412
SYSTEM EVALUATION CIRCUIT
9408
COMMUNICATIONS CIRCUIT
9442
9438
DATA STORAGE
9414
9448
9406
9406
9460

FIG. 98

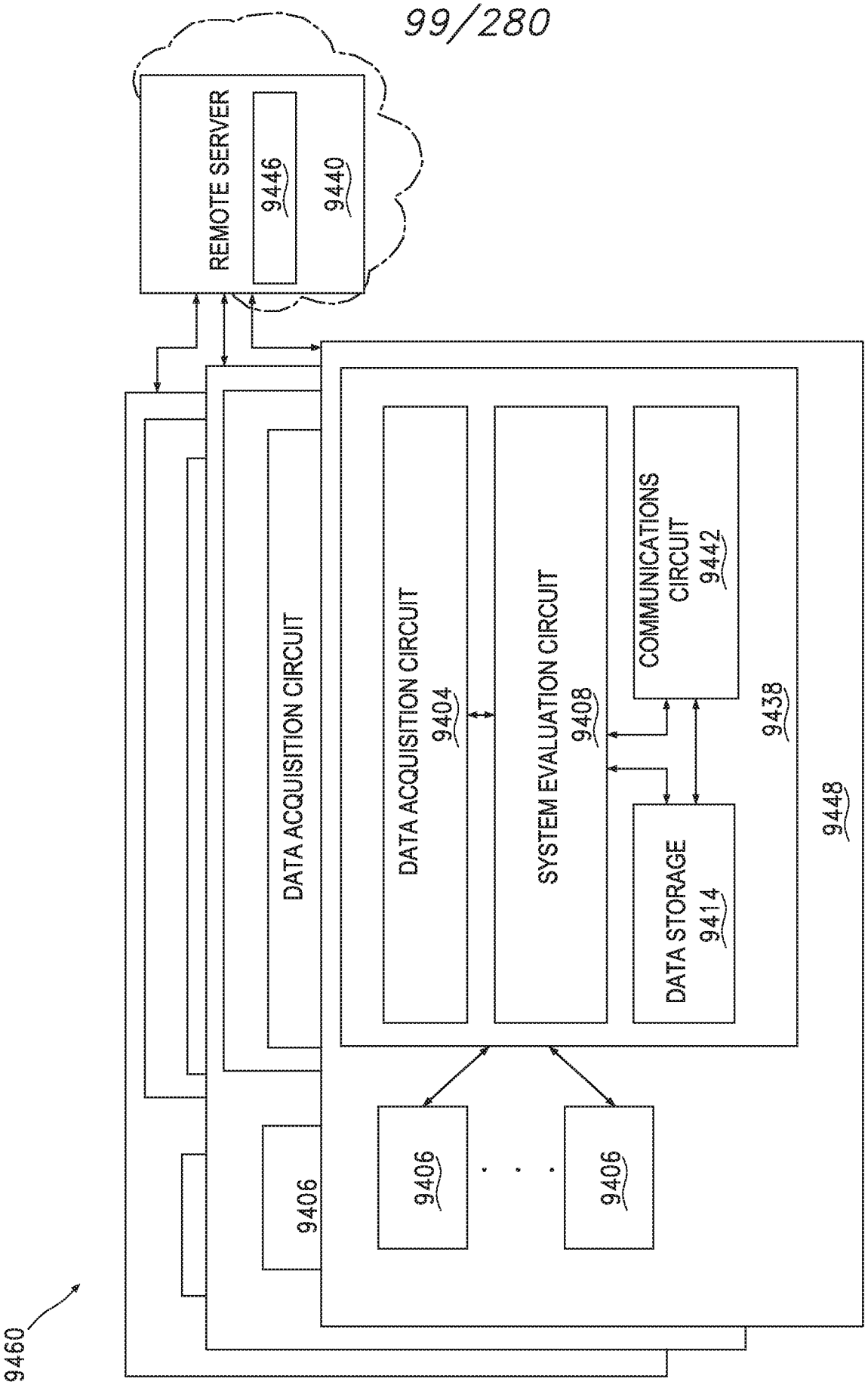
REMOTE SERVER
9446
9440
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT
9404
SYSTEM EVALUATION CIRCUIT
9408
COMMUNICATIONS CIRCUIT
9442
DATA STORAGE
9414
9438
9448
9406
9406
9406
9460

FIG. 99

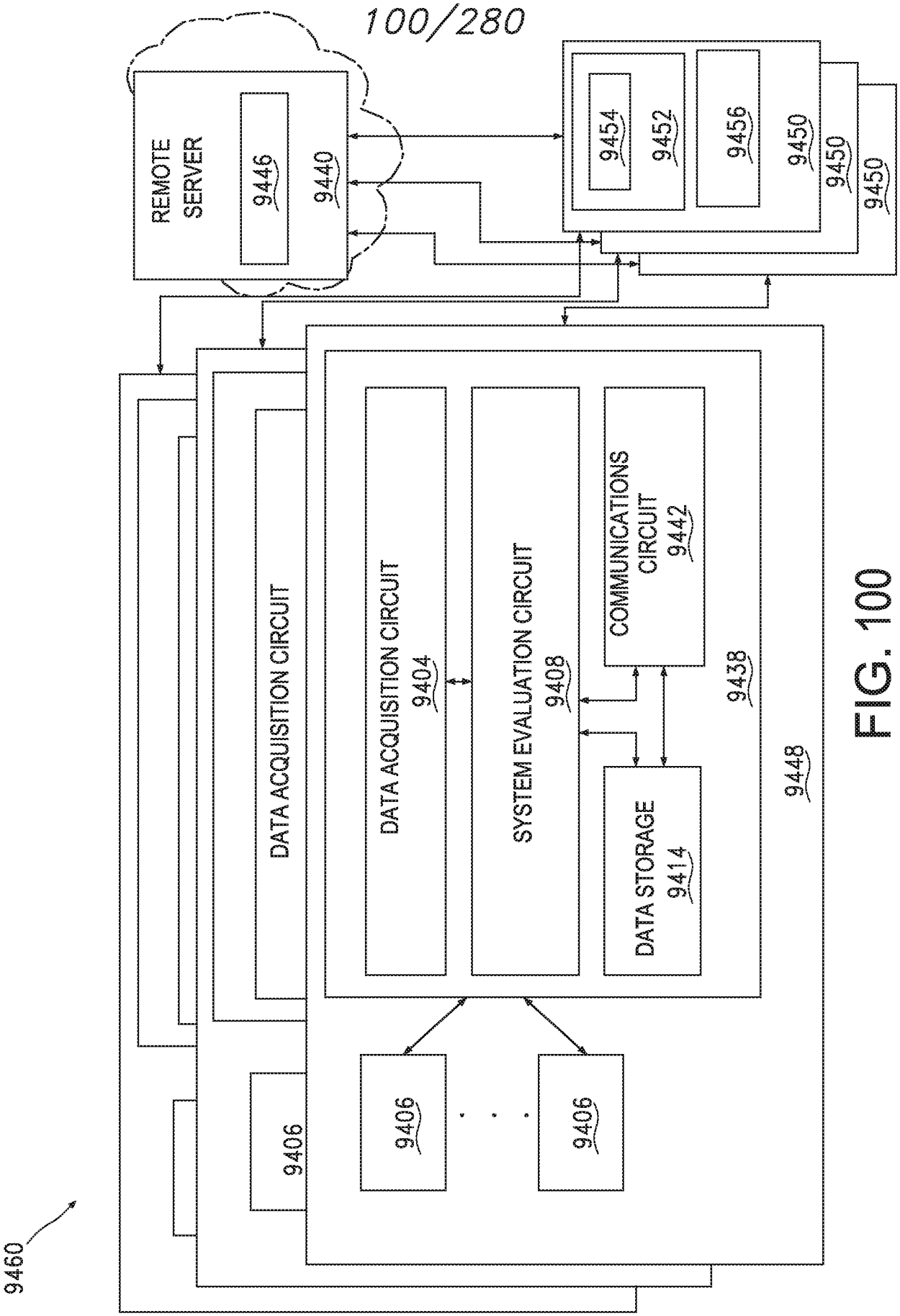
100/280
REMOTE SERVER
9446
9440
9454
9452
9456
9450
9450
9450
9460
9448
9438
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT 9404
SYSTEM EVALUATION CIRCUIT 9408
COMMUNICATIONS CIRCUIT 9442
DATA STORAGE 9414
9406
9406
9406

FIG. 100

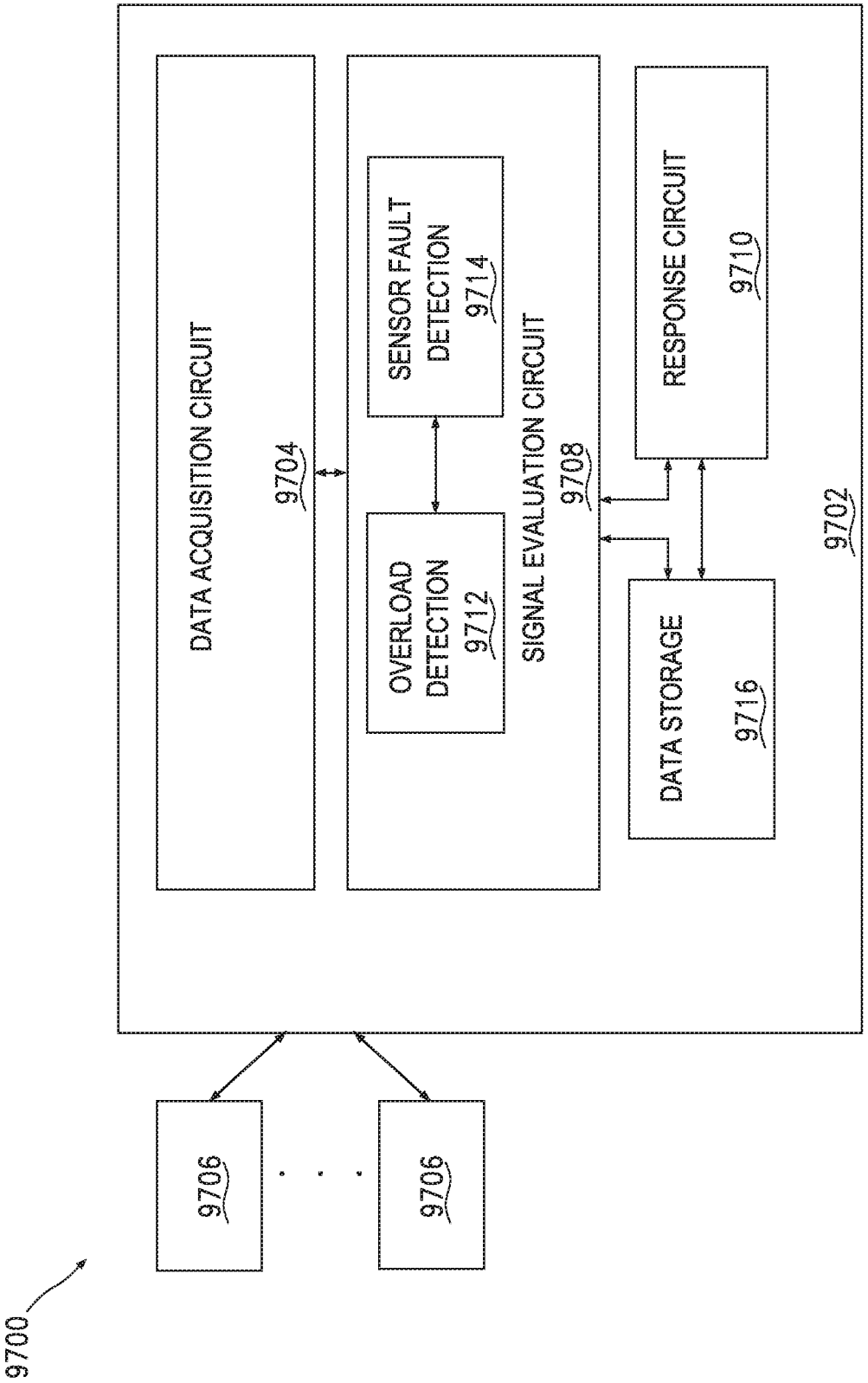
9700
9706
9706
9702
DATA ACQUISITION CIRCUIT
9704
SIGNAL EVALUATION CIRCUIT
9708
SENSOR FAULT DETECTION
9714
OVERLOAD DETECTION
9712
RESPONSE CIRCUIT
9710
DATA STORAGE
9716

FIG. 101

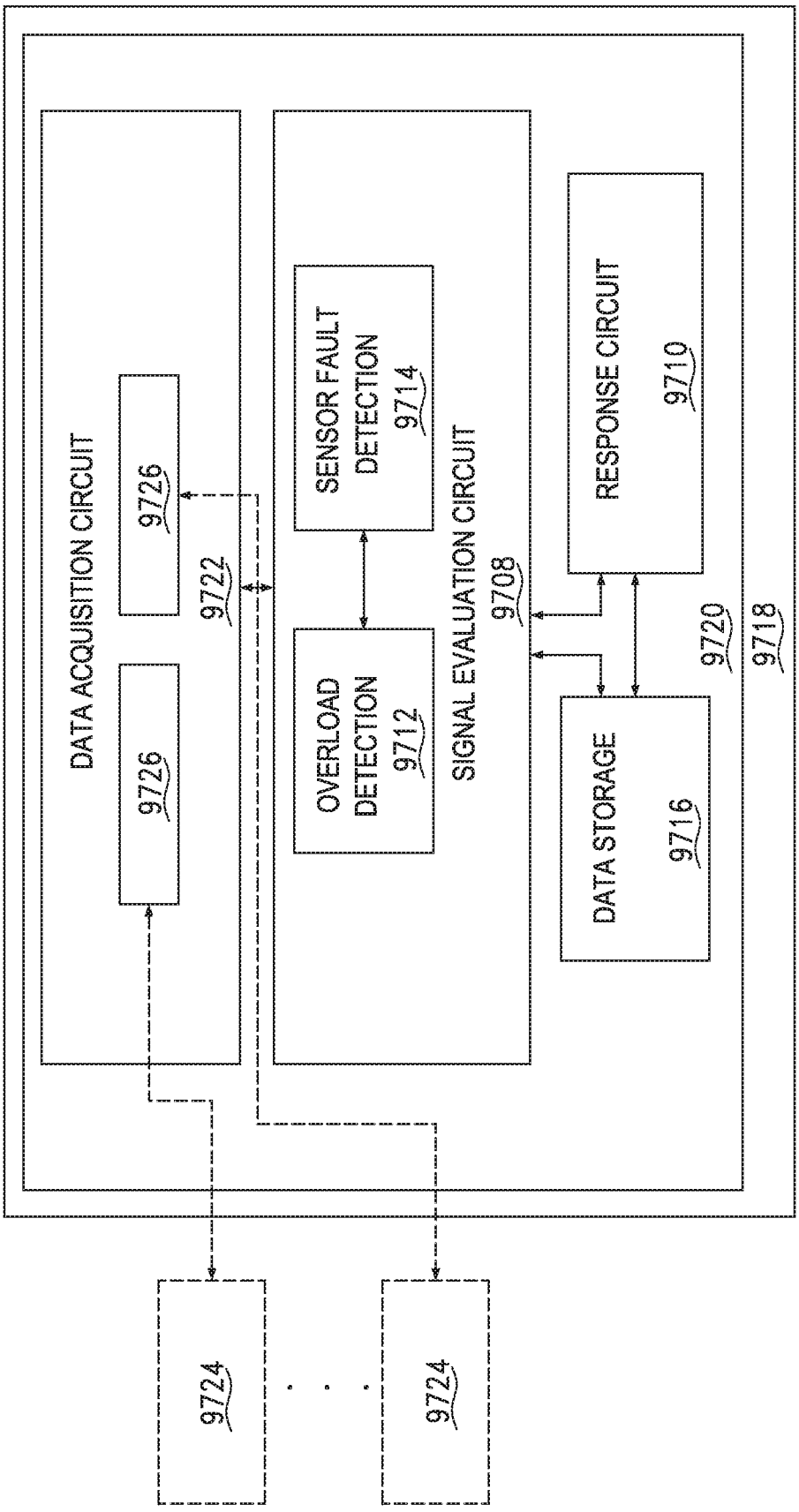
DATA ACQUISITION CIRCUIT
9726
9726
9722
SENSOR FAULT DETECTION 9714
OVERLOAD DETECTION 9712
SIGNAL EVALUATION CIRCUIT 9708
RESPONSE CIRCUIT 9710
DATA STORAGE 9716
9720
9718
9724
9724

FIG. 102

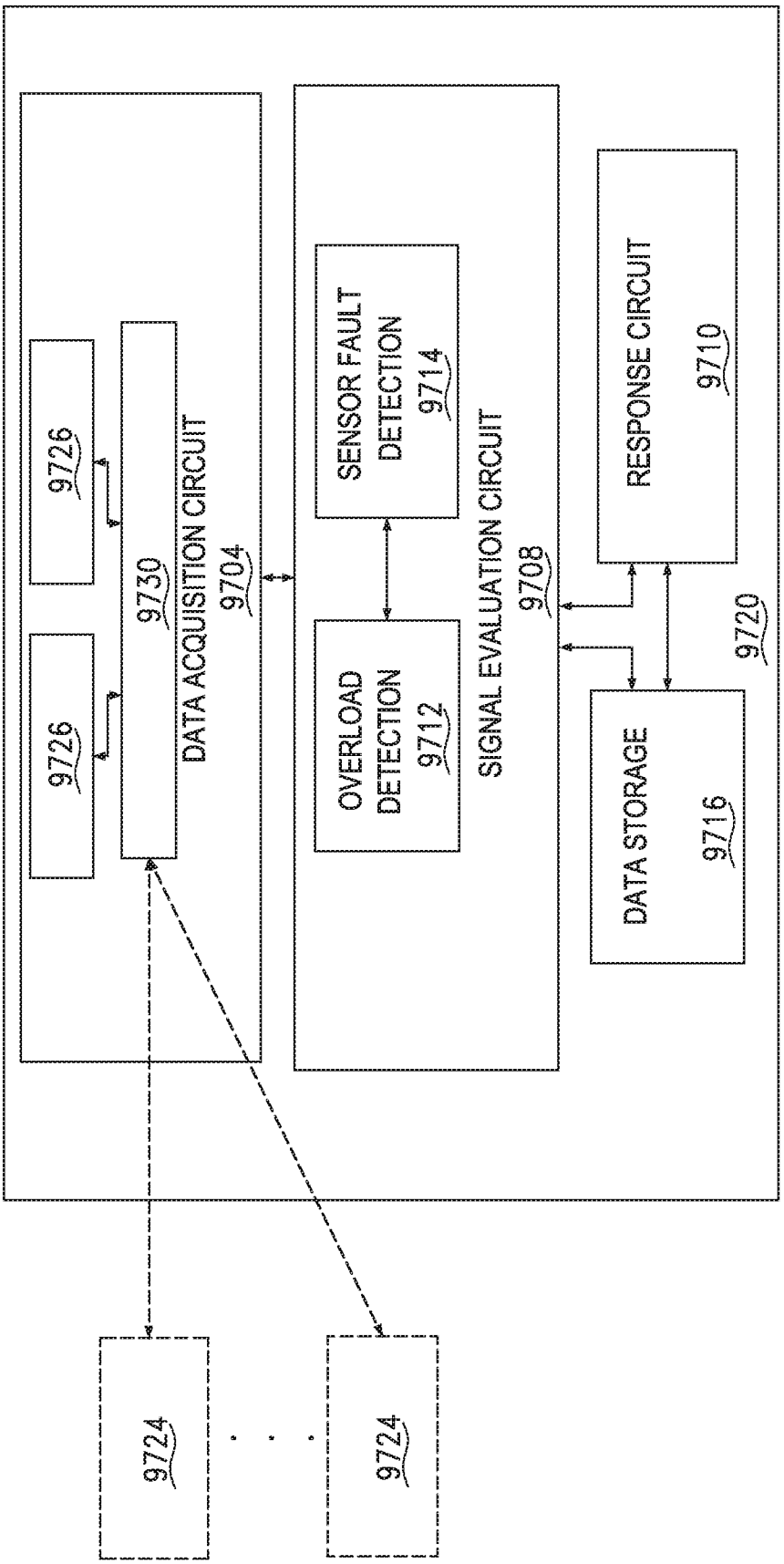
9726
9726
9730
DATA ACQUISITION CIRCUIT
9704
SENSOR FAULT DETECTION
9714
OVERLOAD DETECTION
9712
SIGNAL EVALUATION CIRCUIT
9708
RESPONSE CIRCUIT
9710
9720
DATA STORAGE
9716
9724
9724

FIG. 103

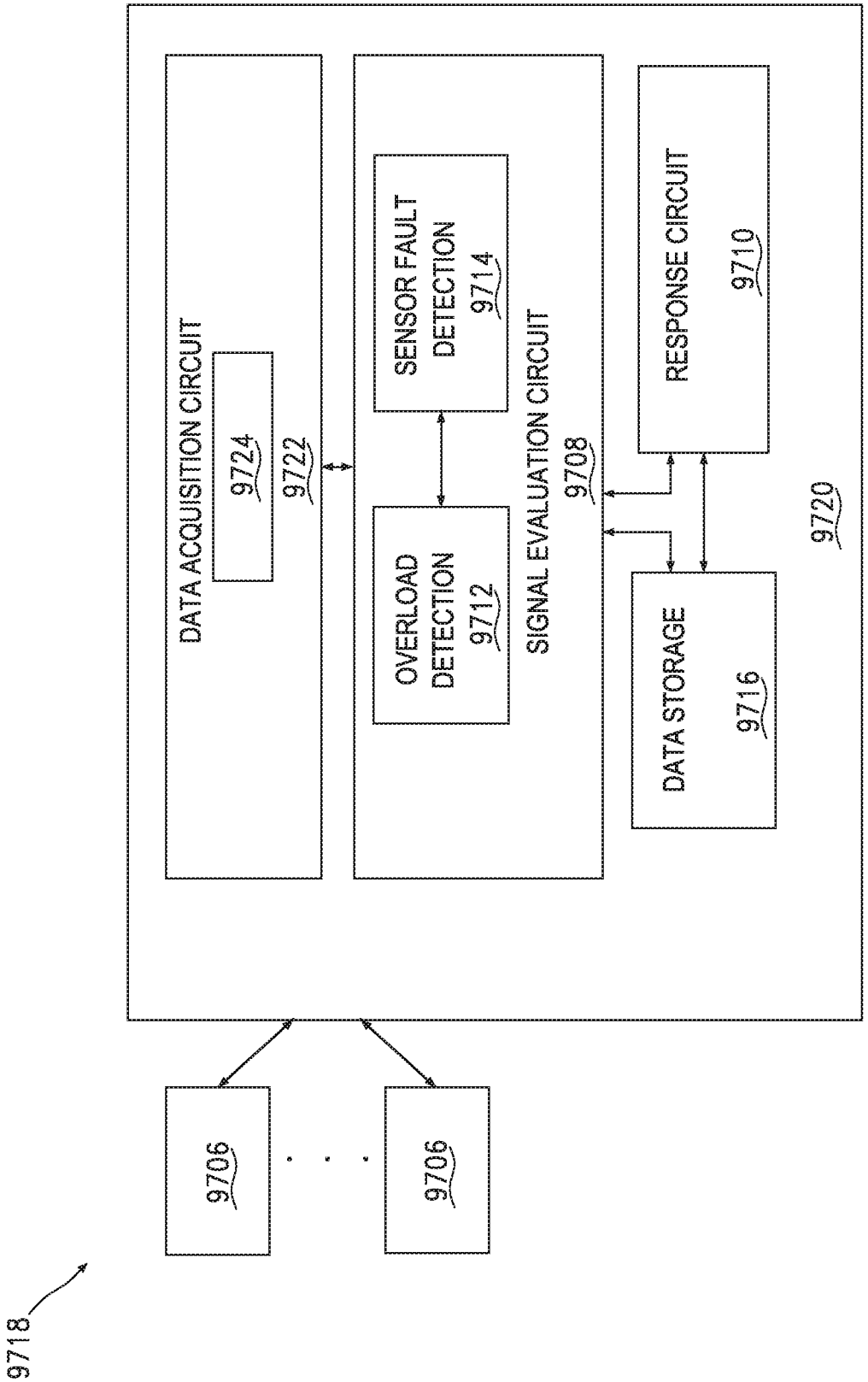
9718
9706
9706
9720
DATA ACQUISITION CIRCUIT
9722
9724
SIGNAL EVALUATION CIRCUIT
9708
SENSOR FAULT DETECTION
9714
OVERLOAD DETECTION
9712
RESPONSE CIRCUIT
9710
DATA STORAGE
9716

FIG. 104

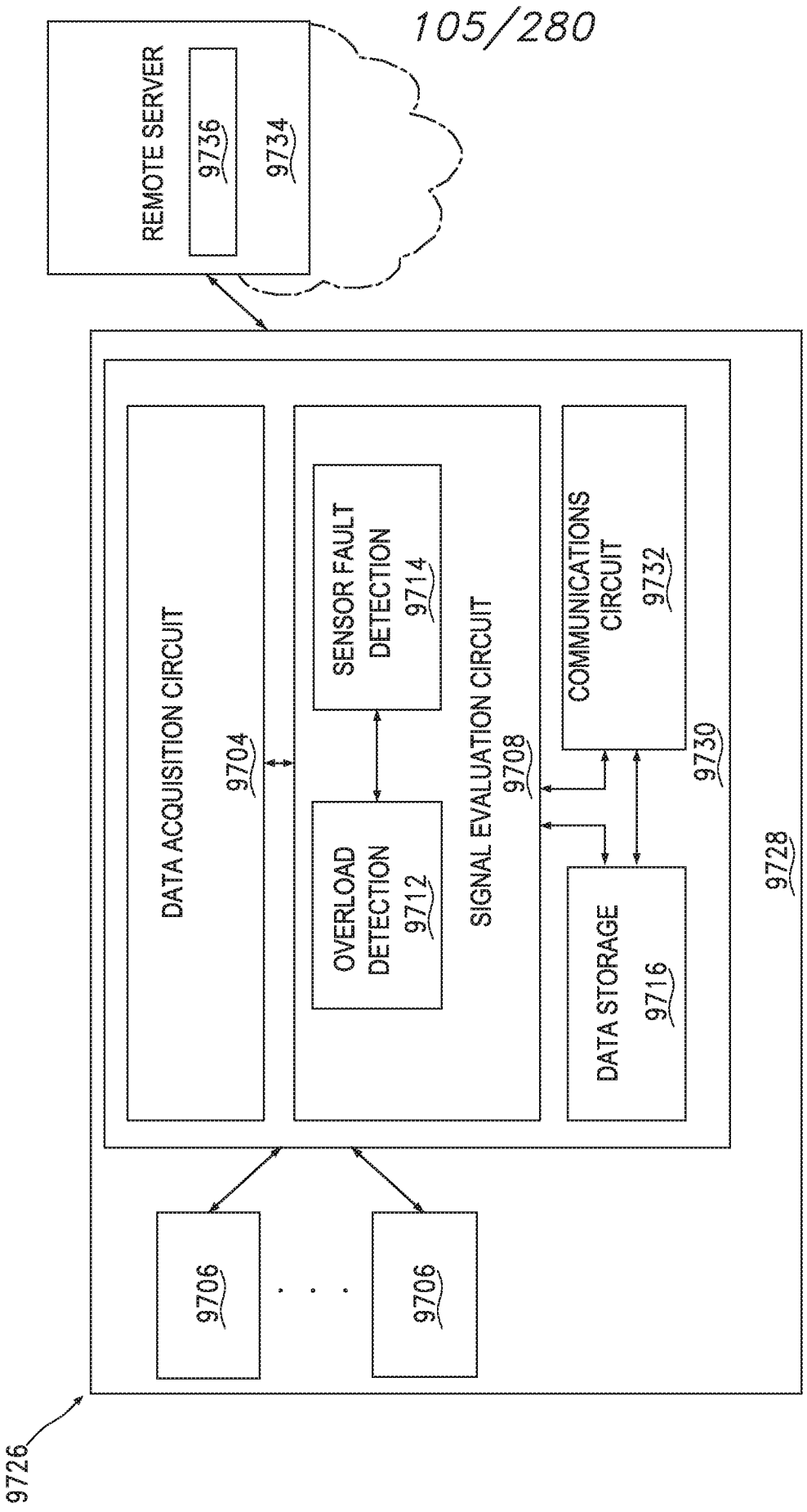
105/280
REMOTE SERVER
9736
9734
9728
DATA ACQUISITION CIRCUIT
9704
SENSOR FAULT DETECTION
9714
OVERLOAD DETECTION
9712
SIGNAL EVALUATION CIRCUIT
9708
COMMUNICATIONS CIRCUIT
9732
9730
DATA STORAGE
9716
9706
9706
9726

FIG. 105

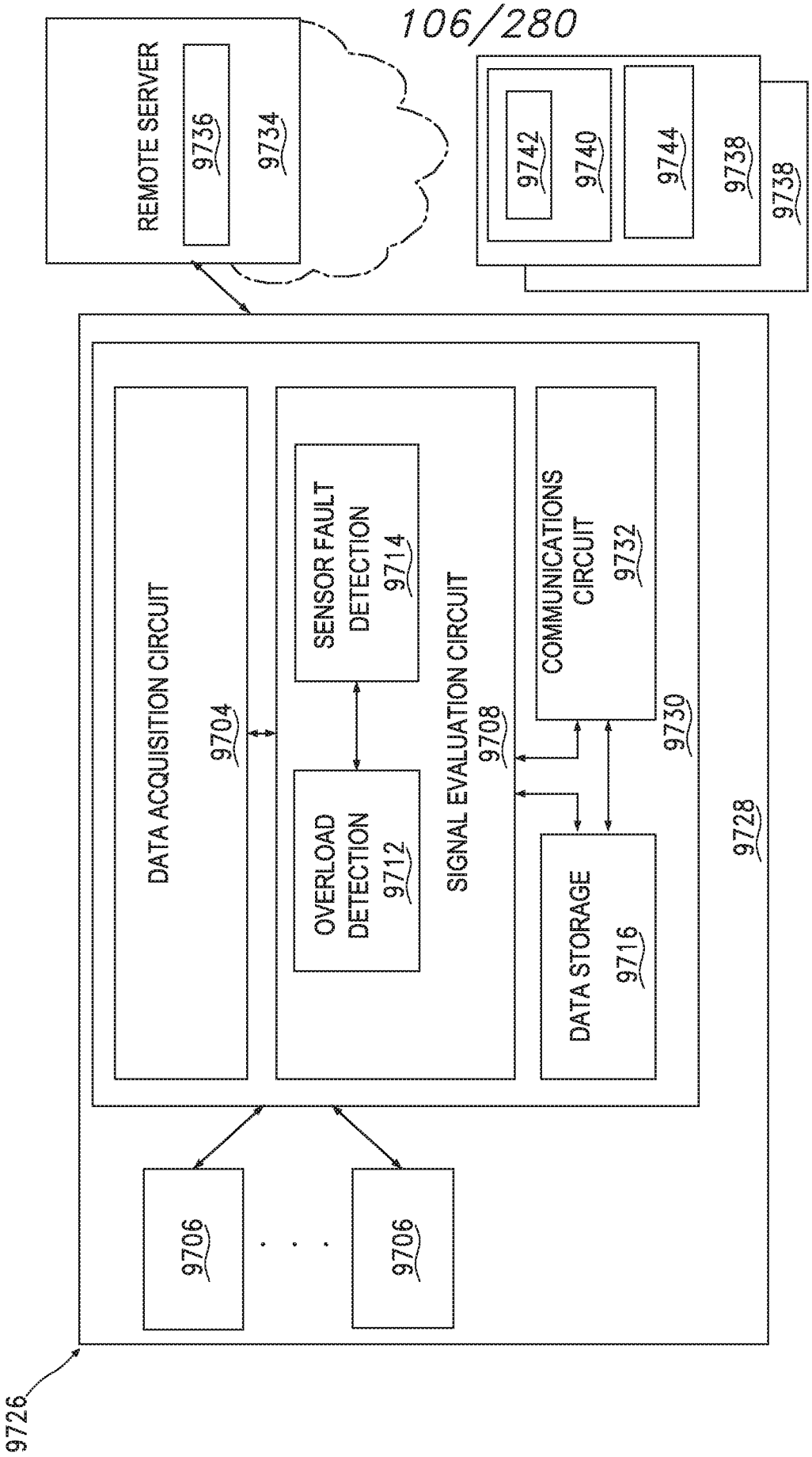
106/280
REMOTE SERVER
9736
9734
9742
9740
9744
9738
9738
9726
9728
DATA ACQUISITION CIRCUIT
9704
SENSOR FAULT DETECTION
9714
SIGNAL EVALUATION CIRCUIT
9708
COMMUNICATIONS CIRCUIT
9732
9730
OVERLOAD DETECTION
9712
DATA STORAGE
9716
9706
9706

FIG. 106

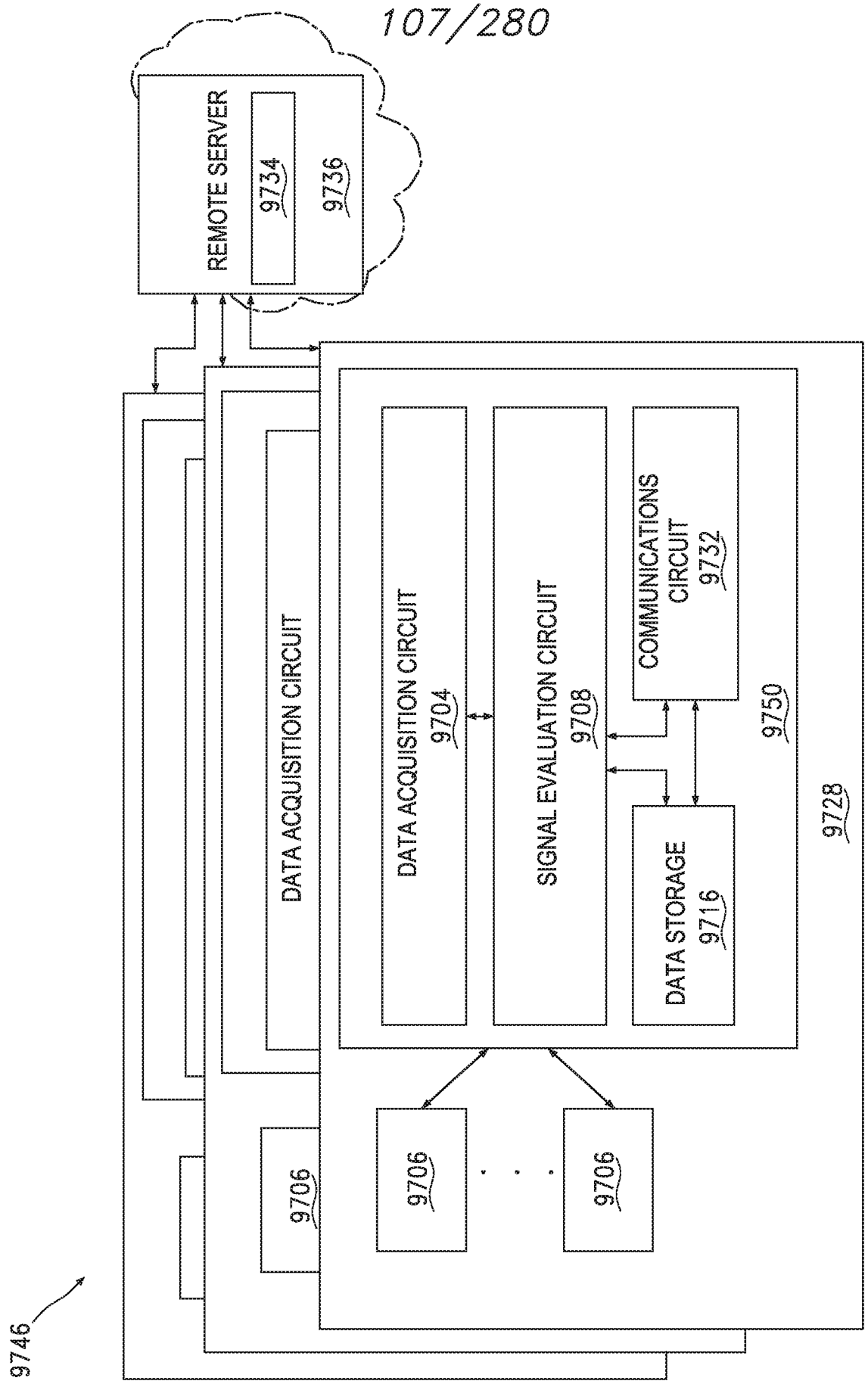
107/280
REMOTE SERVER
9734
9736
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT
9704
SIGNAL EVALUATION CIRCUIT
9708
COMMUNICATIONS CIRCUIT
9732
DATA STORAGE
9716
9750
9728
9706
9706
9706
9746

FIG. 107

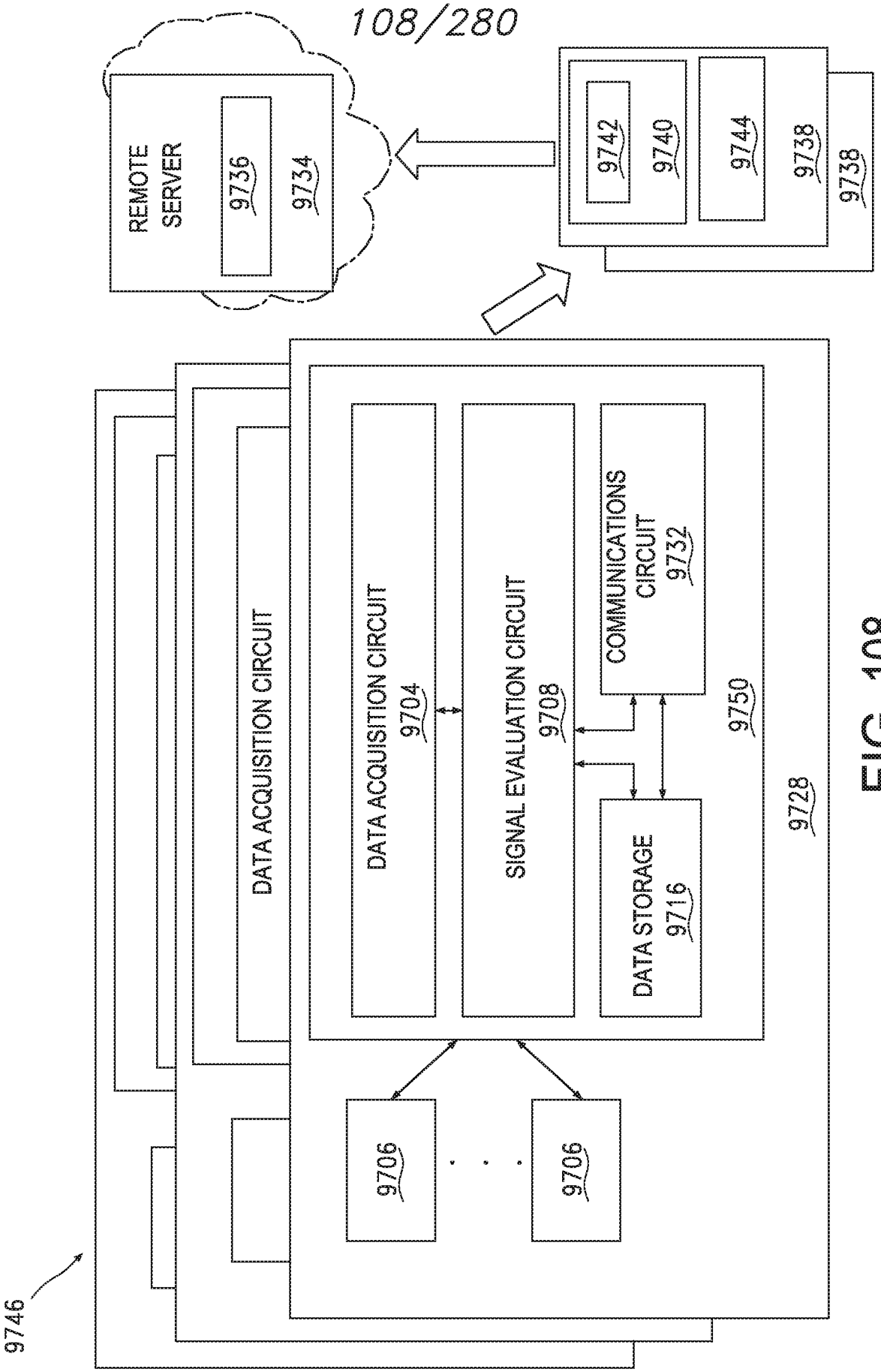
108/280
REMOTE SERVER
9736
9734
9742
9740
9744
9738
9738
9746
DATA ACQUISITION CIRCUIT
DATA ACQUISITION CIRCUIT
9704
SIGNAL EVALUATION CIRCUIT
9708
COMMUNICATIONS CIRCUIT
9732
DATA STORAGE
9716
9750
9728
9706
9706

FIG. 108

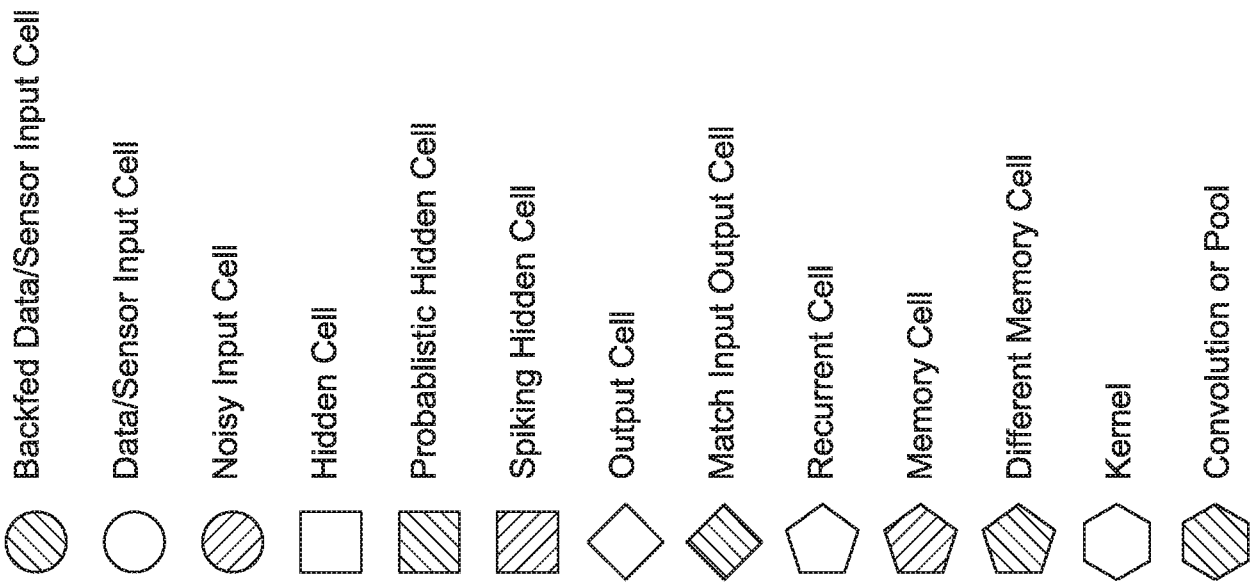
Backfed Data/Sensor Input Cell
Data/Sensor Input Cell
Noisy Input Cell
Hidden Cell
Probablistic Hidden Cell
Spiking Hidden Cell
Output Cell
Match Input Output Cell
Recurrent Cell
Memory Cell
Different Memory Cell
Kernel
Convolution or Pool

FIG. 109

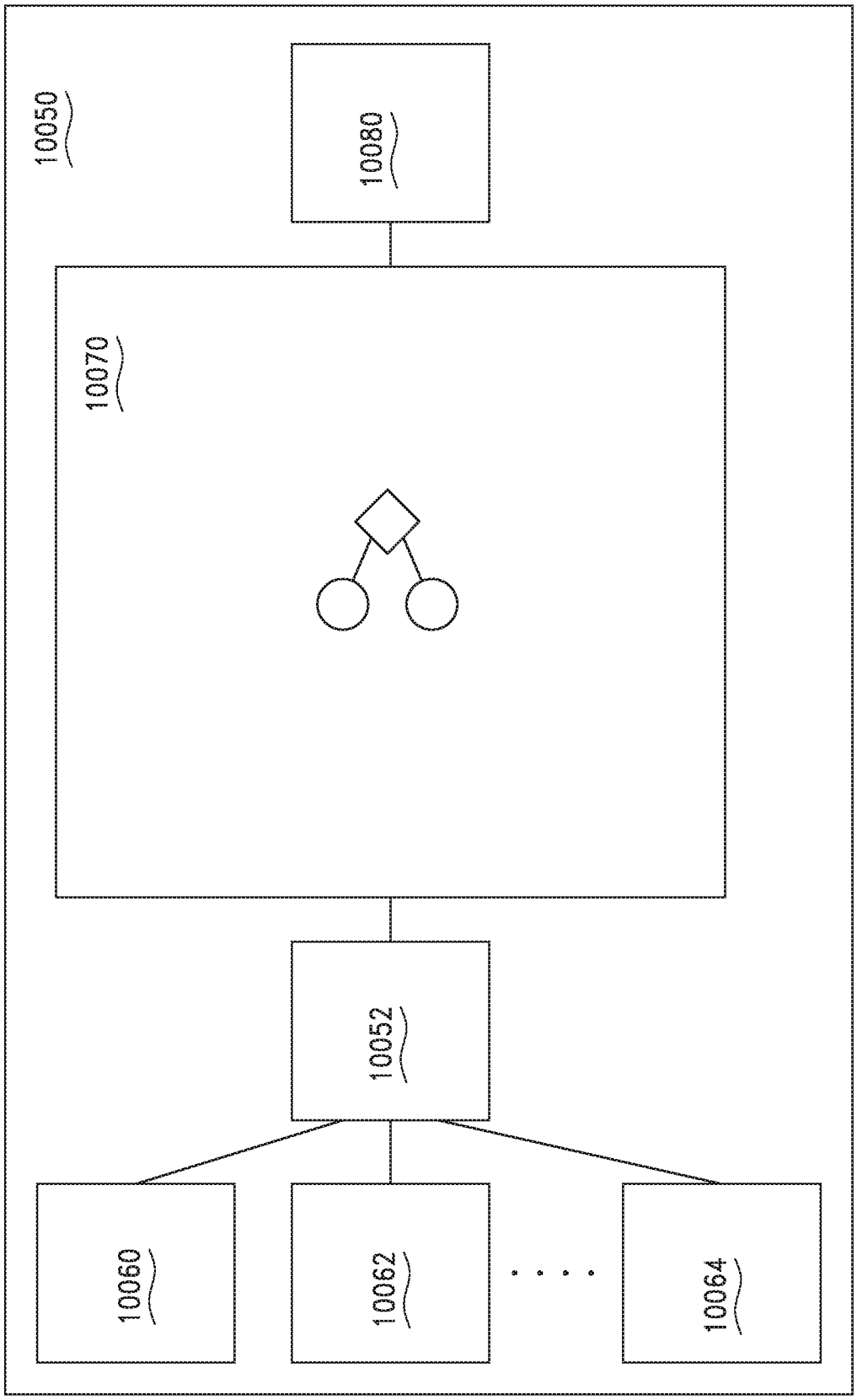

FIG. 110

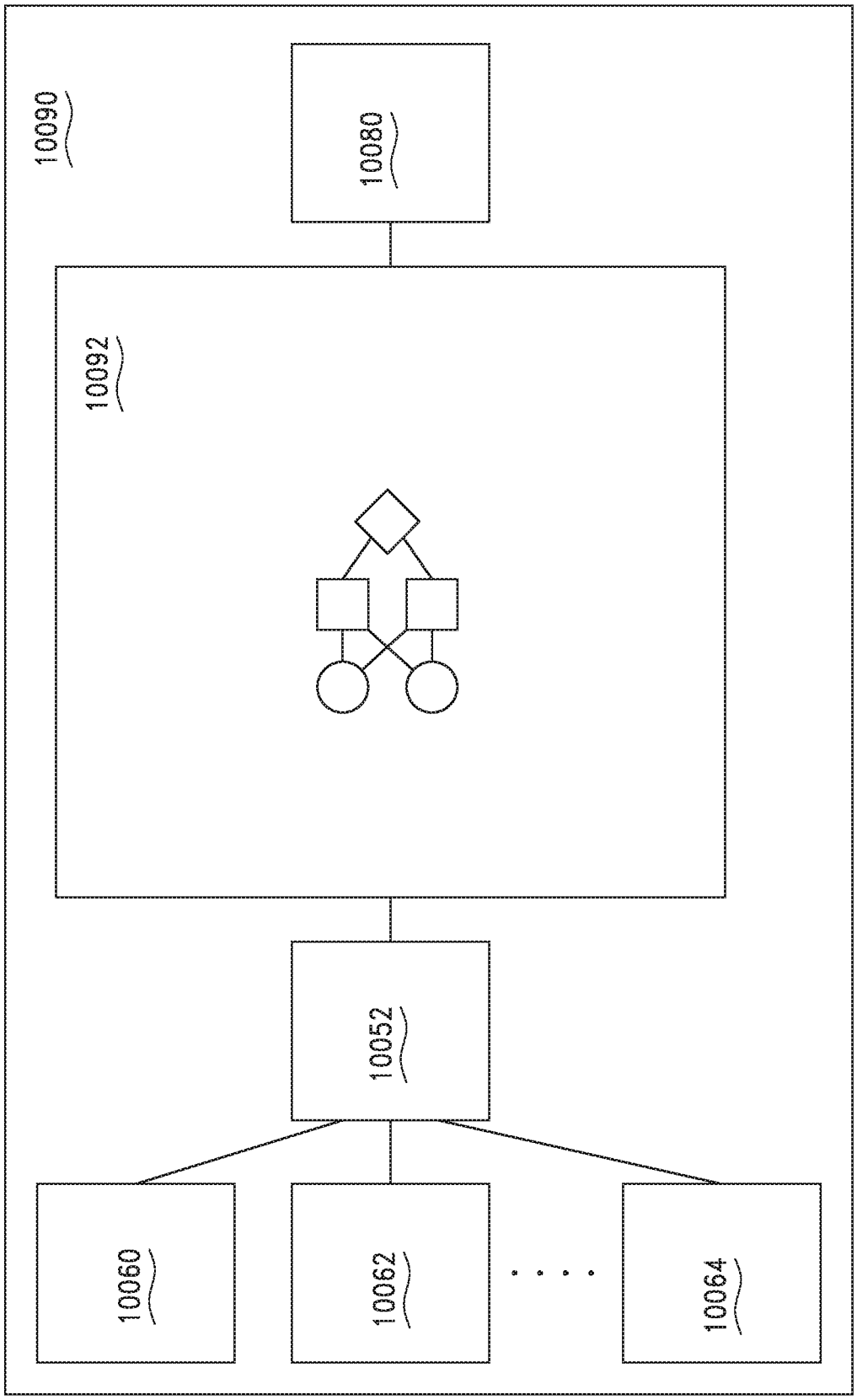

FIG. 111

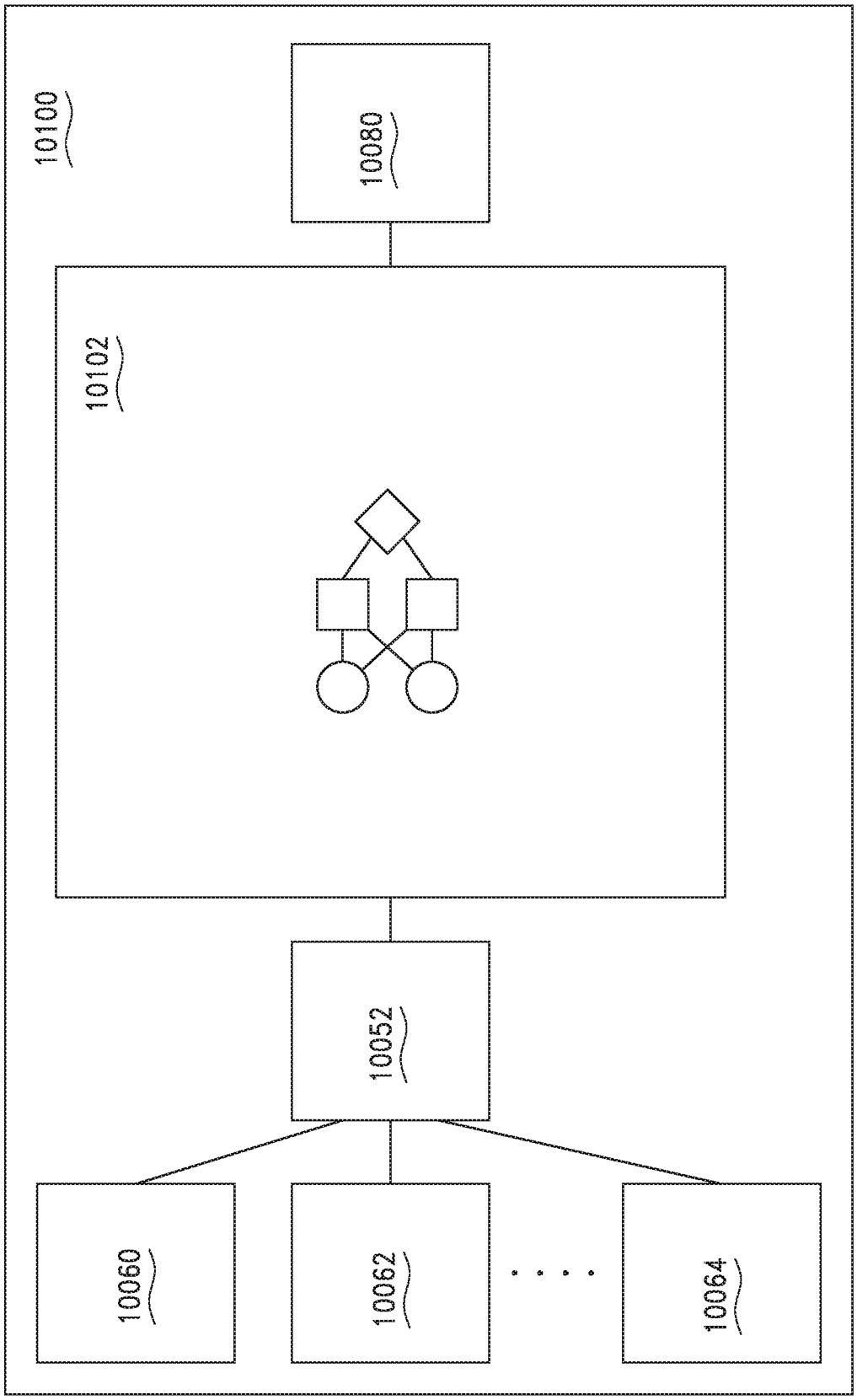

FIG. 112

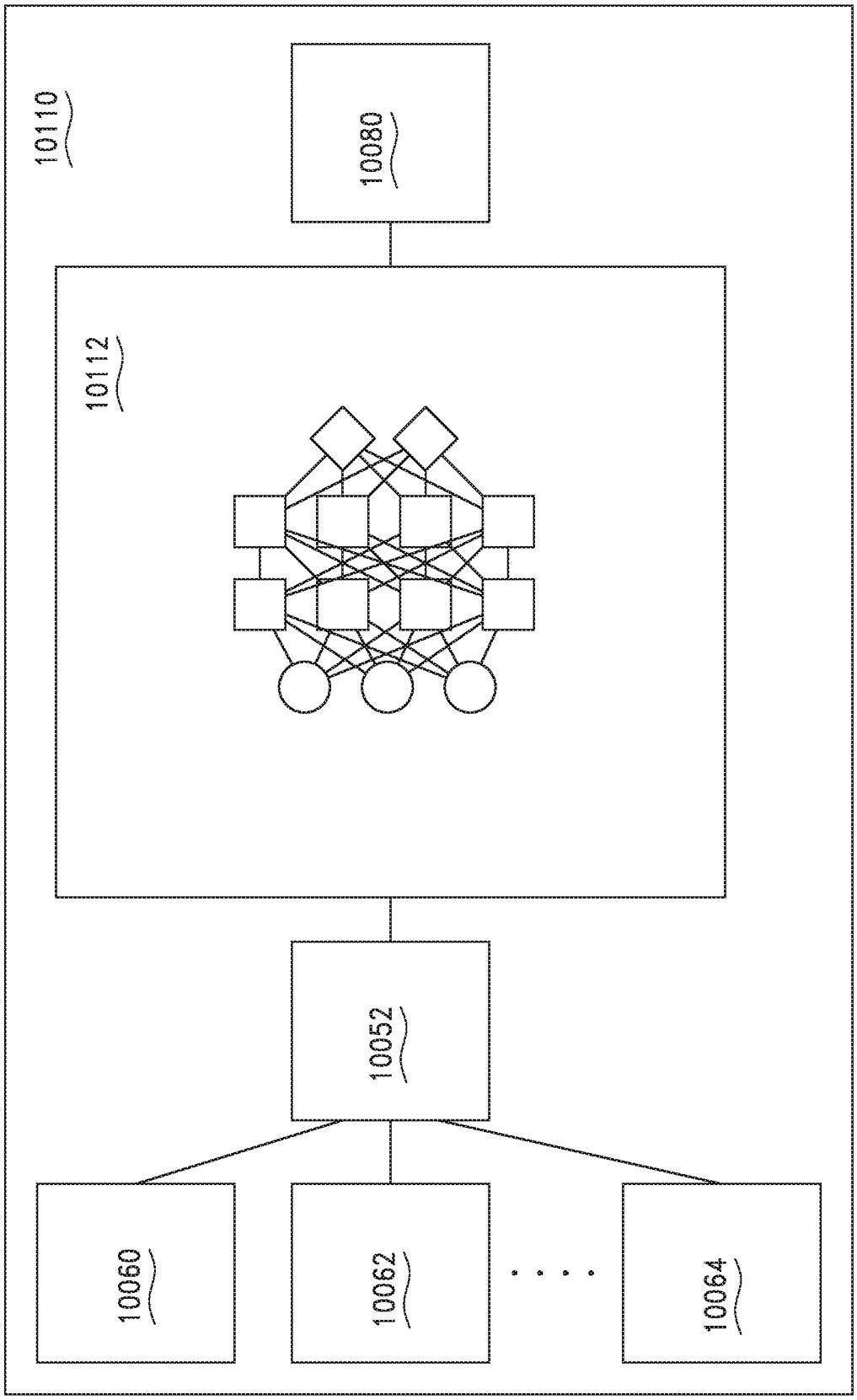

FIG. 113

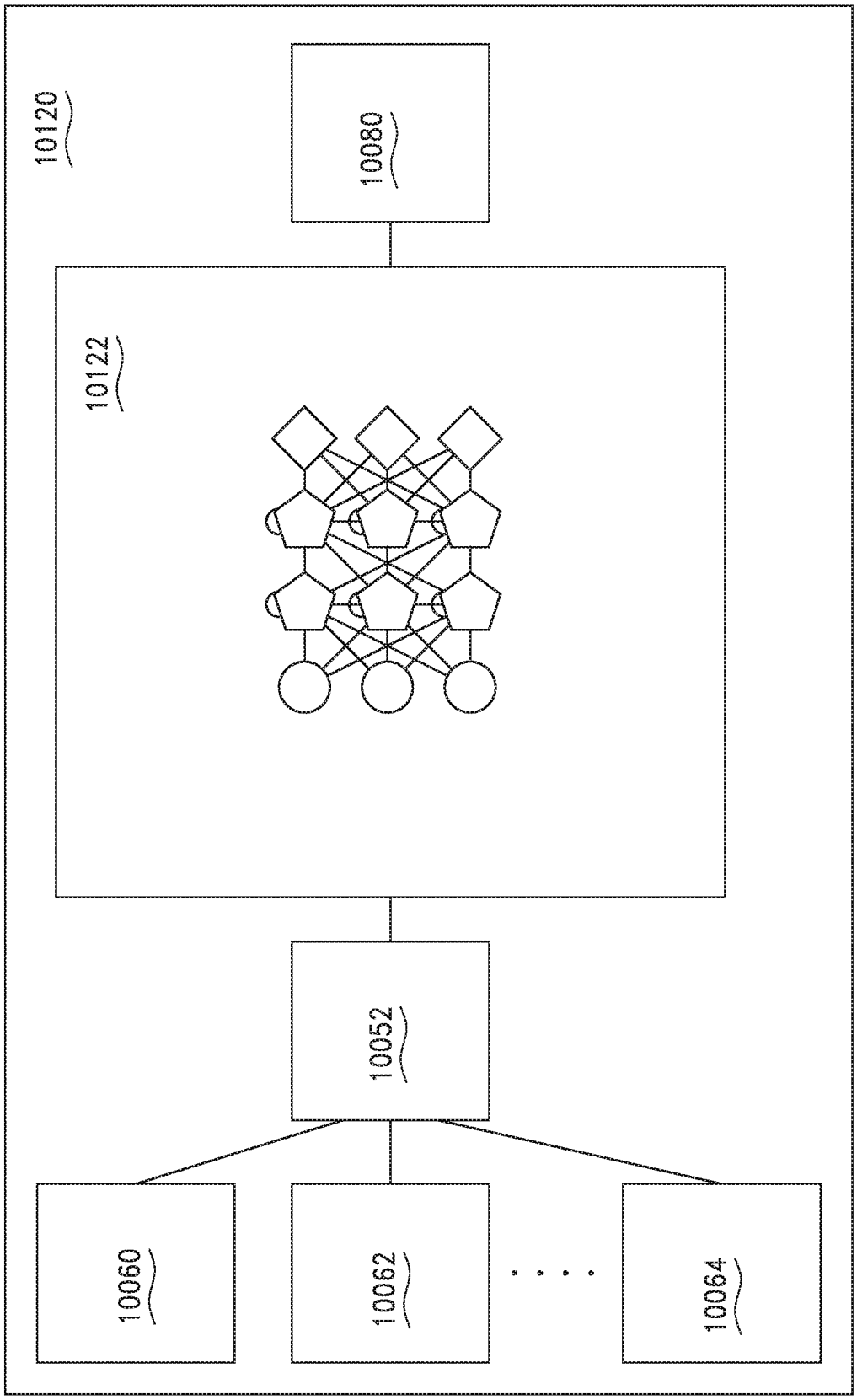

FIG. 114

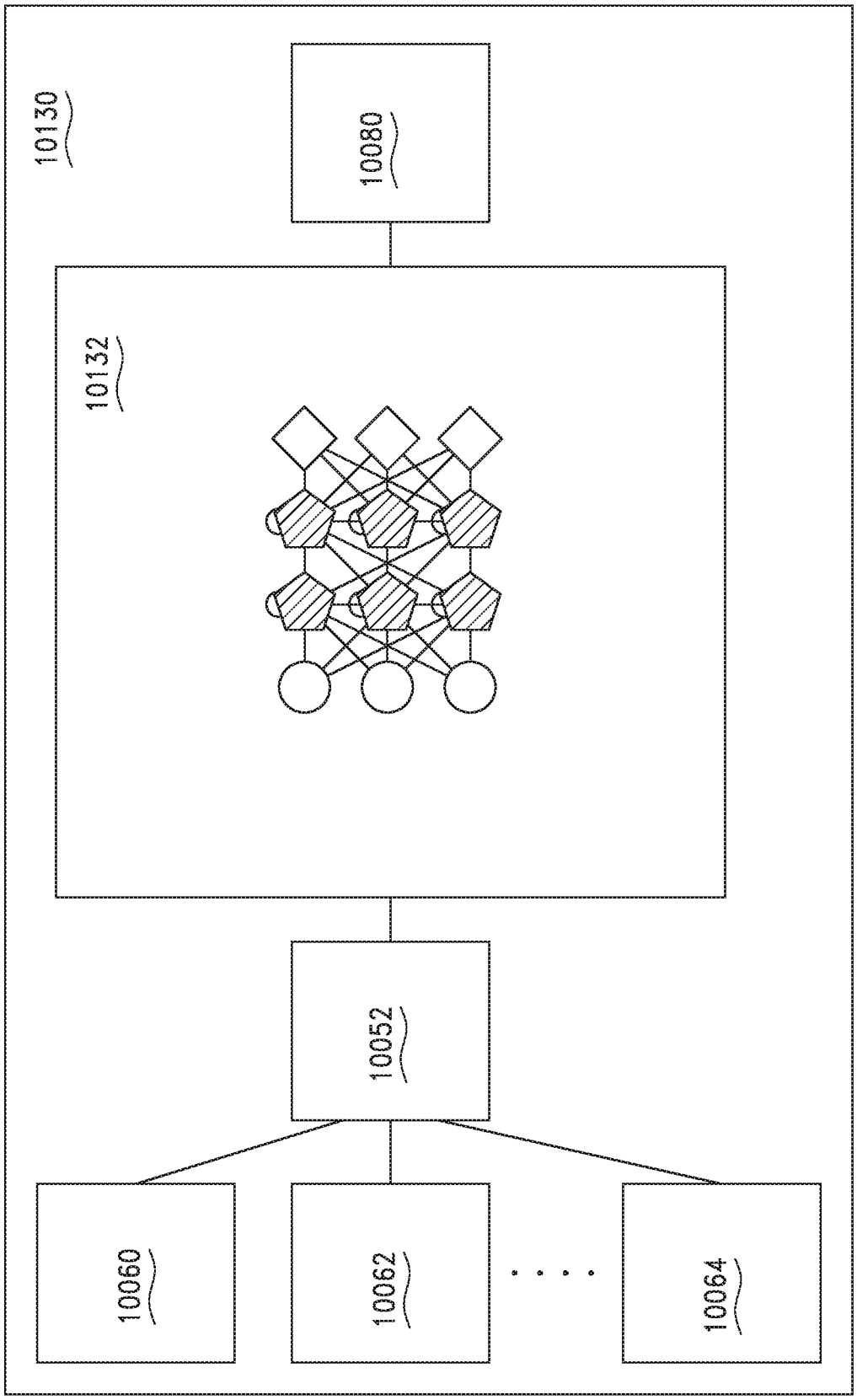

FIG. 115

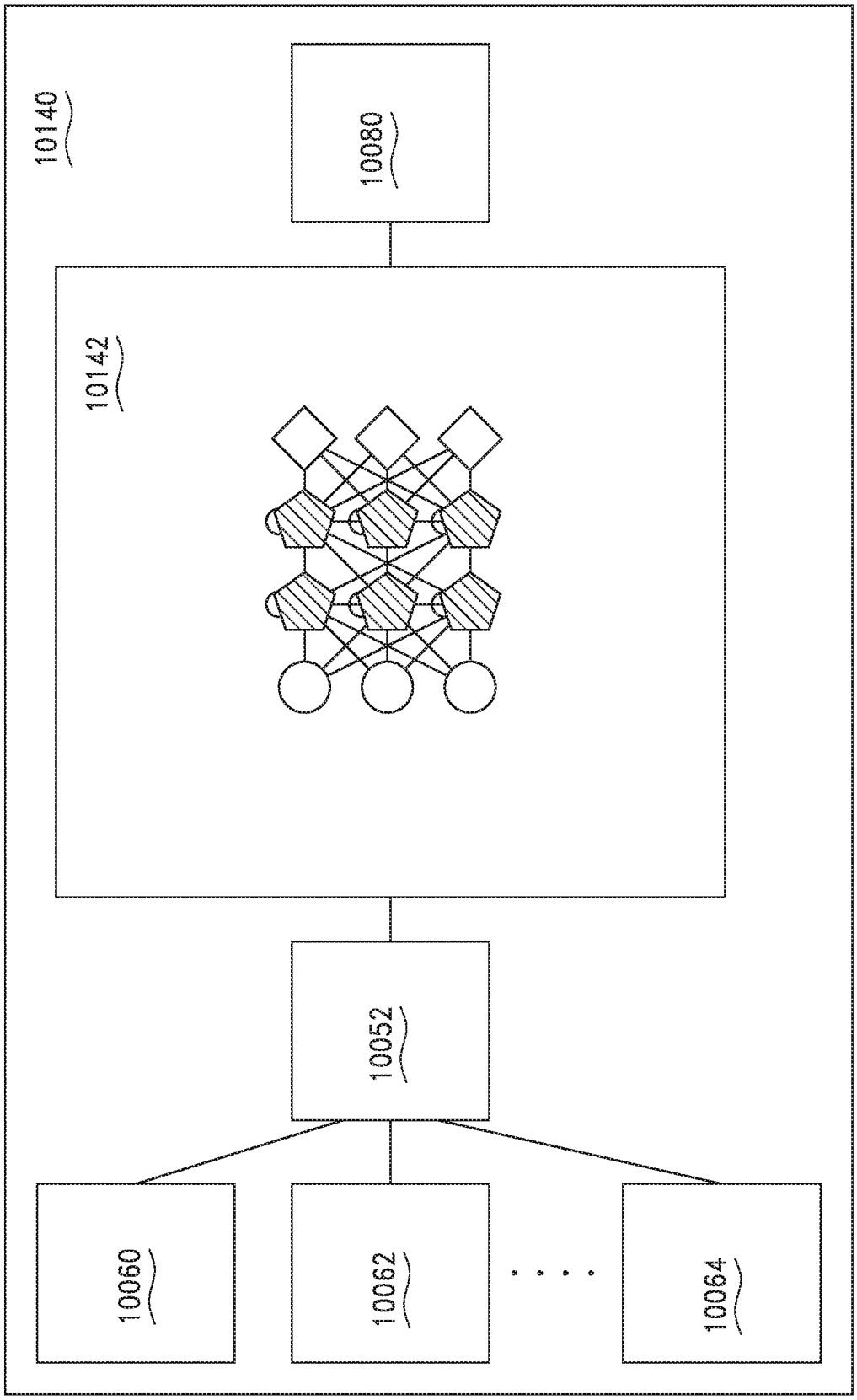

FIG. 116

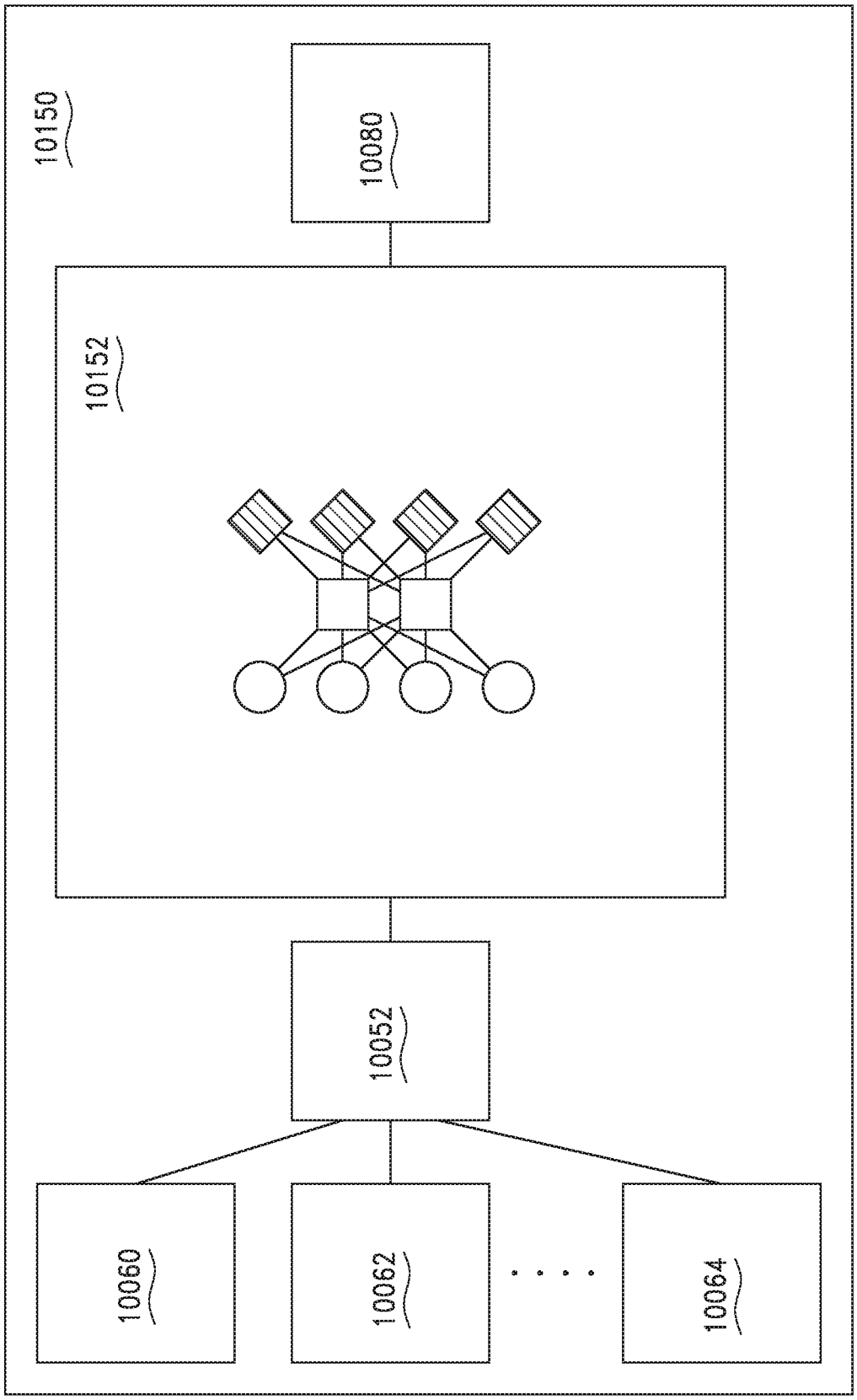

FIG. 117

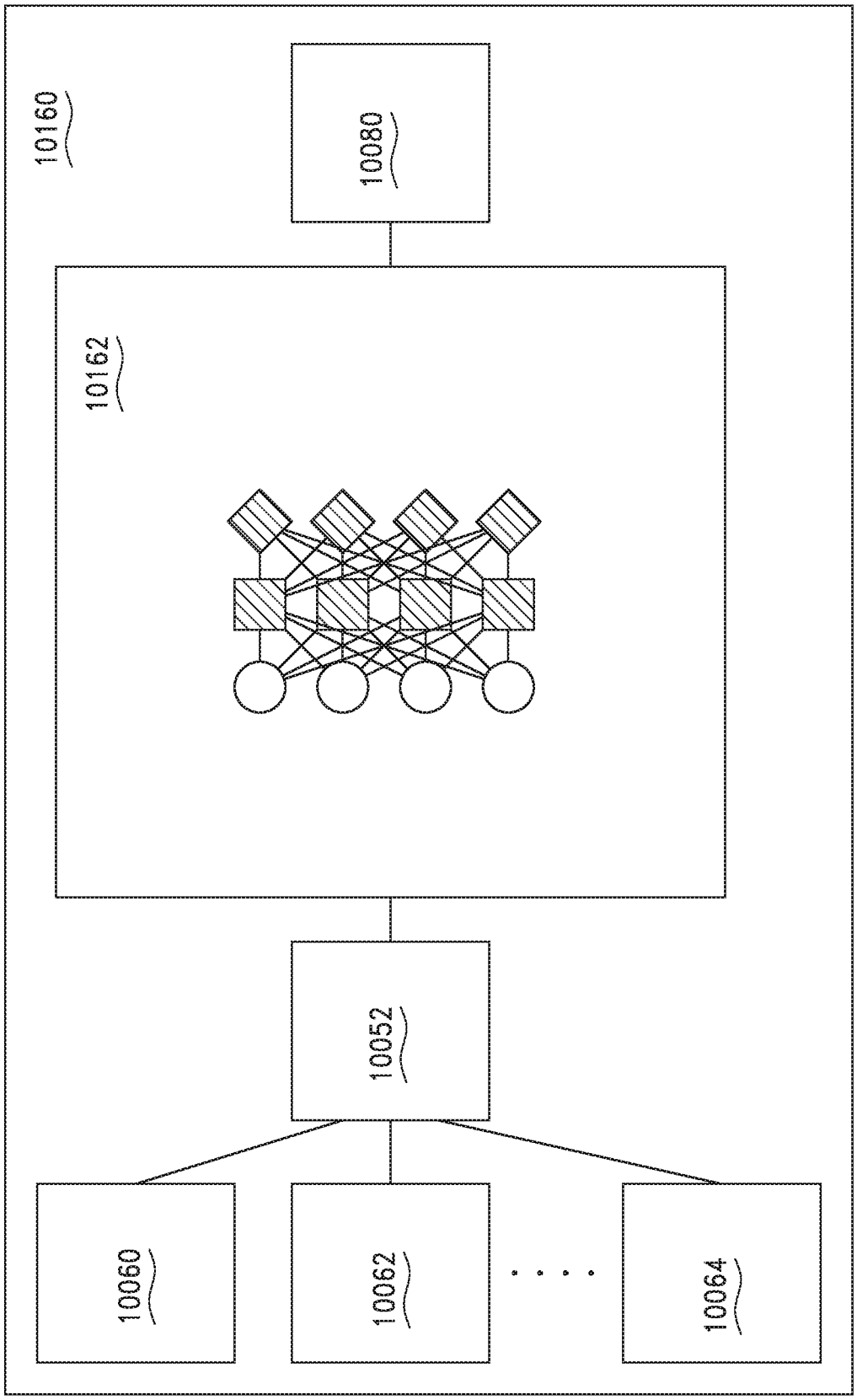

FIG. 118

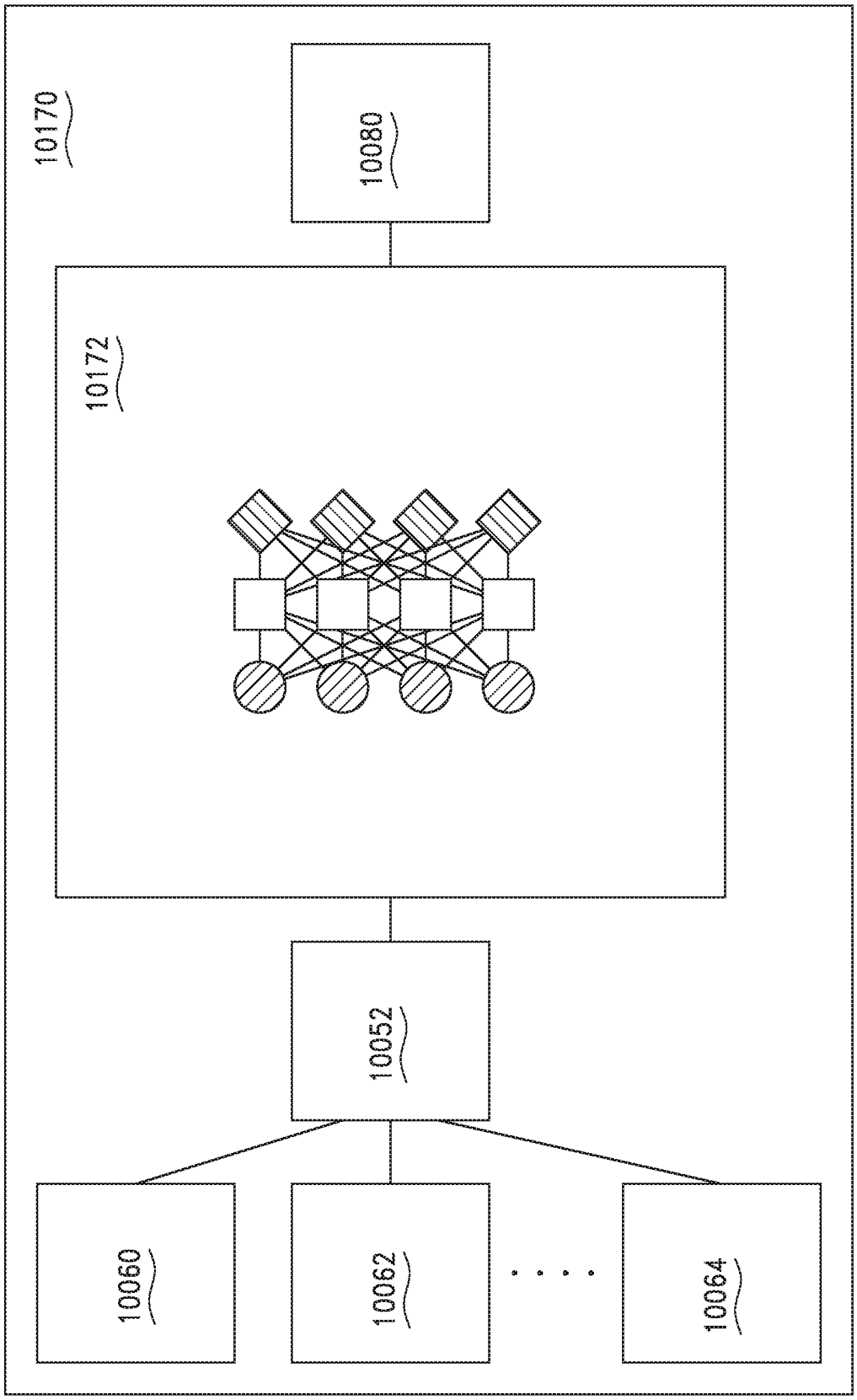

FIG. 119

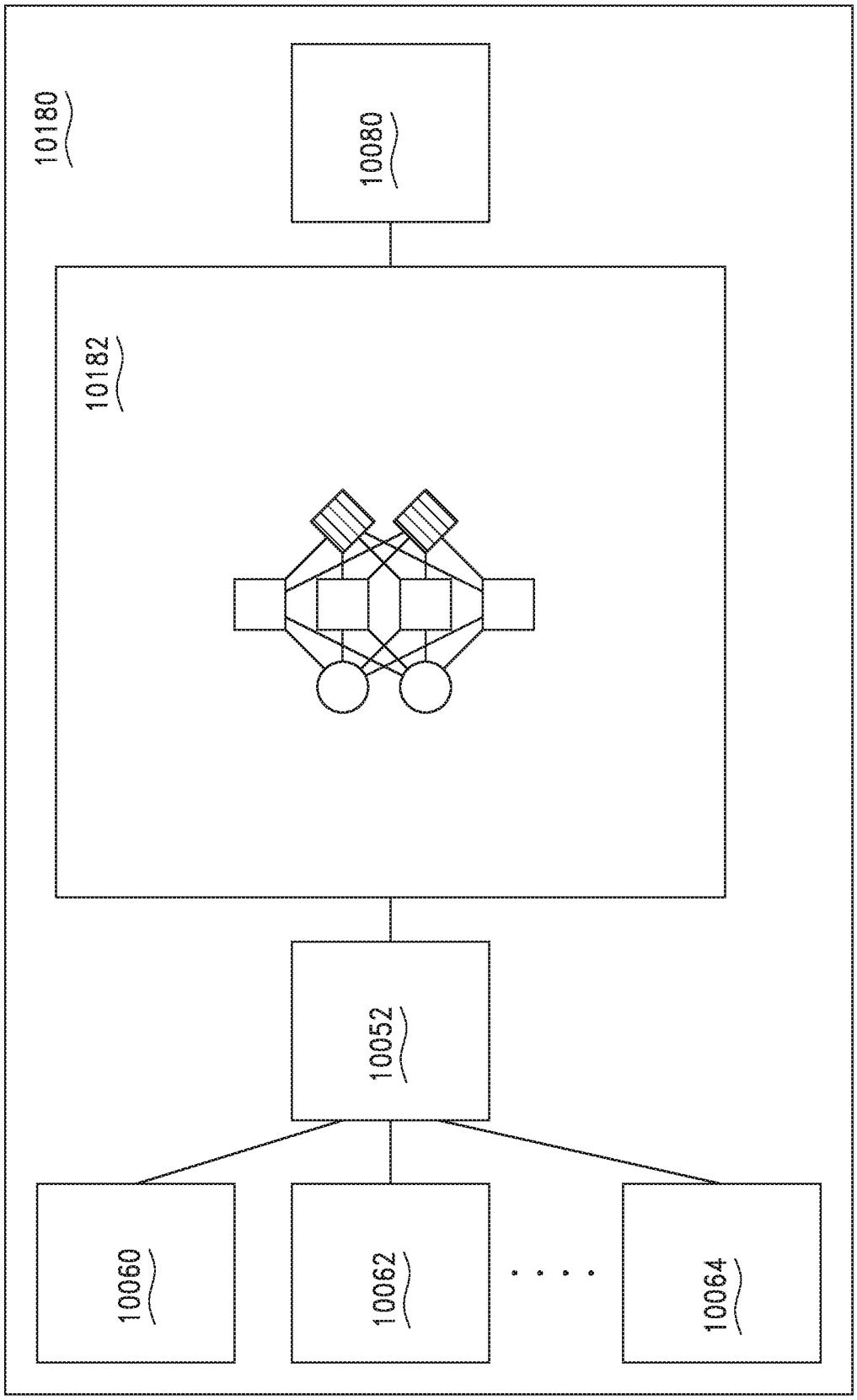

FIG. 120

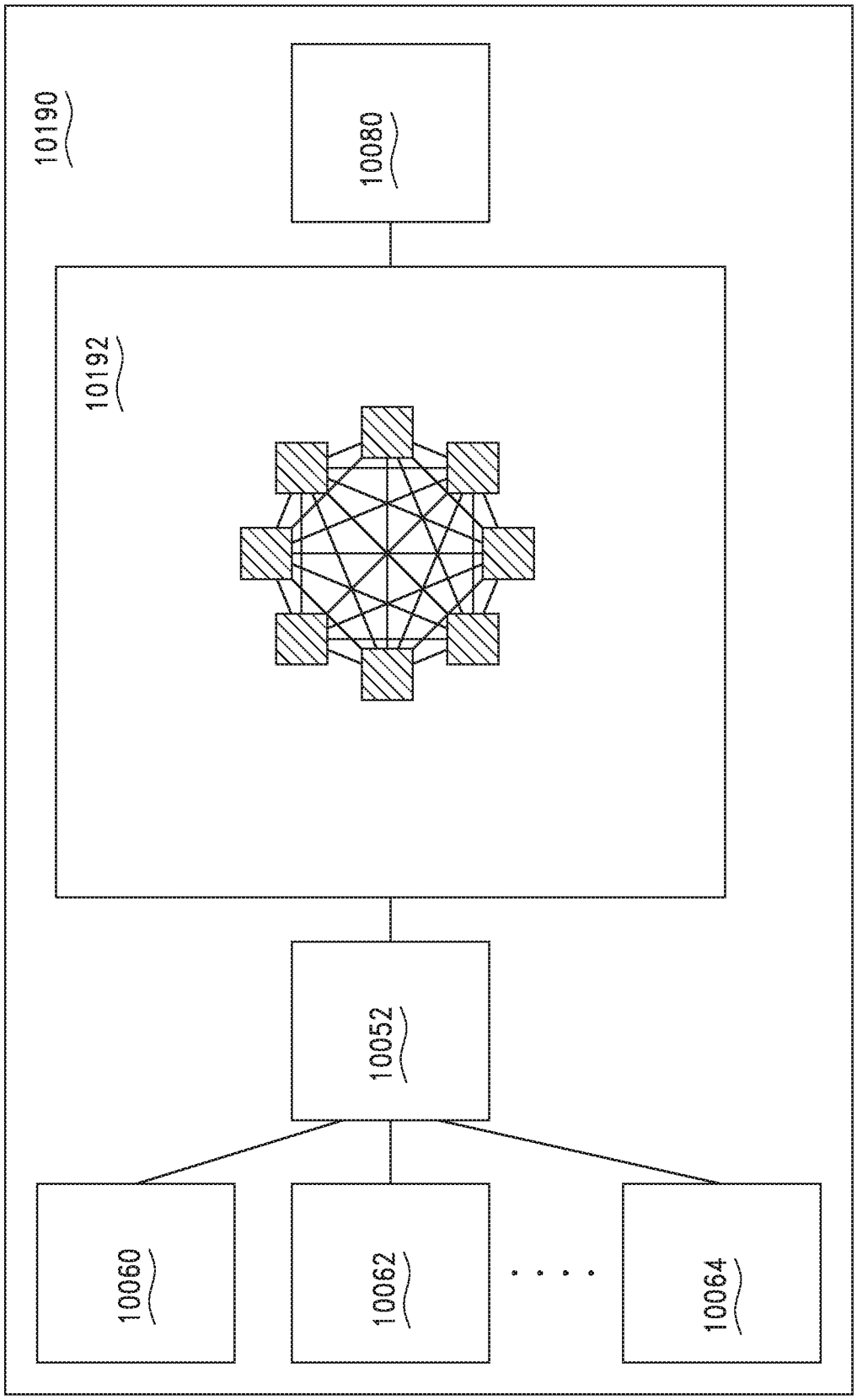

FIG. 121

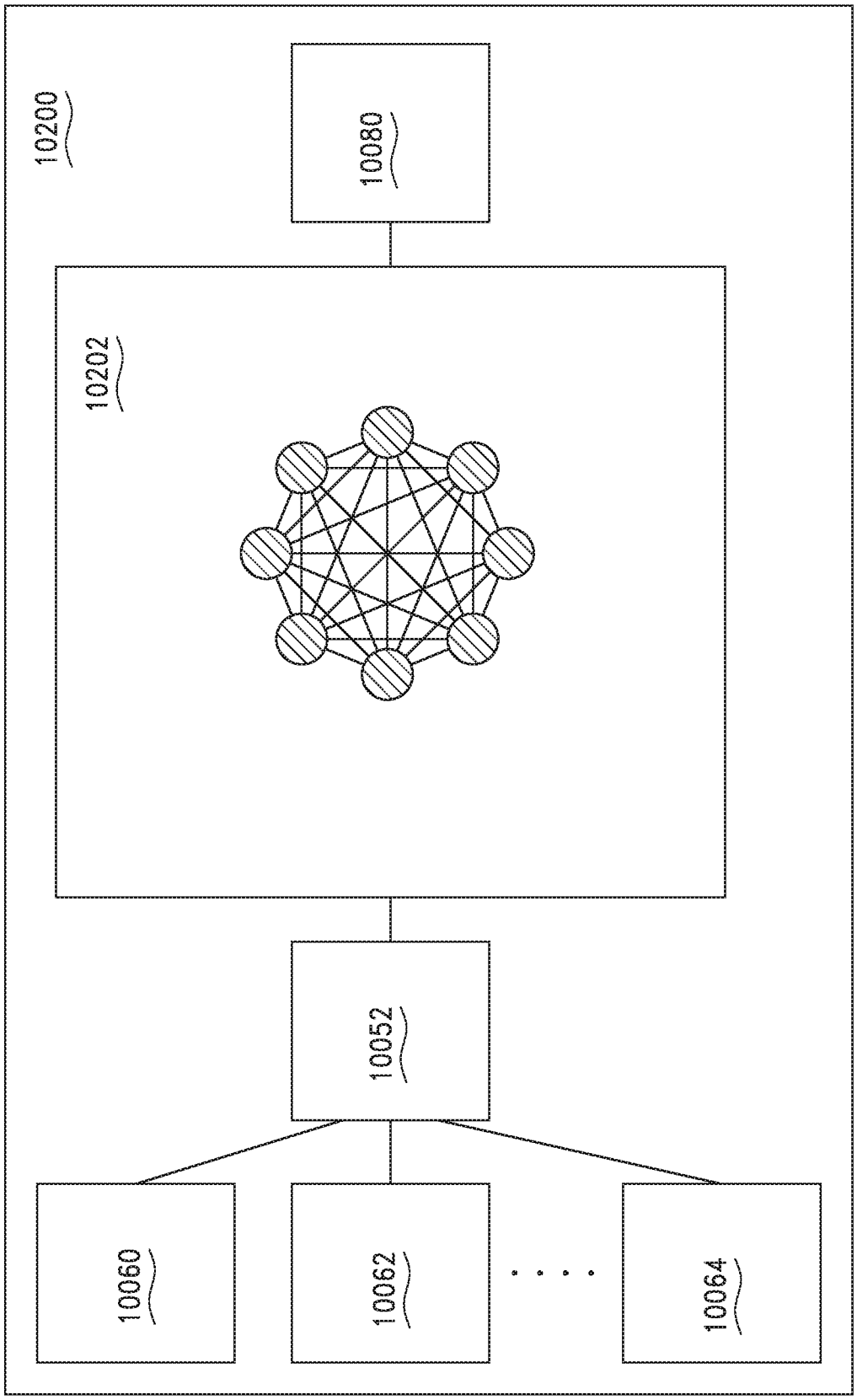

FIG. 122

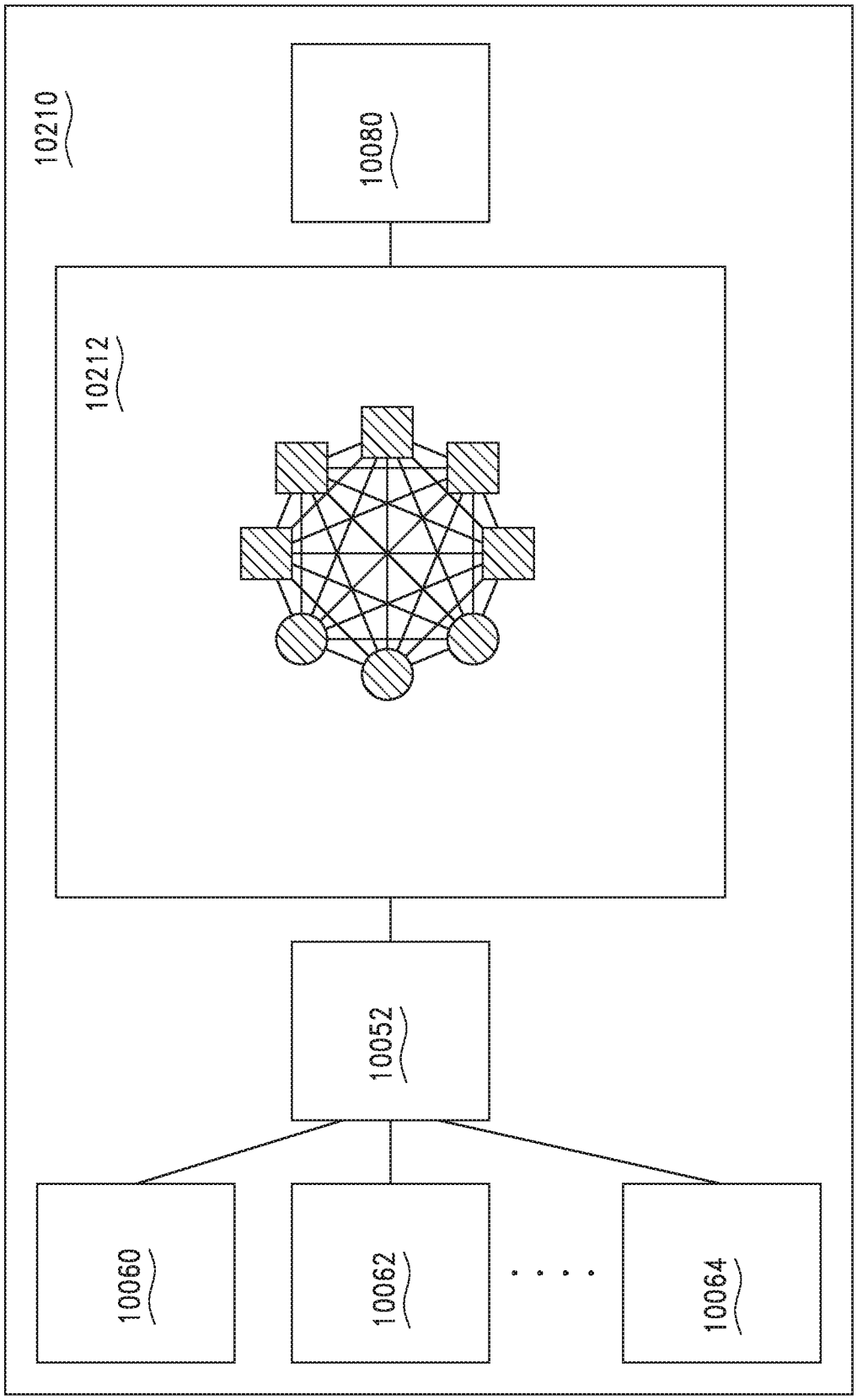

FIG. 123

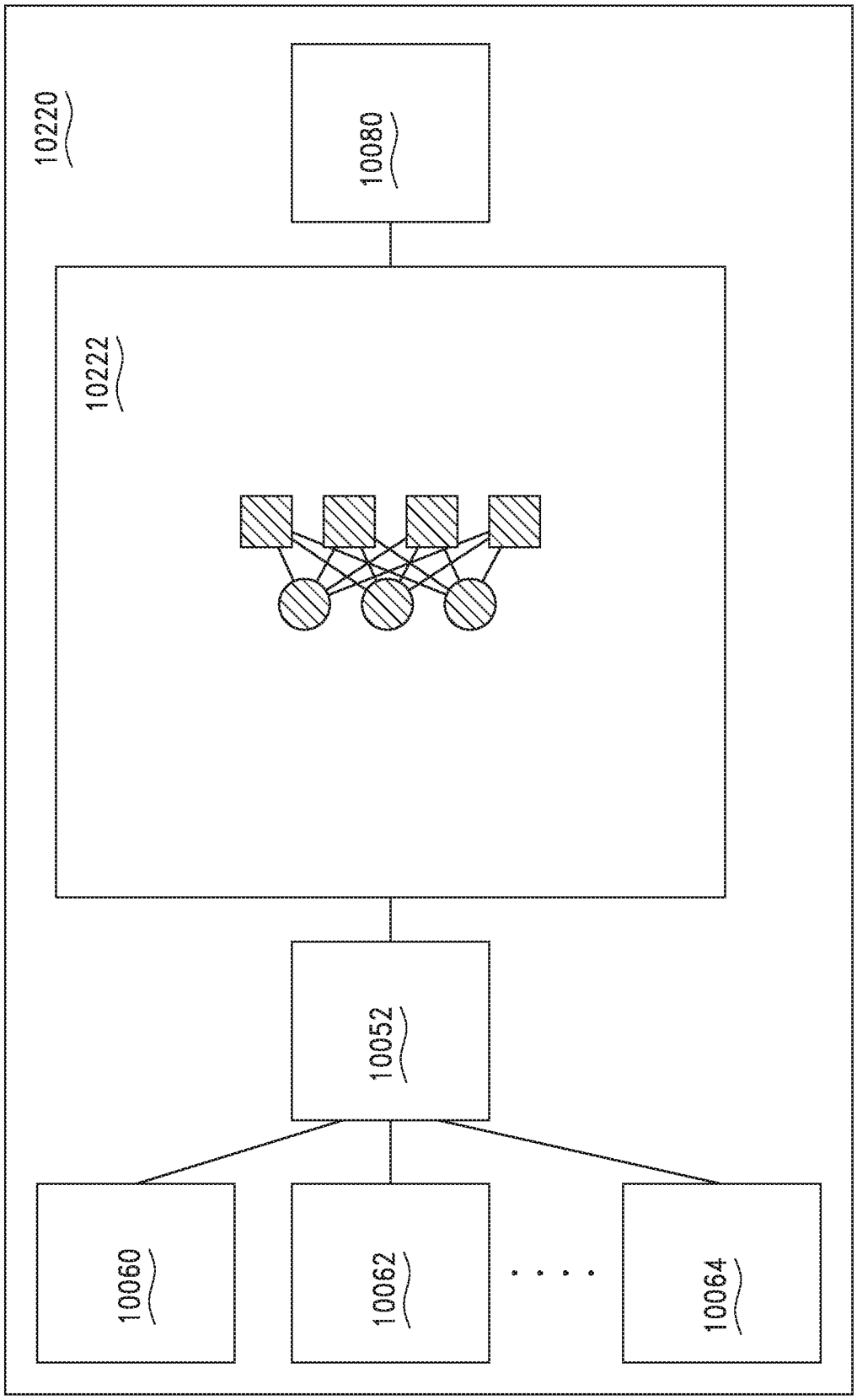

FIG. 124

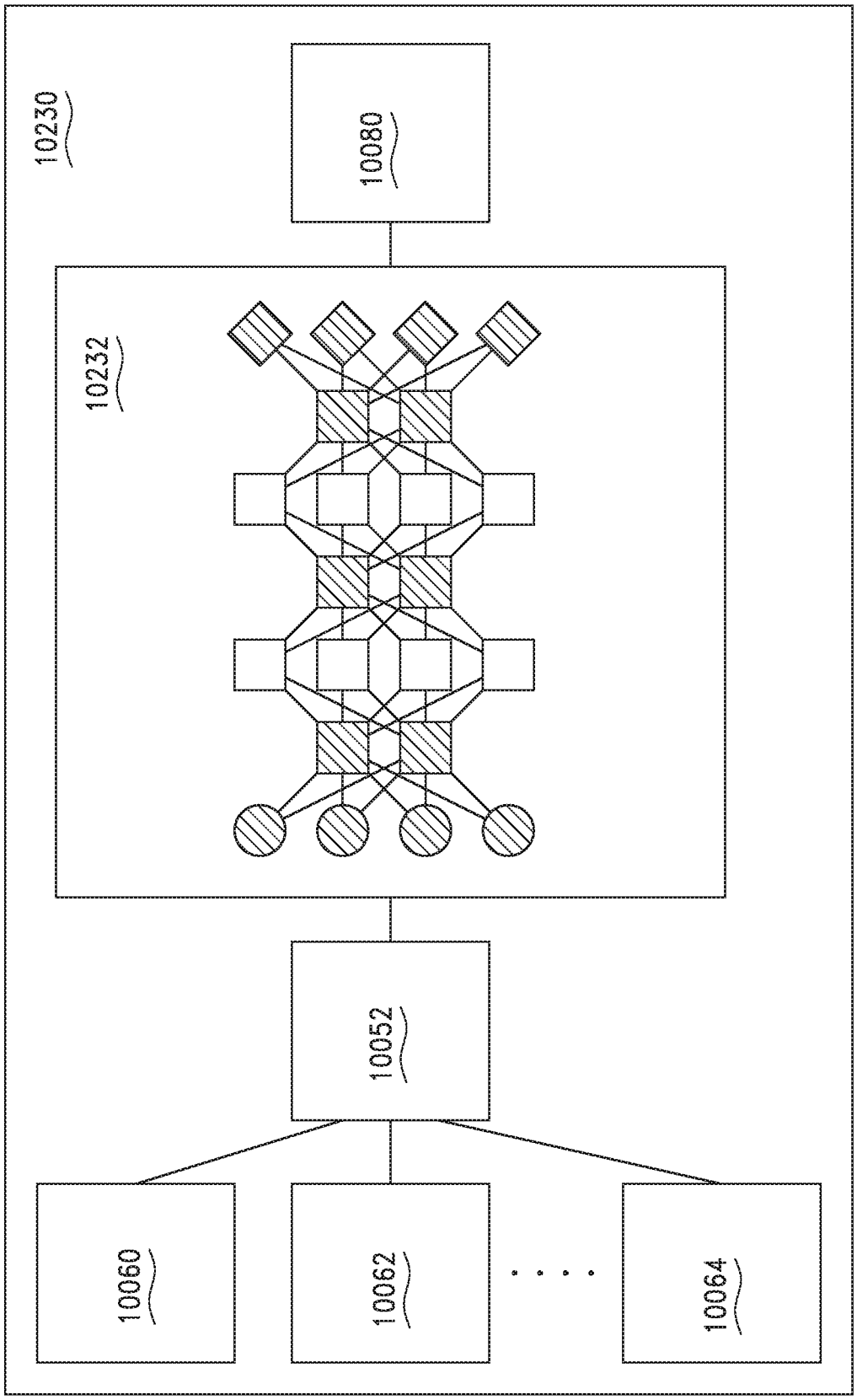

FIG. 125

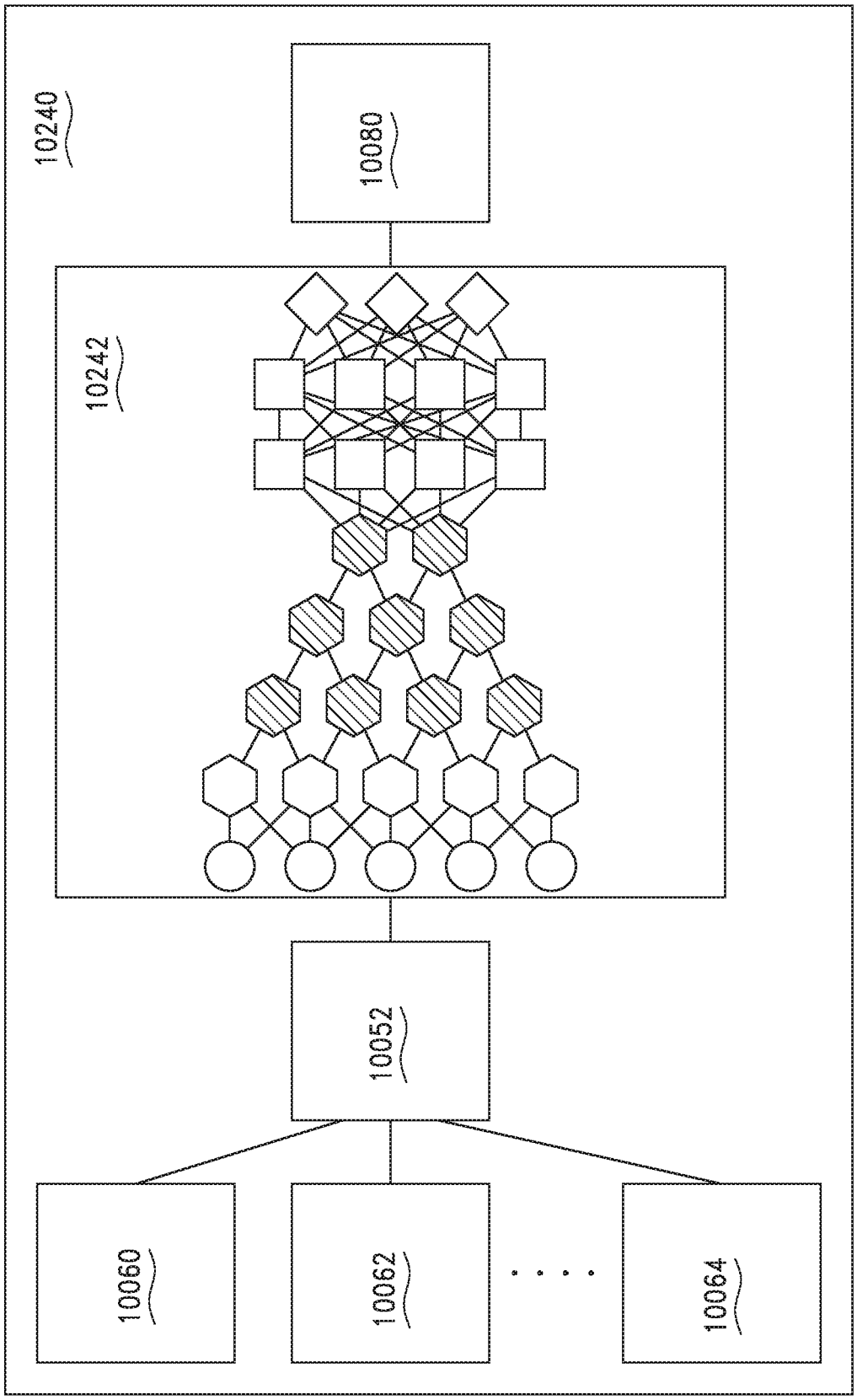

FIG. 126

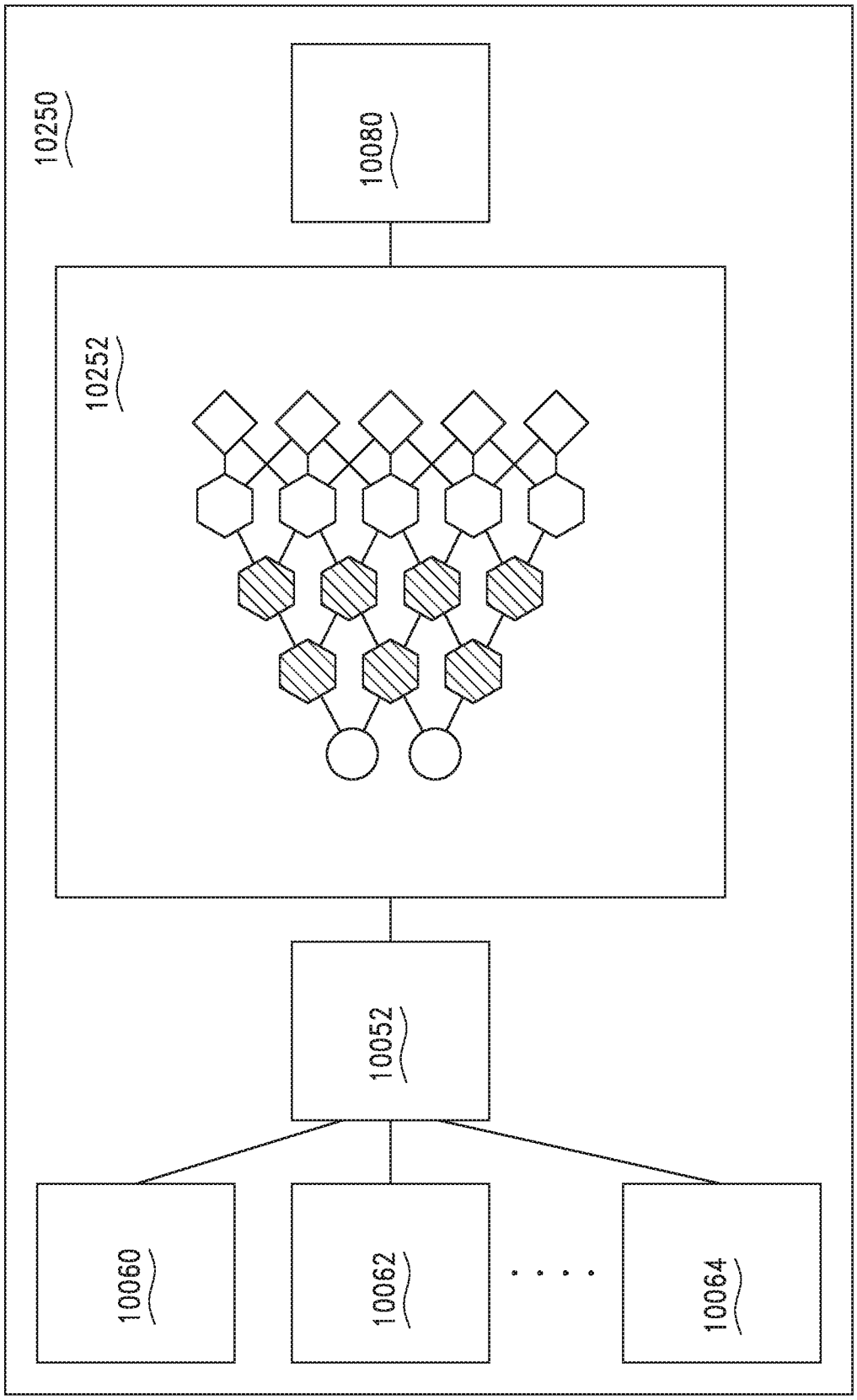

FIG. 127

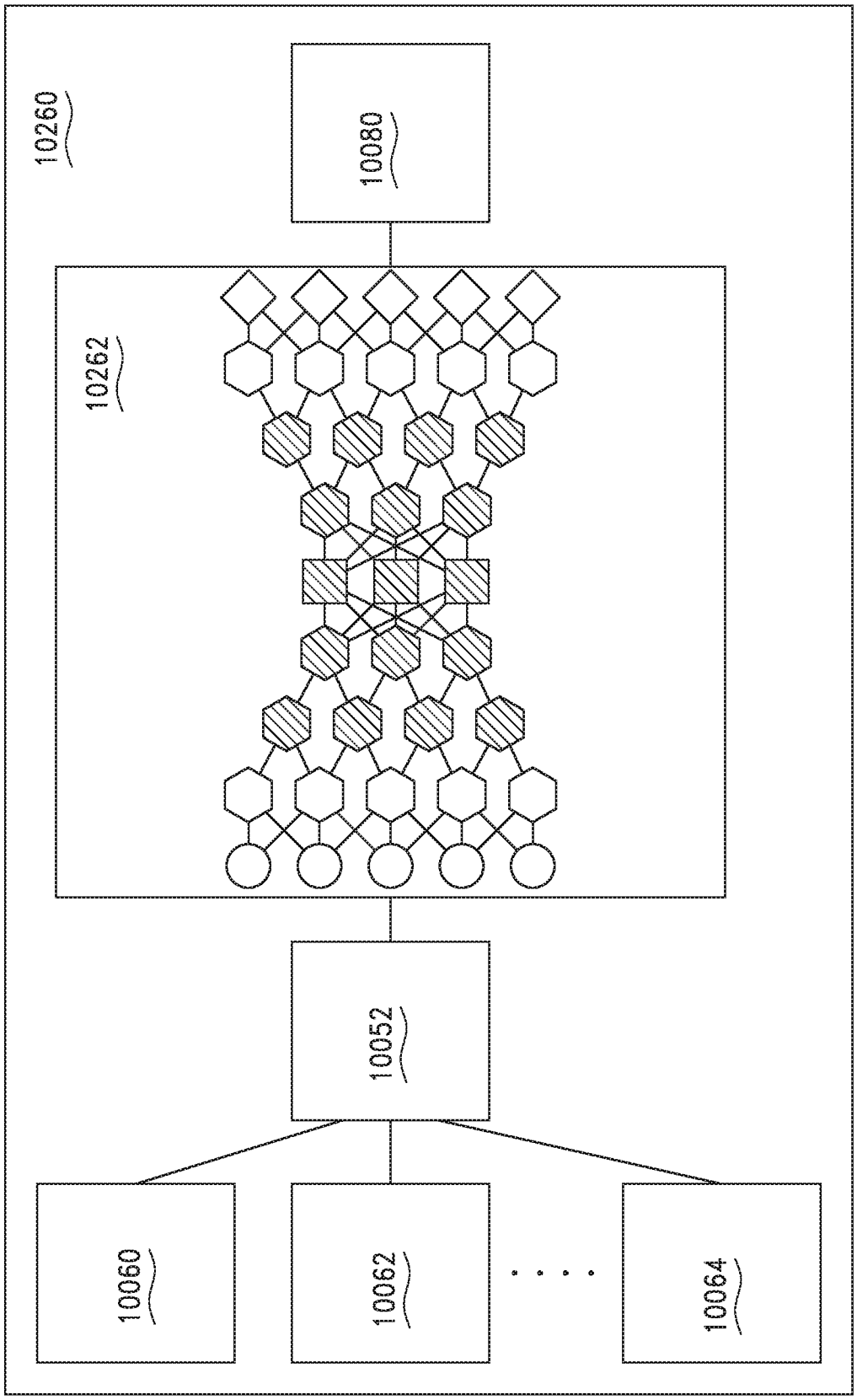

FIG. 128

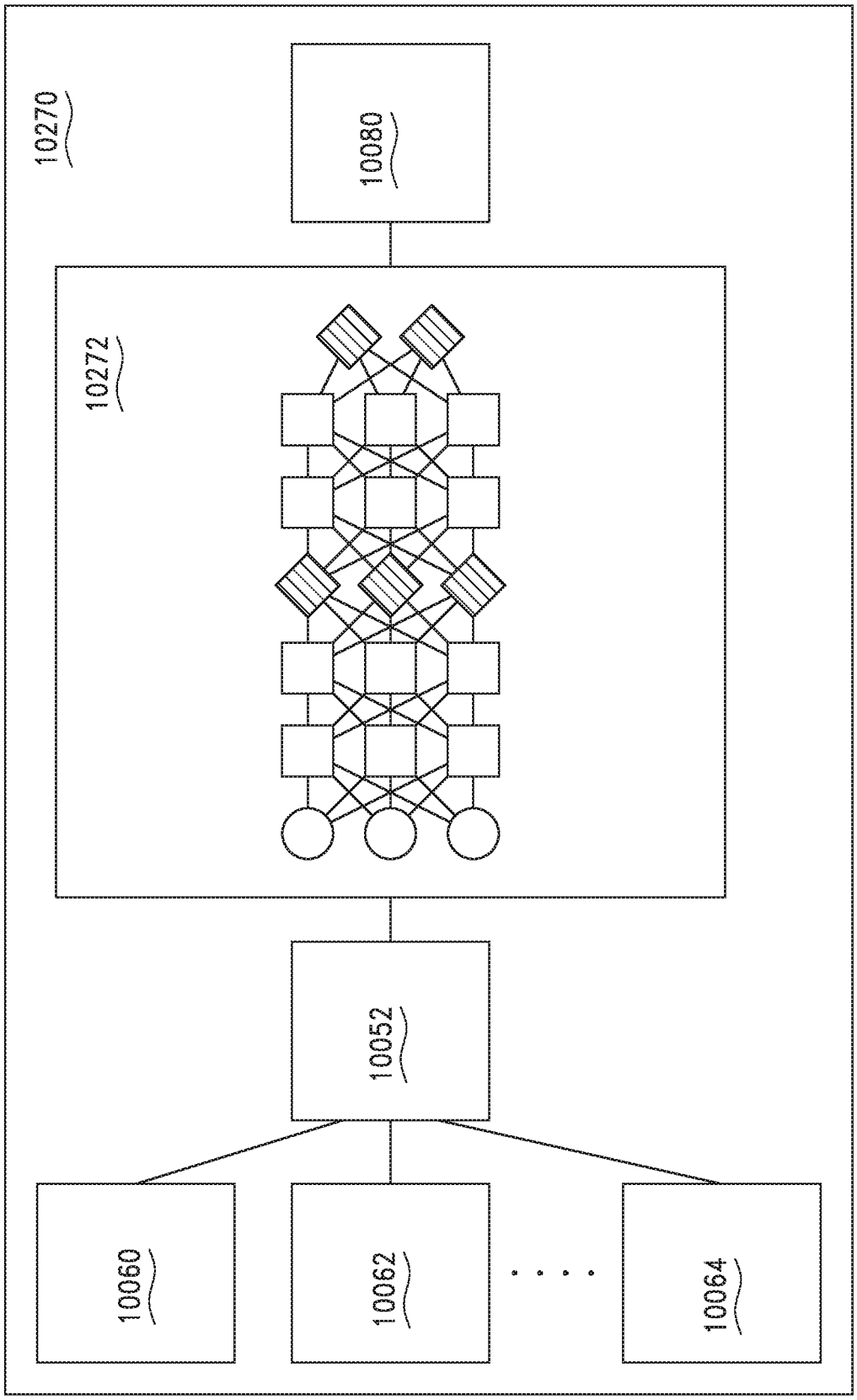

FIG. 129

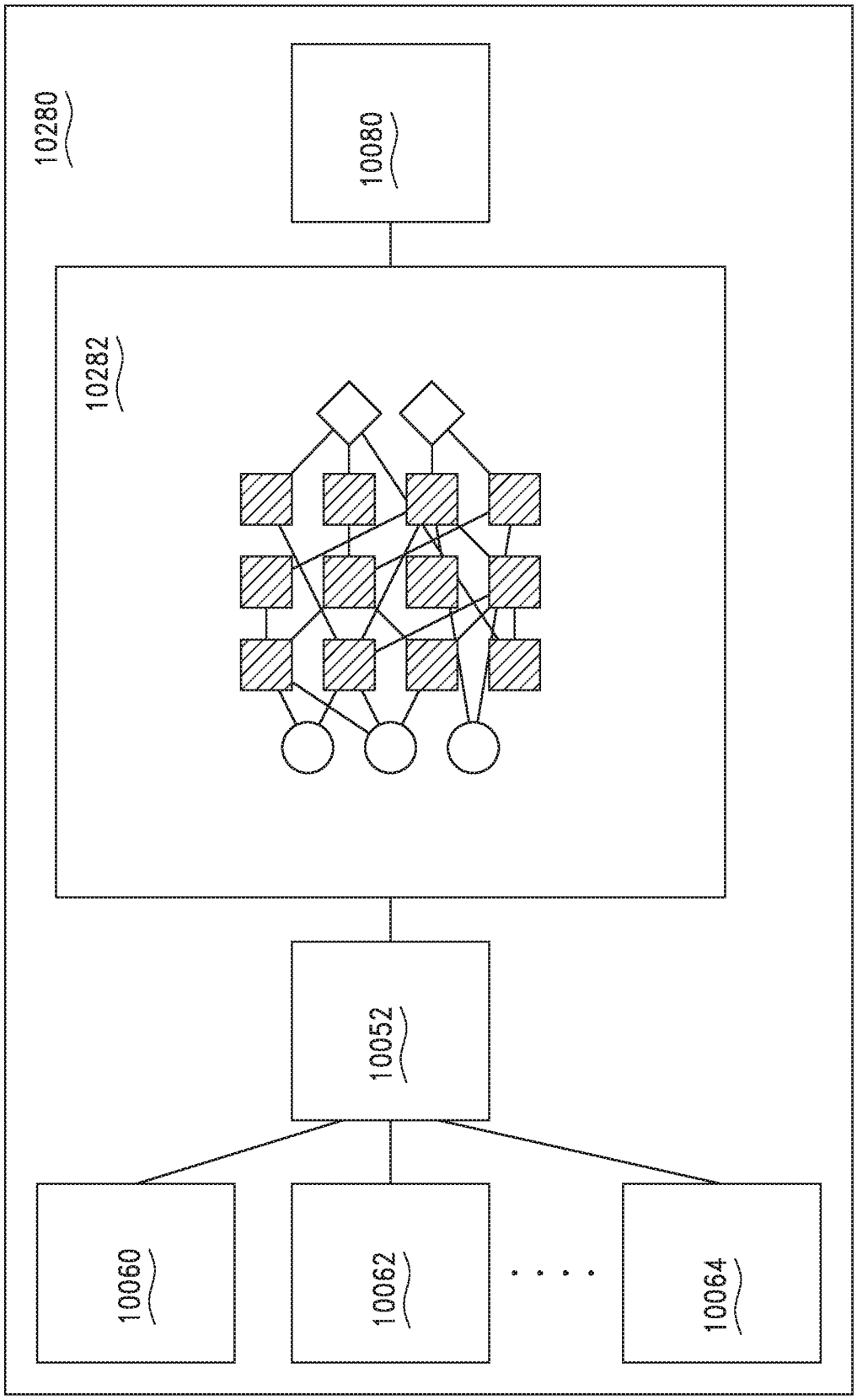

FIG. 130

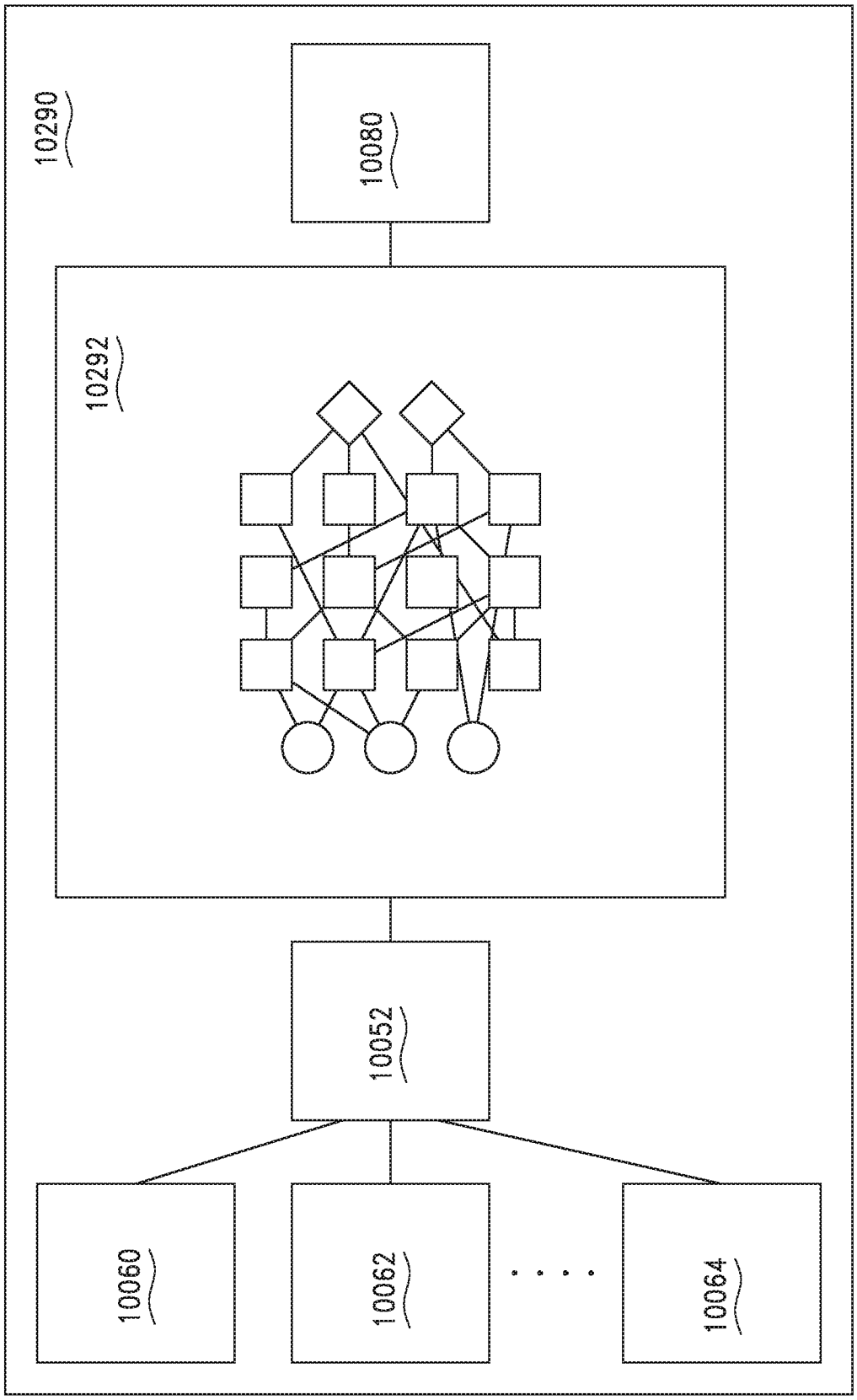

FIG. 131

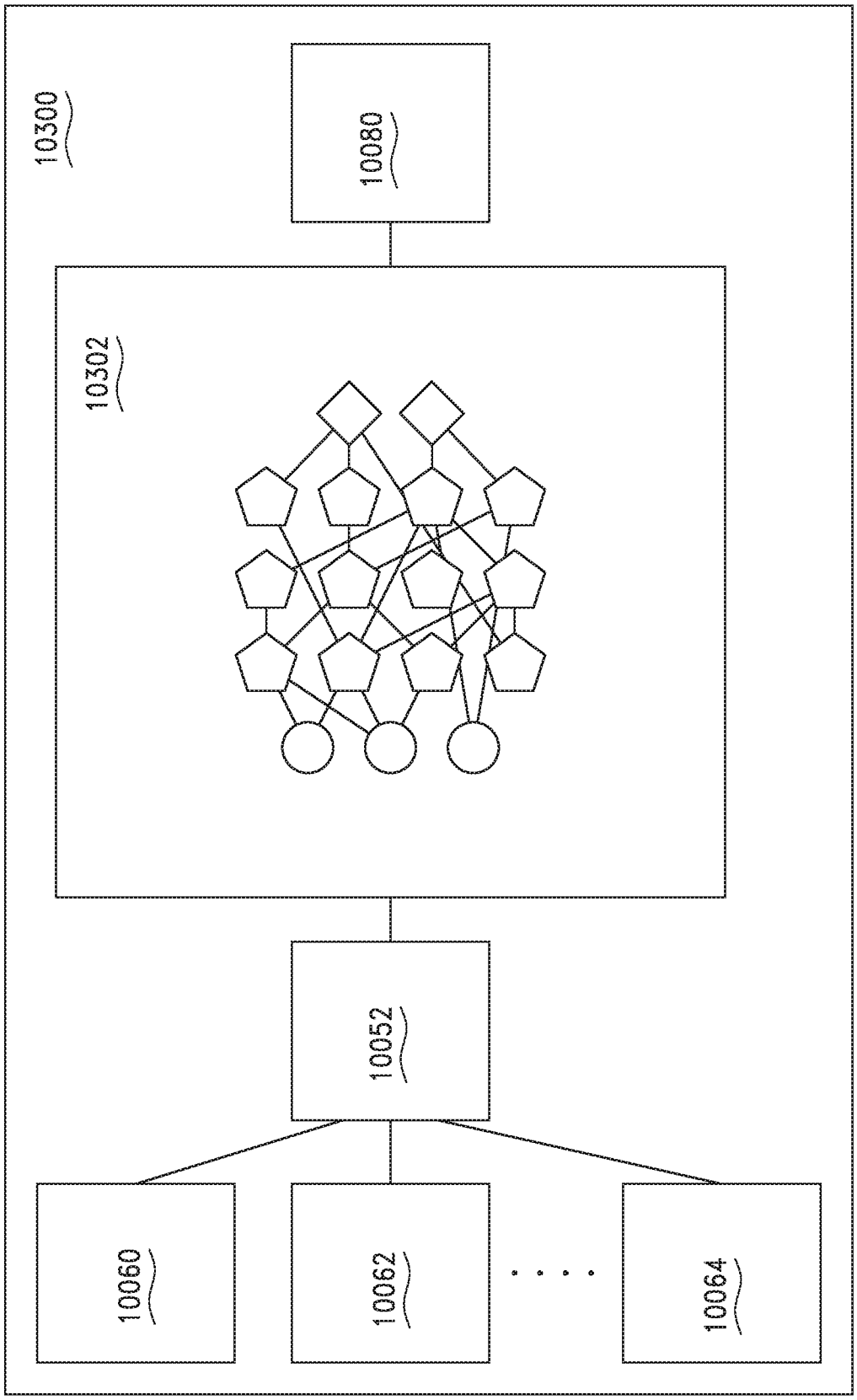

FIG. 132

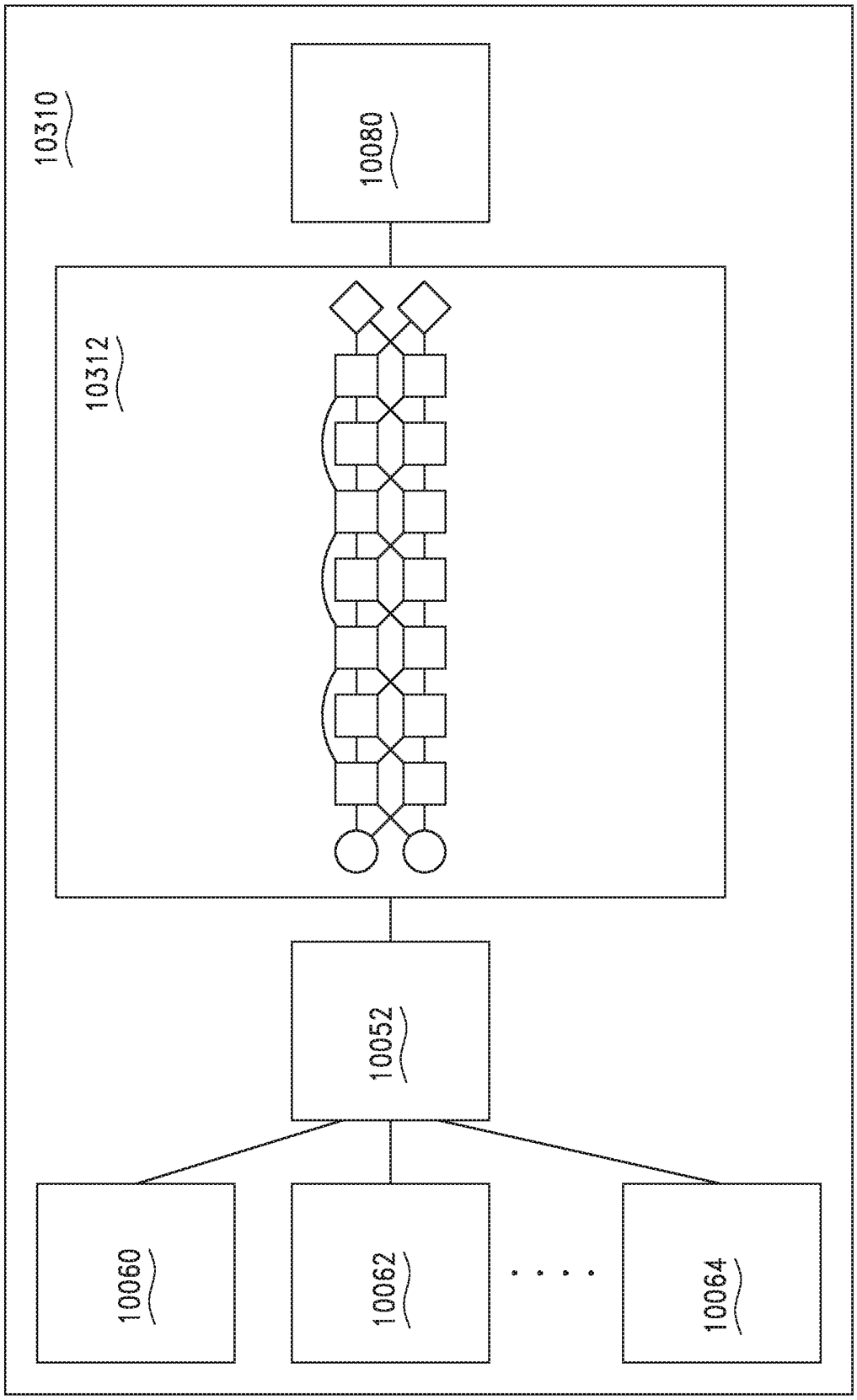

FIG. 133

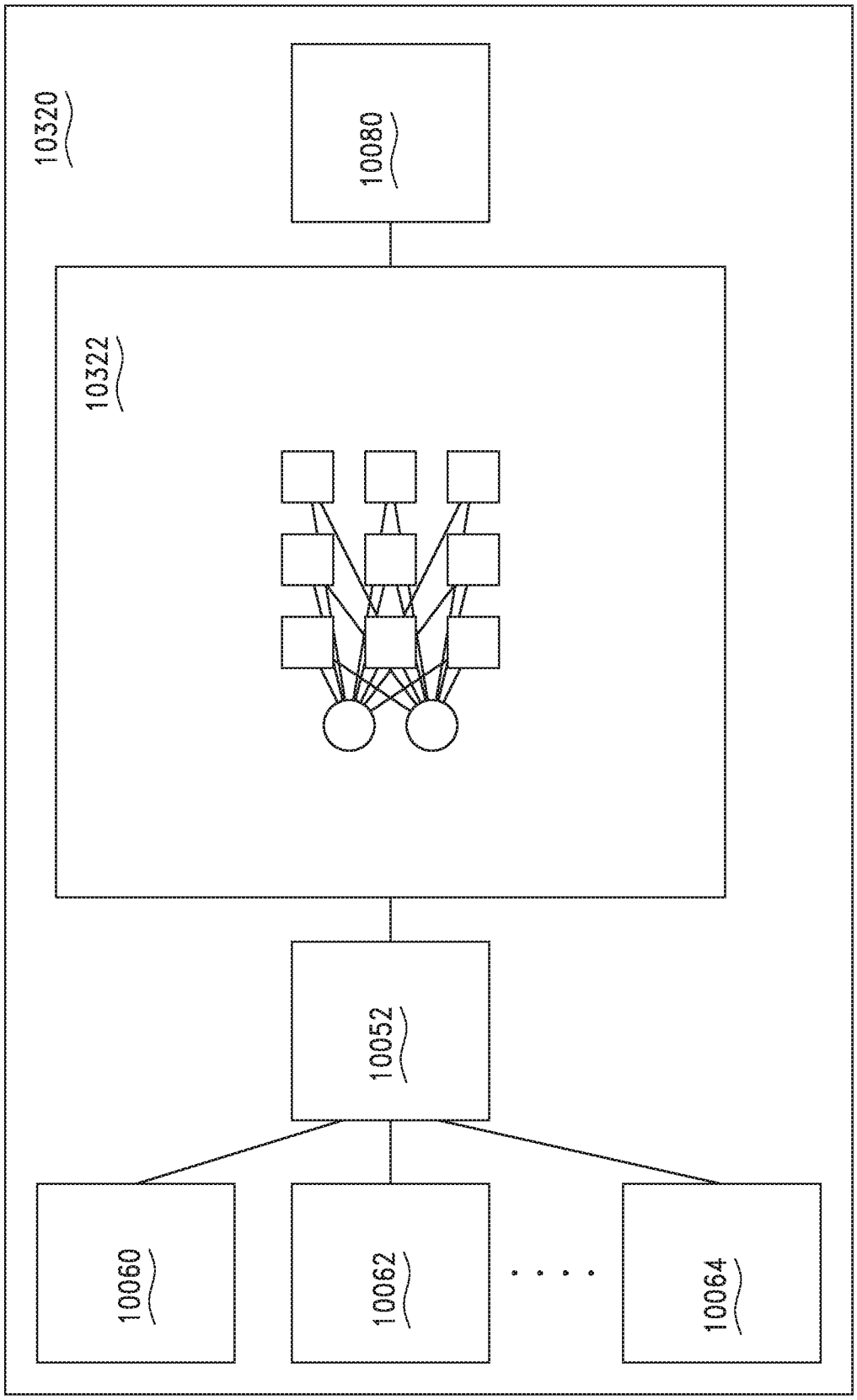

FIG. 134

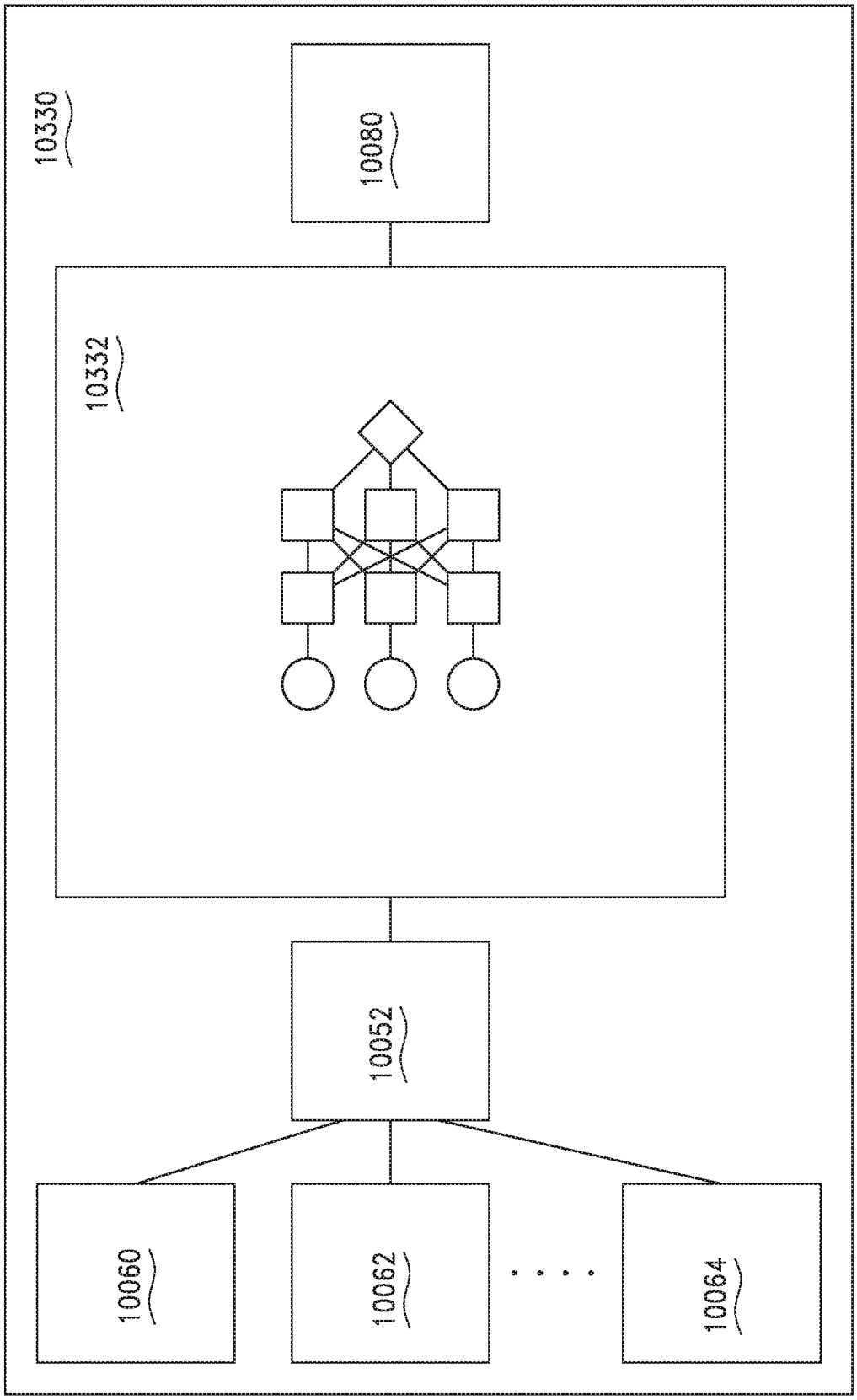

FIG. 135

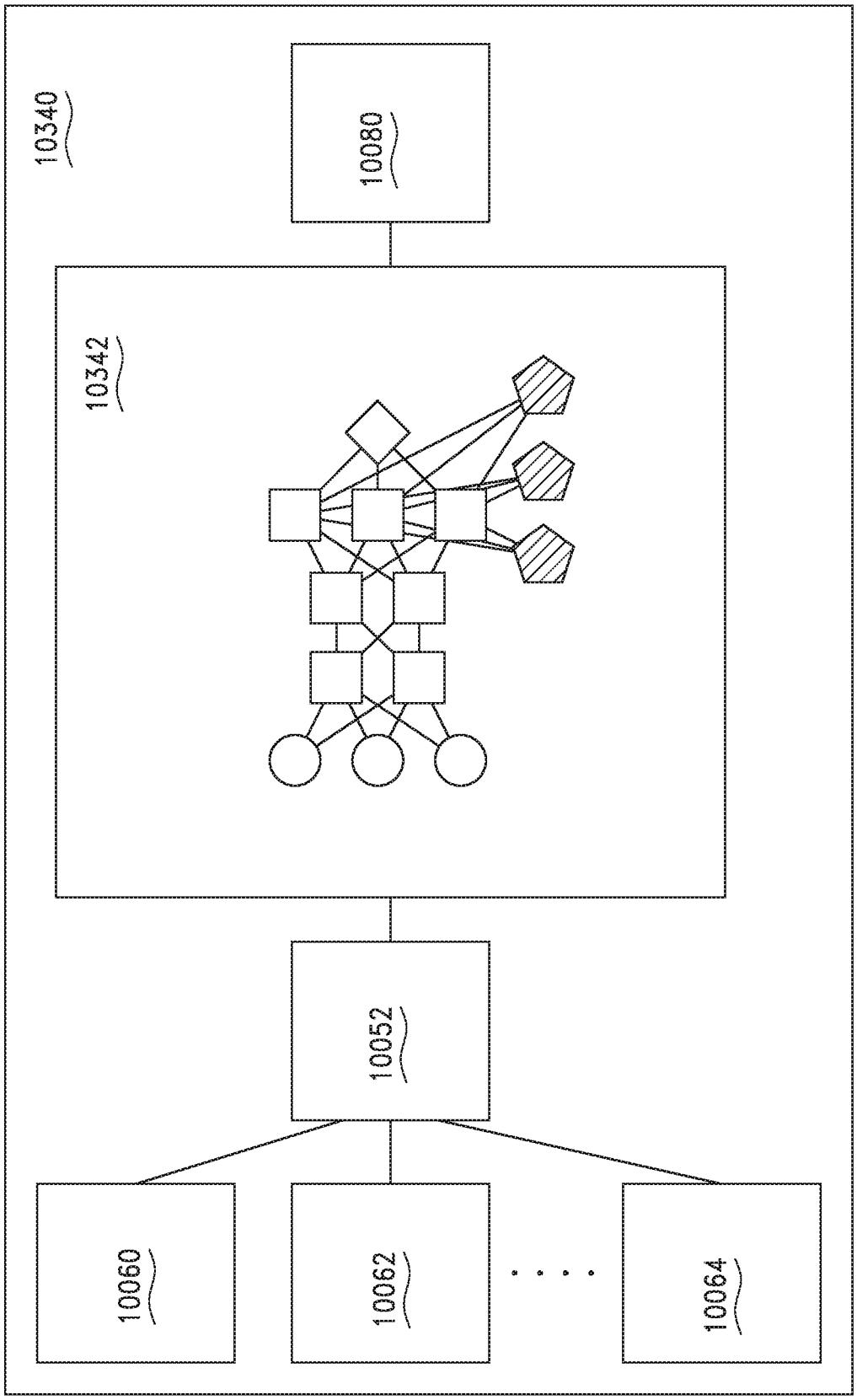

FIG. 136

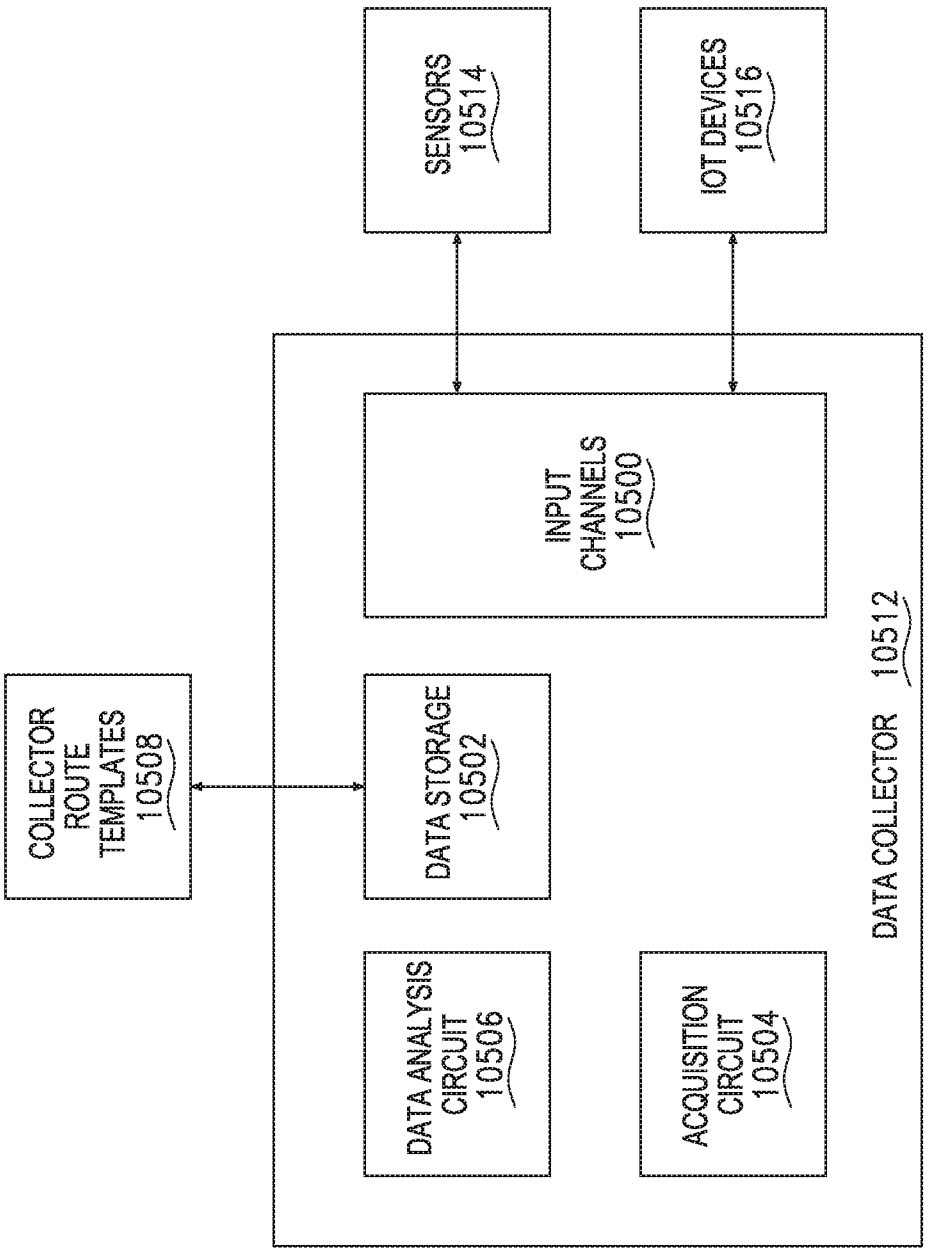
SENSORS
10514
IOT DEVICES
10516
INPUT
CHANNELS
10500
COLLECTOR
ROUTE
TEMPLATES
10508
DATA STORAGE
10502
DATA COLLECTOR 10512
DATA ANALYSIS
CIRCUIT
10506
ACQUISITION
CIRCUIT
10504

FIG. 137

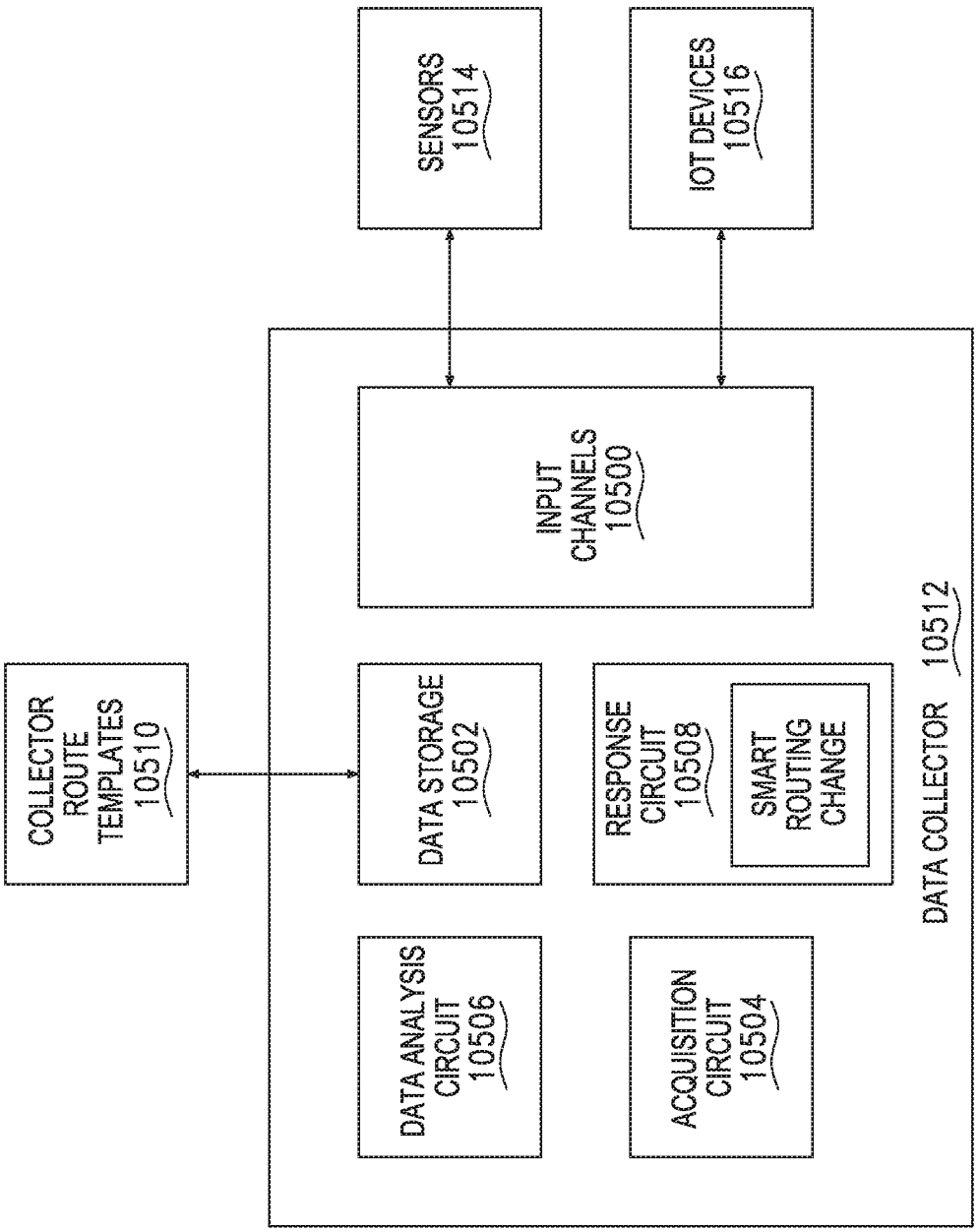
SENSORS 10514
IOT DEVICES 10516
INPUT CHANNELS 10500
COLLECTOR ROUTE TEMPLATES 10510
DATA STORAGE 10502
RESPONSE CIRCUIT 10508
SMART ROUTING CHANGE
DATA COLLECTOR 10512
DATA ANALYSIS CIRCUIT 10506
ACQUISITION CIRCUIT 10504

FIG. 138

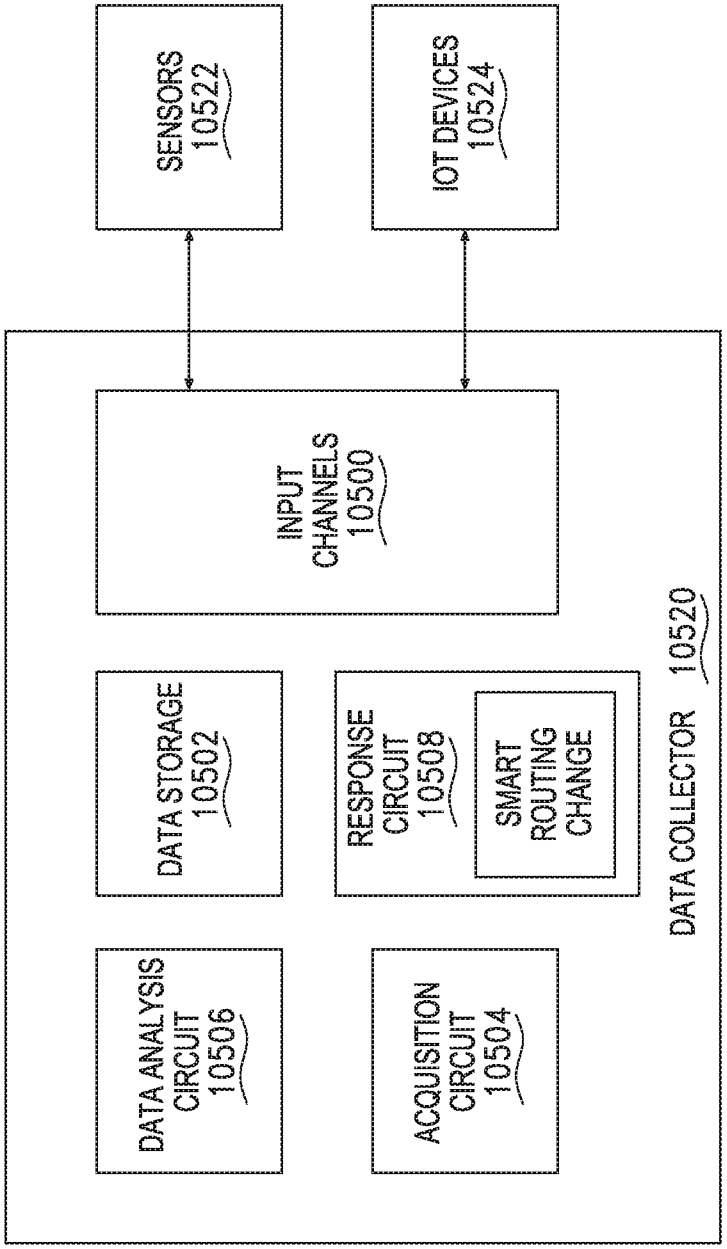
SENSORS
10522
IOT DEVICES
10524
INPUT
CHANNELS
10500
DATA STORAGE
10502
RESPONSE
CIRCUIT
10508
SMART
ROUTING
CHANGE
DATA ANALYSIS
CIRCUIT
10506
ACQUISITION
CIRCUIT
10504
DATA COLLECTOR 10520

FIG. 139

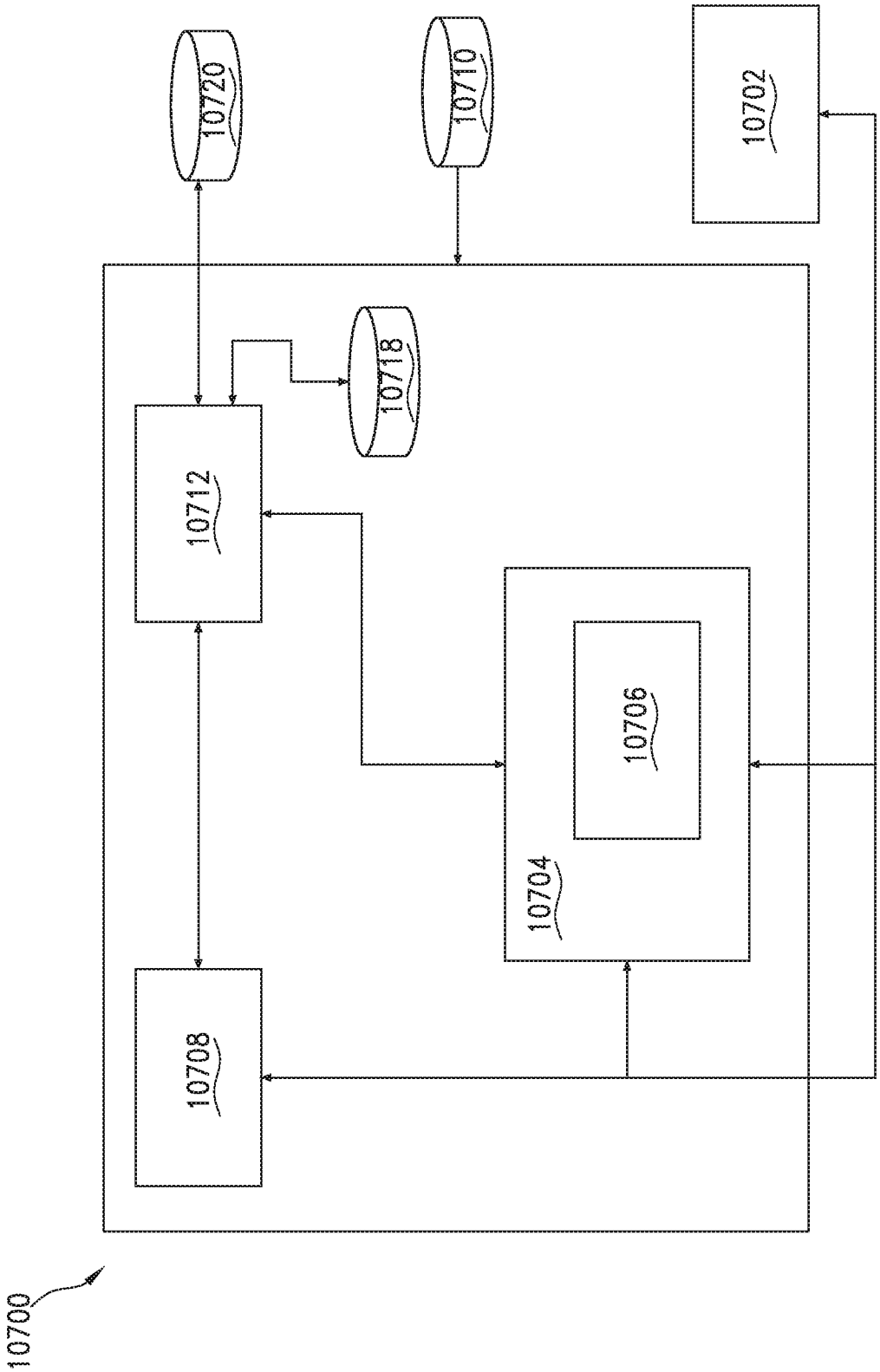

FIG. 140

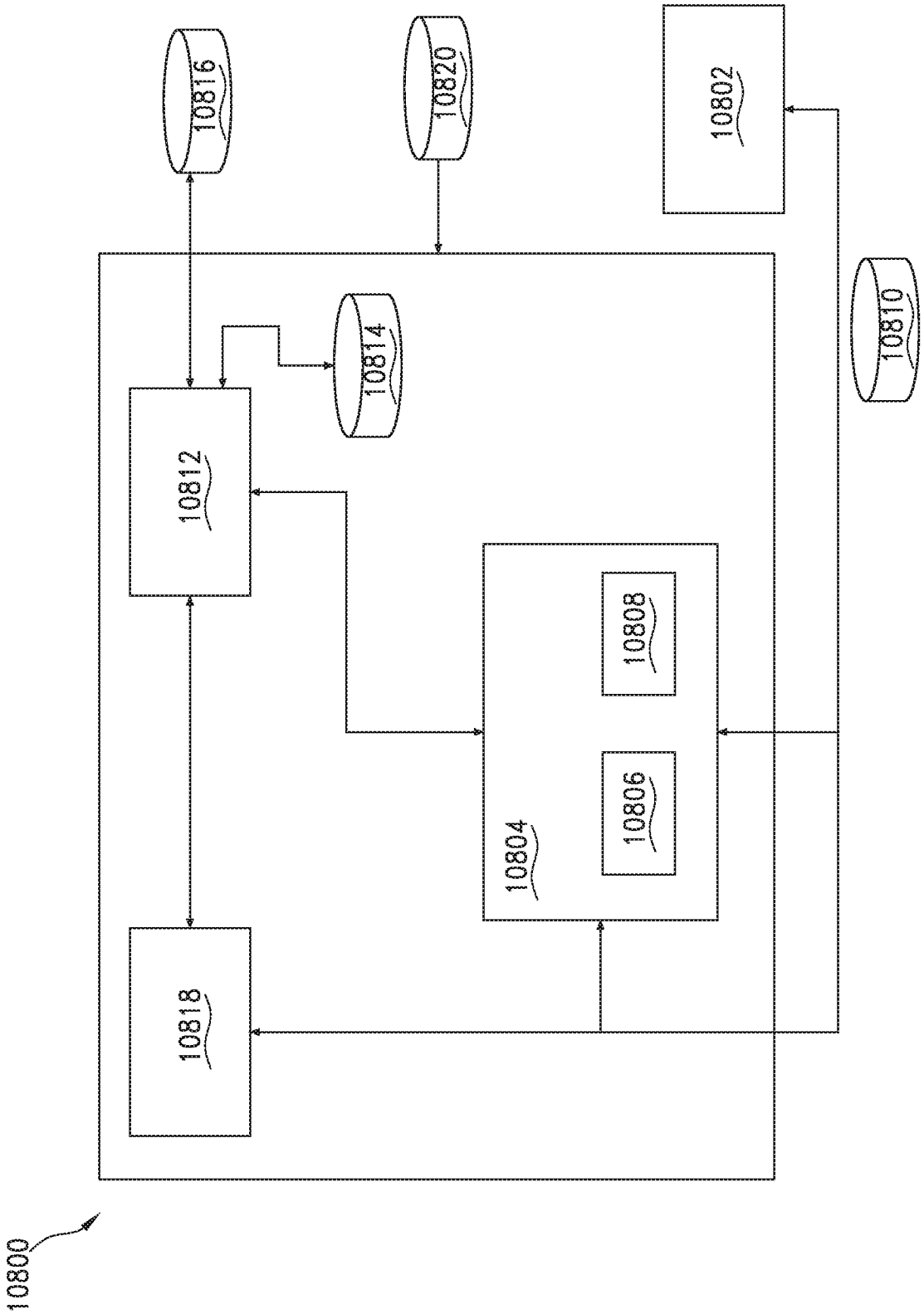
10816
10820
10802
10810
10814
10812
10808
10806
10804
10818
10800

FIG. 141

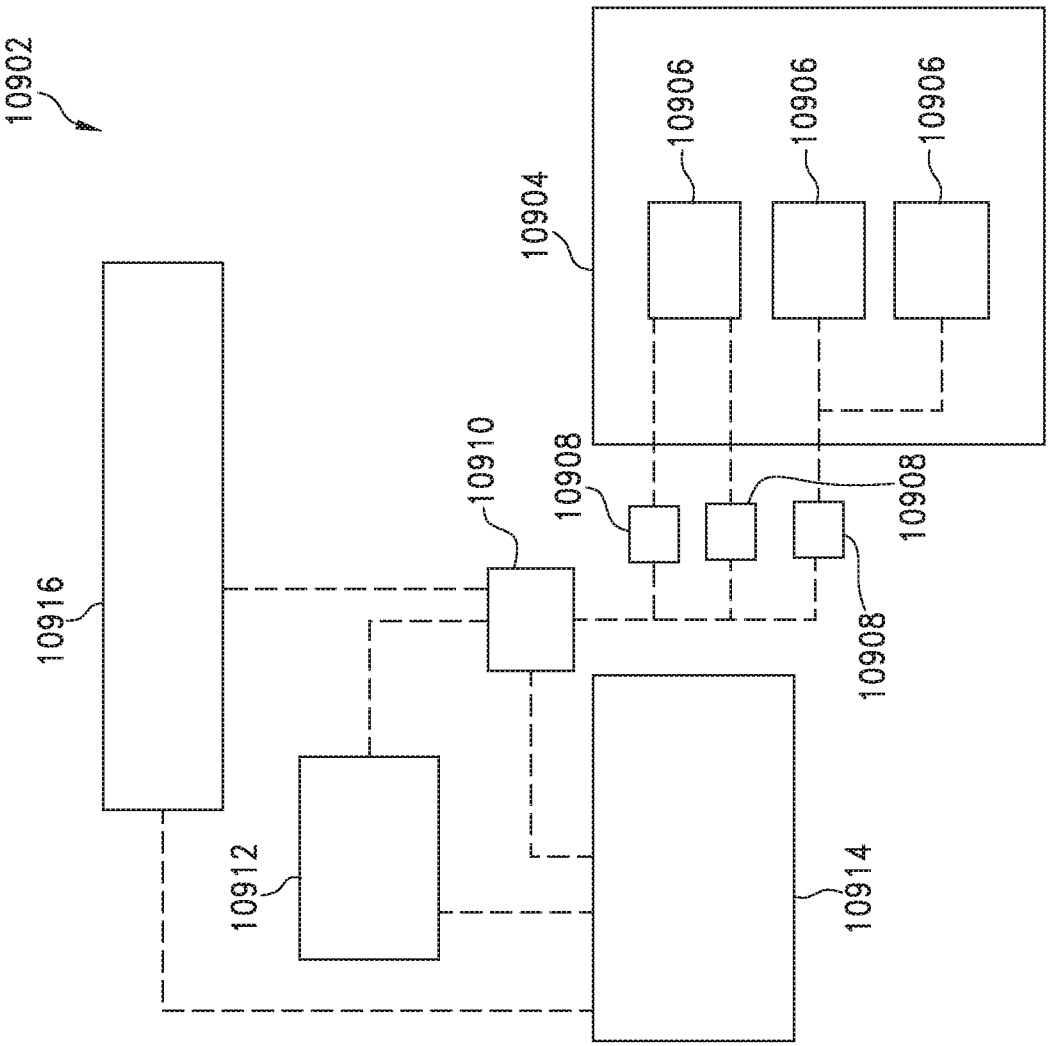
10902
10904
10906
10906
10906
10908
10908
10908
10910
10912
10914
10916

FIG. 142

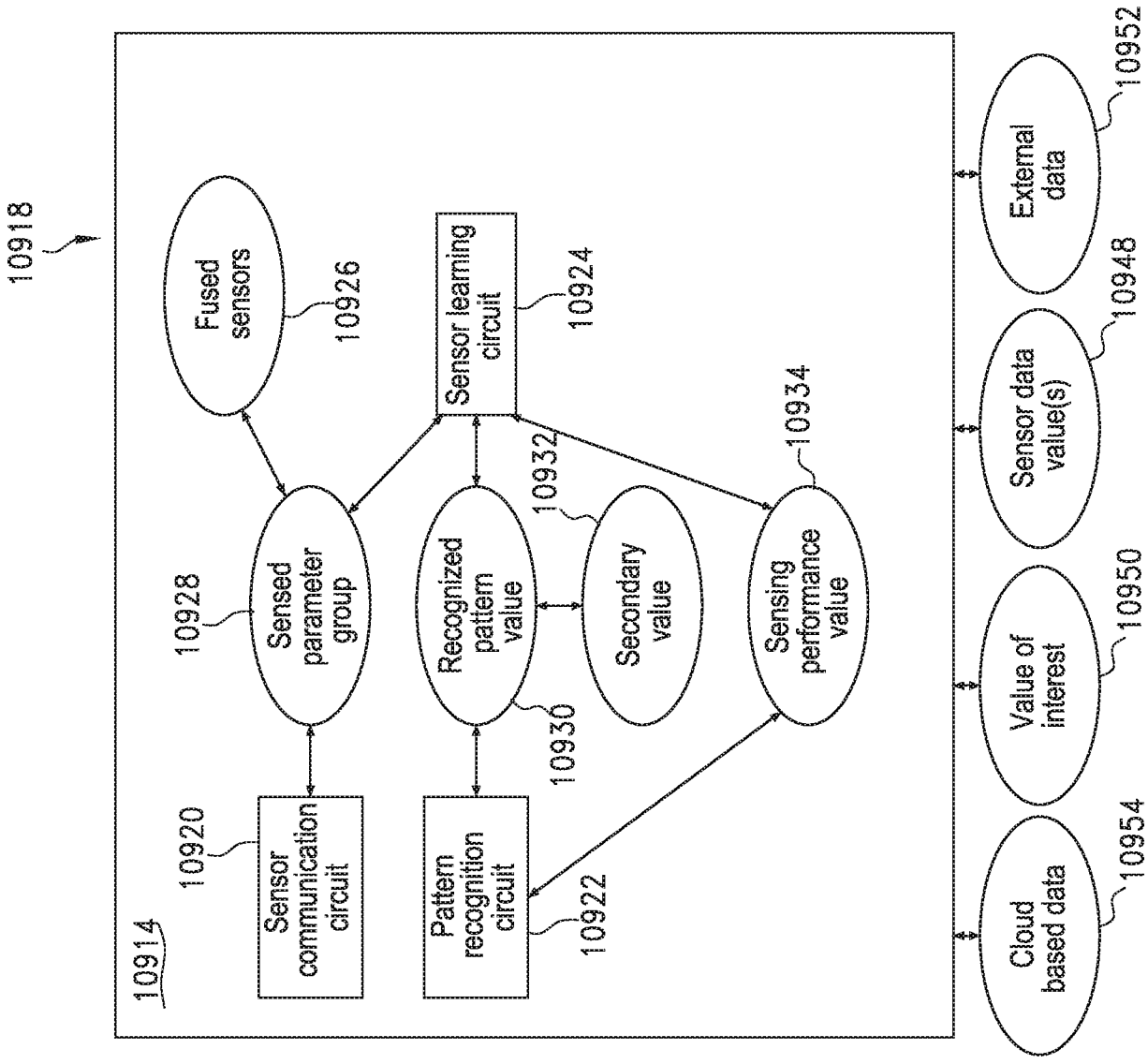
10918
10914
Sensor communication circuit
10920
Pattern recognition circuit
10922
Sensed parameter group
10928
Recognized pattern value
10930
Secondary value
10932
Sensing performance value
10934
Fused sensors
10926
Sensor learning circuit
10924
Cloud based data
10954
Value of interest
10950
Sensor data value(s)
10948
External data
10952

FIG. 143

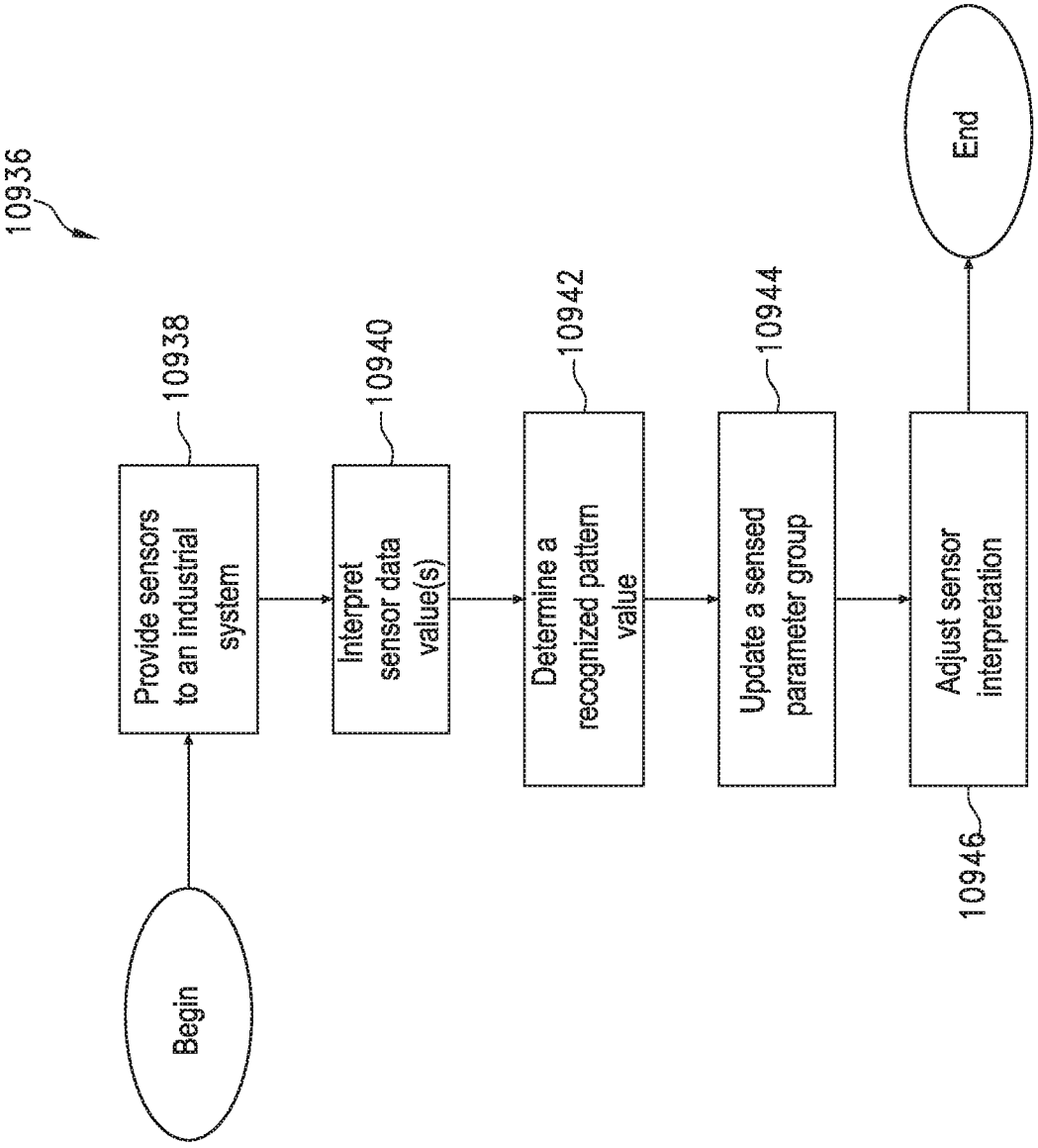
10936
Begin
Provide sensors to an industrial system
10938
Interpret sensor data value(s)
10940
Determine a recognized pattern value
10942
Update a sensed parameter group
10944
Adjust sensor interpretation
10946
End

FIG. 144

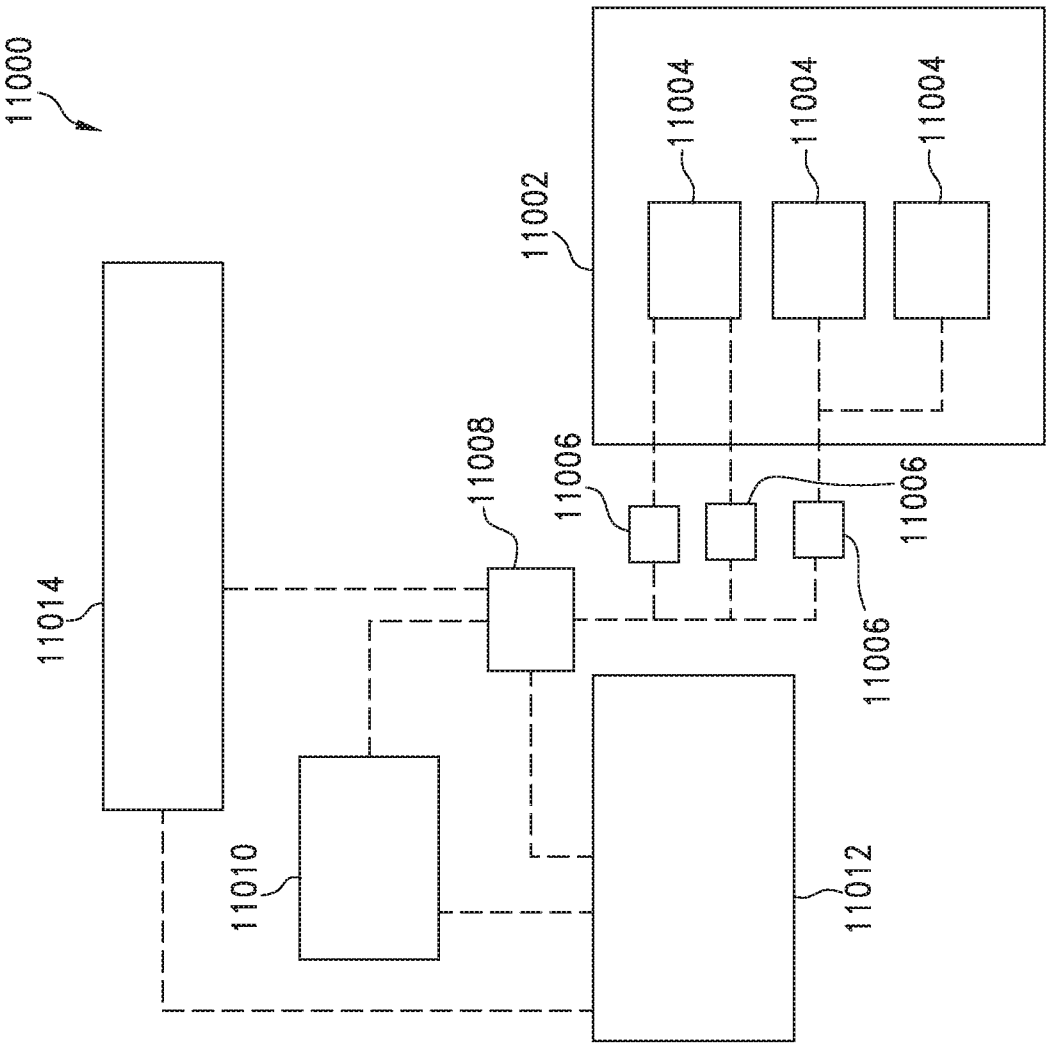
11000
11002
11004
11004
11004
11006
11006
11006
11008
11010
11012
11014

FIG. 145

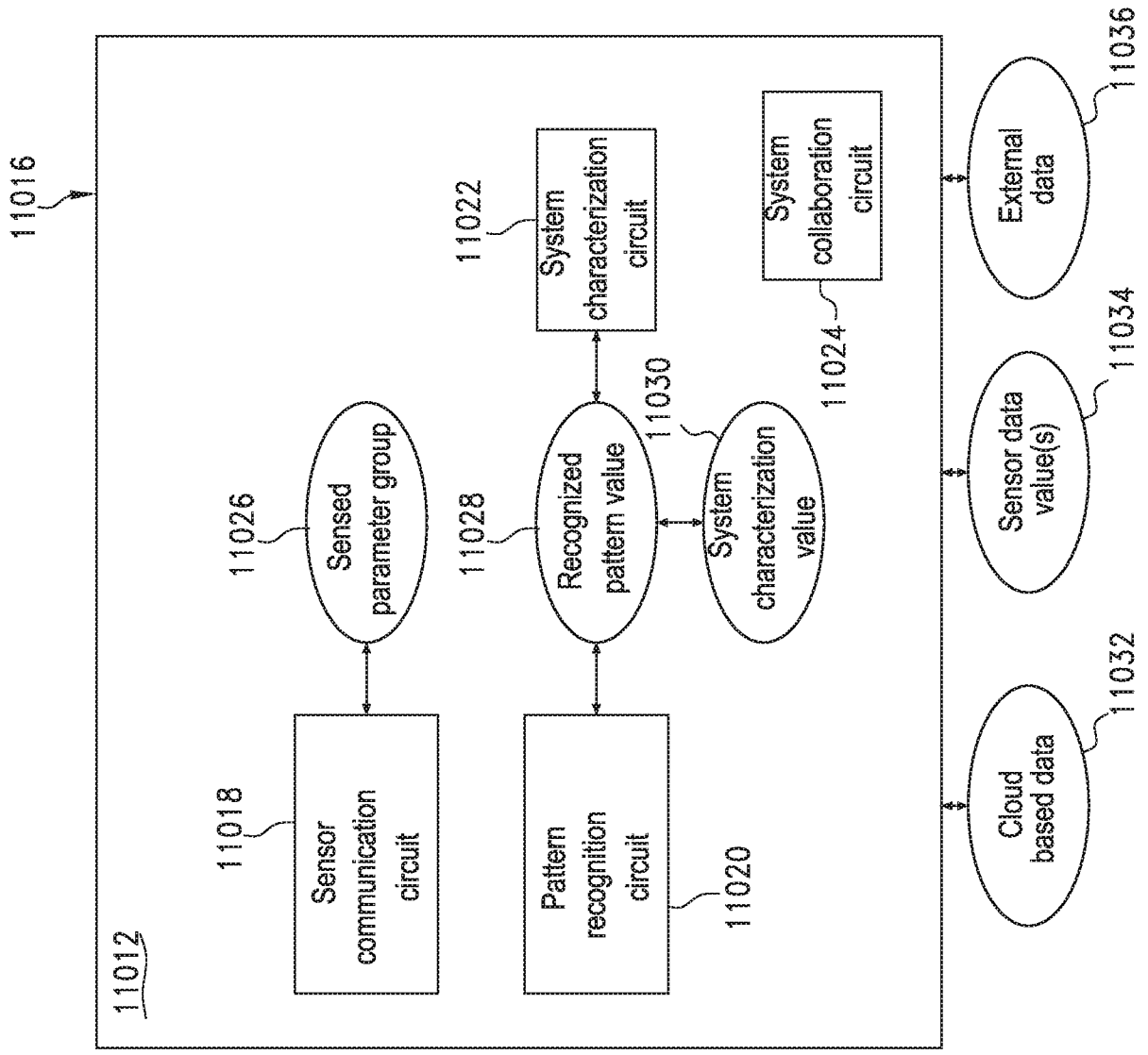
11016
11012
11018
Sensor communication circuit
11026
Sensed parameter group
11020
Pattern recognition circuit
11028
Recognized pattern value
11030
System characterization value
11022
System characterization circuit
11024
System collaboration circuit
11032
Cloud based data
11034
Sensor data value(s)
11036
External data

FIG. 146

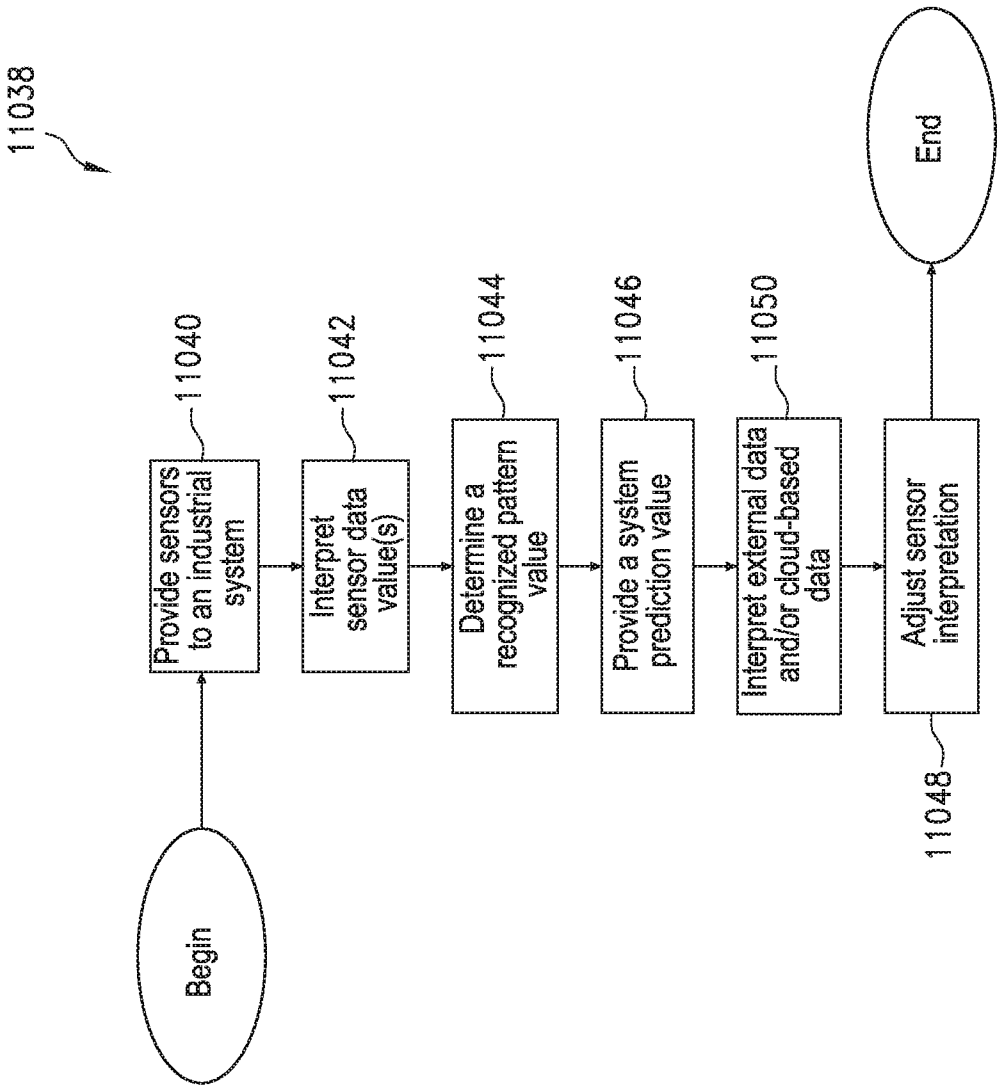
11038
Begin
Provide sensors to an industrial system
11040
Interpret sensor data value(s)
11042
Determine a recognized pattern value
11044
Provide a system prediction value
11046
Interpret external data and/or cloud-based data
11050
Adjust sensor interpretation
11048
End

FIG. 147

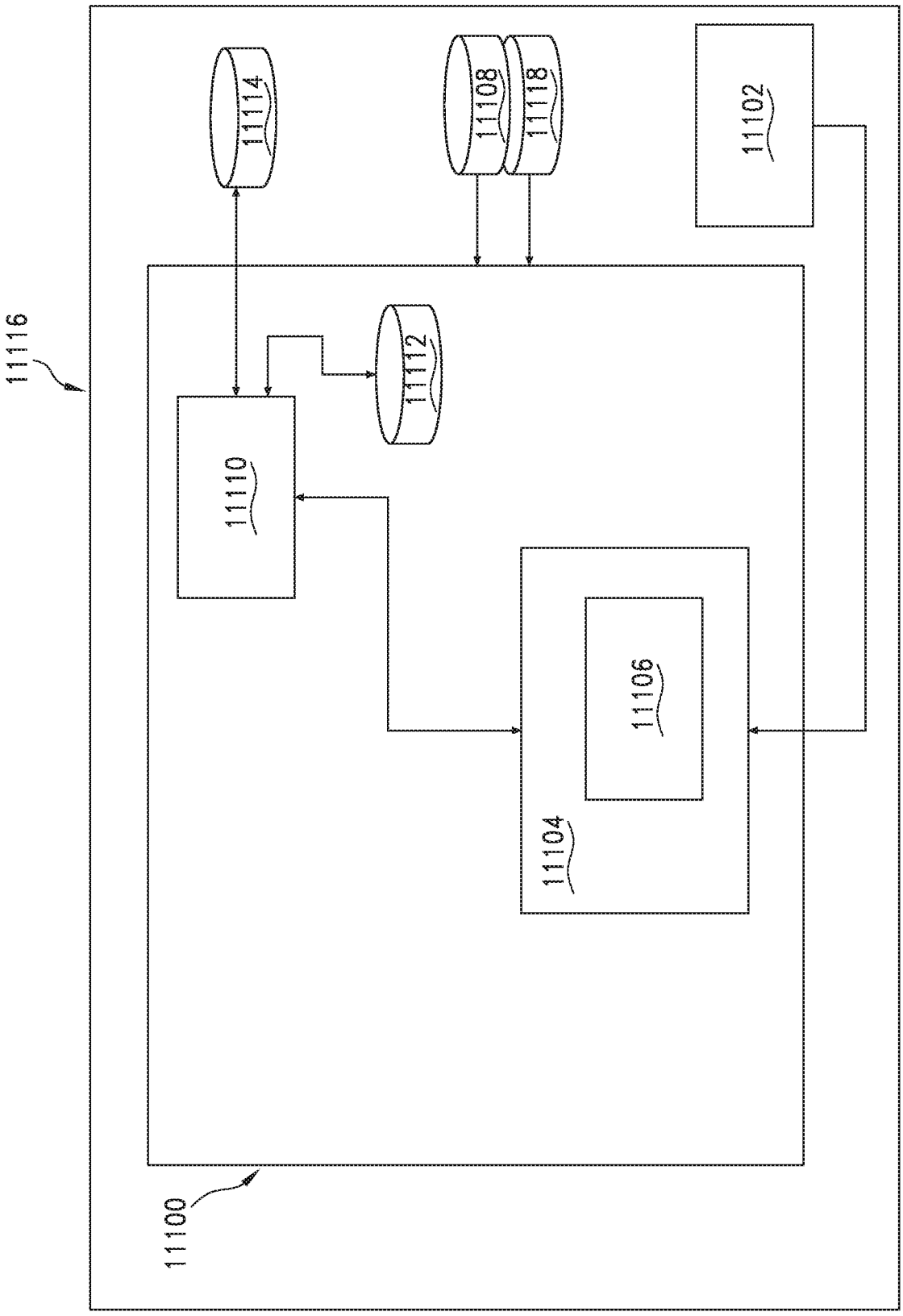
11116
11114
11108
11118
11102
11112
11110
11106
11104
11100

FIG. 148

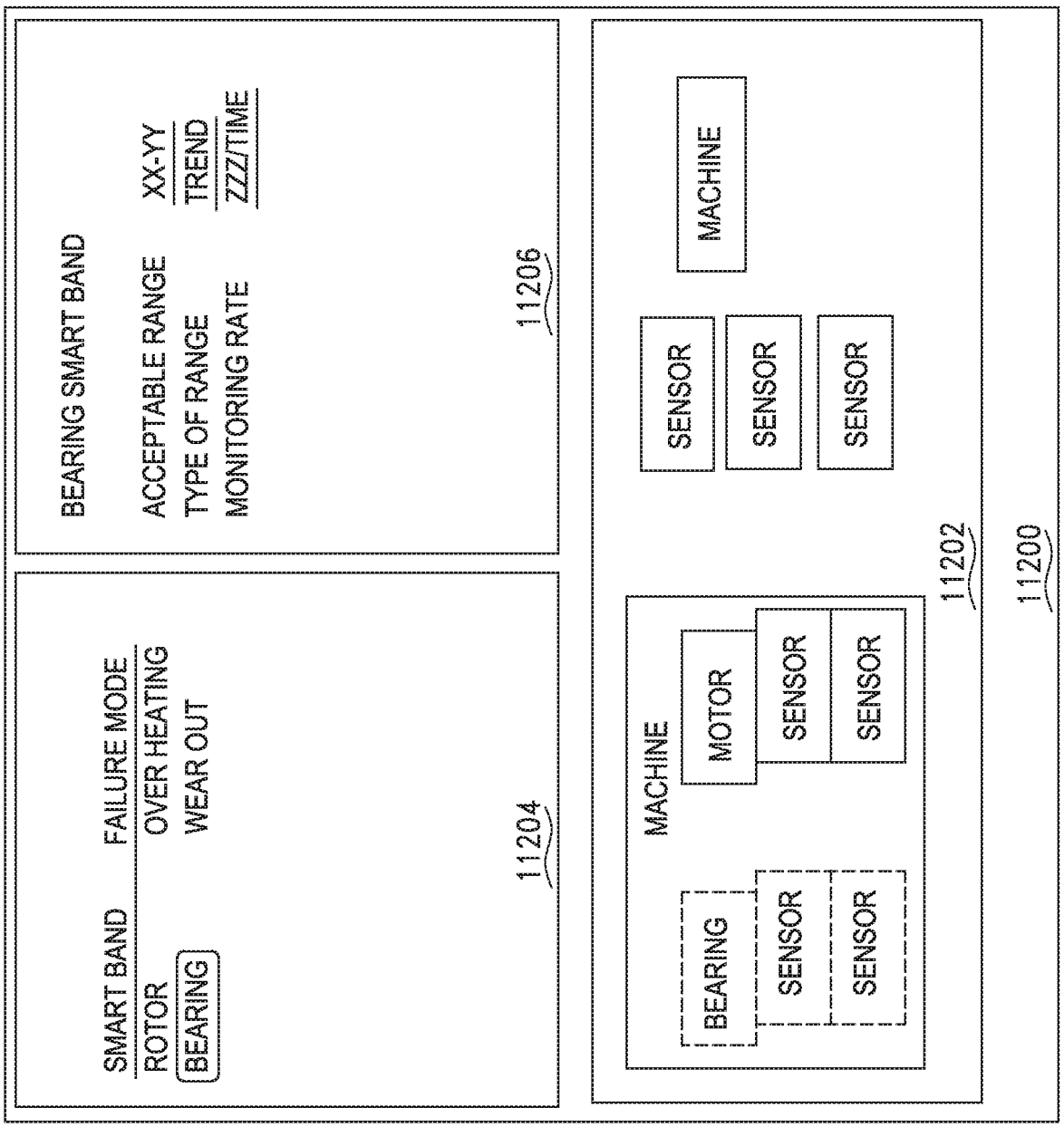
BEARING SMART BAND
ACCEPTABLE RANGE XX-YY
TYPE OF RANGE TREND
MONITORING RATE ZZZ/TIME
11206
SMART BAND FAILURE MODE
ROTOR OVER HEATING
BEARING WEAR OUT
11204
MACHINE
SENSOR
SENSOR
SENSOR
MACHINE
BEARING
MOTOR
SENSOR
SENSOR
SENSOR
SENSOR
11202
11200

FIG. 149

150/280

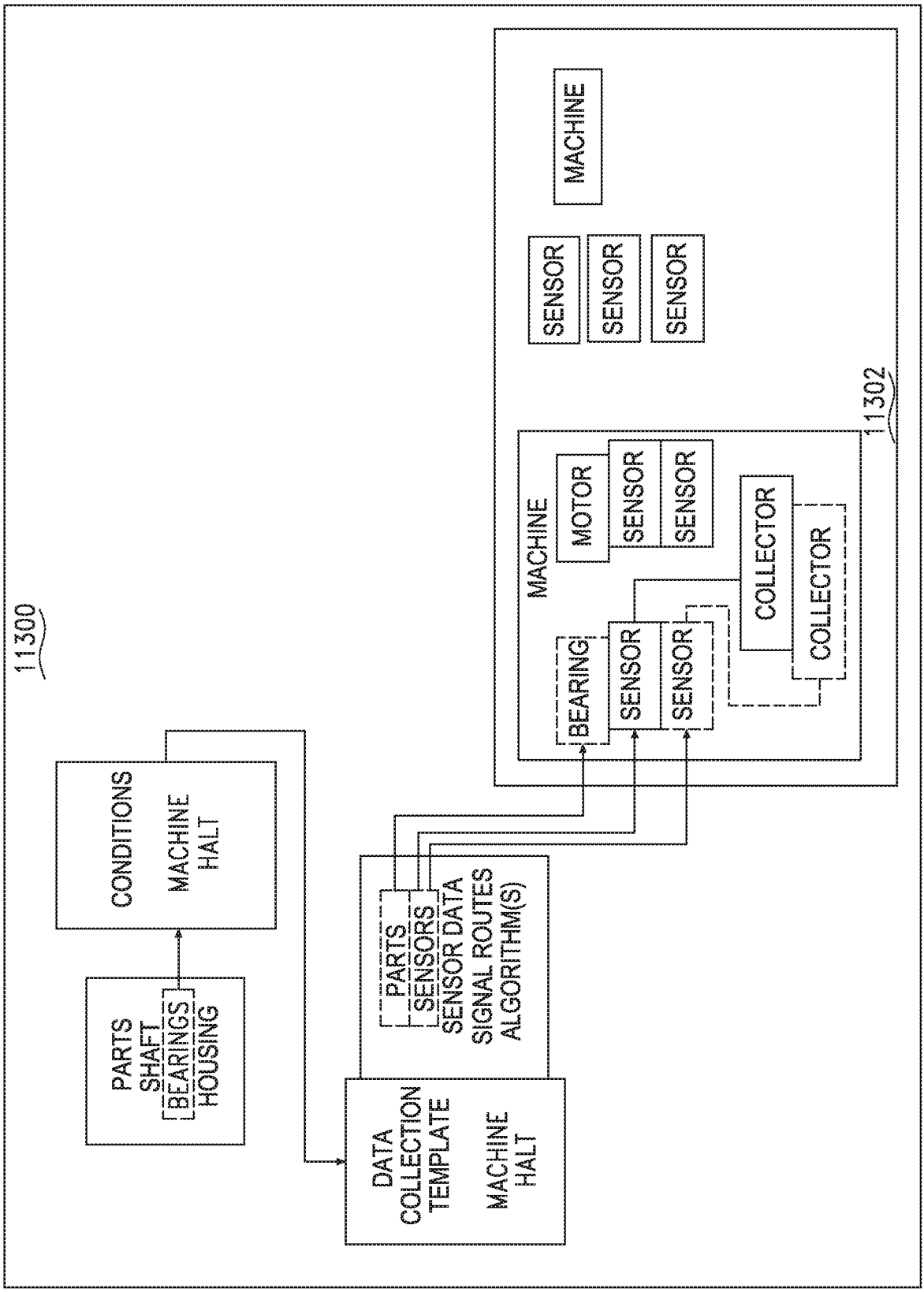

FIG. 150

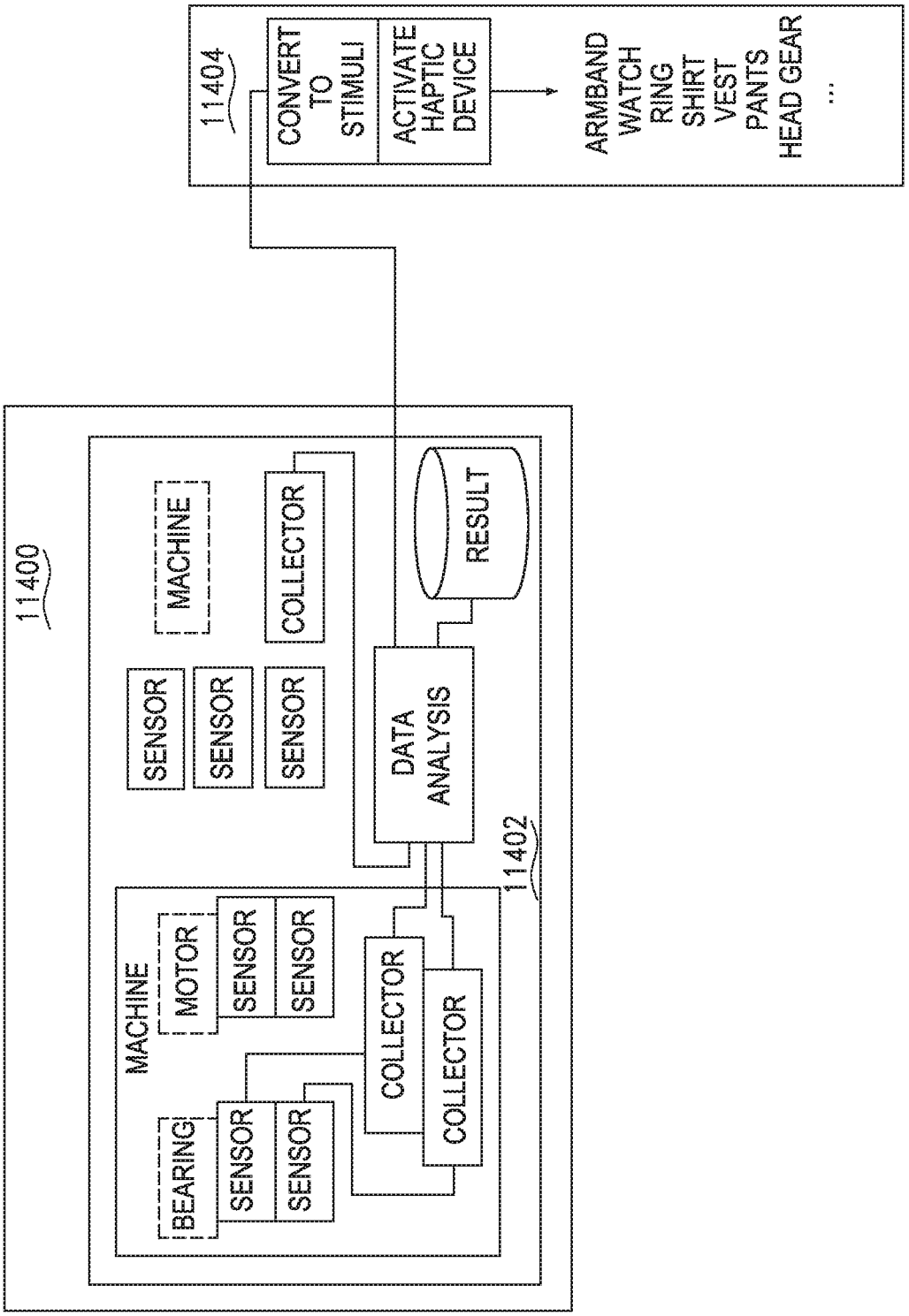
11400
11404
CONVERT TO STIMULI
ACTIVATE HAPTIC DEVICE
ARMBAND
WATCH
RING
SHIRT
VEST
PANTS
HEAD GEAR
...
MACHINE
SENSOR
SENSOR
SENSOR
COLLECTOR
RESULT
DATA ANALYSIS
11402
MACHINE
MOTOR
SENSOR
SENSOR
BEARING
SENSOR
SENSOR
COLLECTOR
COLLECTOR

FIG. 151

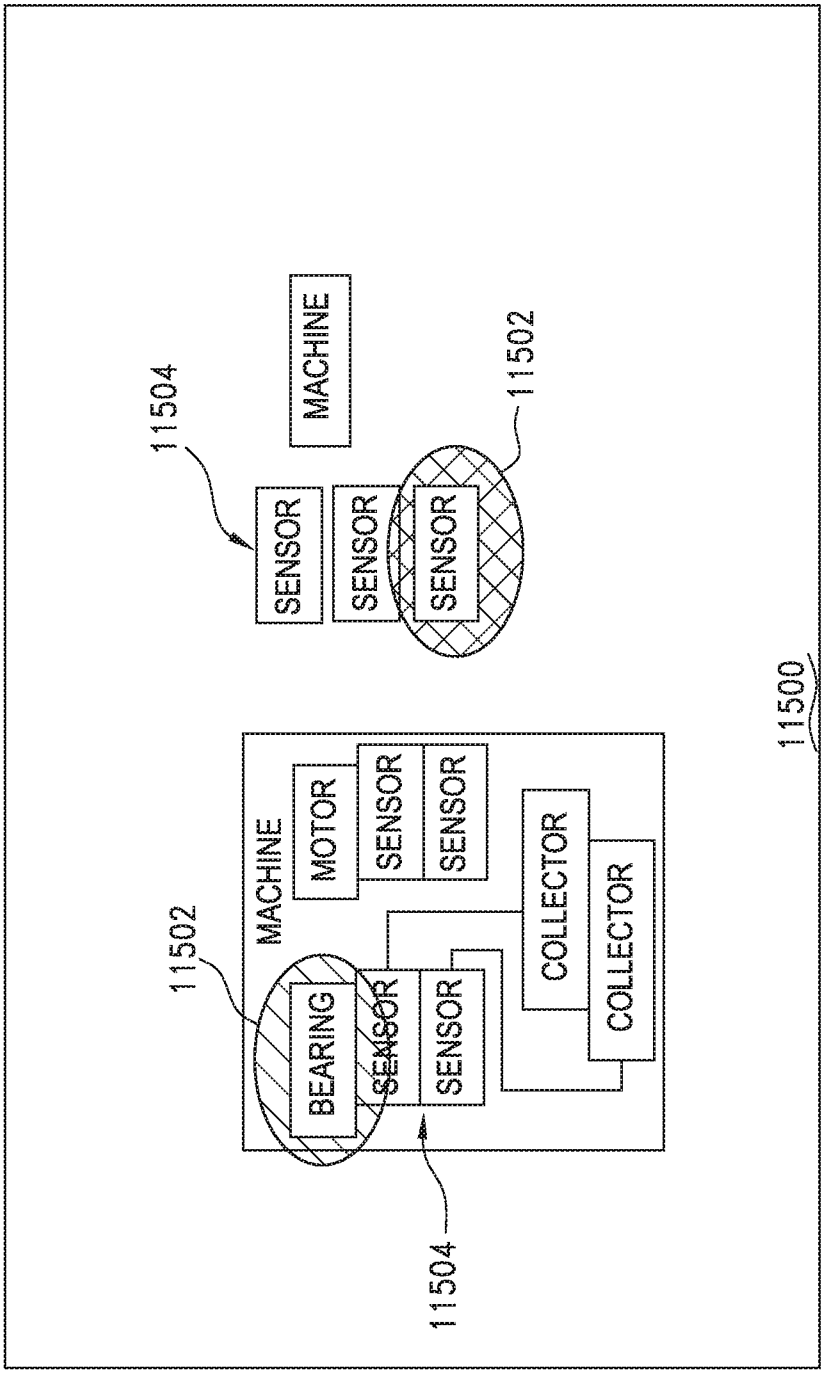
11500
MACHINE
11504
SENSOR
SENSOR
SENSOR
11502
MACHINE
MOTOR
SENSOR
SENSOR
11502
BEARING
SENSOR
SENSOR
COLLECTOR
COLLECTOR
11504

FIG. 152

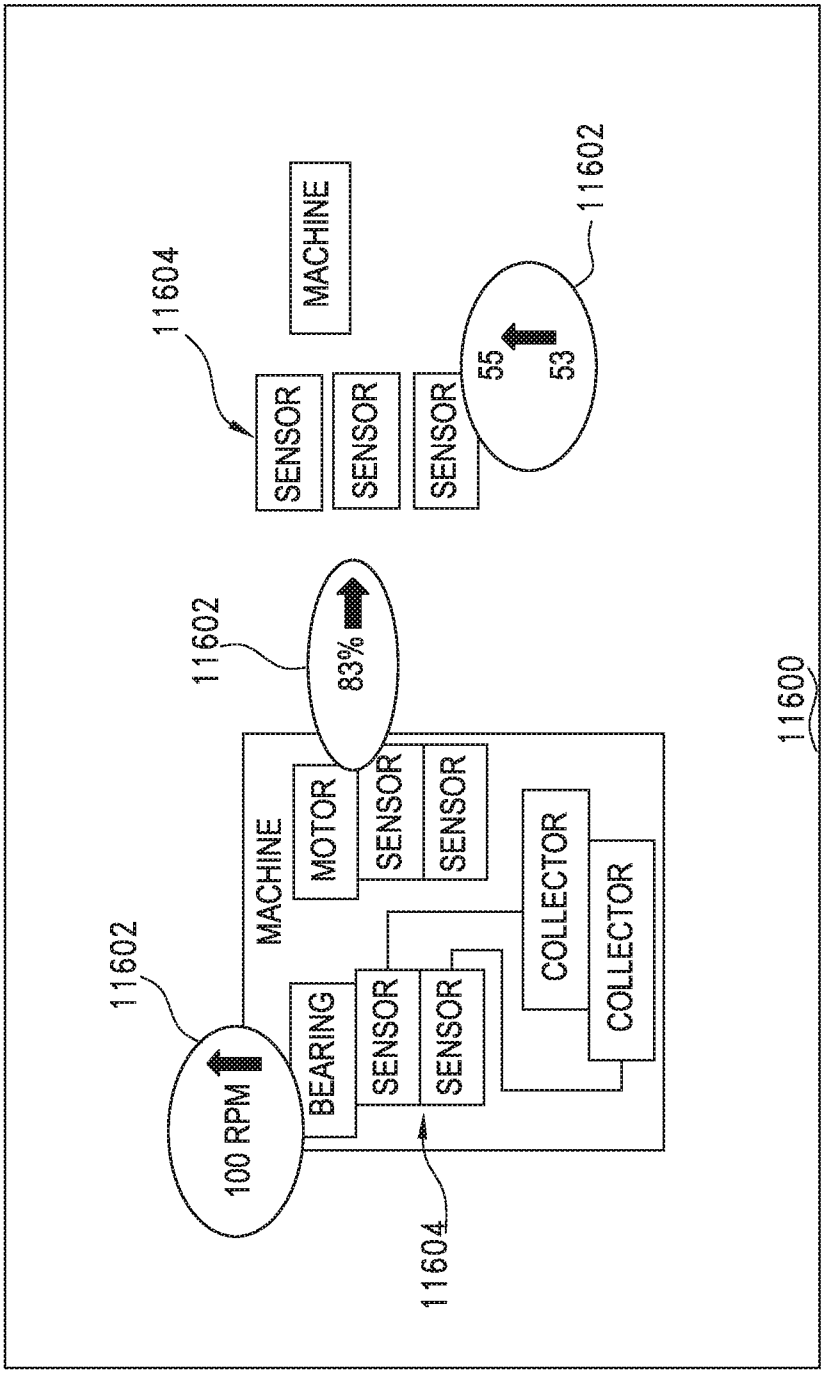
11600
11602
100 RPM
BEARING
SENSOR
SENSOR
11604
MACHINE
MOTOR
SENSOR
SENSOR
11602
83%
COLLECTOR
COLLECTOR
11604
SENSOR
SENSOR
SENSOR
MACHINE
11602
55
53

FIG. 153

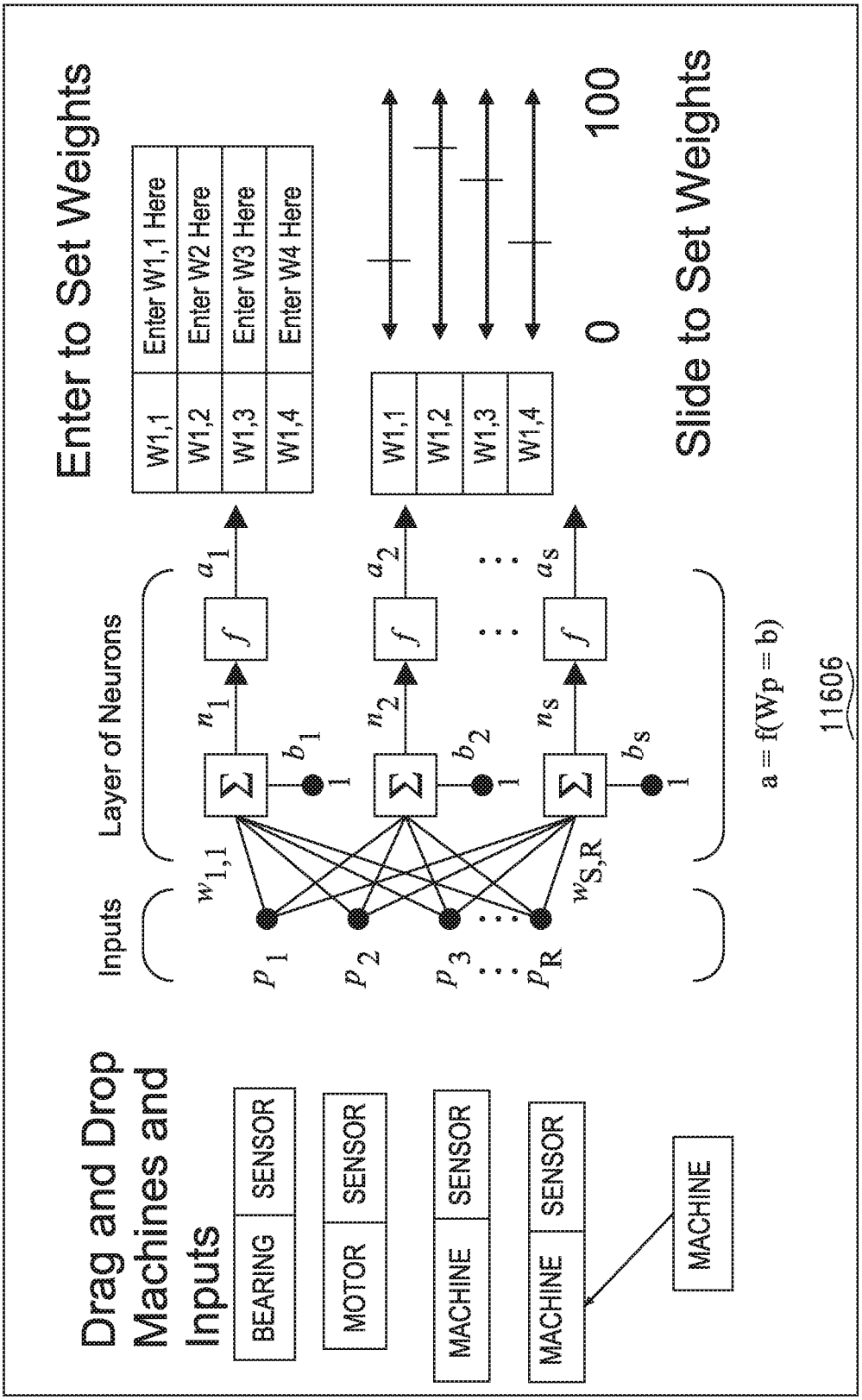
Drag and Drop Machines and Inputs
BEARING
SENSOR
MOTOR
SENSOR
MACHINE
SENSOR
MACHINE
SENSOR
MACHINE
Inputs
Layer of Neurons
Enter to Set Weights
W1,1
W1,2
W1,3
W1,4
Enter W1,1 Here
Enter W2 Here
Enter W3 Here
Enter W4 Here
Slide to Set Weights
0
100
a = f(Wp = b)
11606

FIG. 154

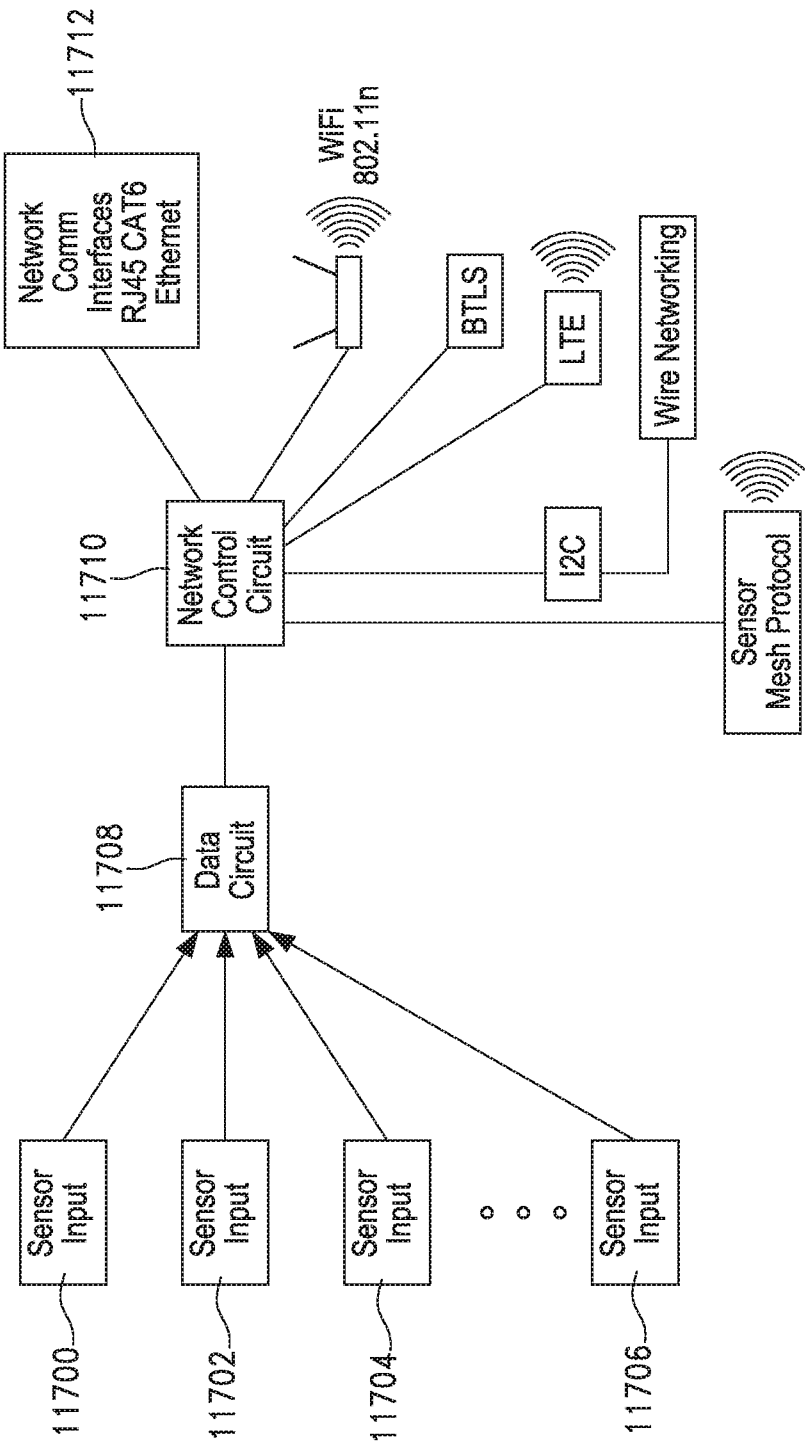
11712
Network Comm Interfaces RJ45 CAT6 Ethernet
WiFi 802.11n
BTLS
LTE
Wire Networking
11710
Network Control Circuit
I2C
Sensor Mesh Protocol
11708
Data Circuit
Sensor Input
Sensor Input
Sensor Input
Sensor Input
11700
11702
11704
11706

FIG. 155

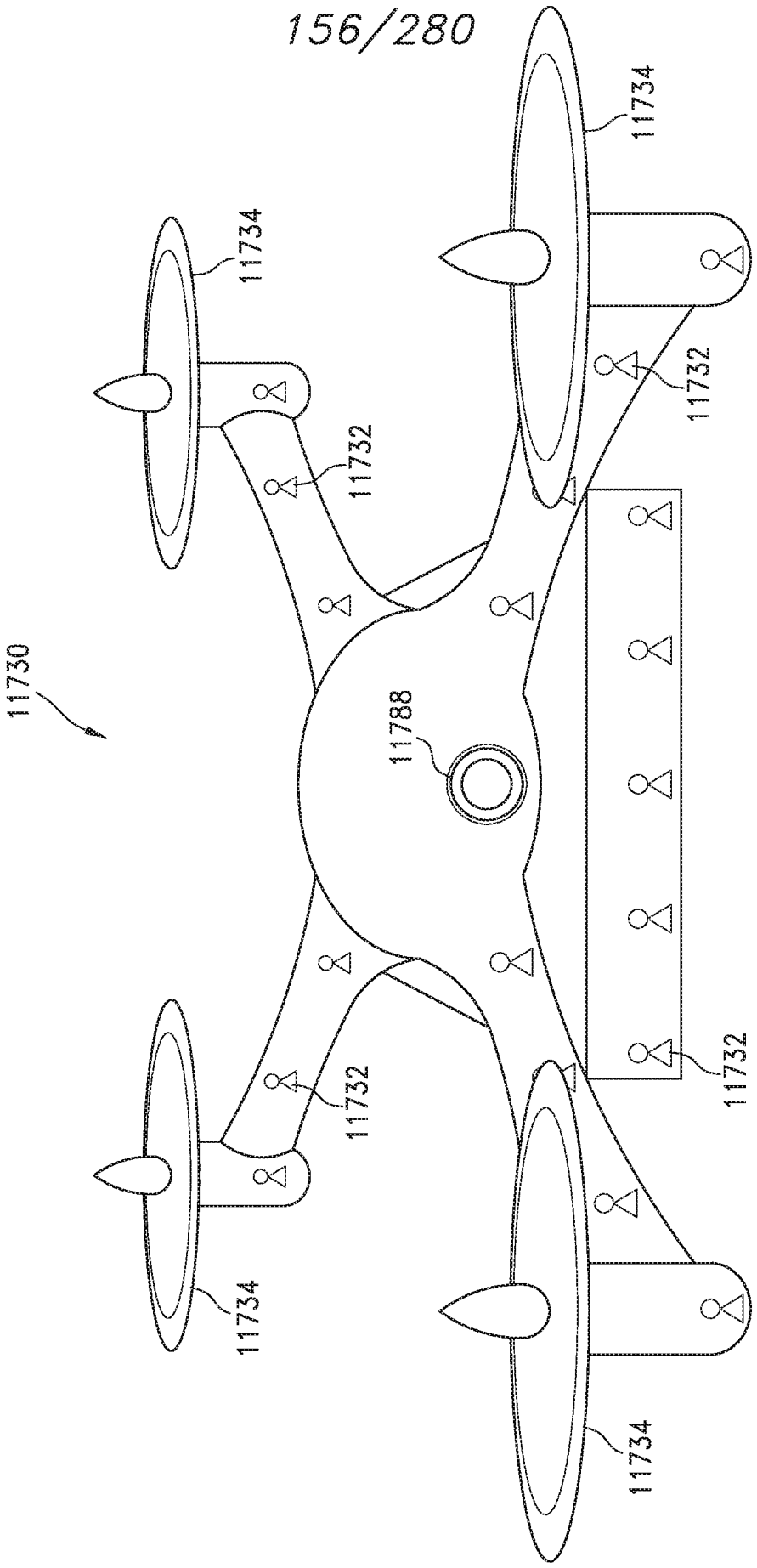
11730
11734
11734
11734
11734
11732
11732
11732
11732
11732
11788

FIG. 156

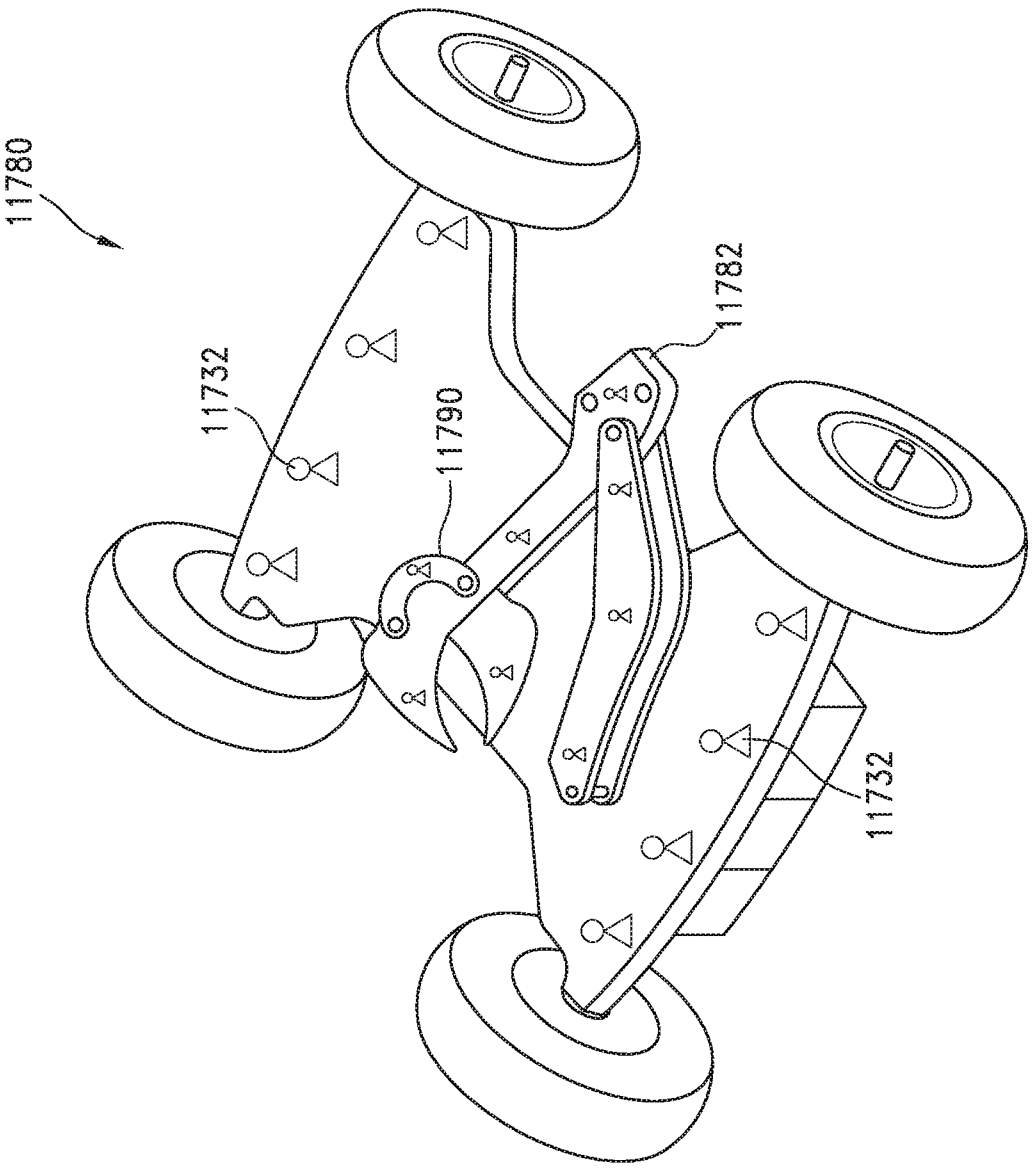

FIG. 157

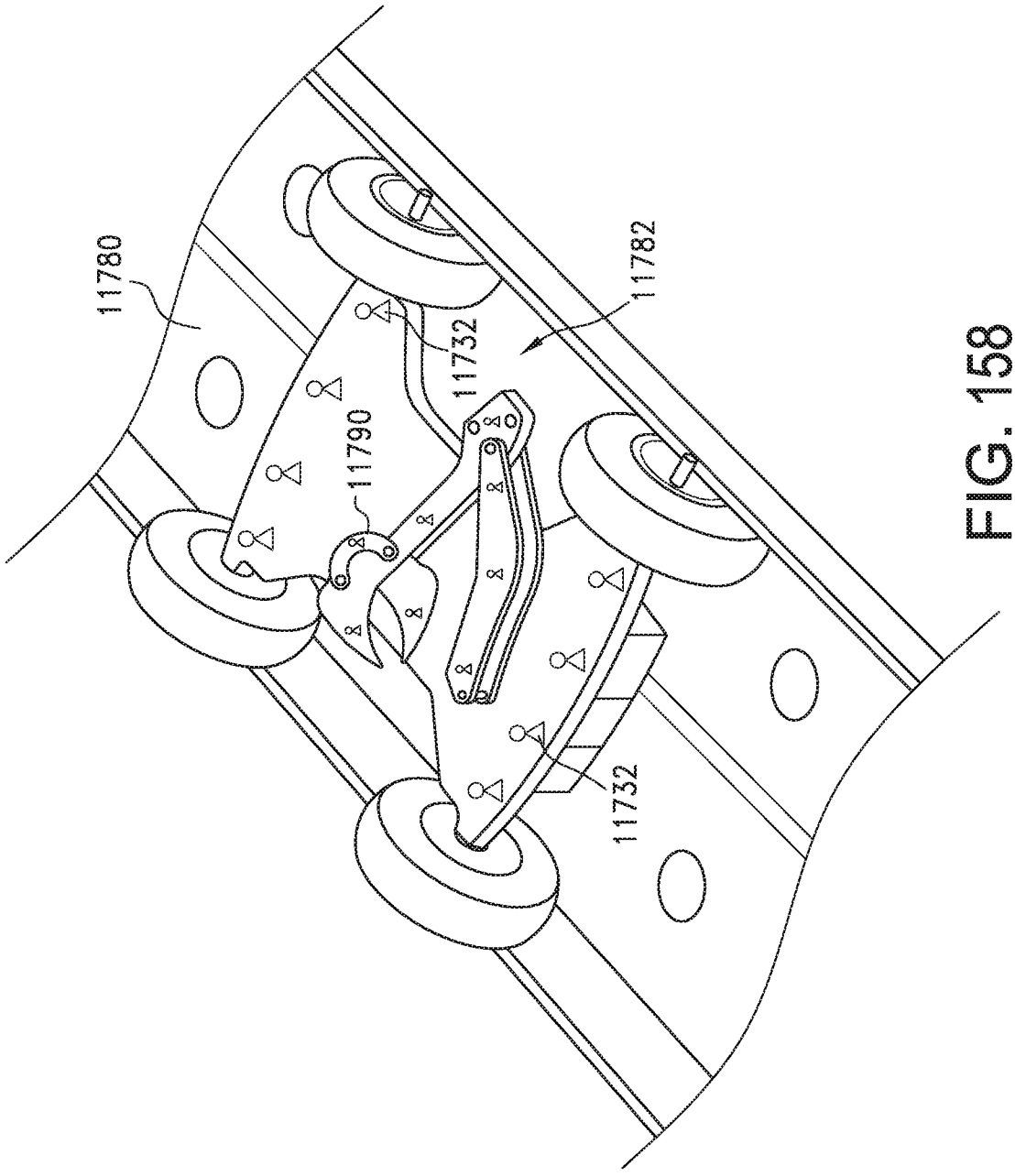

FIG. 158

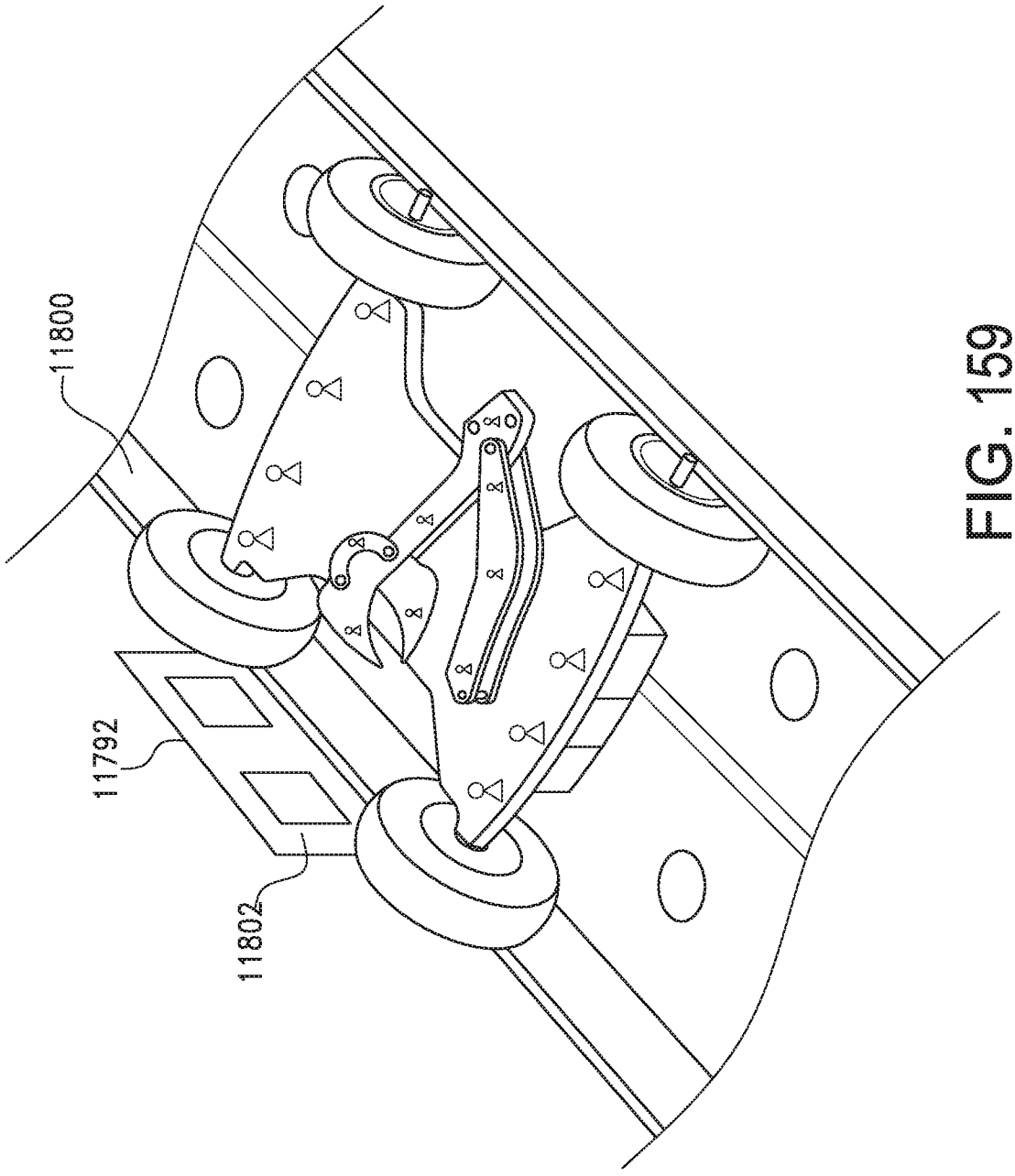

FIG. 159

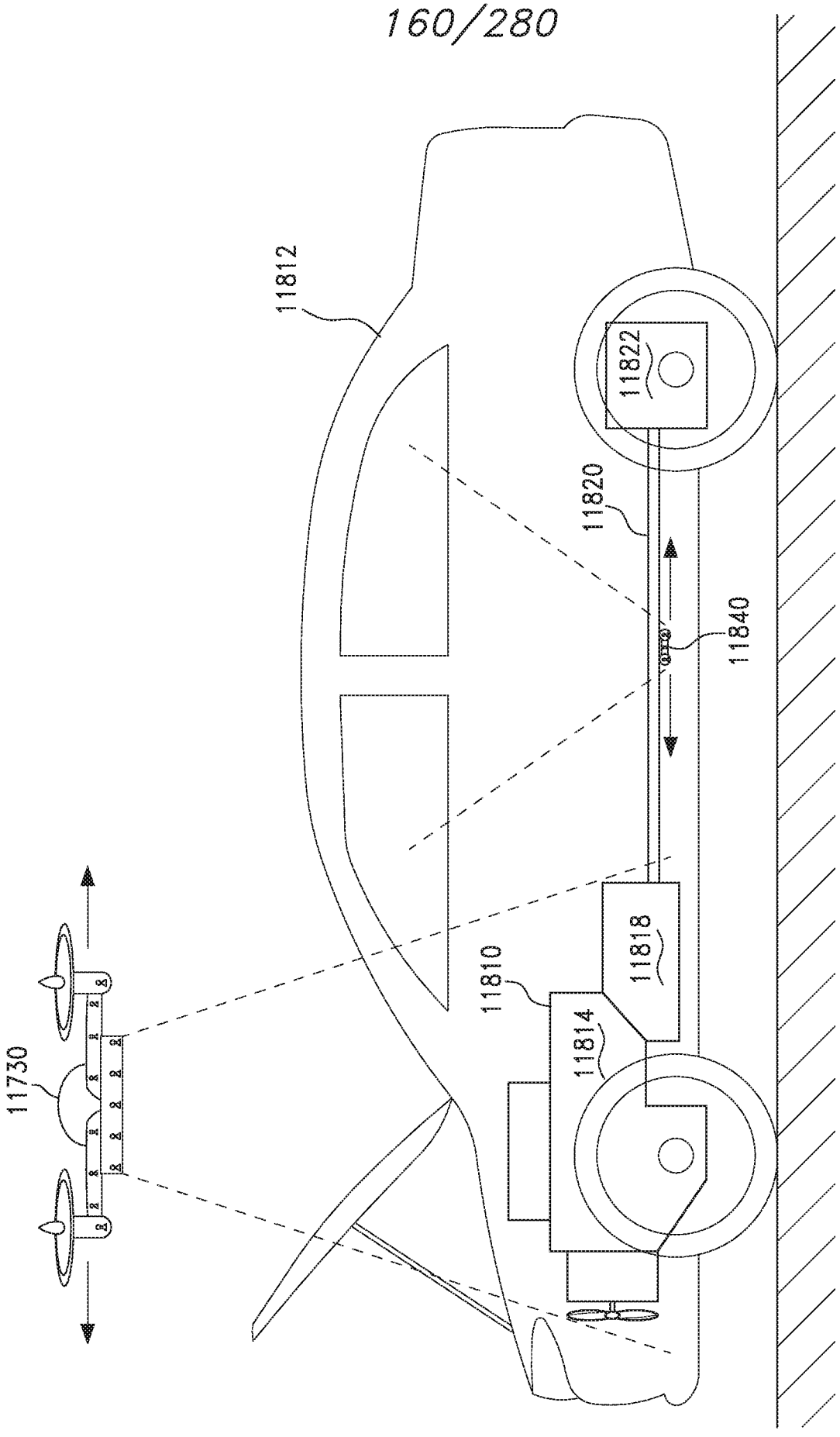

FIG. 160

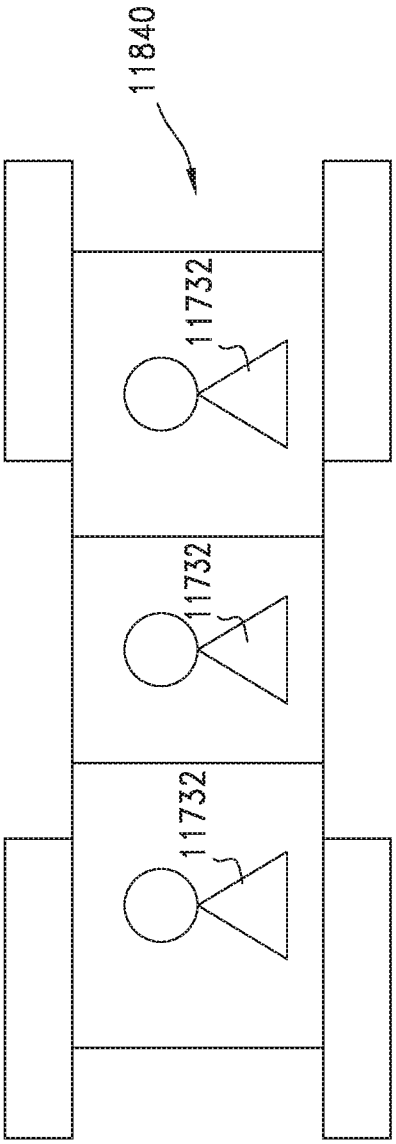

FIG. 161

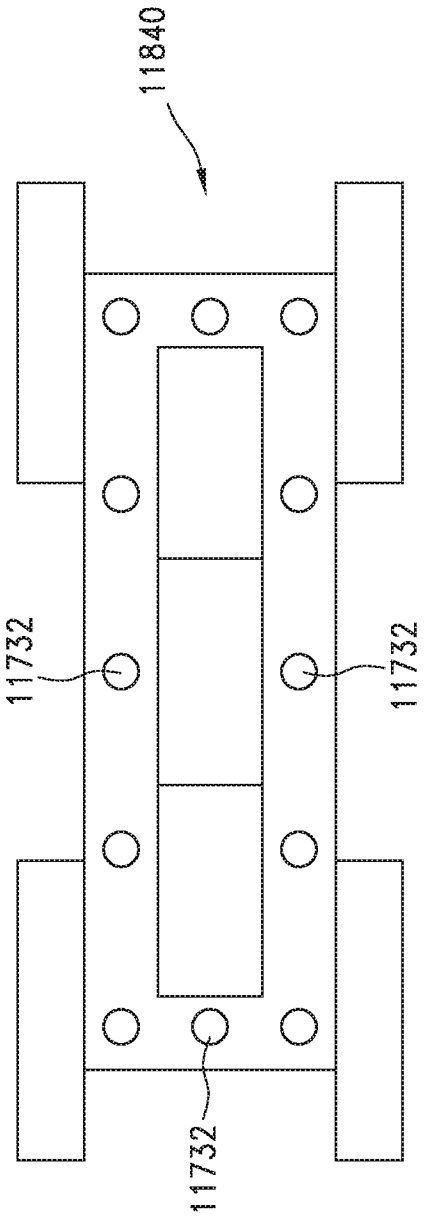

FIG. 162

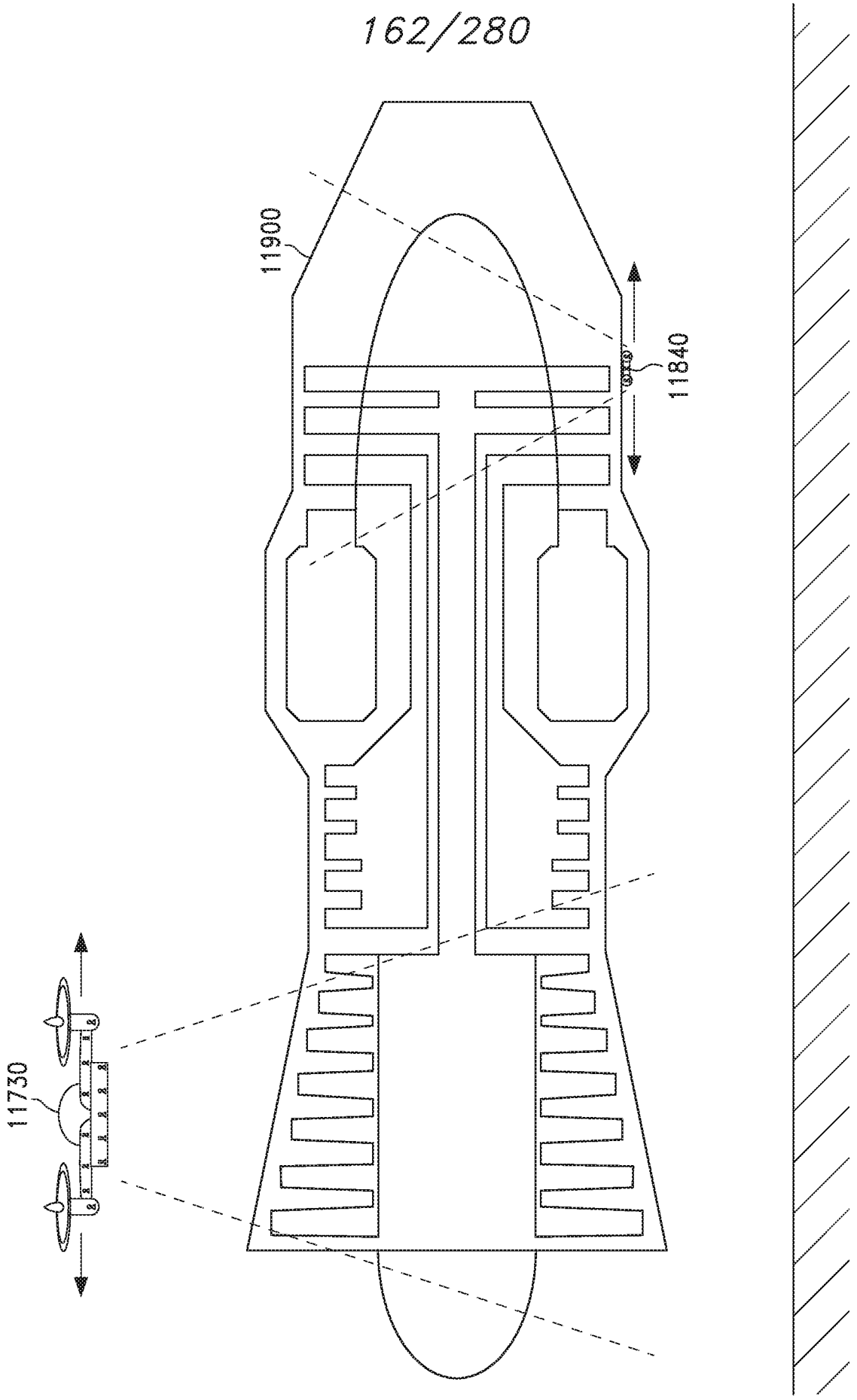

FIG. 163

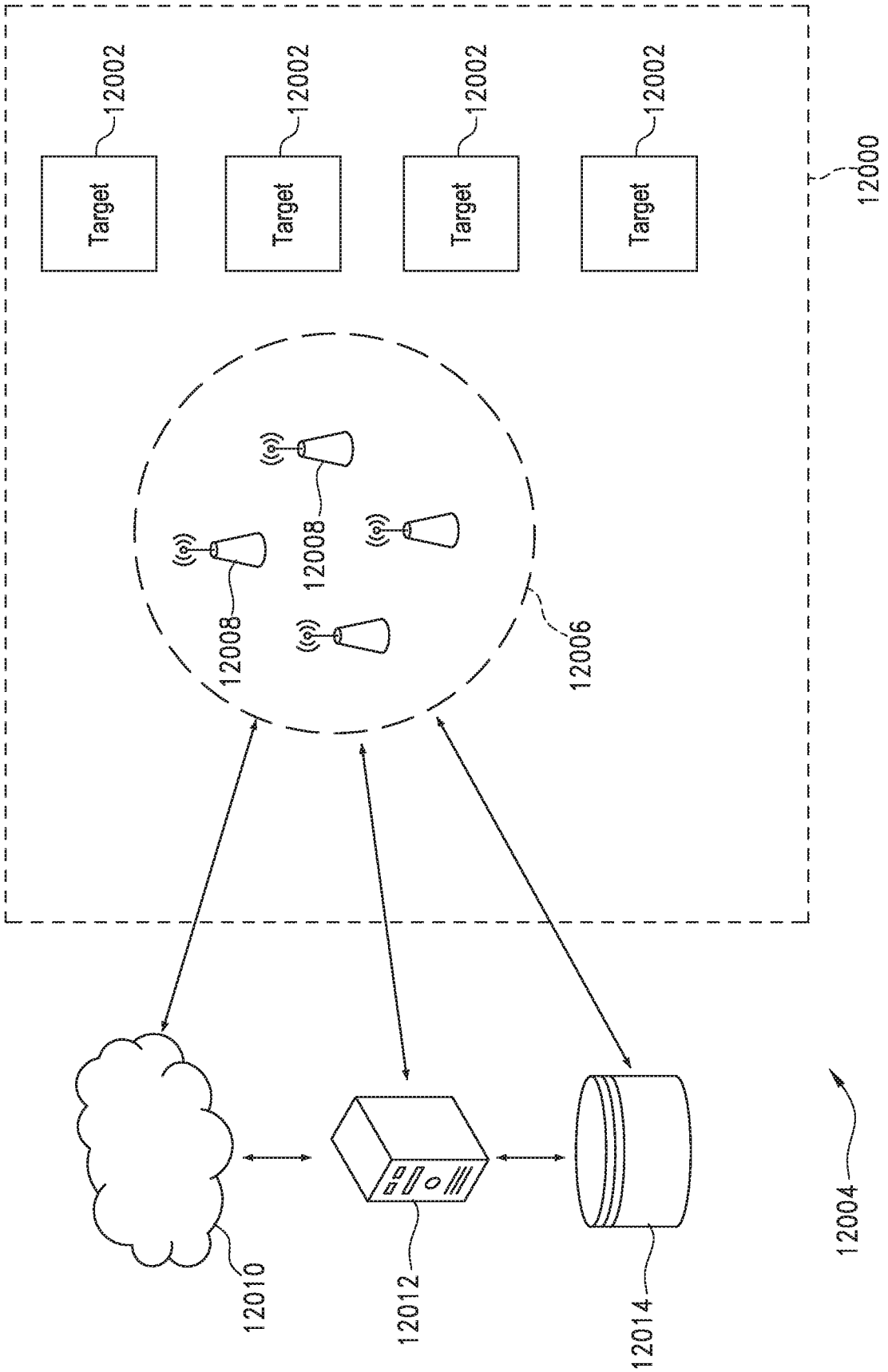
12002
Target
12002
Target
12002
Target
12002
Target
12000
12008
12008
12006
12010
12012
12014
12004

FIG. 164

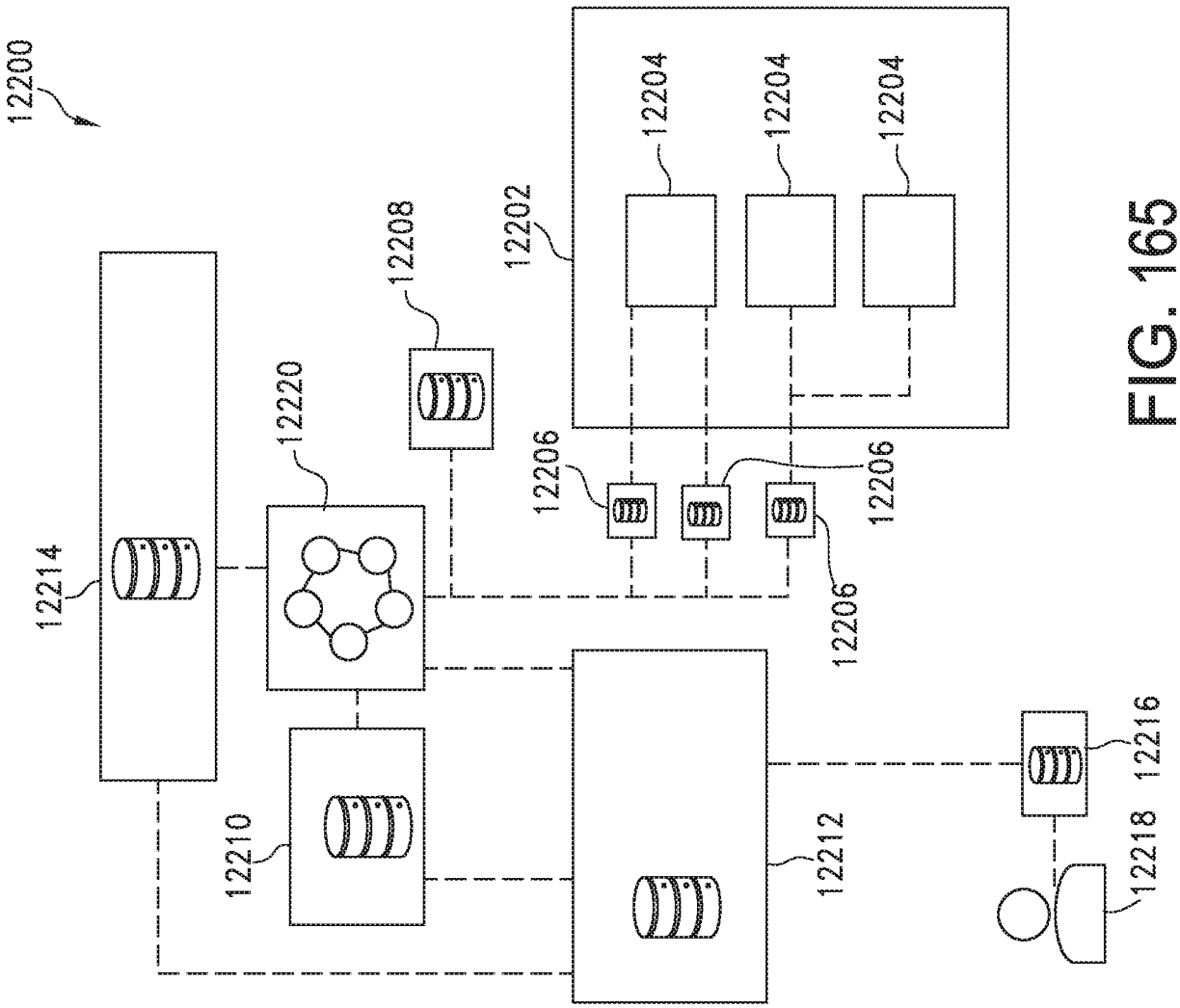
12200
12202
12204
12204
12204
12206
12206
12206
12208
12210
12212
12214
12216
12218
12220

FIG. 165

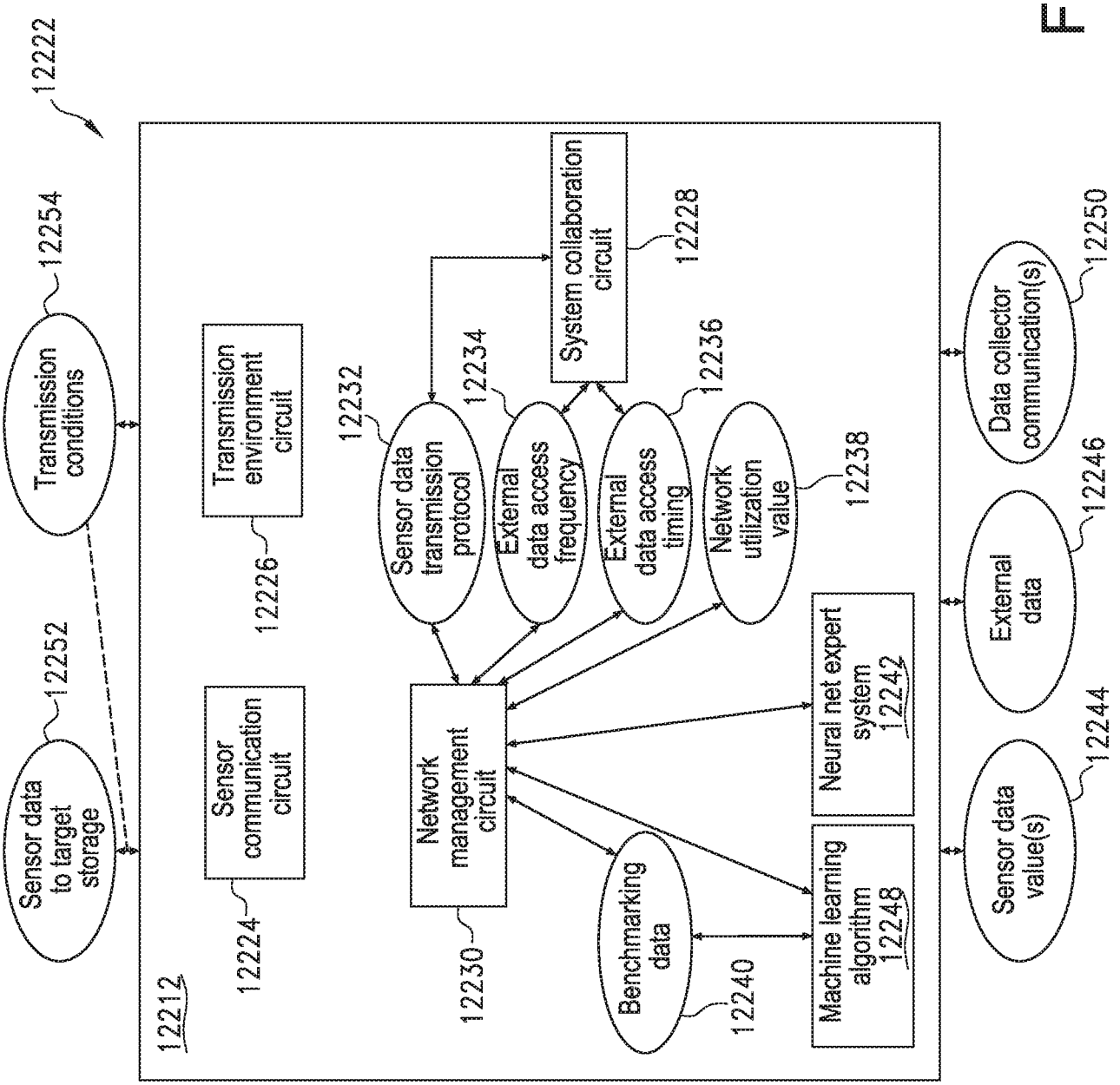
12222
12254
Transmission conditions
12252
Sensor data to target storage
12212
Transmission environment circuit
12226
Sensor communication circuit
12224
12232
Sensor data transmission protocol
12234
External data access frequency
System collaboration circuit
12228
12236
External data access timing
Network utilization value
12238
Network management circuit
12230
Neural net expert system 12242
Machine learning algorithm 12248
Benchmarking data
12240
Data collector communication(s)
12250
External data
12246
Sensor data value(s)
12244

FIG. 166

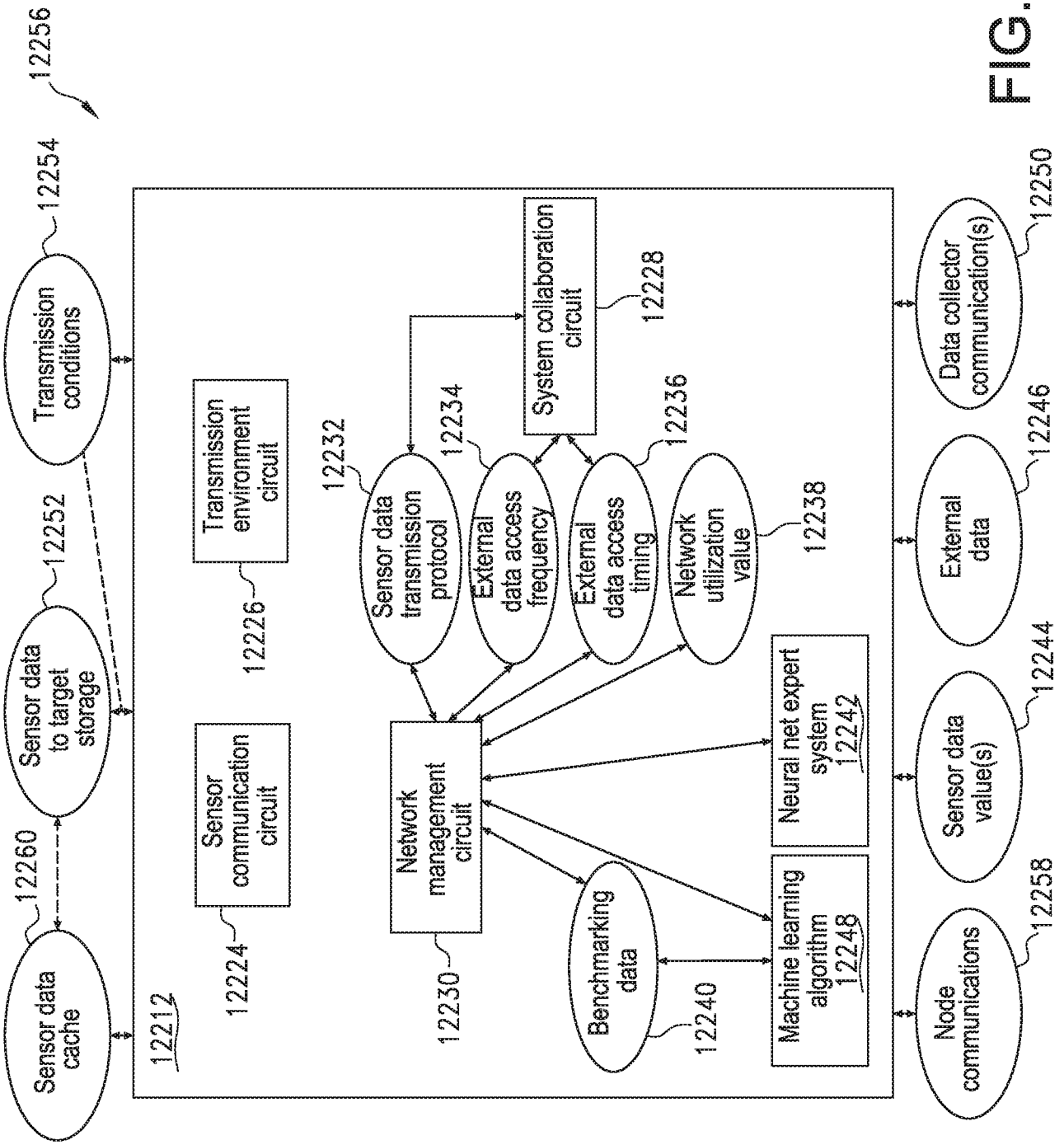
12256
12254
Transmission conditions
12252
Sensor data to target storage
12260
Sensor data cache
12212
Transmission environment circuit
12226
Sensor communication circuit
12224
Network management circuit
12230
12232
Sensor data transmission protocol
12234
External data access frequency
System collaboration circuit
12228
12236
External data access timing
Network utilization value
12238
Neural net expert system 12242
Machine learning algorithm 12248
Benchmarking data
12240
Data collector communication(s)
12250
External data
12246
Sensor data value(s)
12244
Node communications
12258

FIG. 167

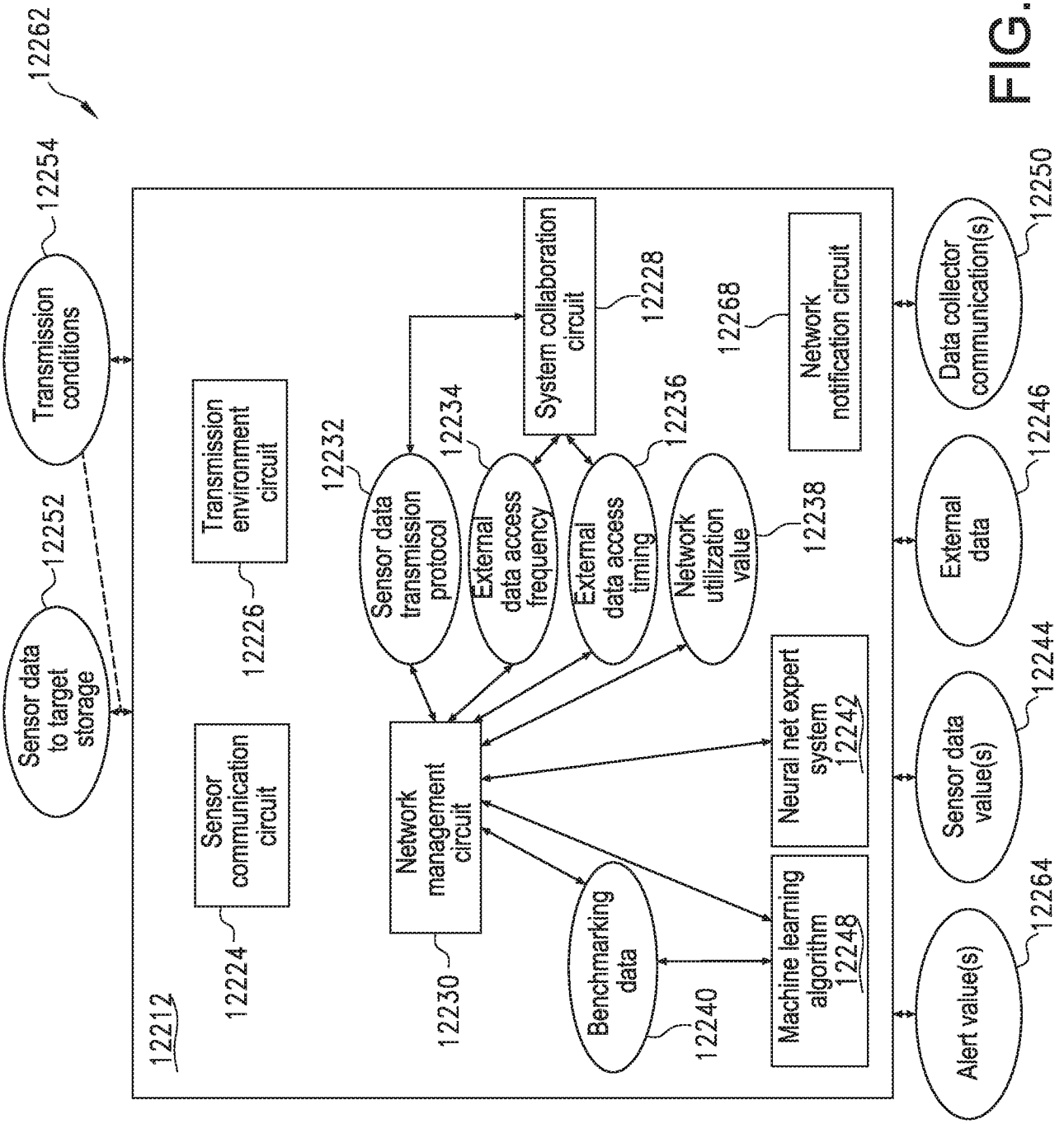
12262
12254
Transmission conditions
12252
Sensor data to target storage
12212
Sensor communication circuit
12224
Transmission environment circuit
12226
Network management circuit
12230
12232
Sensor data transmission protocol
12234
External data access frequency
System collaboration circuit
12228
12236
External data access timing
Network utilization value
12238
12268
Network notification circuit
Neural net expert system 12242
Machine learning algorithm 12248
Benchmarking data
12240
Data collector communication(s)
12250
External data
12246
Sensor data value(s)
12244
Alert value(s)
12264

FIG. 168

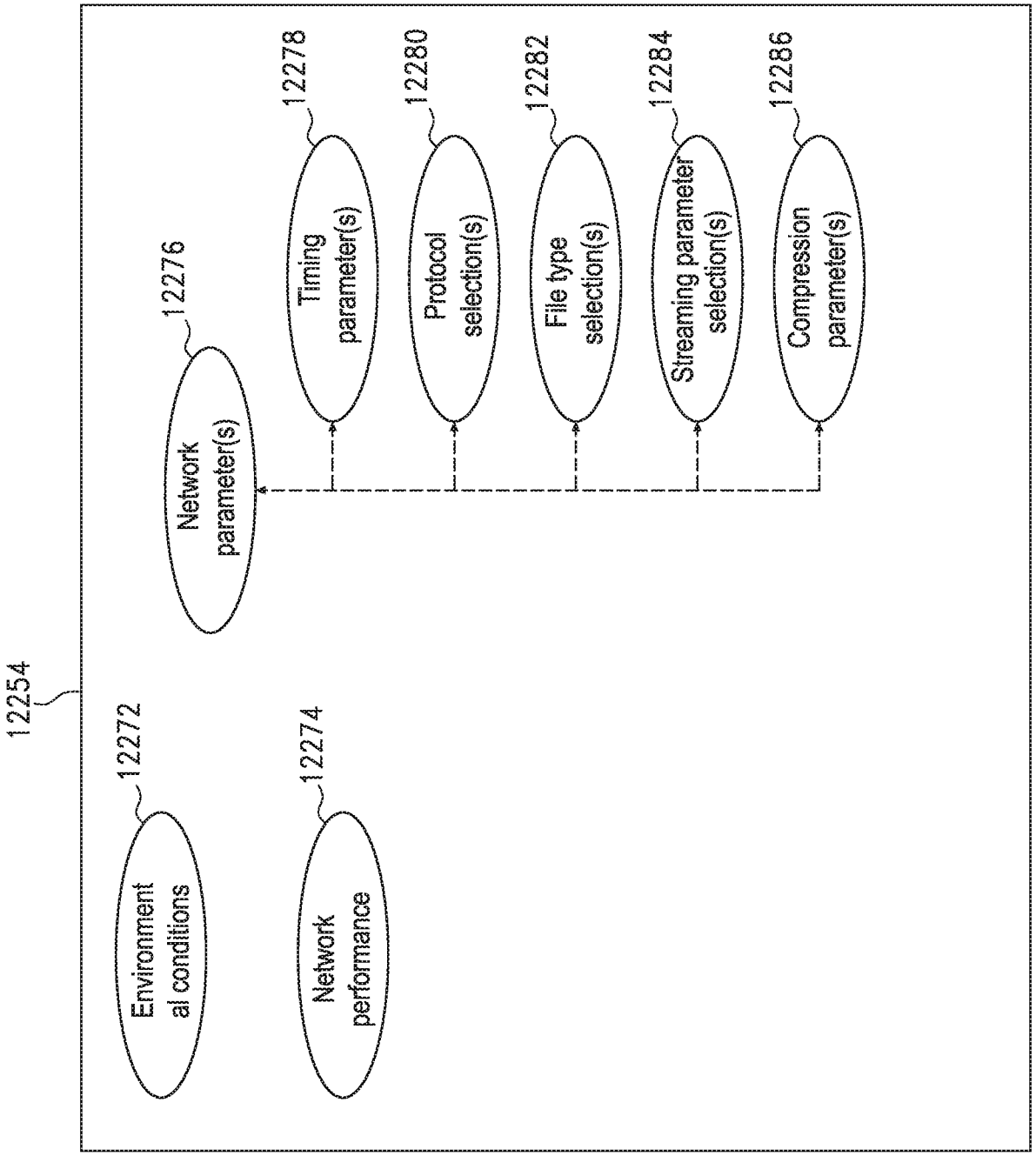
12254
12272
Environmental conditions
12274
Network performance
12276
Network parameter(s)
12278
Timing parameter(s)
12280
Protocol selection(s)
12282
File type selection(s)
12284
Streaming parameter selection(s)
12286
Compression parameter(s)

FIG. 169

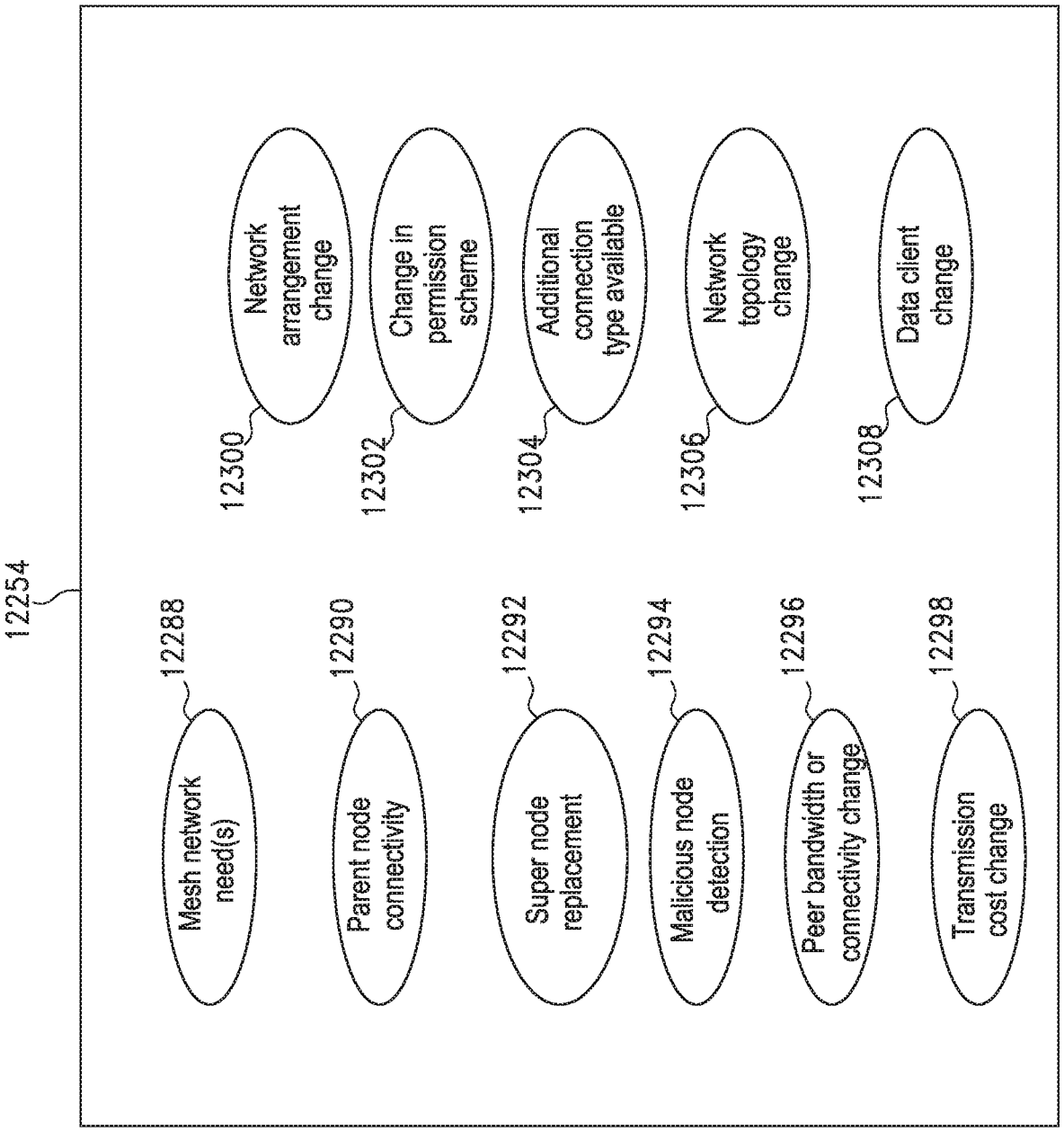
12254
12288
Mesh network need(s)
12290
Parent node connectivity
12292
Super node replacement
12294
Malicious node detection
12296
Peer bandwidth or connectivity change
12298
Transmission cost change
12300
Network arrangement change
12302
Change in permission scheme
12304
Additional connection type available
12306
Network topology change
12308
Data client change

FIG. 170

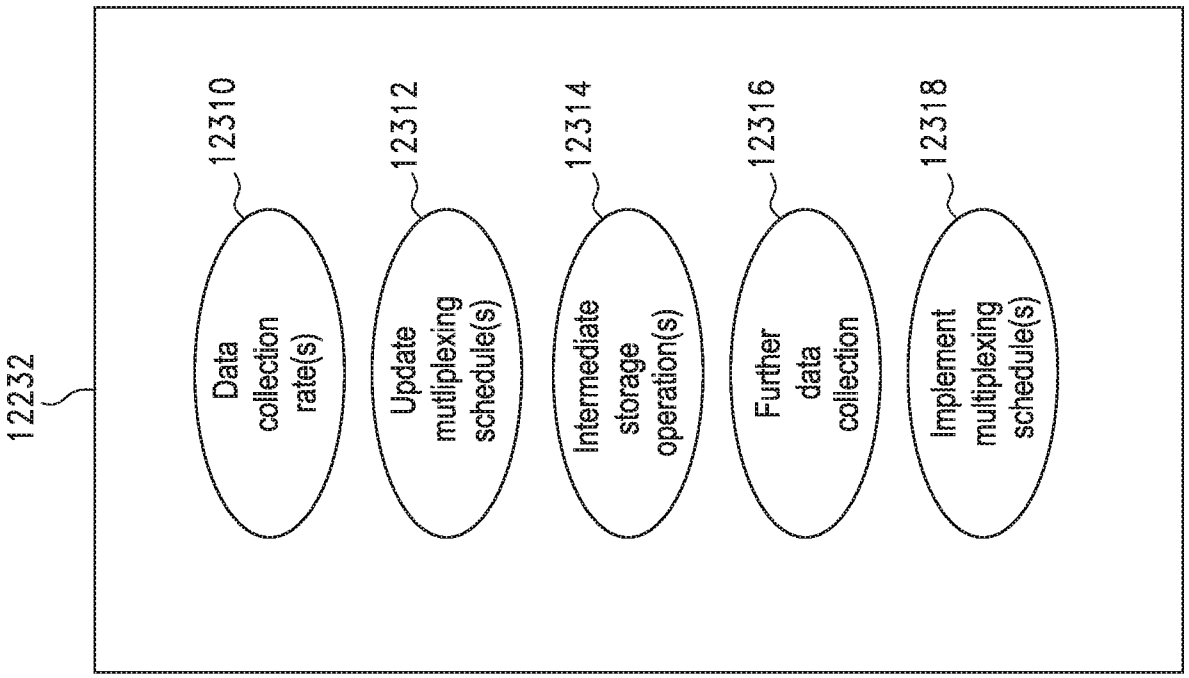
12232
12310
Data collection rate(s)
12312
Update mutliplexing schedule(s)
12314
Intermediate storage operation(s)
12316
Further data collection
12318
Implement multiplexing schedule(s)

FIG. 171

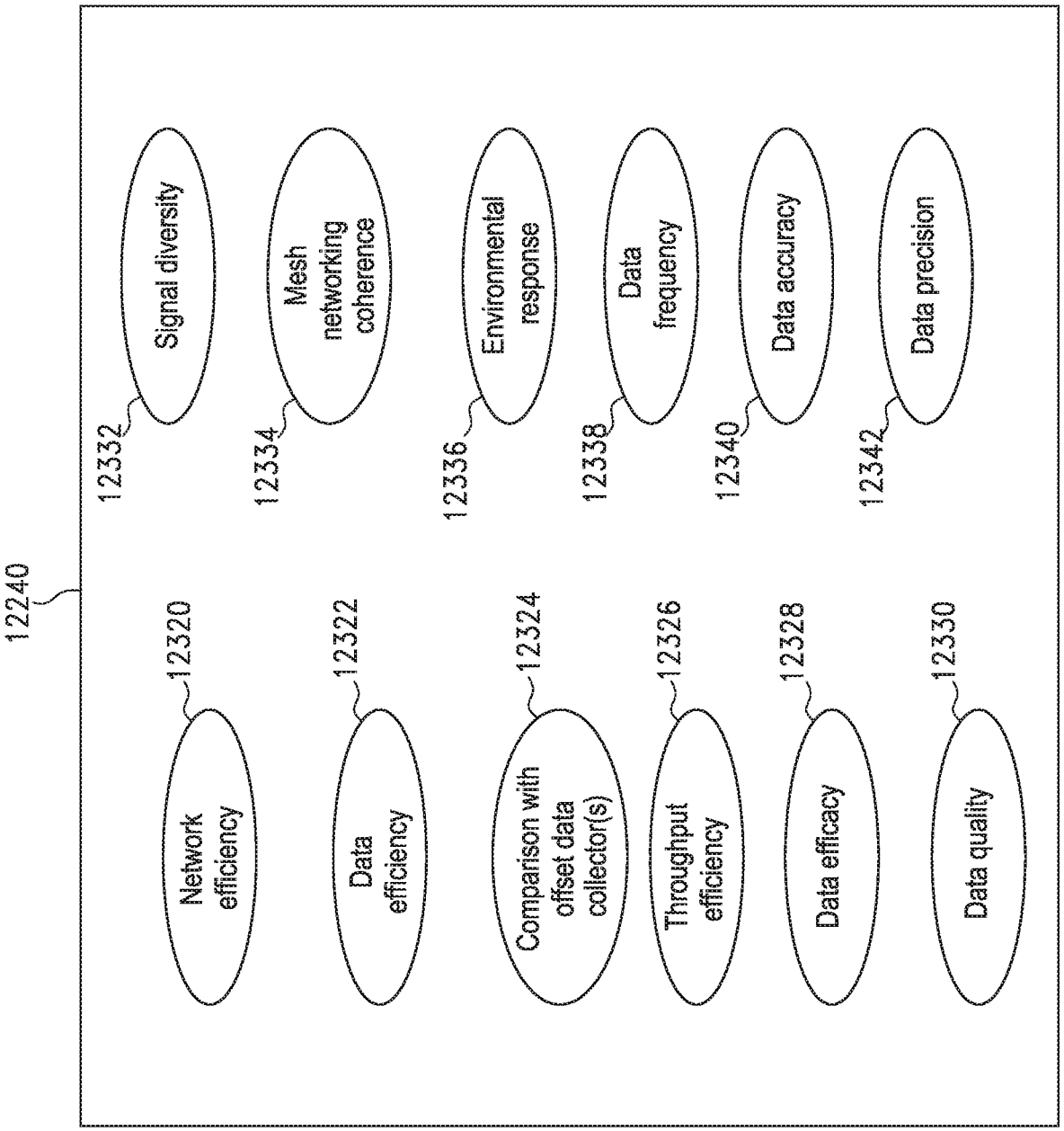
12240
12320
Network efficiency
12322
Data efficiency
12324
Comparison with offset data collector(s)
12326
Throughput efficiency
12328
Data efficacy
12330
Data quality
12332
Signal diversity
12334
Mesh networking coherence
12336
Environmental response
12338
Data frequency
12340
Data accuracy
12342
Data precision

FIG. 172

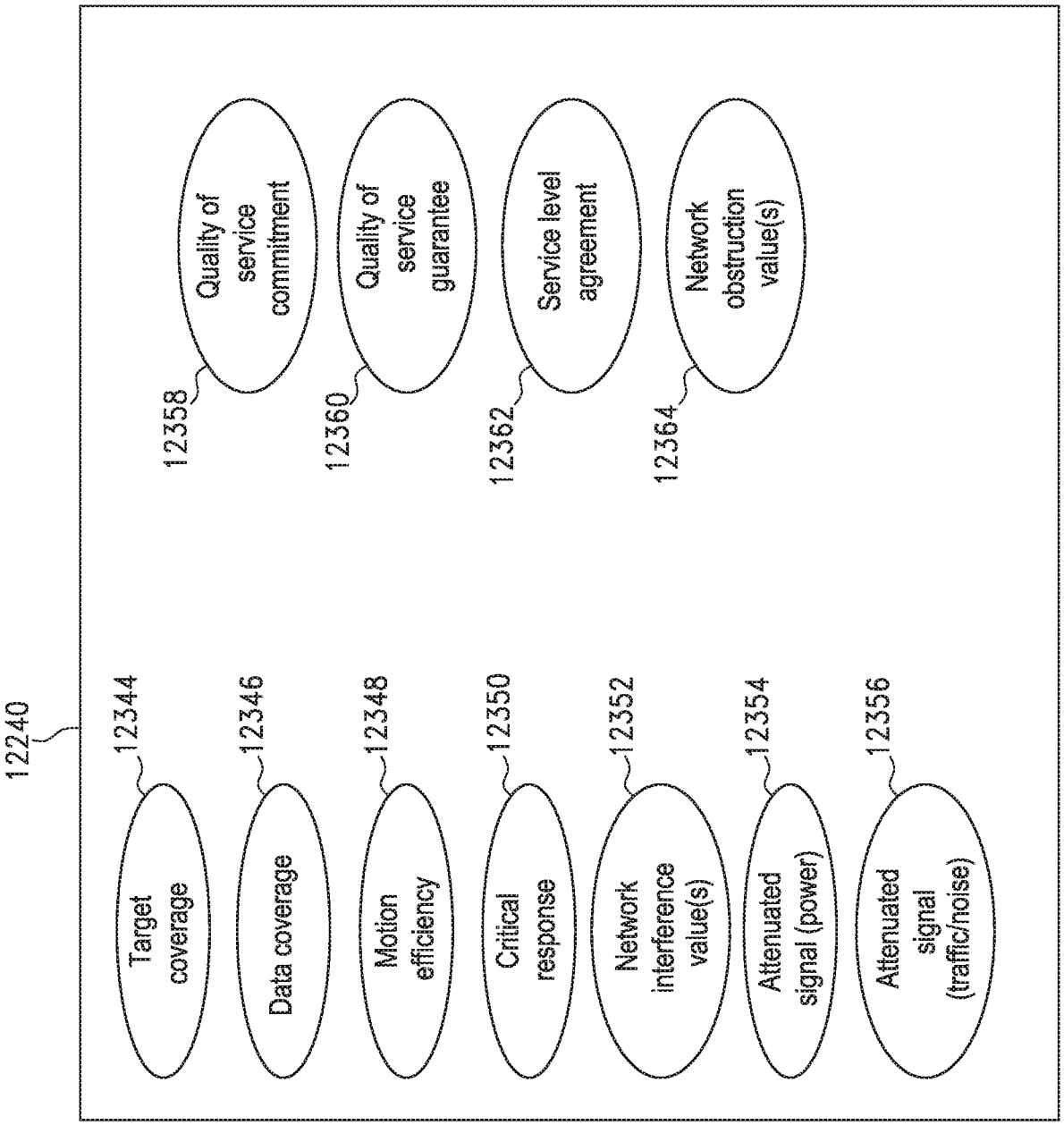
12240
12344
Target coverage
12346
Data coverage
12348
Motion efficiency
12350
Critical response
12352
Network interference value(s)
12354
Attenuated signal (power)
12356
Attenuated signal (traffic/noise)
12358
Quality of service commitment
12360
Quality of service guarantee
12362
Service level agreement
12364
Network obstruction value(s)

FIG. 173

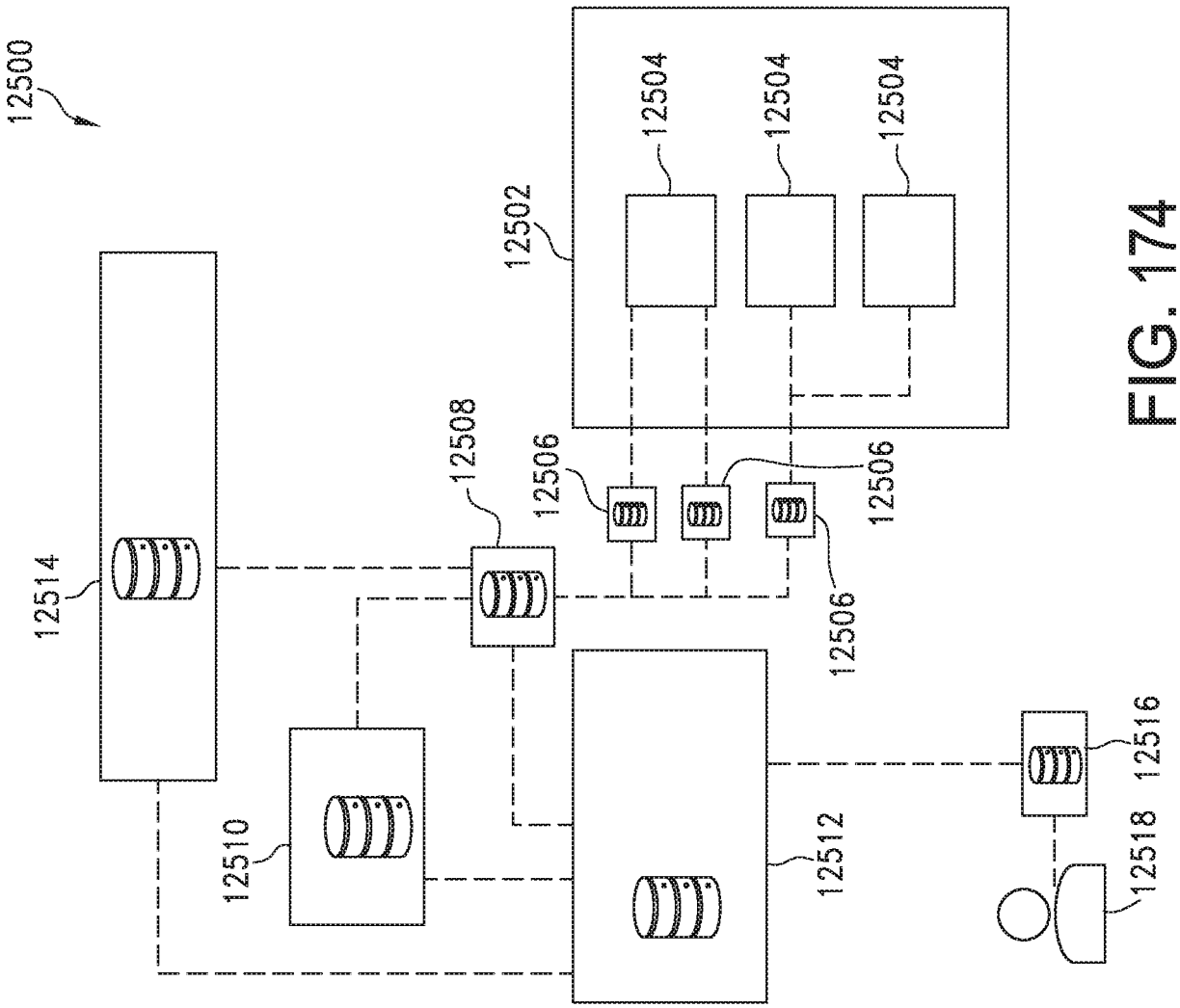
12500
12502
12504
12504
12504
12506
12506
12506
12508
12510
12512
12514
12516
12518

FIG. 174

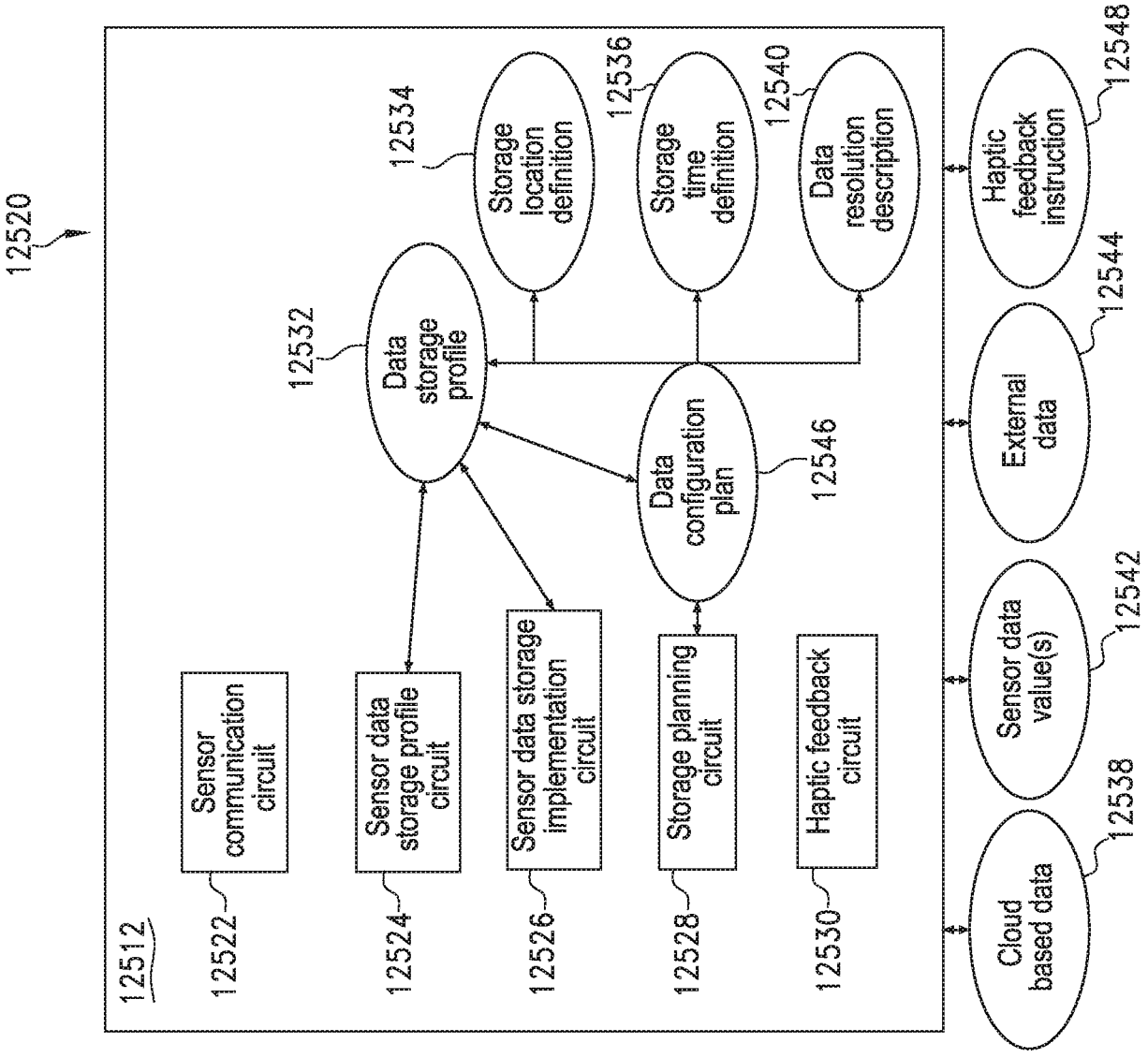
12520
12512
Sensor communication circuit
12522
Sensor data storage profile circuit
12524
Sensor data storage implementation circuit
12526
Storage planning circuit
12528
Haptic feedback circuit
12530
Data storage profile
12532
Storage location definition
12534
Storage time definition
12536
Data resolution description
12540
Data configuration plan
12546
Cloud based data
12538
Sensor data value(s)
12542
External data
12544
Haptic feedback instruction
12548

FIG. 175

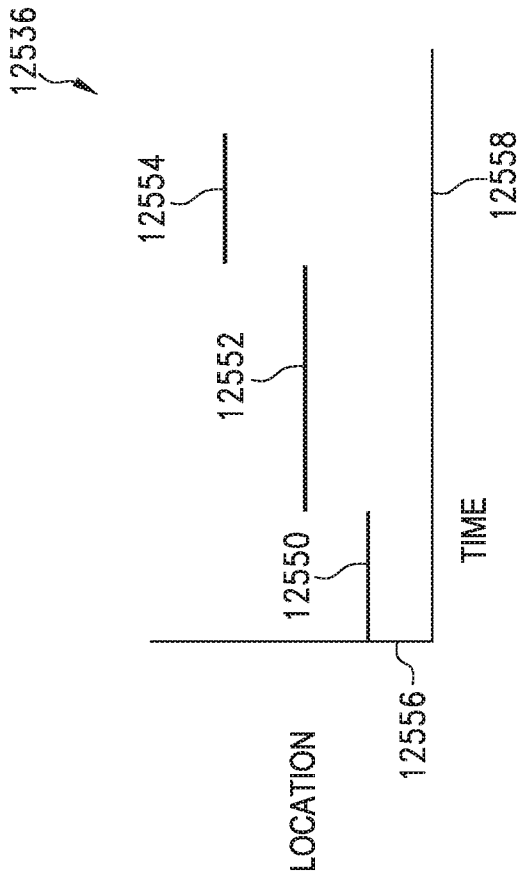

FIG. 176

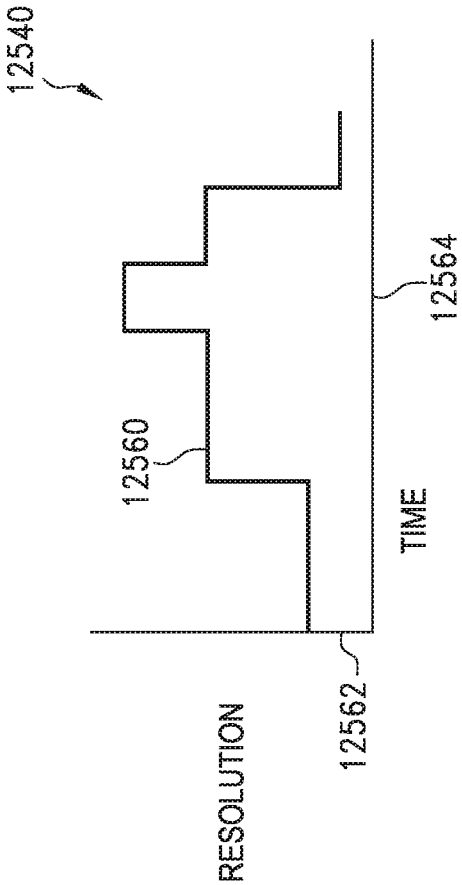

FIG. 177

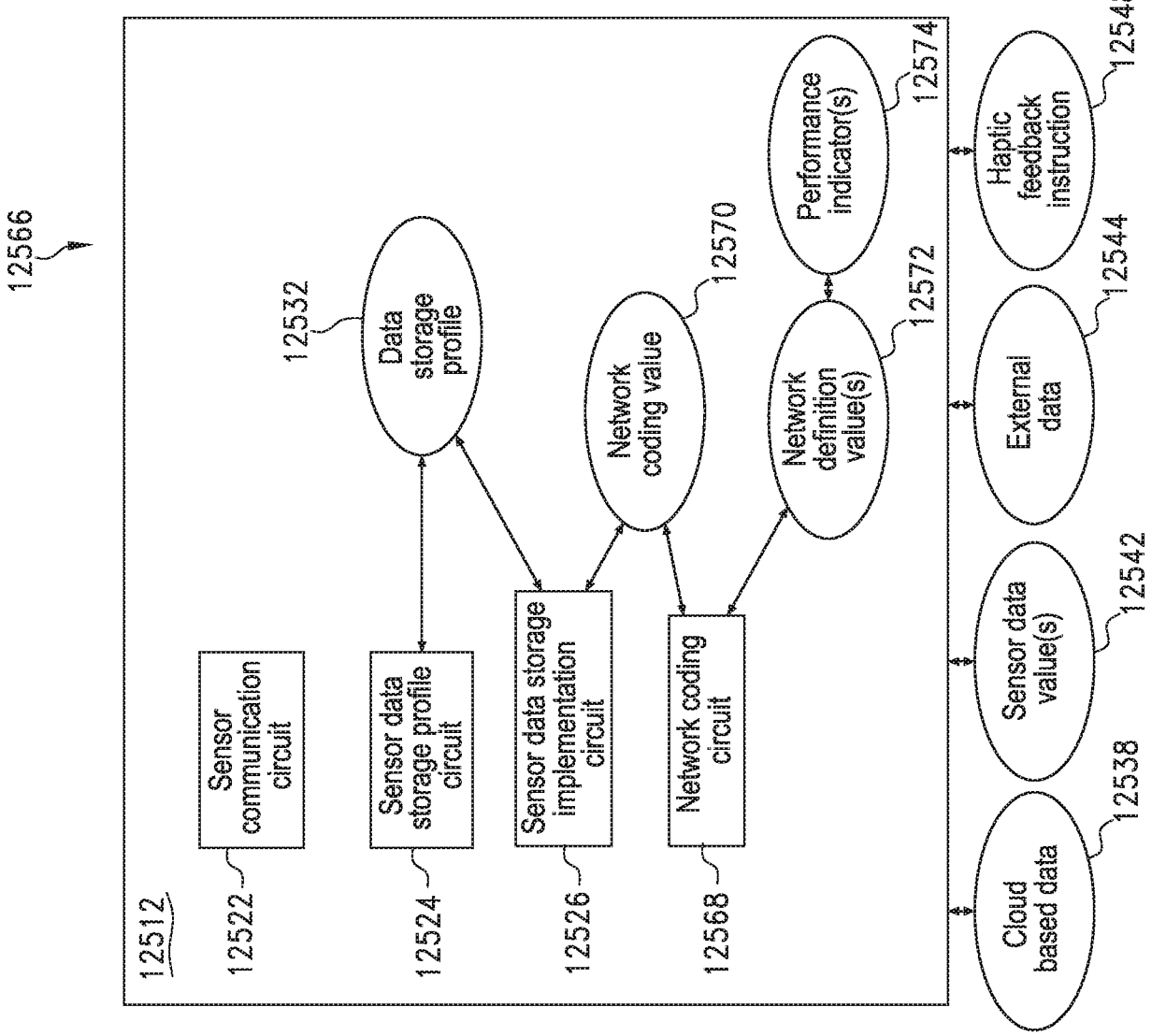
12566
12512
Sensor communication circuit
12522
Sensor data storage profile circuit
12524
Sensor data storage implementation circuit
12526
Network coding circuit
12568
Data storage profile
12532
Network coding value
12570
Network definition value(s)
12572
Performance indicator(s)
12574
Haptic feedback instruction
12548
External data
12544
Sensor data value(s)
12542
Cloud based data
12538

FIG. 178

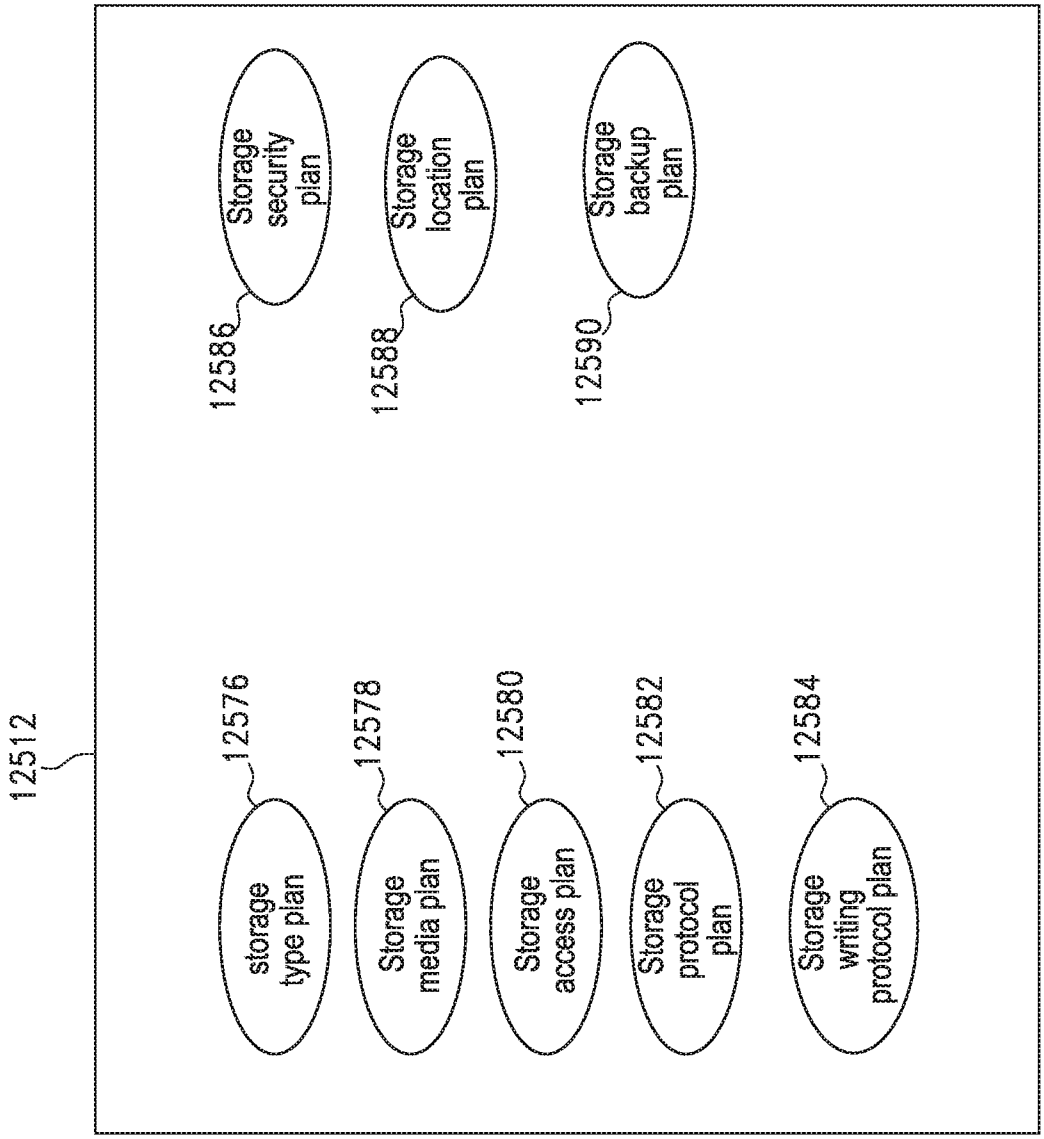
12512
12576
storage type plan
12578
Storage media plan
12580
Storage access plan
12582
Storage protocol plan
12584
Storage writing protocol plan
12586
Storage security plan
12588
Storage location plan
12590
Storage backup plan

FIG. 179

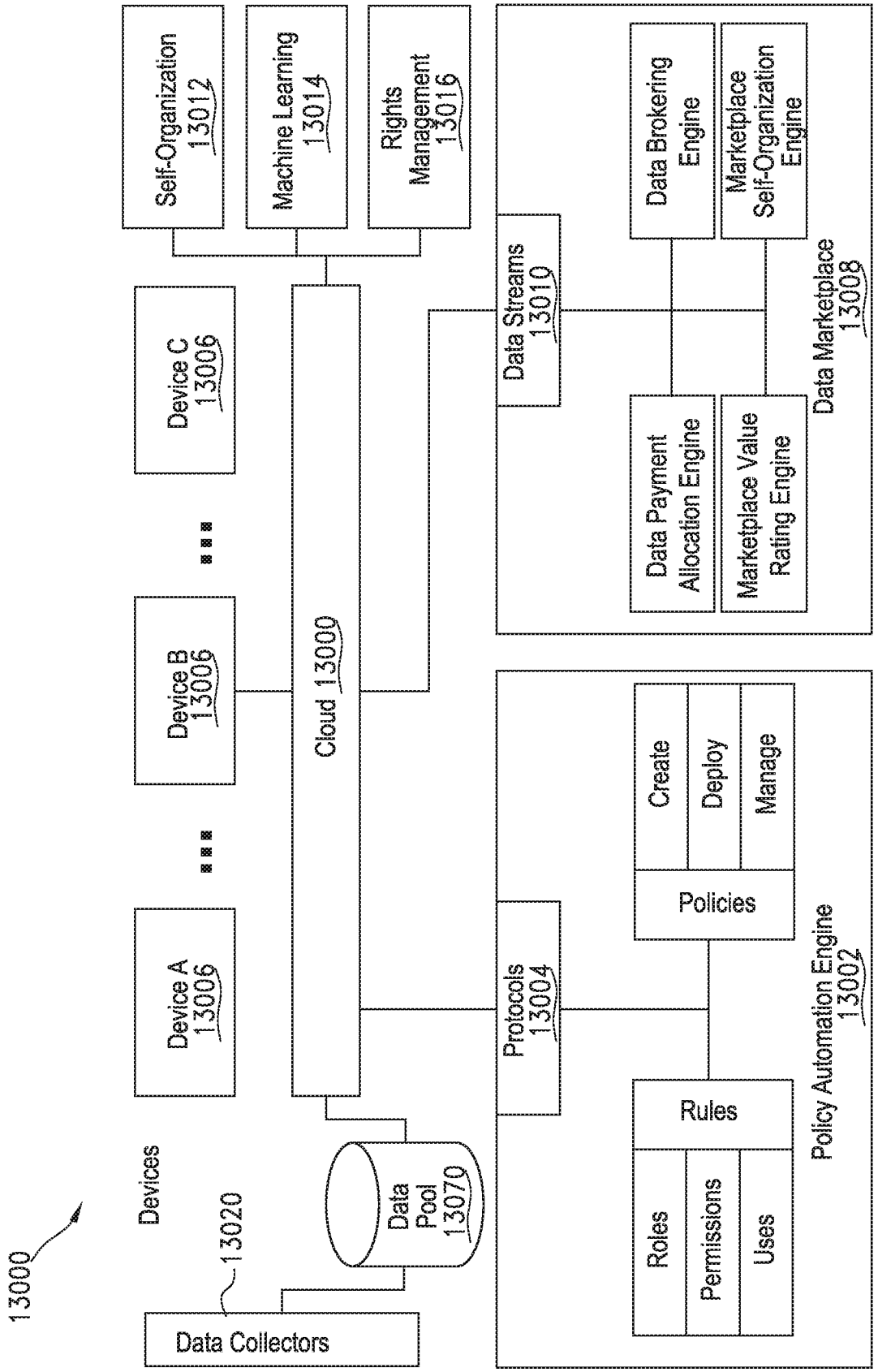
13000
Devices
13020
Data Collectors
Device A 13006
Device B 13006
Device C 13006
Cloud 13000
Data Pool 13070
Protocols 13004
Self-Organization 13012
Machine Learning 13014
Rights Management 13016
Data Streams 13010
Data Brokering Engine
Marketplace Self-Organization Engine
Data Payment Allocation Engine
Marketplace Value Rating Engine
Data Marketplace 13008
Policy Automation Engine 13002
Create
Deploy
Manage
Policies
Rules
Roles
Permissions
Uses

FIG. 180

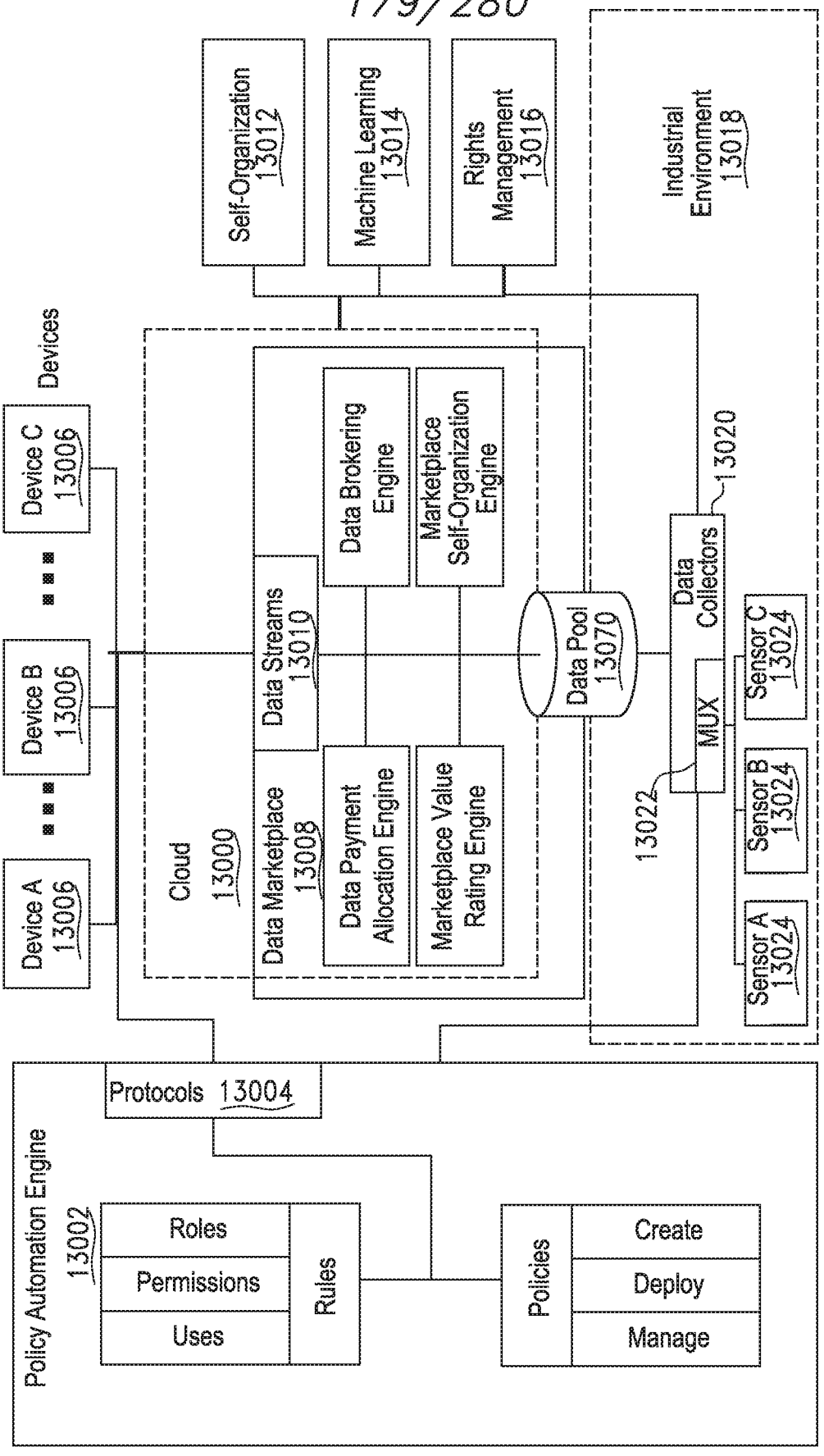
Self-Organization 13012
Machine Learning 13014
Rights Management 13016
Industrial Environment 13018
Devices
Device C 13006
Device B 13006
Device A 13006
Cloud 13000
Data Streams 13010
Data Marketplace 13008
Data Brokering Engine
Marketplace Self-Organization Engine
Data Payment Allocation Engine
Marketplace Value Rating Engine
Data Pool 13070
Data Collectors
13020
MUX
13022
Sensor C 13024
Sensor B 13024
Sensor A 13024
Protocols 13004
Policy Automation Engine
13002
Roles
Permissions
Uses
Rules
Policies
Create
Deploy
Manage

FIG. 181

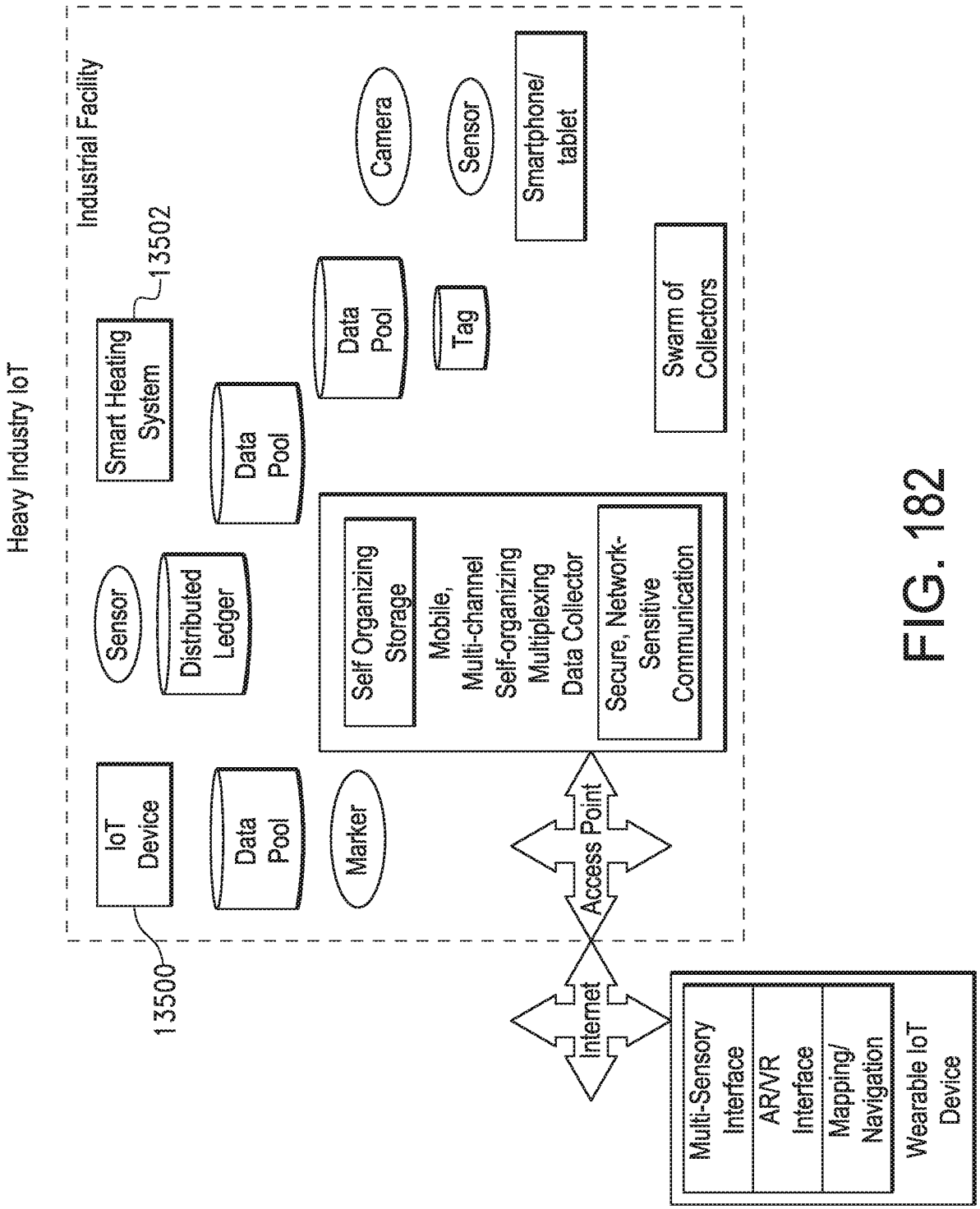
Heavy Industry IoT
Industrial Facility
13502
Smart Heating System
Sensor
Distributed Ledger
Data Pool
Data Pool
Tag
Camera
Sensor
Smartphone/ tablet
Swarm of Collectors
Self Organizing Storage
Mobile, Multi-channel Self-organizing Multiplexing Data Collector
Secure, Network-Sensitive Communication
IoT Device
Data Pool
Marker
Access Point
Internet
13500
Multi-Sensory Interface
AR/VR Interface
Mapping/ Navigation
Wearable IoT Device

FIG. 182

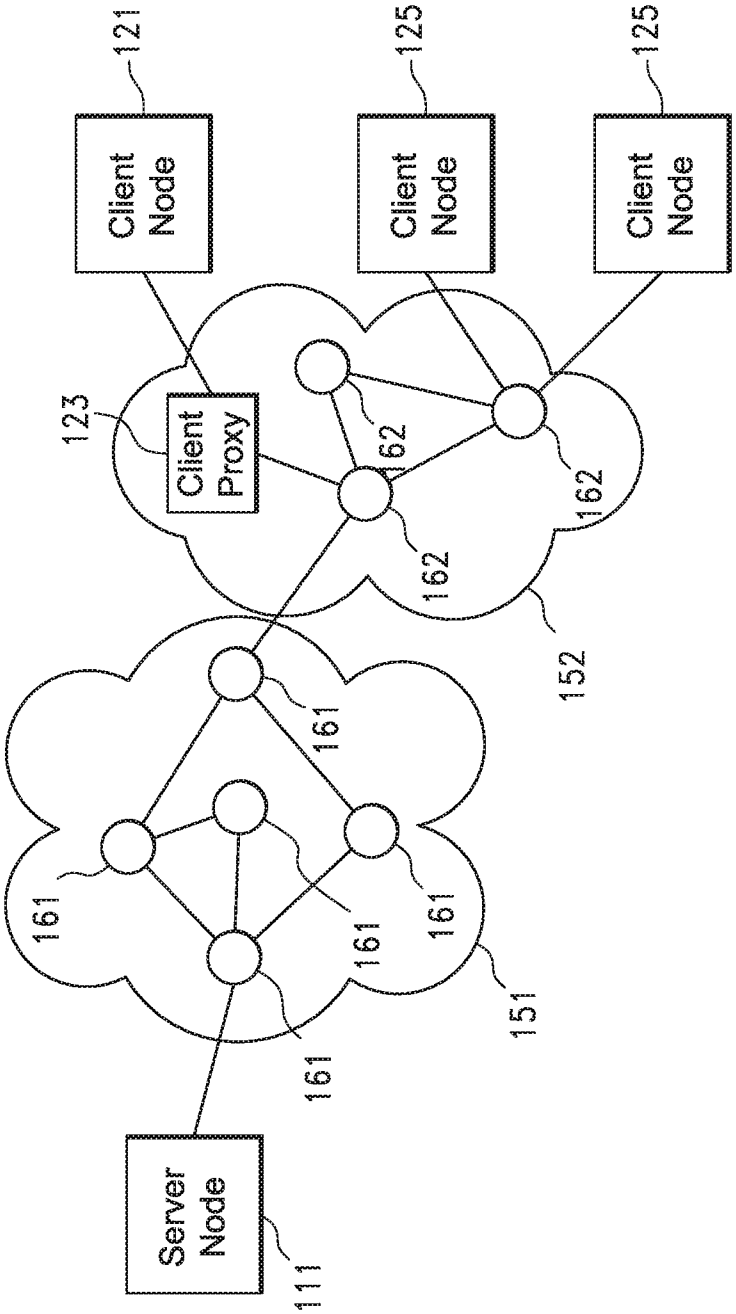
Client Node
121
Client Node
125
Client Node
125
123
Client Proxy
162
162
162
152
161
161
161
161
151
161
Server Node
111

FIG. 183

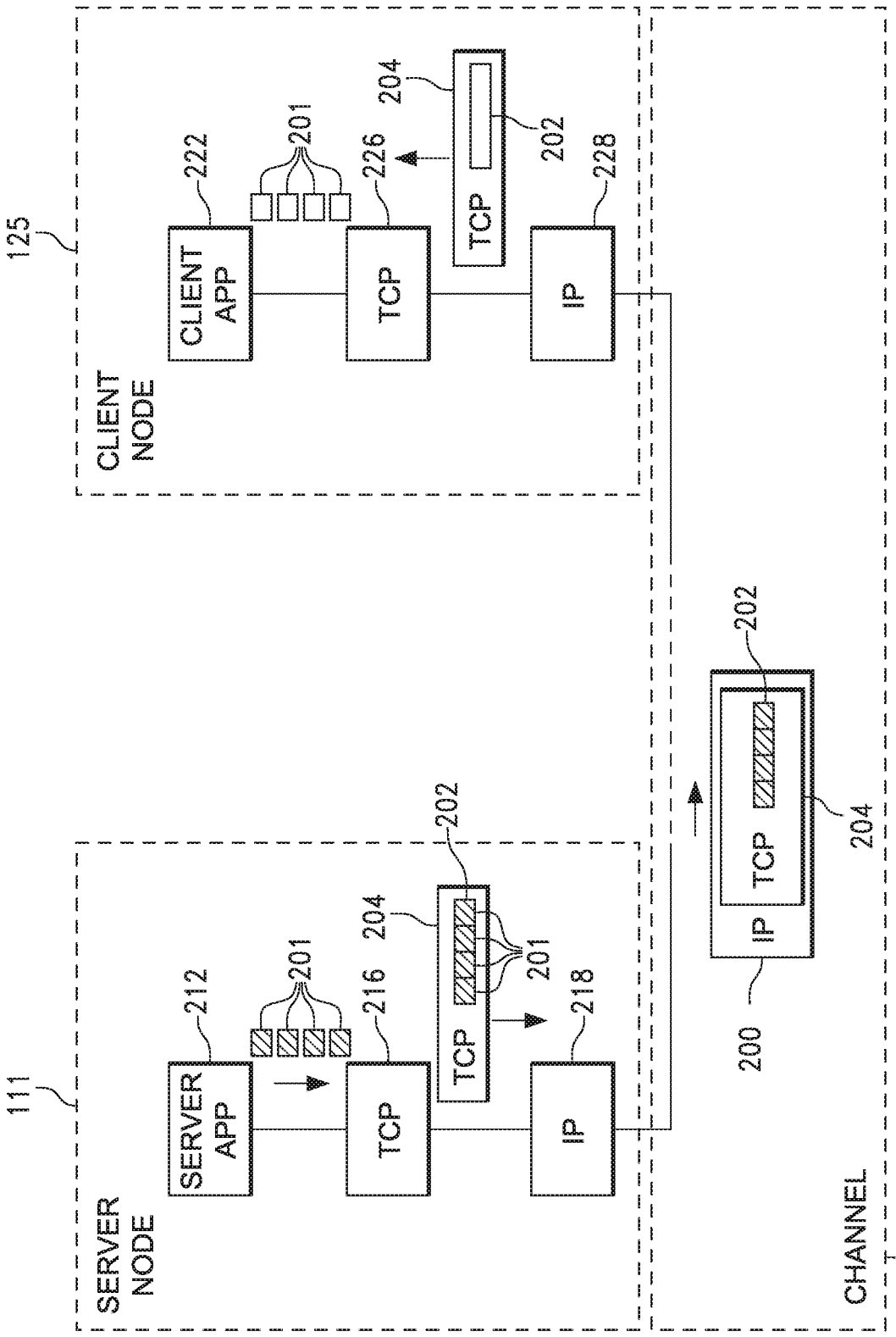
125
CLIENT NODE
CLIENT APP
222
201
226
TCP
204
TCP
202
IP
228
111
SERVER NODE
SERVER APP
212
201
216
TCP
204
202
TCP
201
IP
218
200
IP
TCP
202
204
CHANNEL
230

FIG. 184

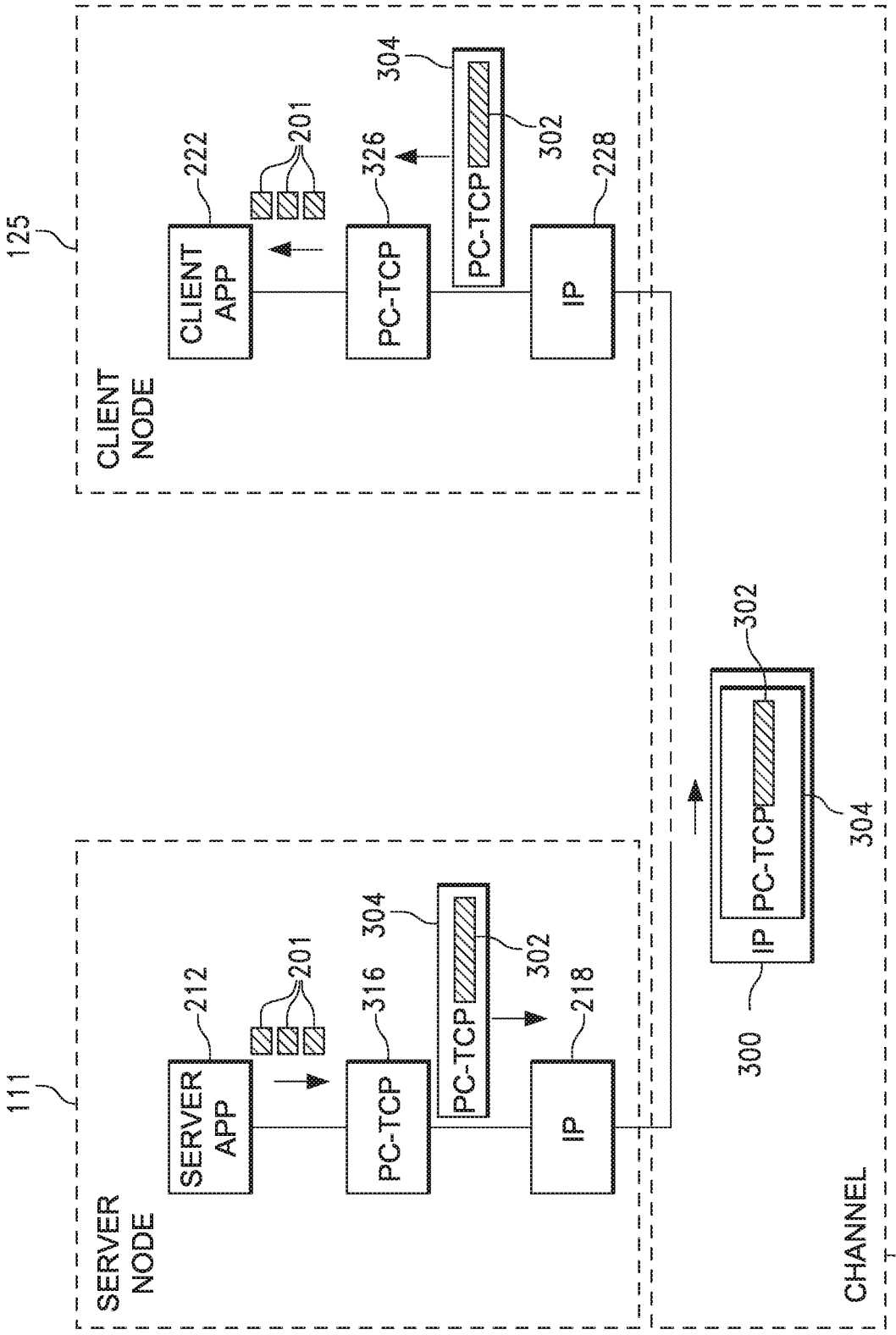
125
CLIENT NODE
CLIENT APP
222
201
PC-TCP
326
304
PC-TCP
302
IP
228
111
SERVER NODE
SERVER APP
212
201
PC-TCP
316
304
PC-TCP
302
IP
218
300
IP
PC-TCP
302
304
CHANNEL
230

FIG. 185

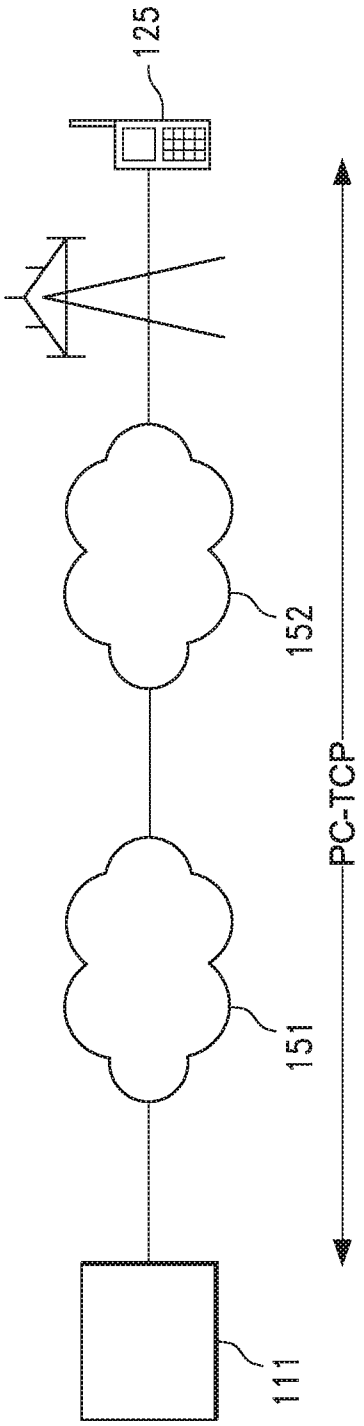

FIG. 186

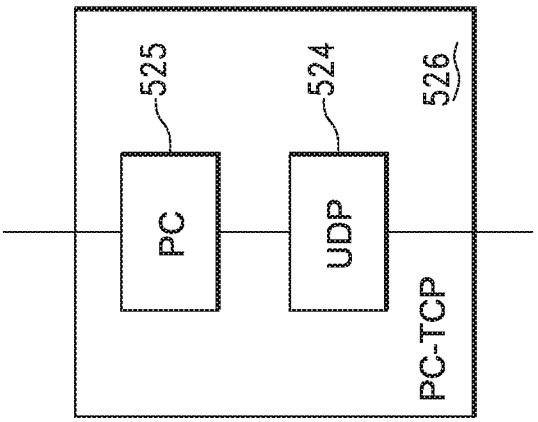

FIG. 187

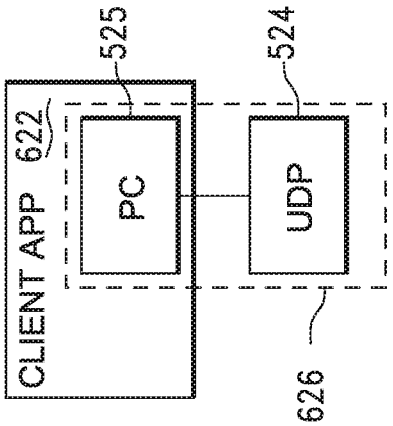

FIG. 188

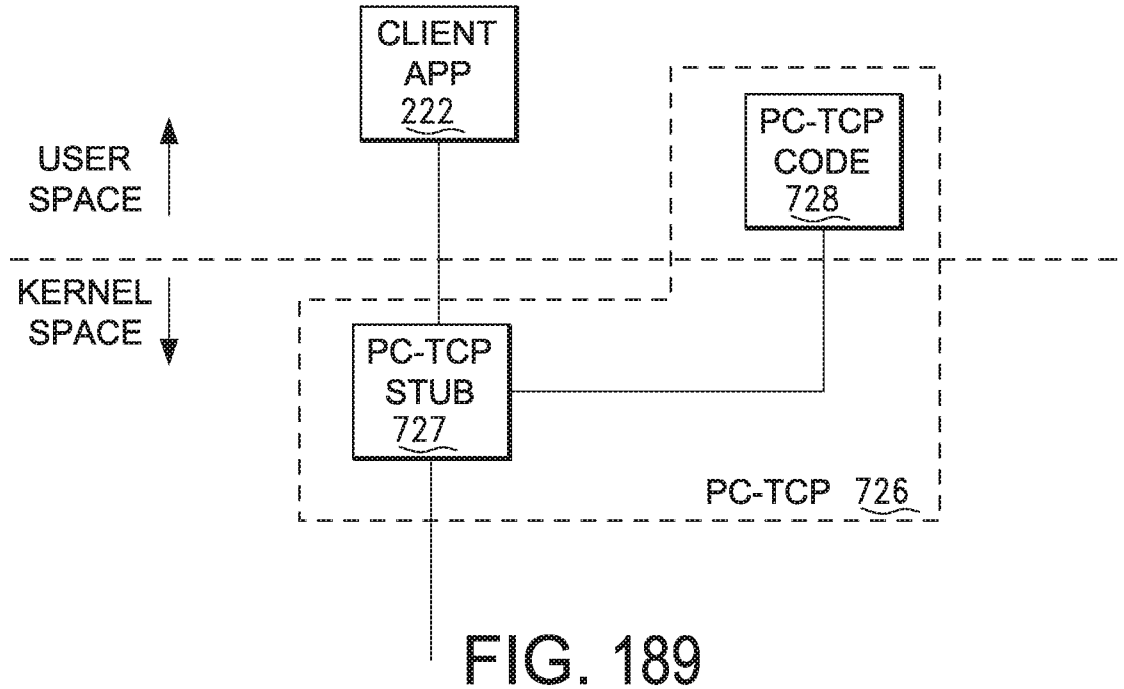

FIG. 189

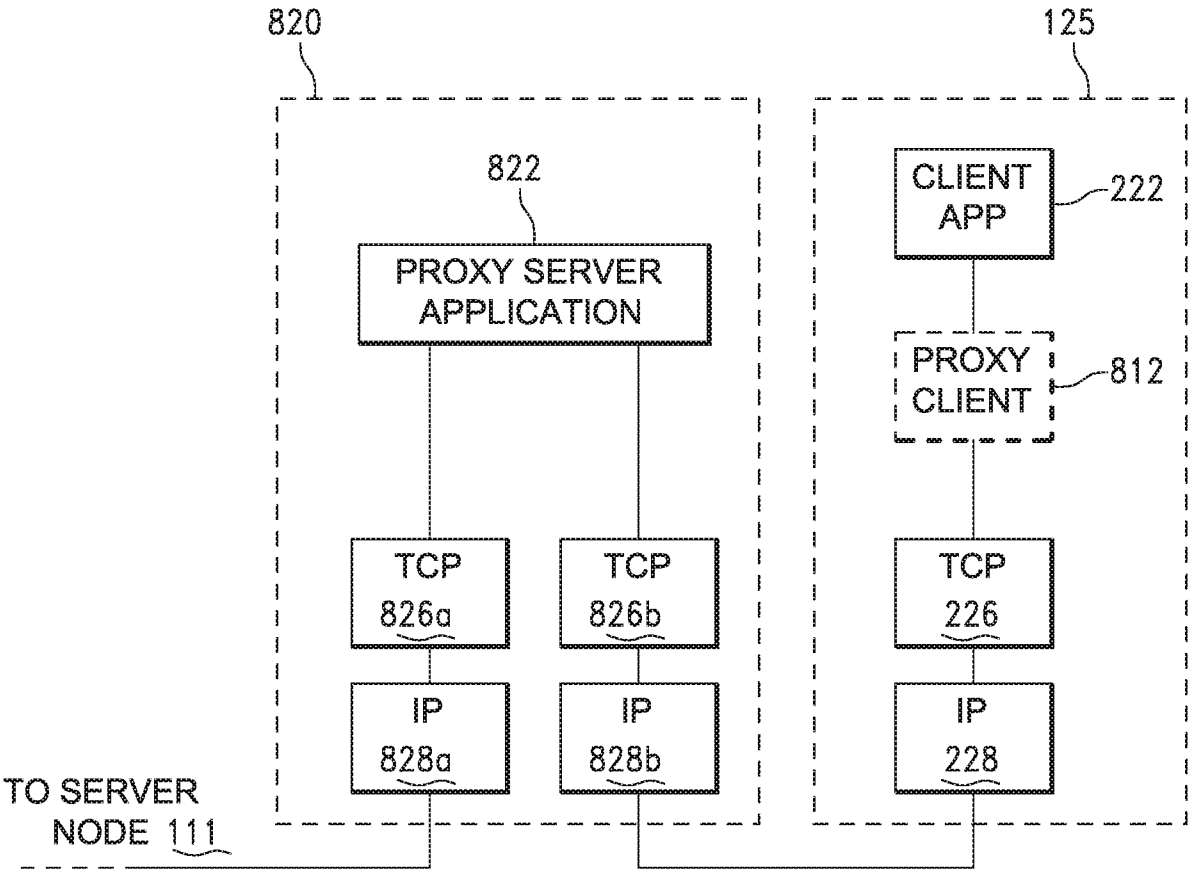

FIG. 190

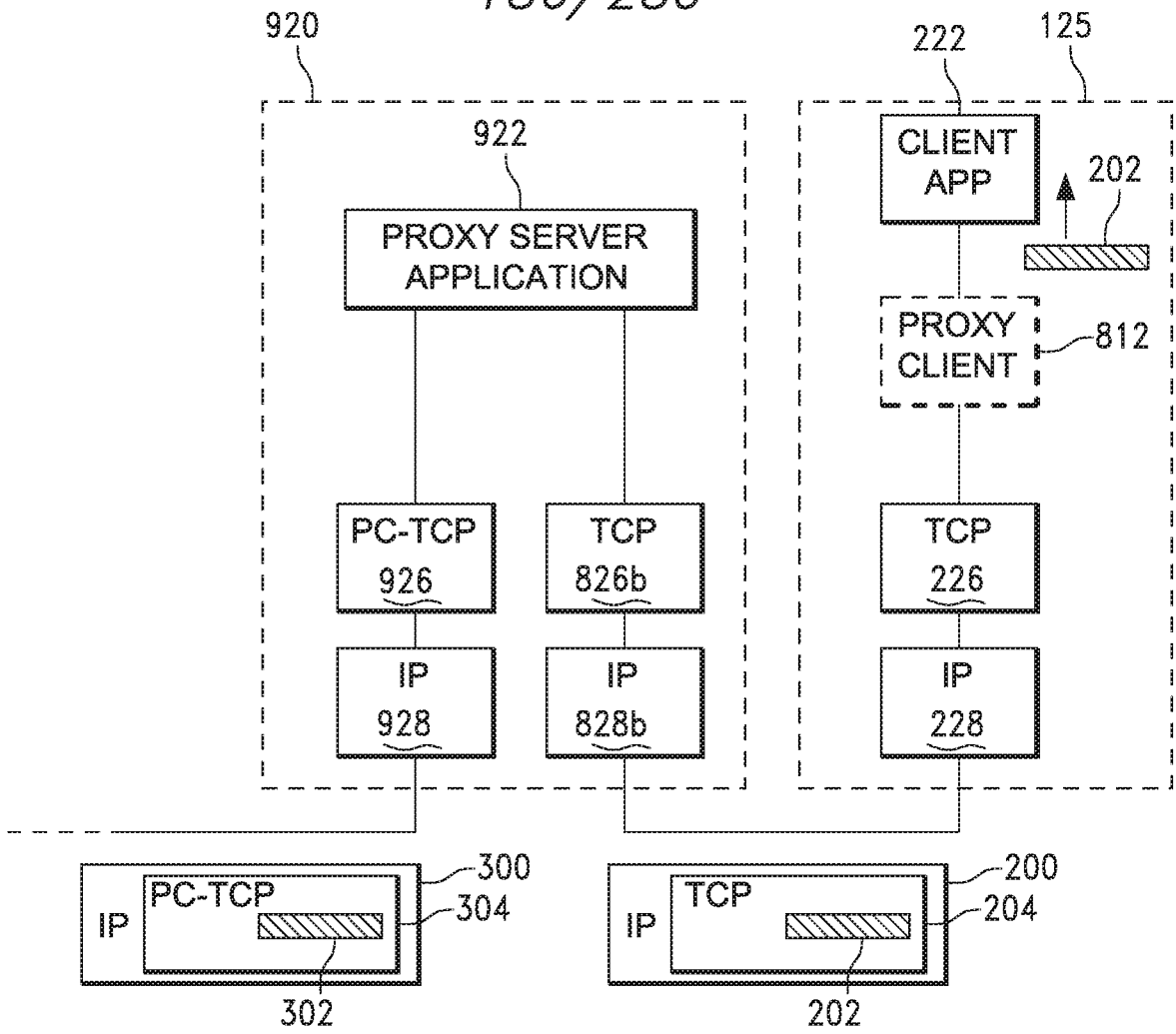

FIG. 191

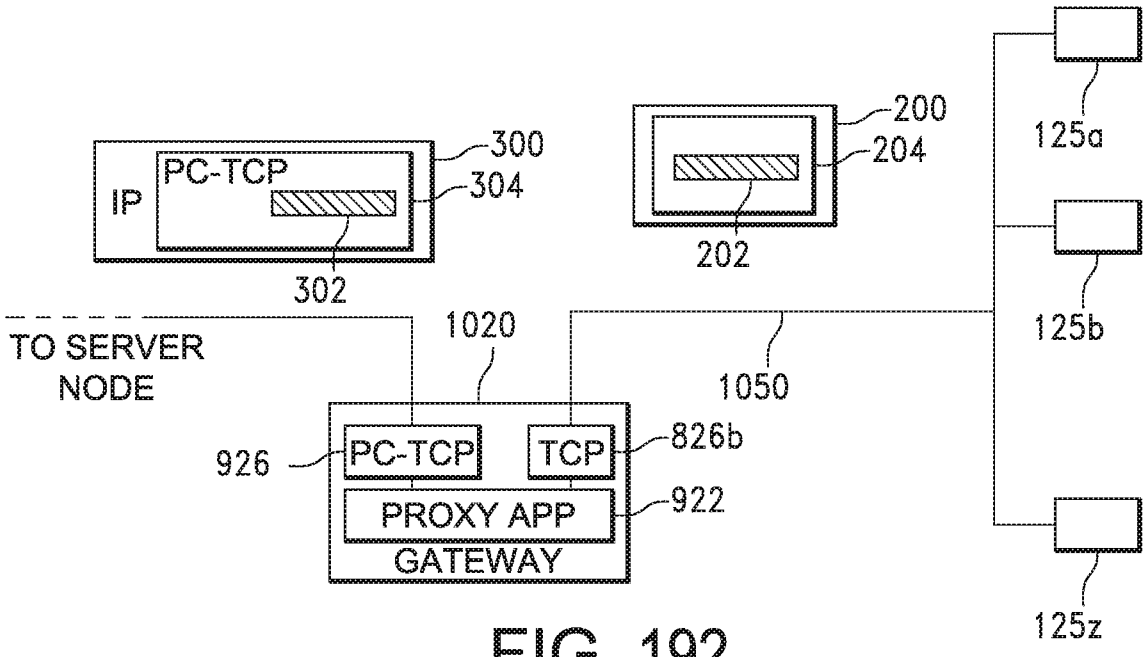

FIG. 192

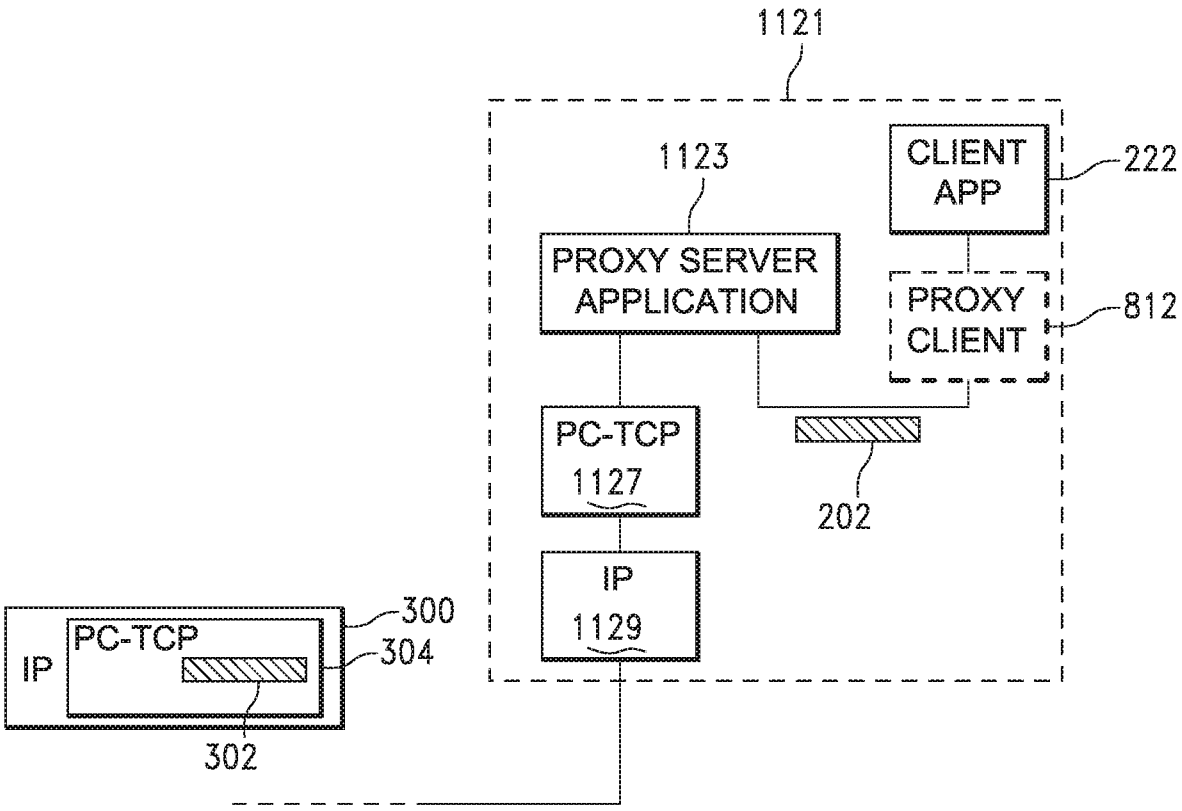

FIG. 193

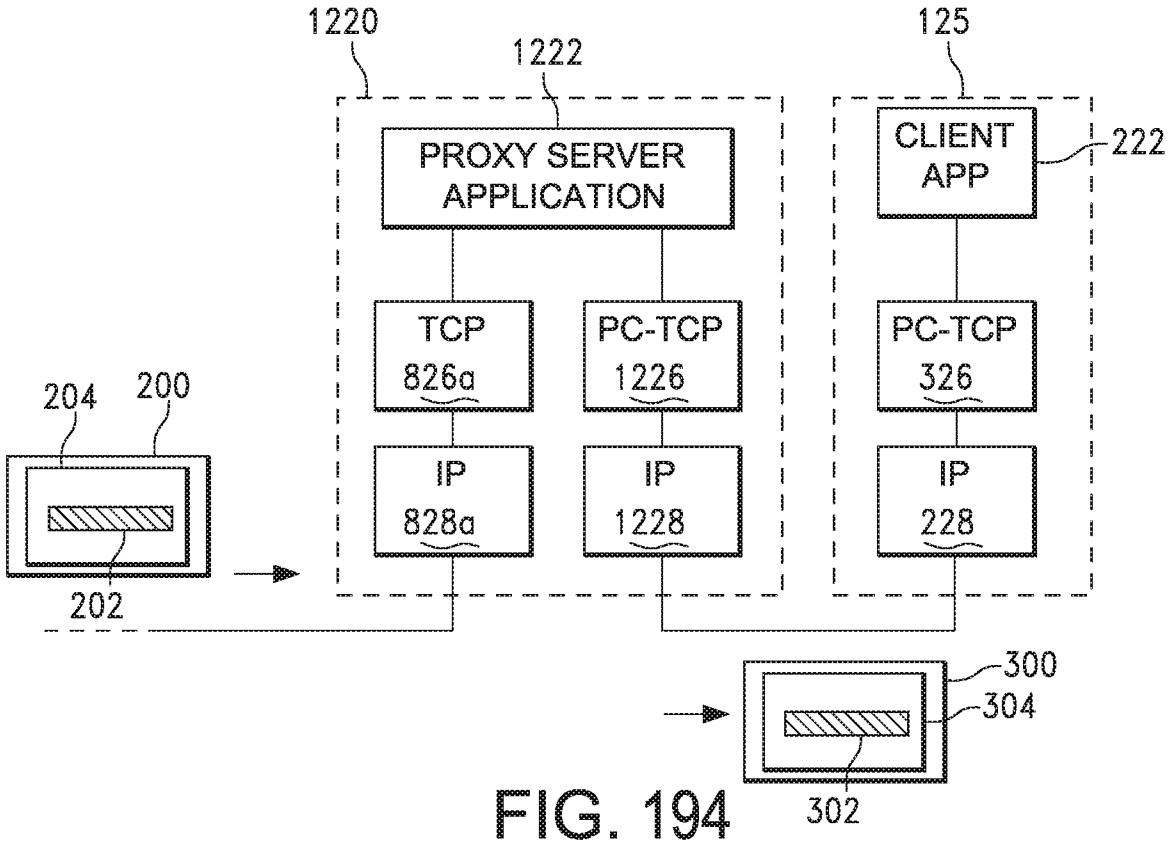

FIG. 194

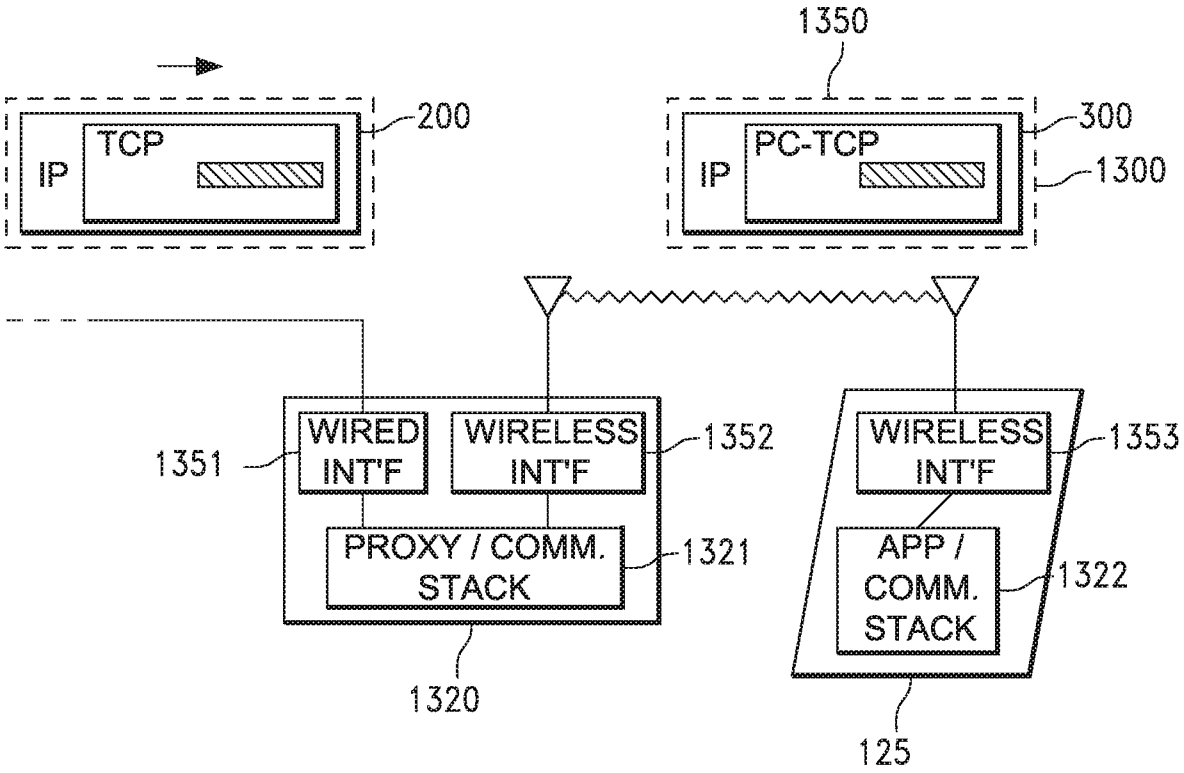

FIG. 195

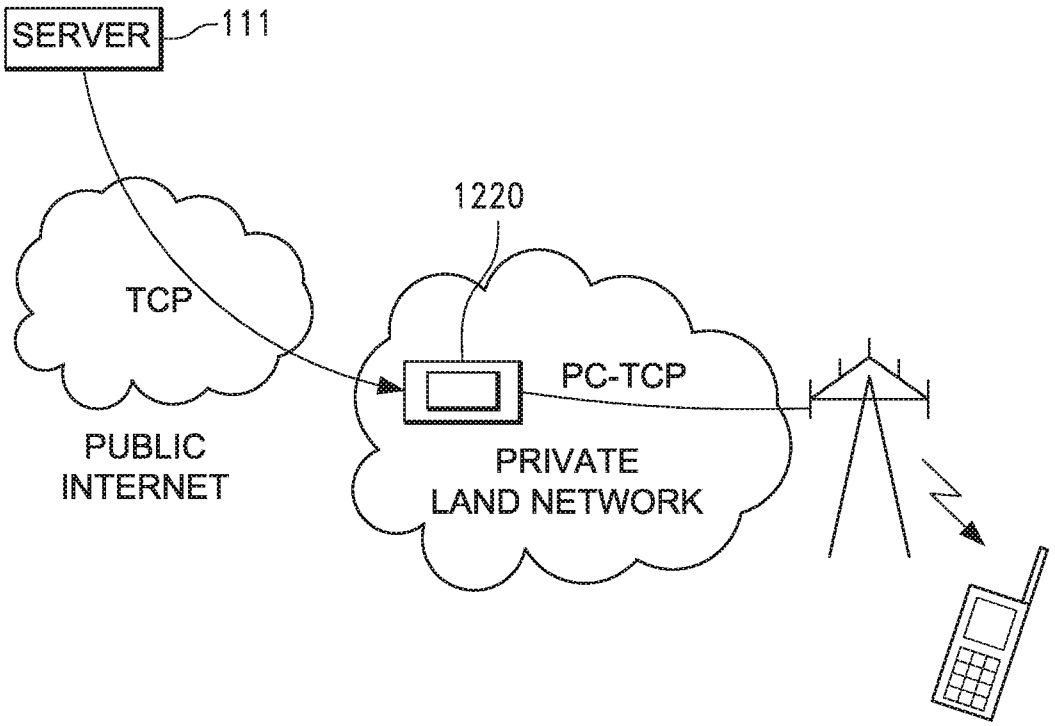

FIG. 196

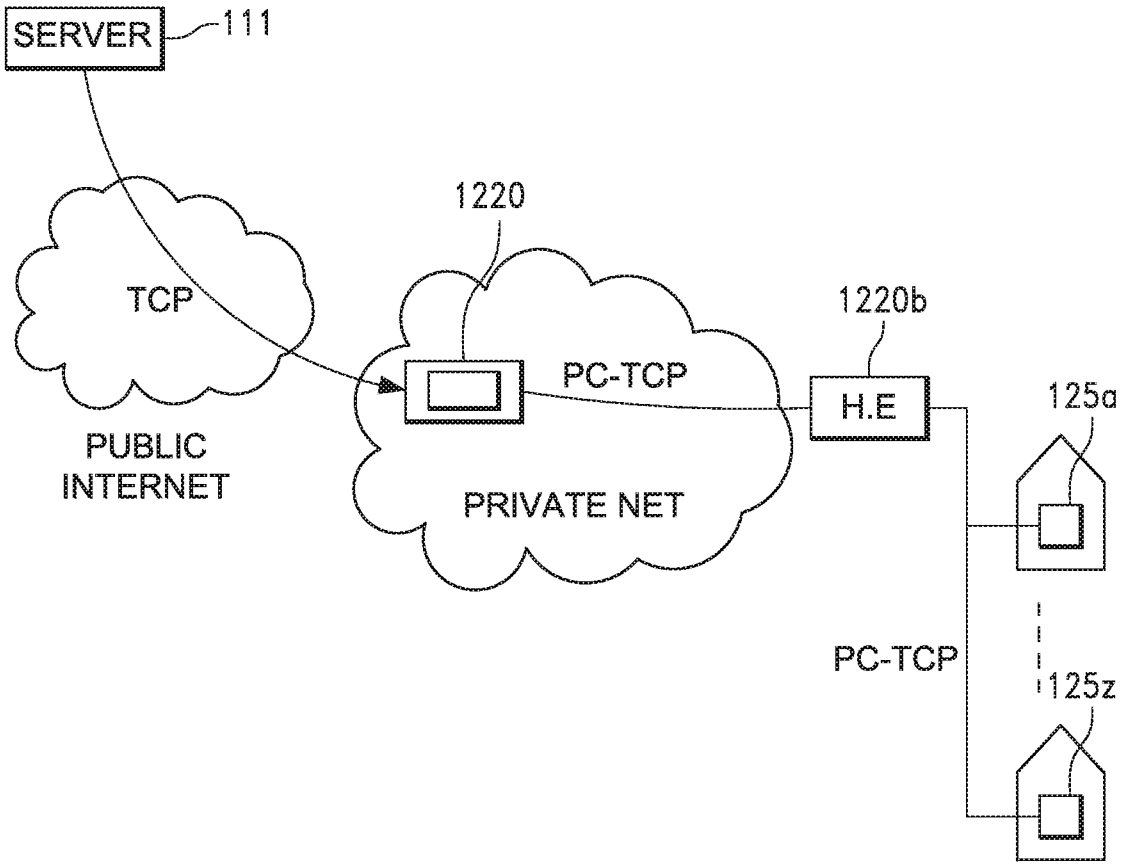

FIG. 197

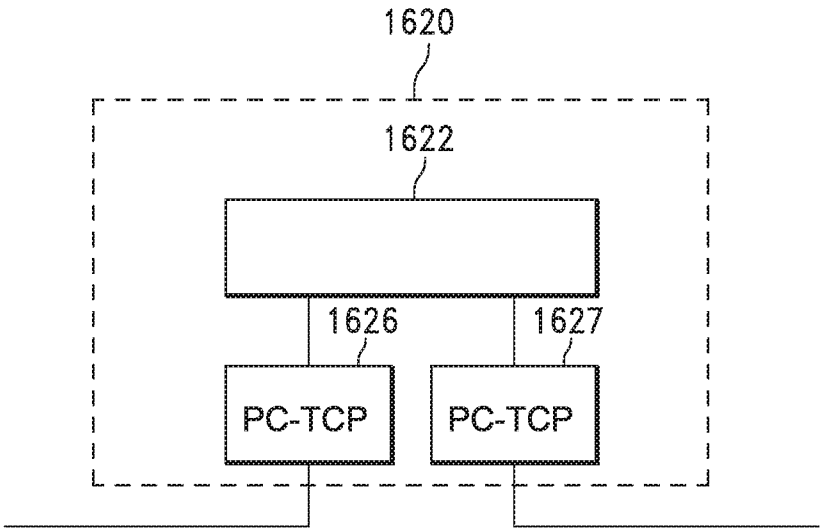

FIG. 198

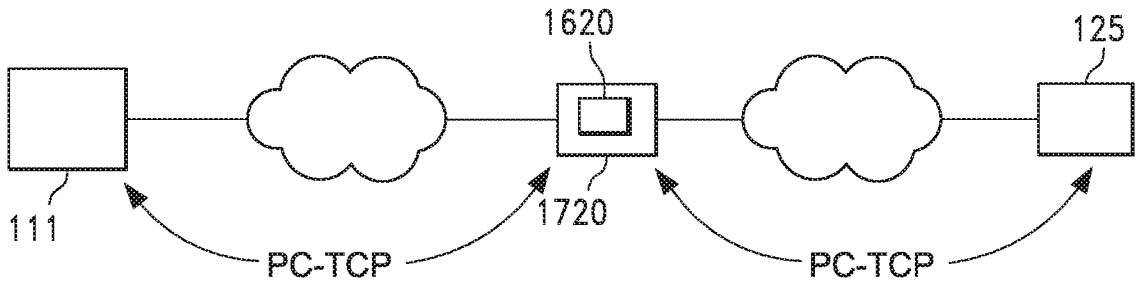

FIG. 199

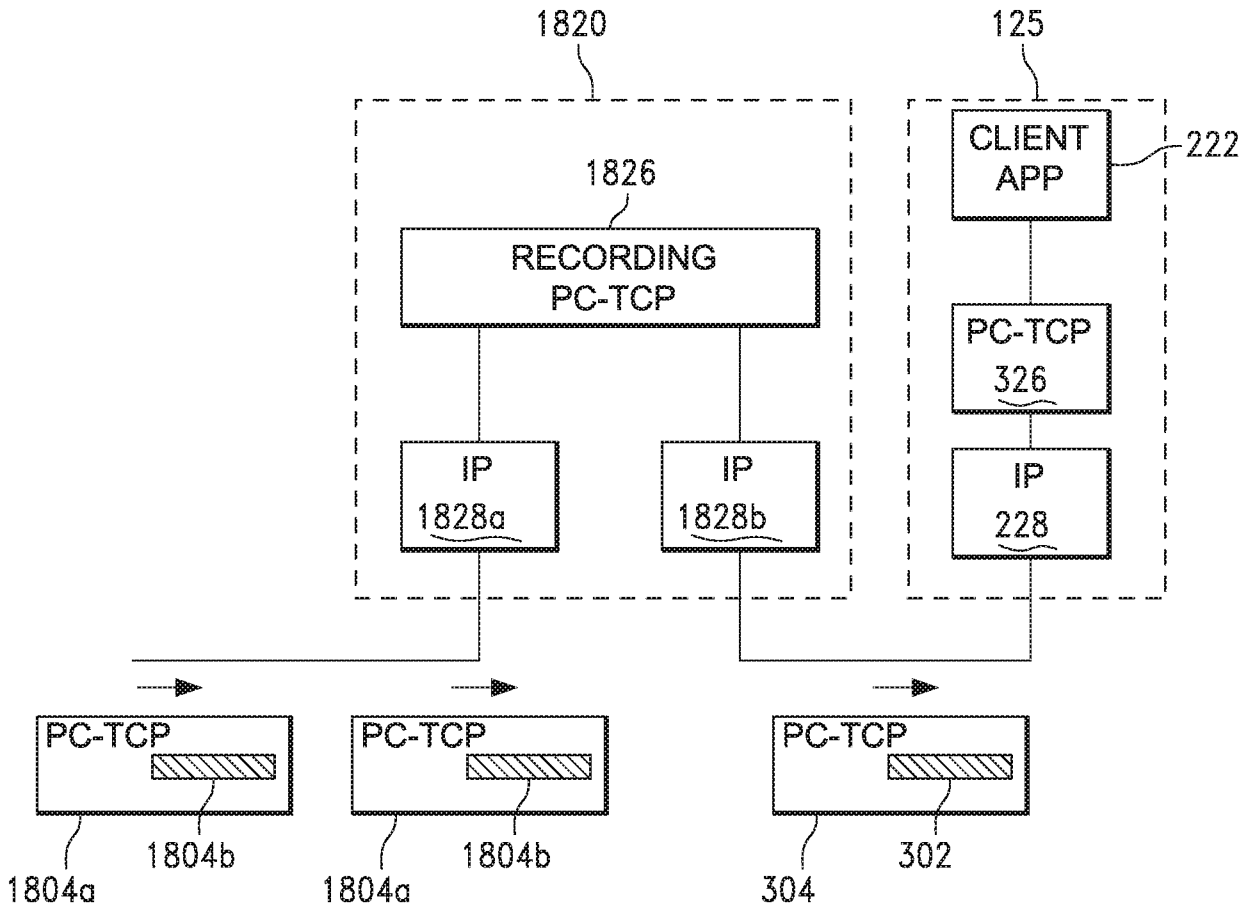

FIG. 200

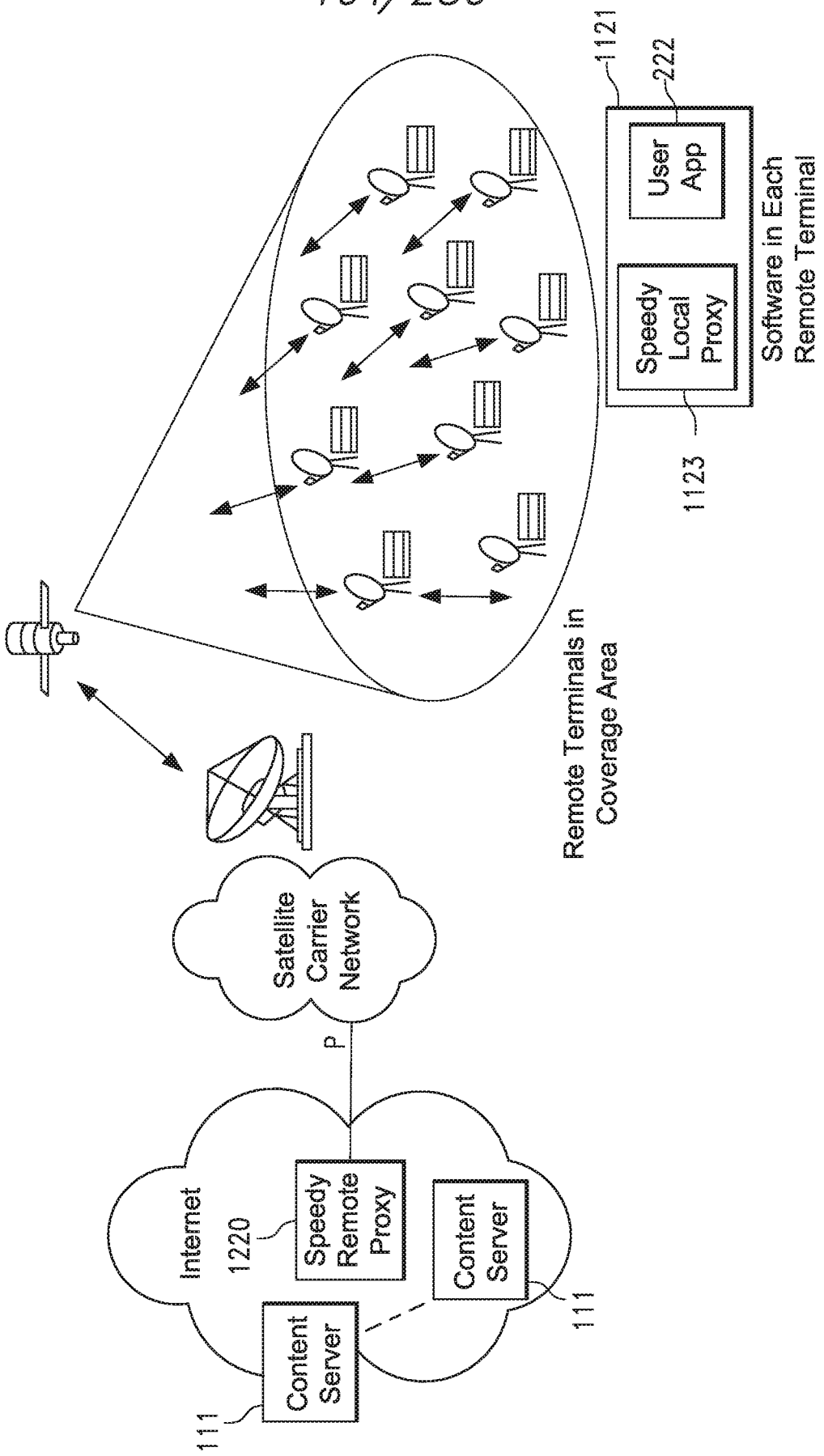
Internet
1220
Speedy Remote Proxy
Content Server
111
Content Server
111
P
Satellite Carrier Network
Remote Terminals in Coverage Area
1121
222
User App
Speedy Local Proxy
Software in Each Remote Terminal
1123

FIG. 201

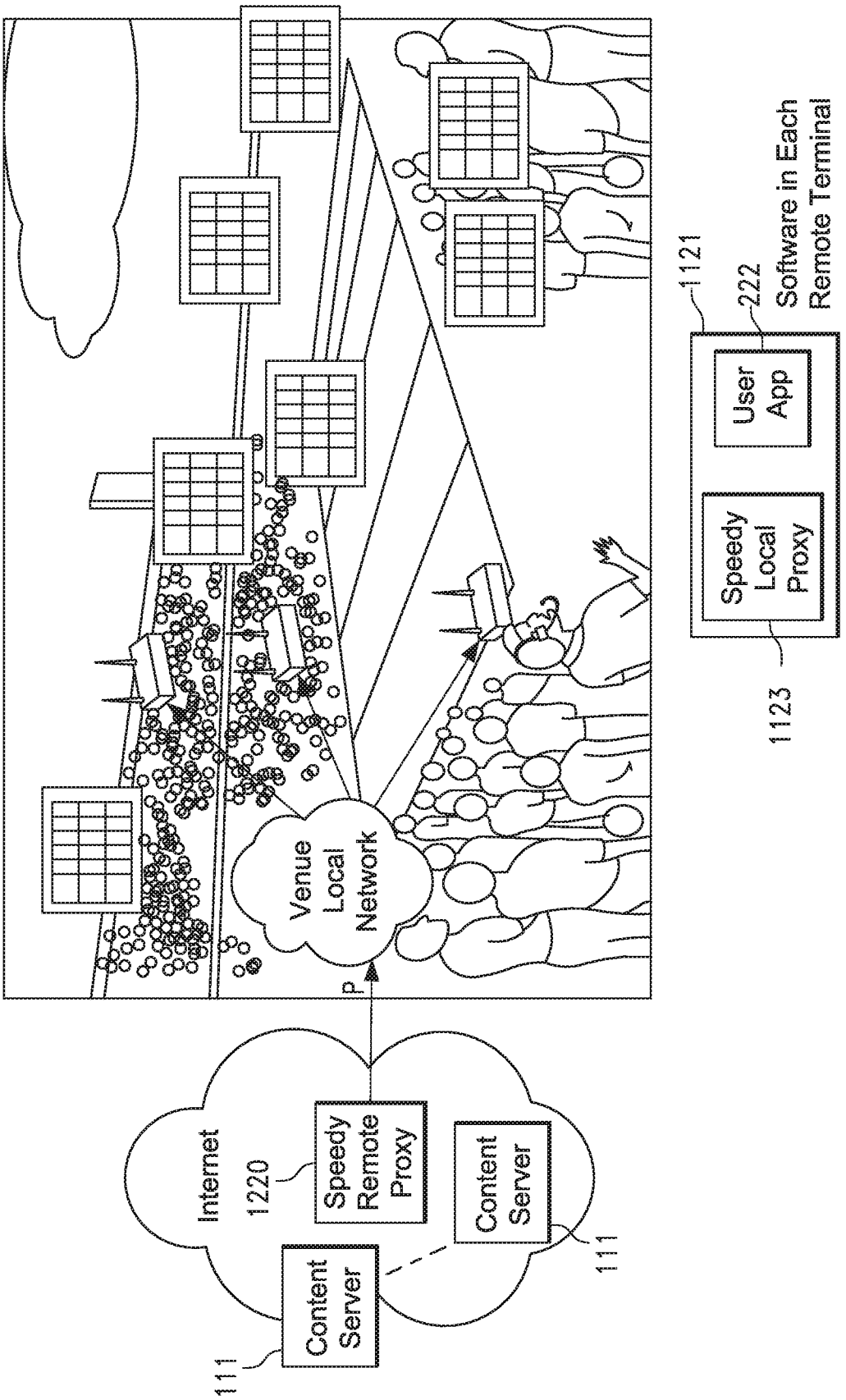
Internet
1220
Speedy Remote Proxy
Content Server
111
Content Server
111
Venue Local Network
1121
222
Software in Each Remote Terminal
User App
Speedy Local Proxy
1123

FIG. 202

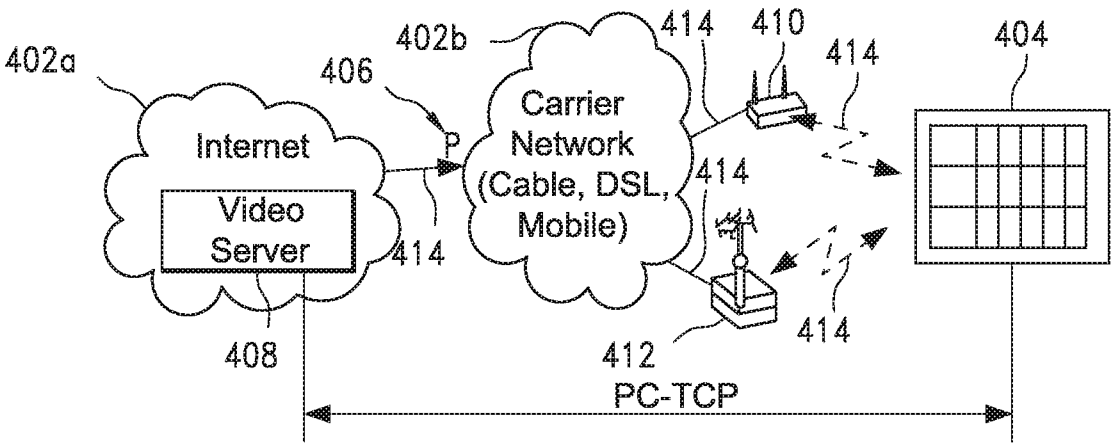

FIG. 203

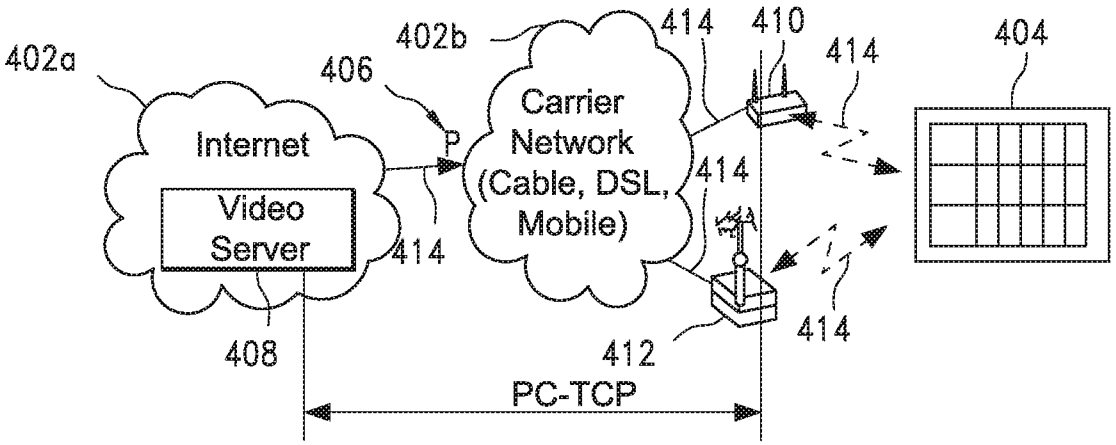

FIG. 204

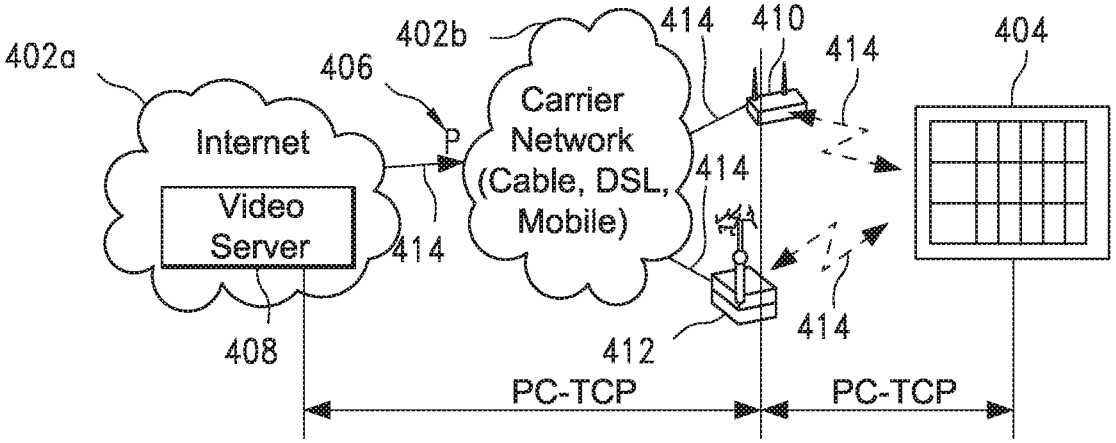

FIG. 205

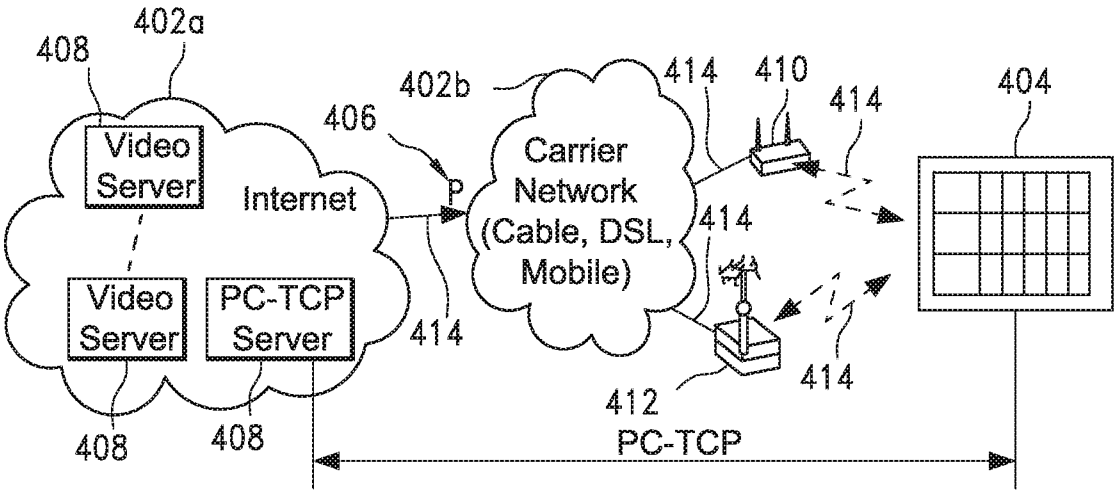

FIG. 206

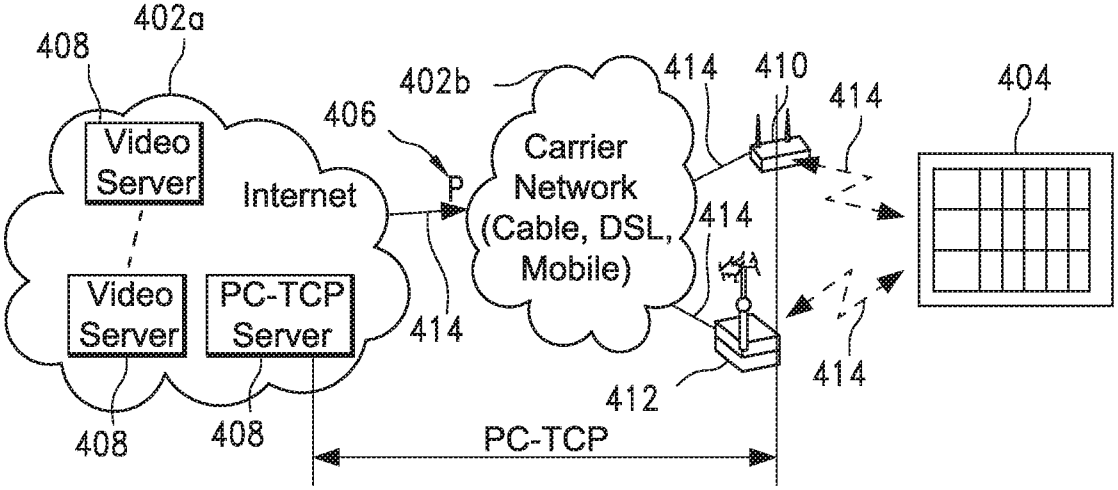

FIG. 207

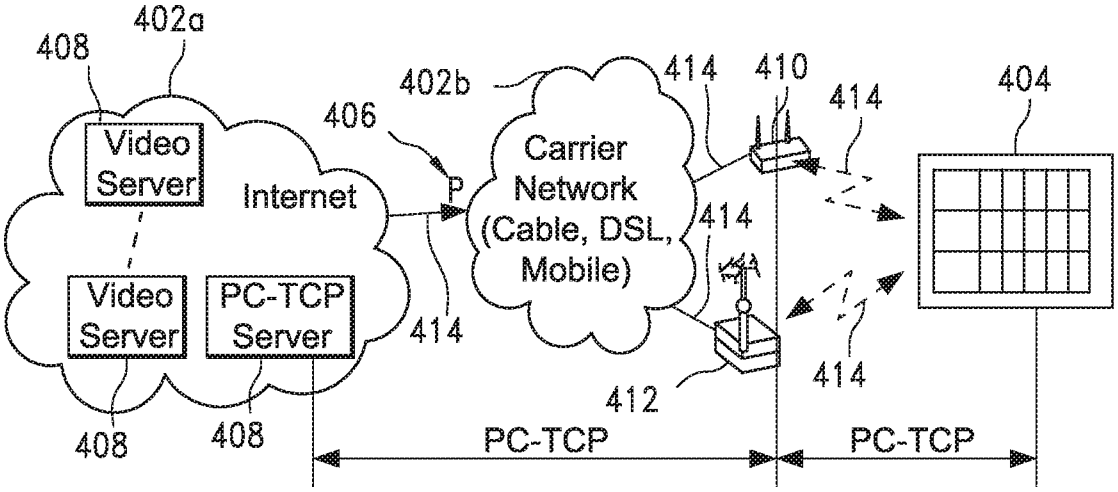

FIG. 208

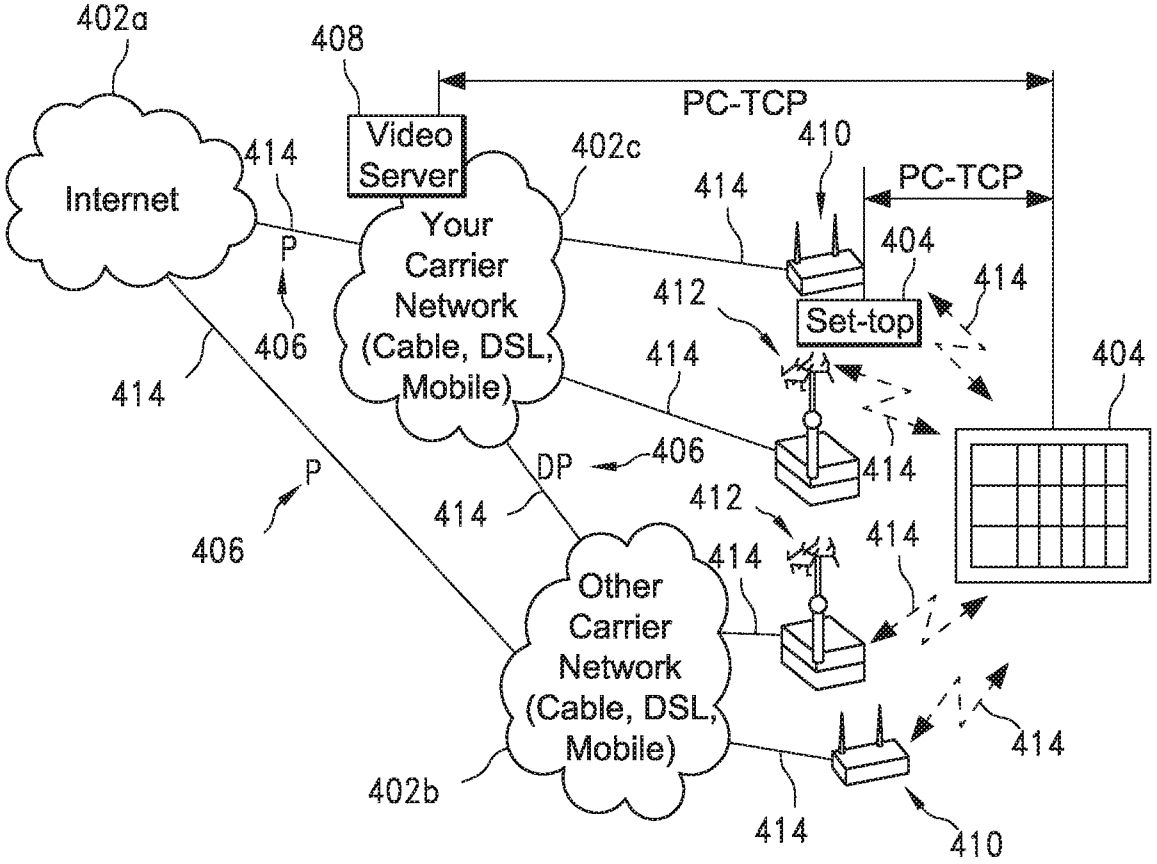

FIG. 209

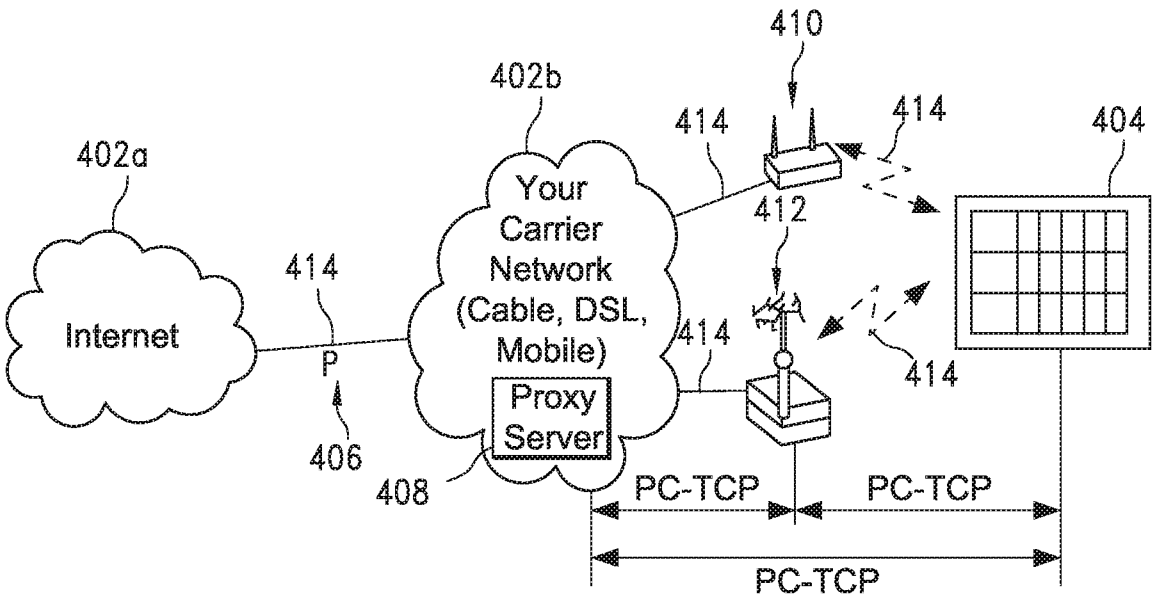

FIG. 210

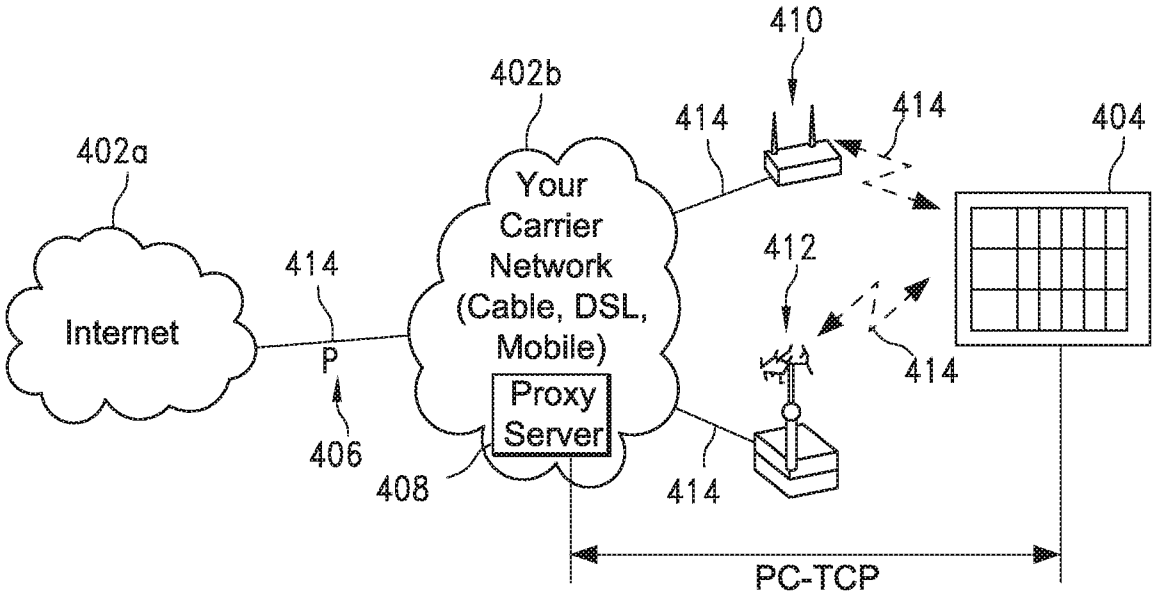

FIG. 211

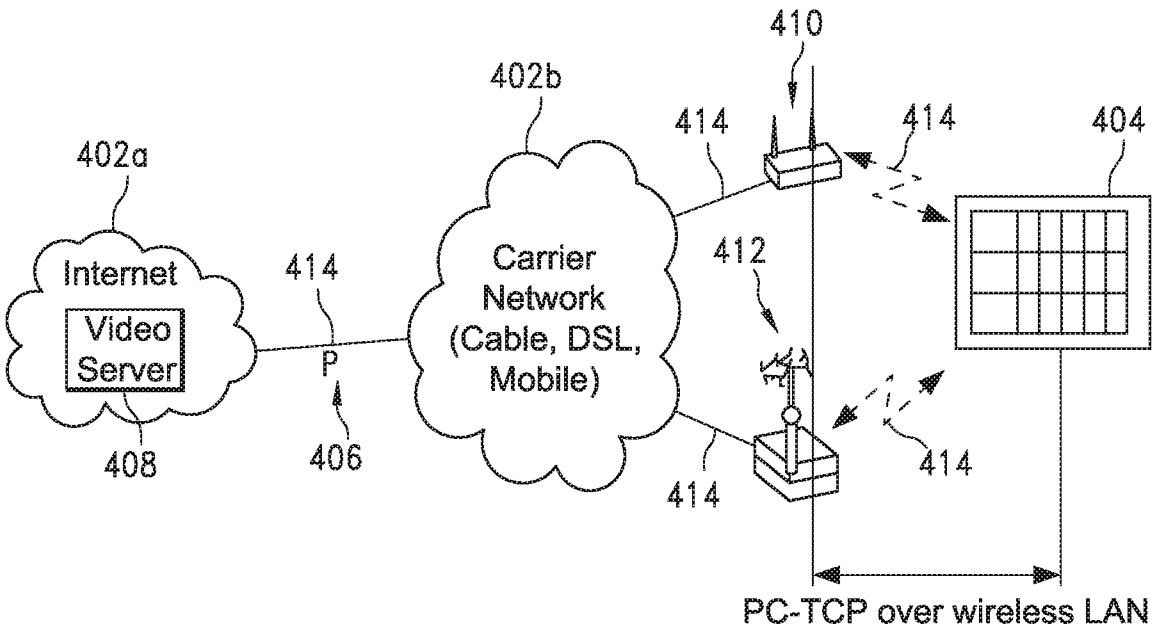

FIG. 212

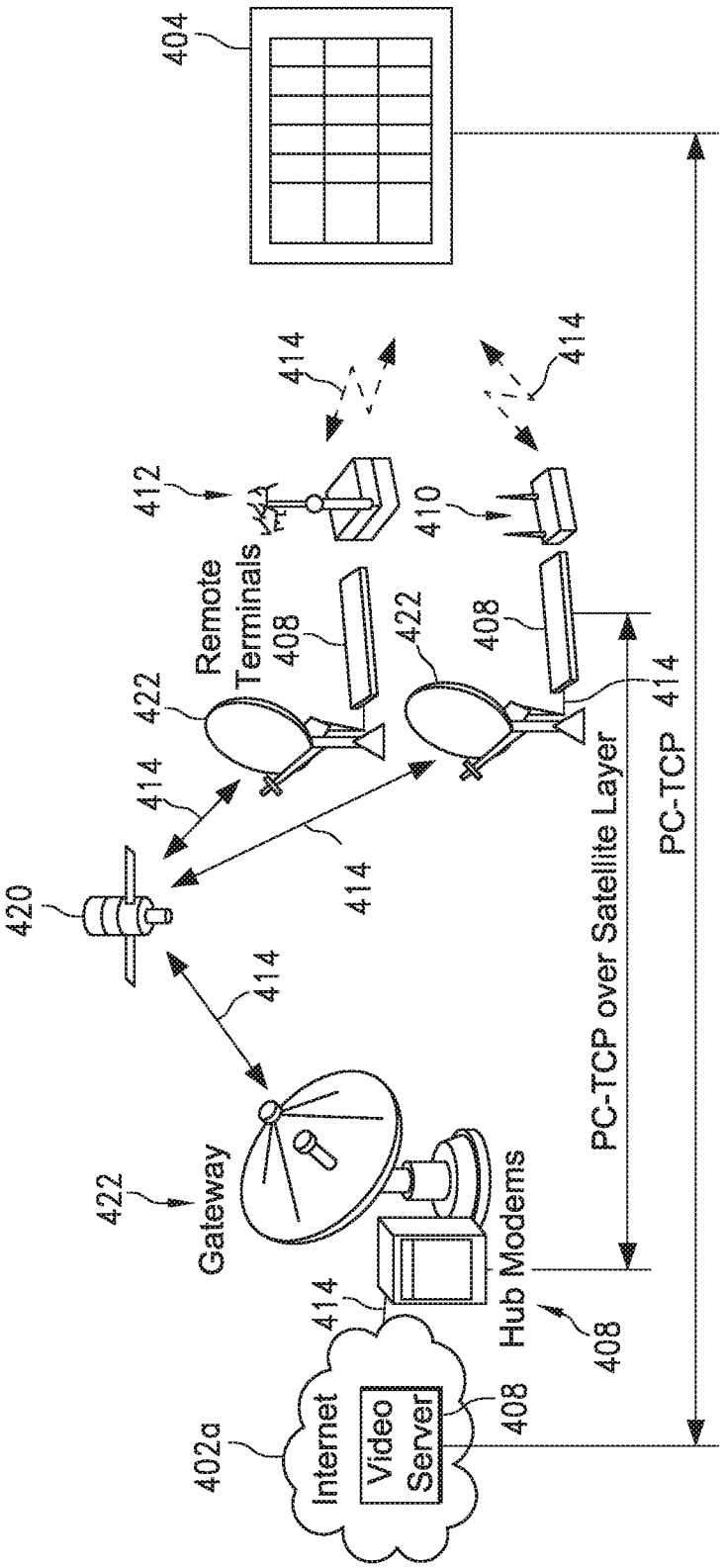
404
414
414
412
410
Remote Terminals
408
422
408
422
422
414
414
420
414
422
Gateway
Hub Modems
408
414
Internet
Video Server
408
402a
PC-TCP over Satellite Layer
PC-TCP 414

FIG. 213

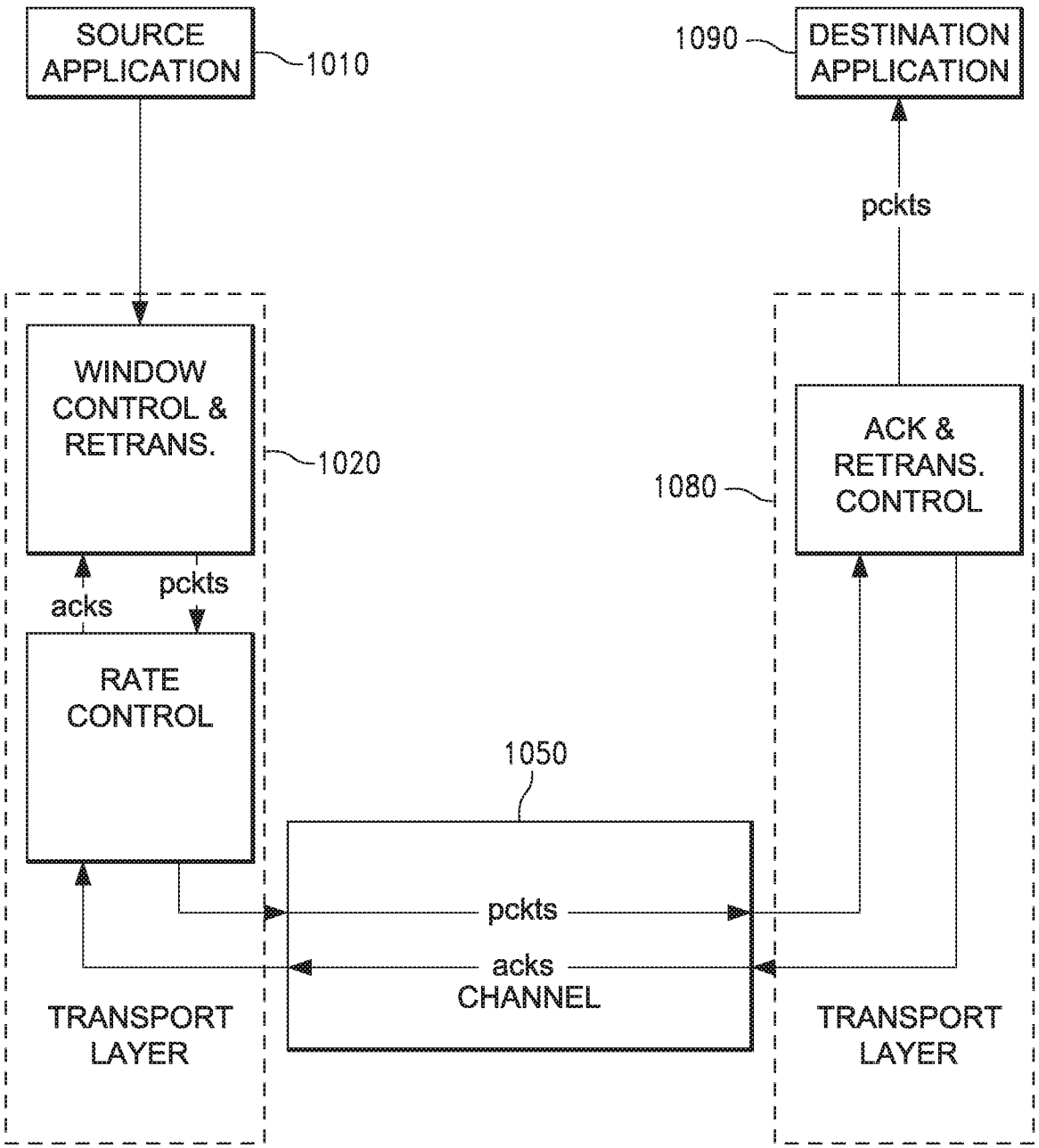
SOURCE APPLICATION
1010
1090
DESTINATION APPLICATION
pckts
WINDOW CONTROL & RETRANS.
1020
ACK & RETRANS. CONTROL
1080
acks
pckts
RATE CONTROL
1050
pckts
acks
CHANNEL
TRANSPORT LAYER
TRANSPORT LAYER

FIG. 214

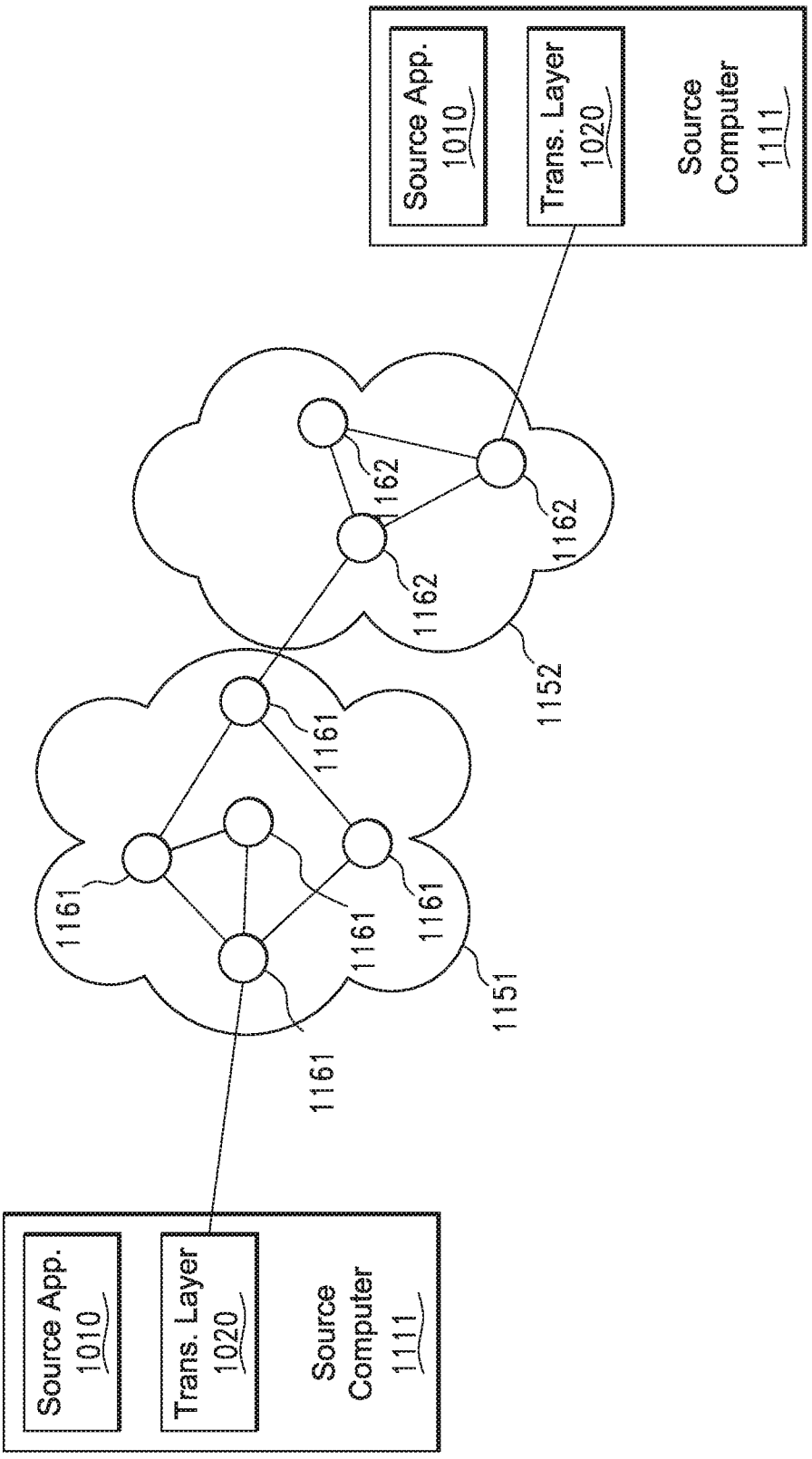
Source App. 1010
Trans. Layer 1020
Source Computer 1111
Source App. 1010
Trans. Layer 1020
Source Computer 1111
1161
1161
1161
1161
1161
1151
1152
1162
1162
1162

FIG. 215

200/280

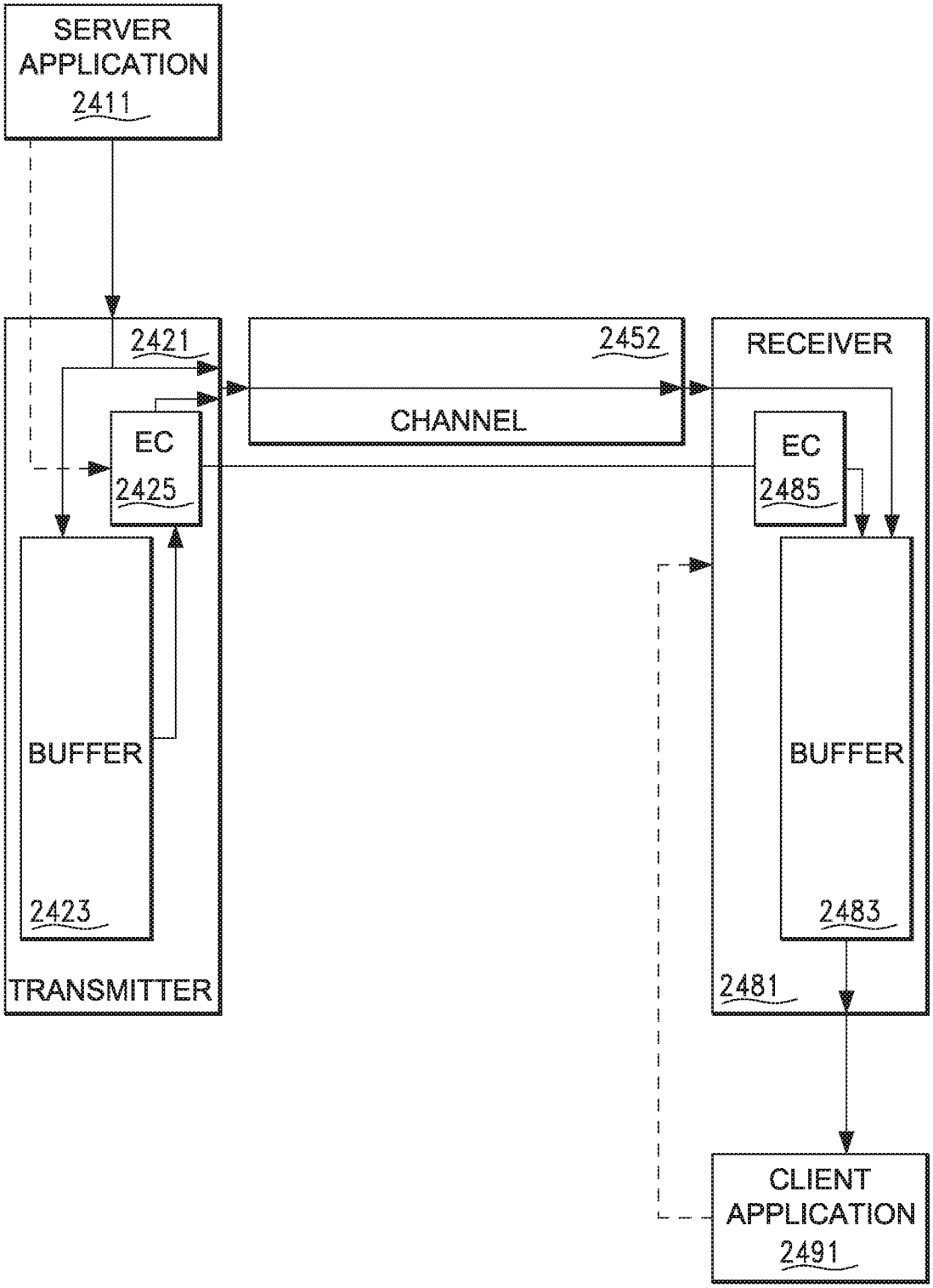

FIG. 216

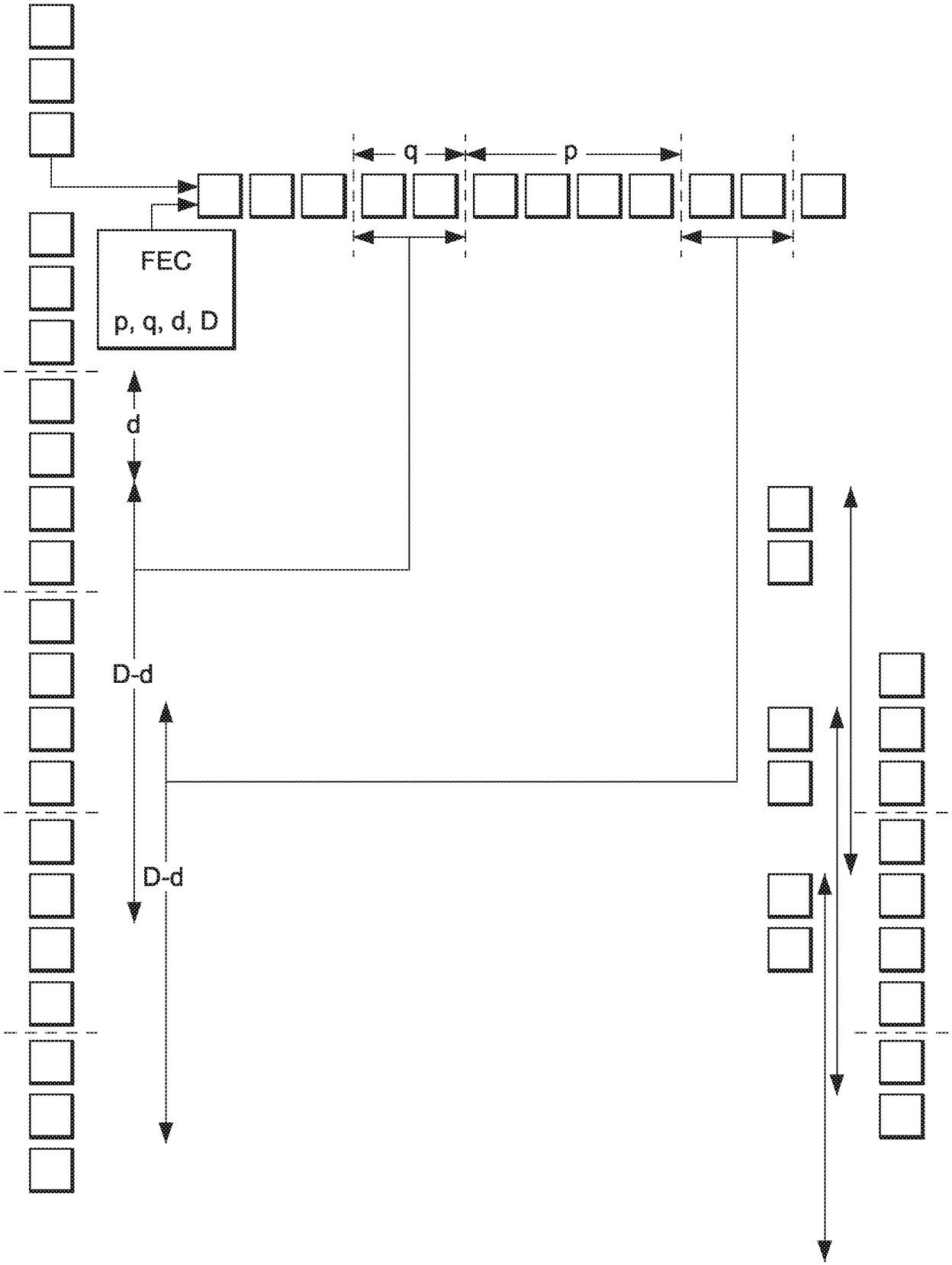

FIG. 217

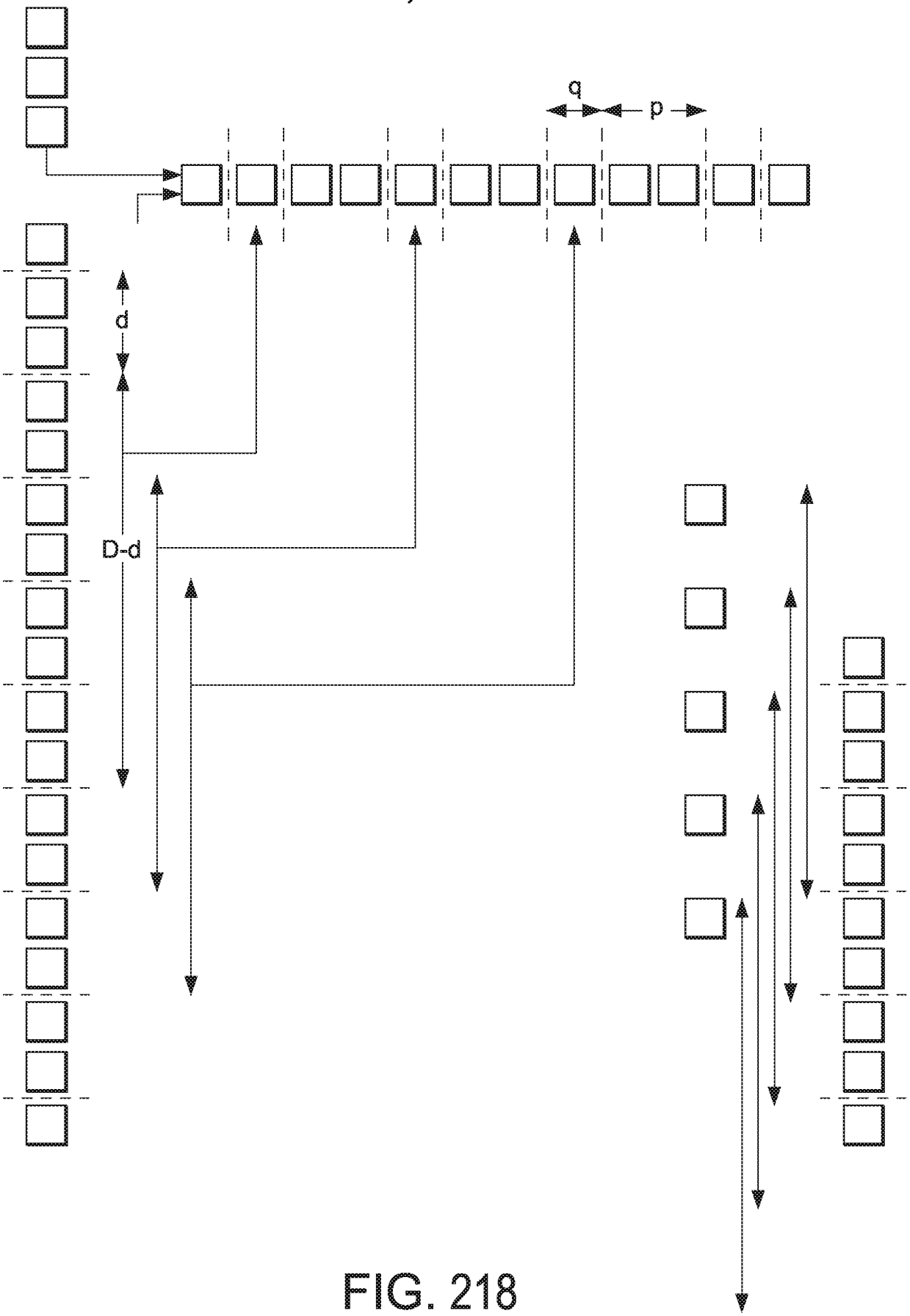

FIG. 218

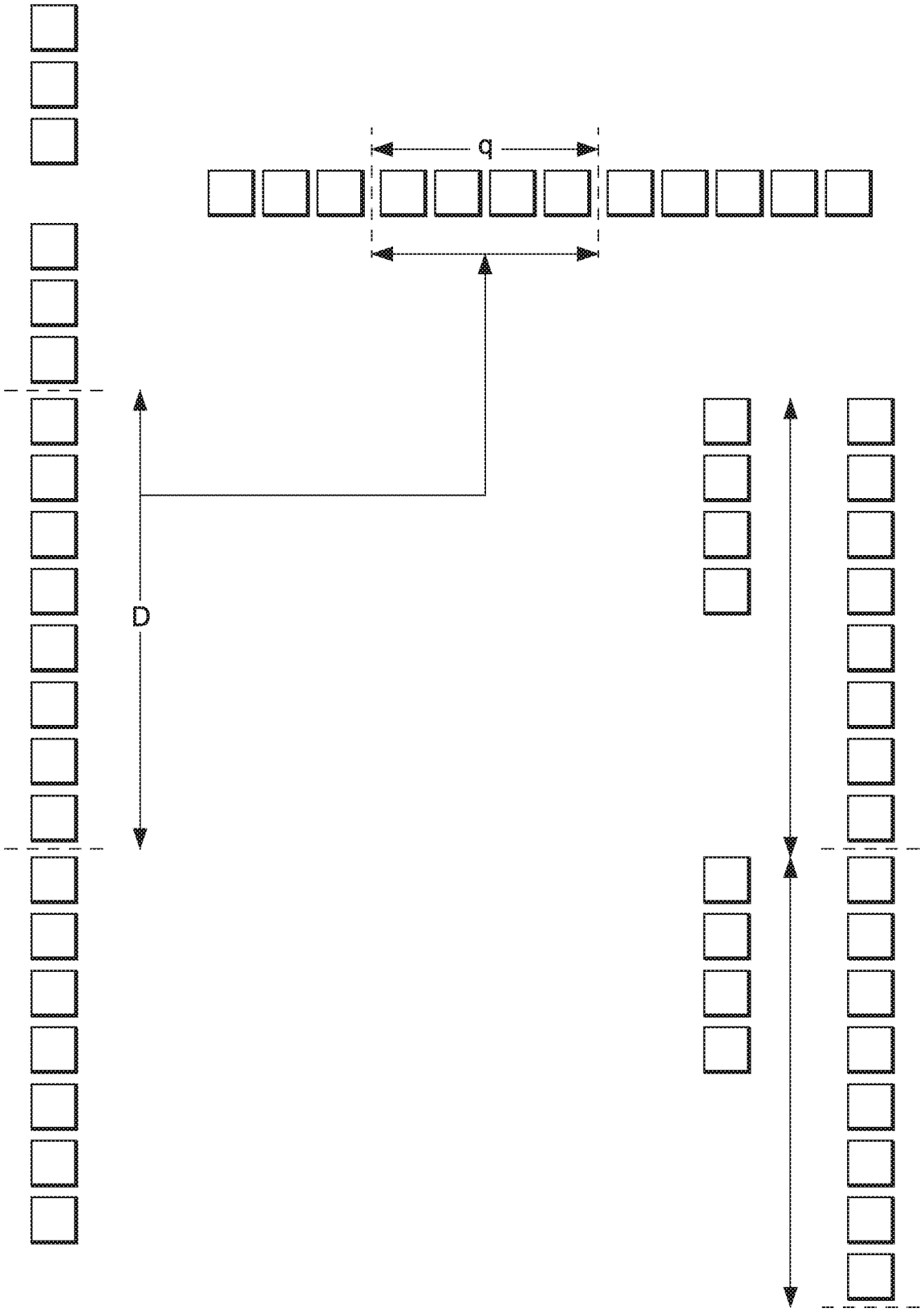

FIG. 219

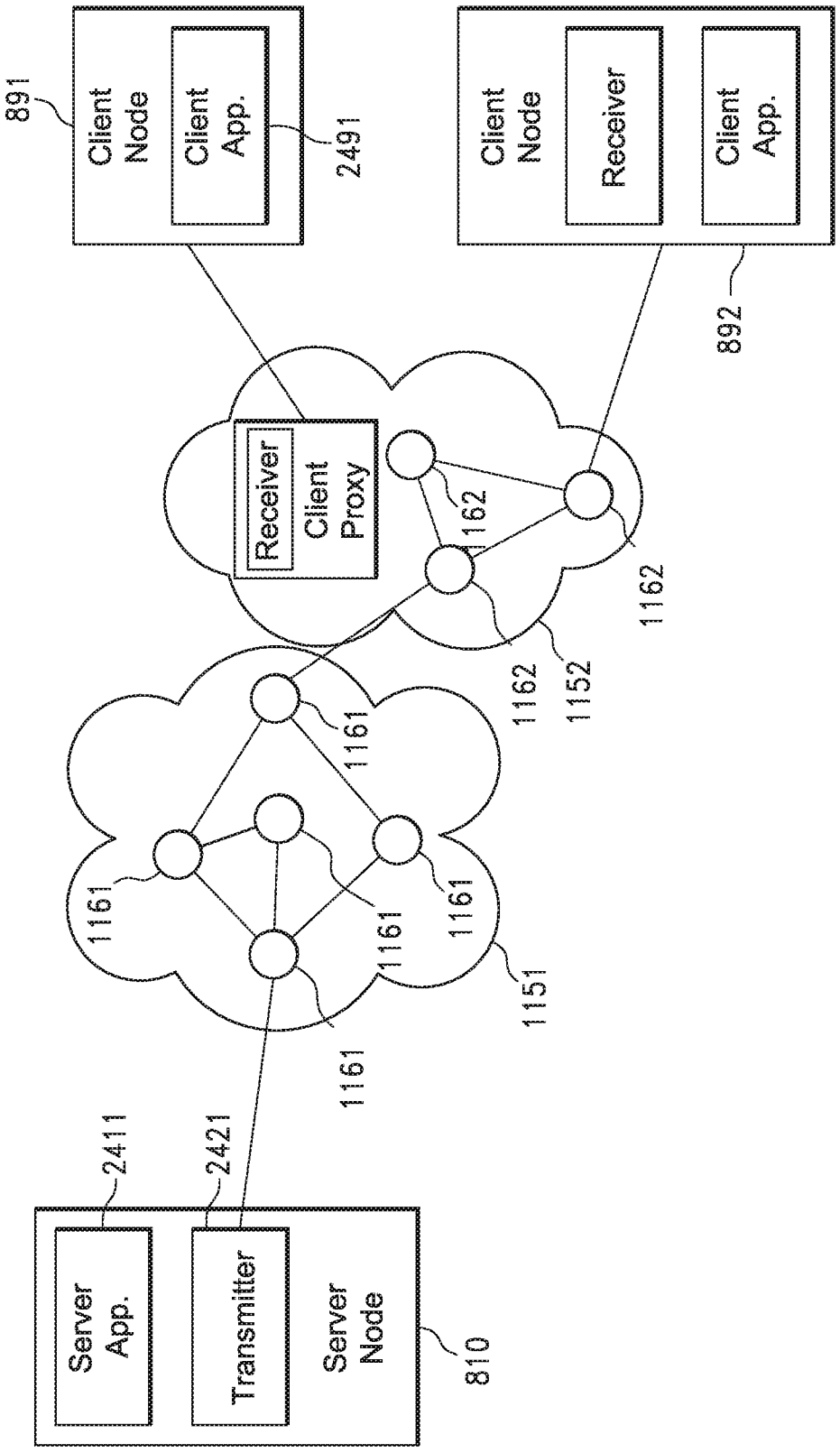
891
Client Node
Client App.
2491
Client Node
Receiver
Client App.
892
Receiver
Client Proxy
162
1162
1162
1152
1161
1161
1161
1161
1151
1161
2411
2421
Server App.
Transmitter
Server Node
810

FIG. 220

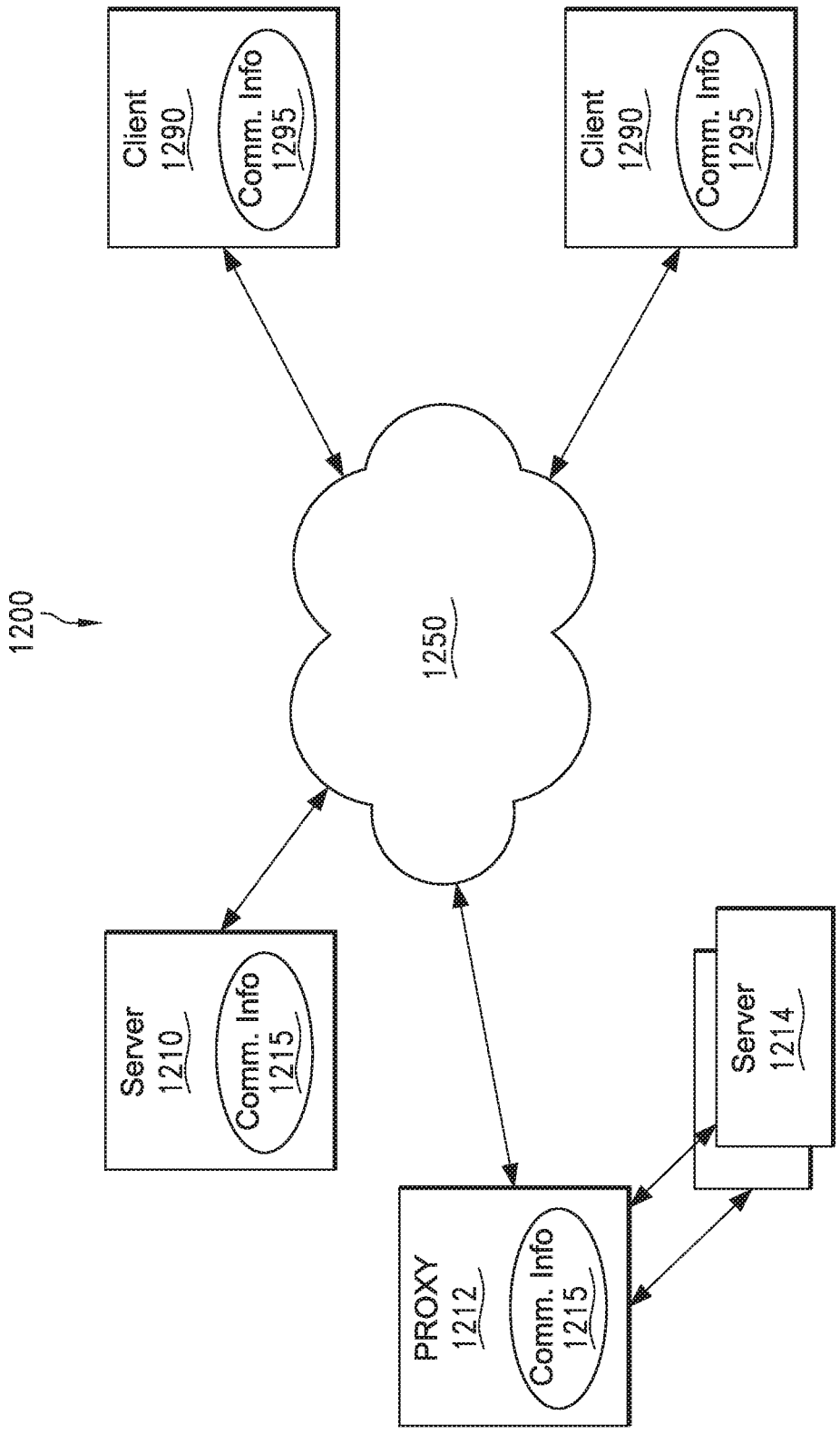
1200
Client 1290
Comm. Info 1295
Client 1290
Comm. Info 1295
1250
Server 1210
Comm. Info 1215
Server 1214
PROXY 1212
Comm. Info 1215

FIG. 221

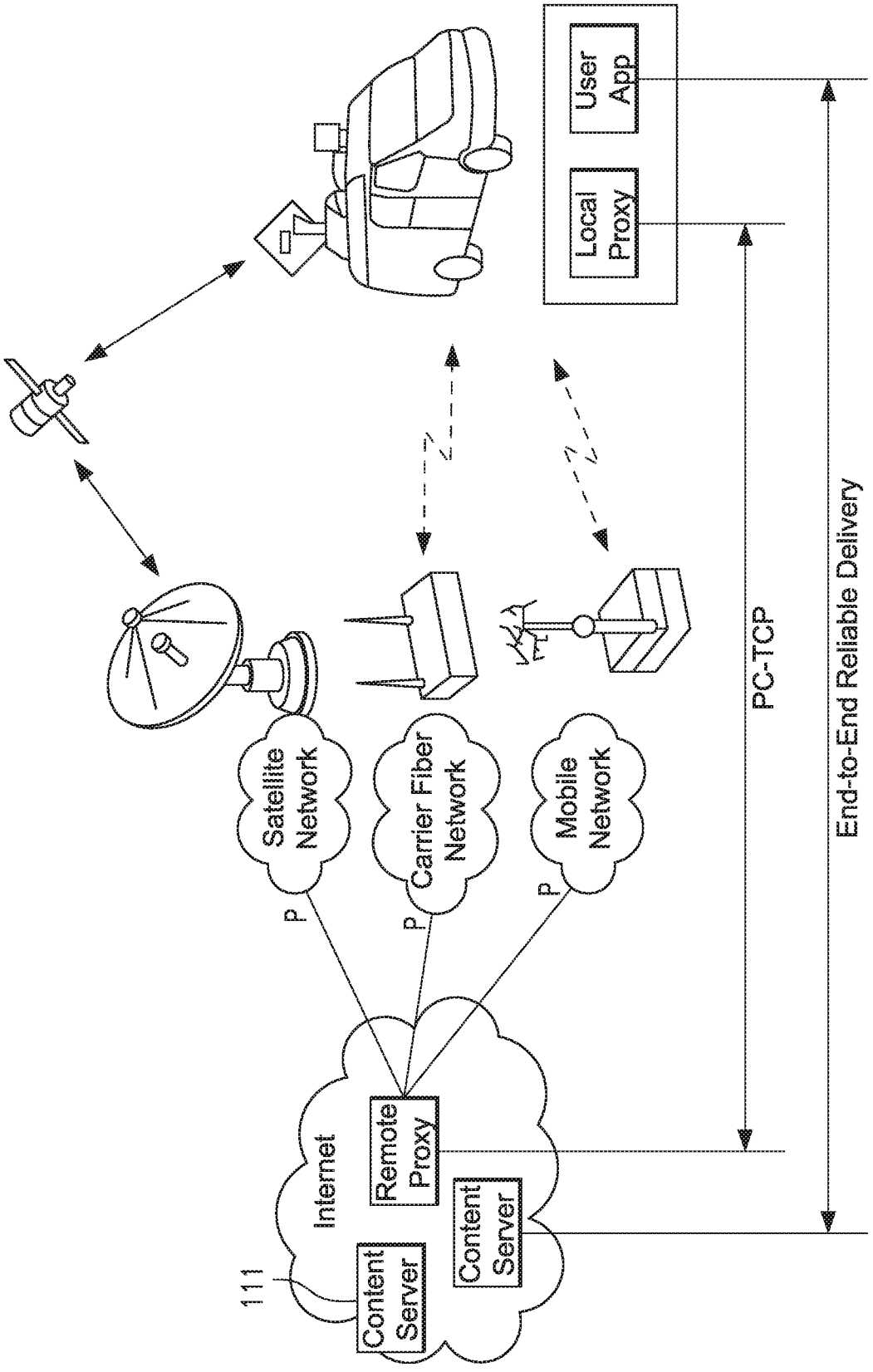
User App
Local Proxy
PC-TCP
End-to-End Reliable Delivery
Satellite Network
Carrier Fiber Network
Mobile Network
P
P
P
Internet
Remote Proxy
Content Server
Content Server
111

FIG. 222

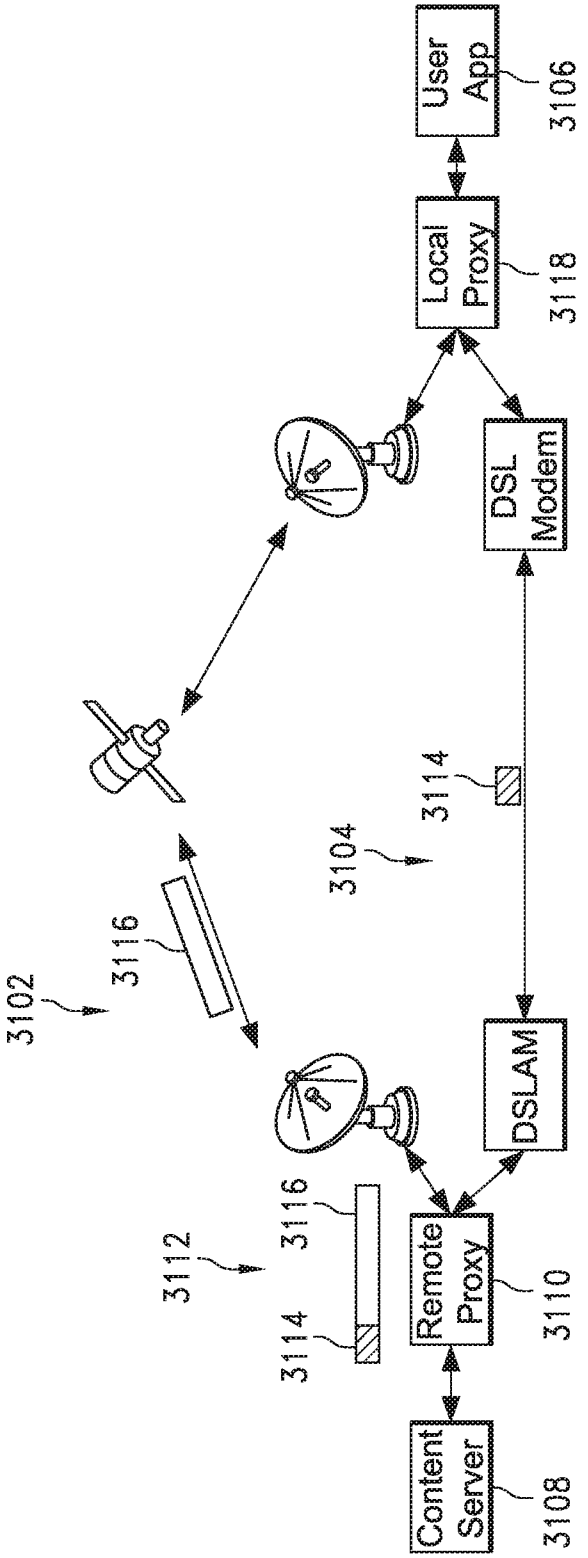
User App
3106
Local Proxy
3118
DSL Modem
3114
3104
3116
3102
DSLAM
3116
3112
3114
Remote Proxy
3110
Content Server
3108

FIG. 223

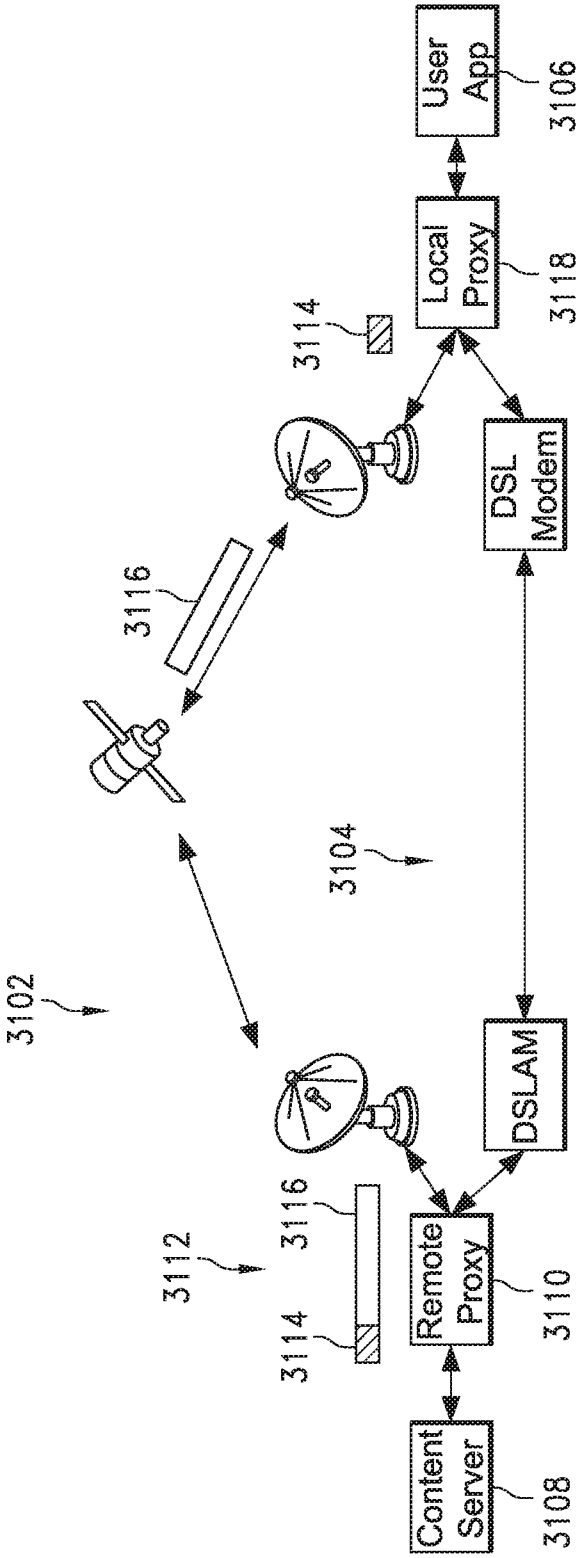
User App
3106
Local Proxy
3118
3114
DSL Modem
3116
3104
3102
DSLAM
3116
3112
3114
Remote Proxy
3110
Content Server
3108

FIG. 224

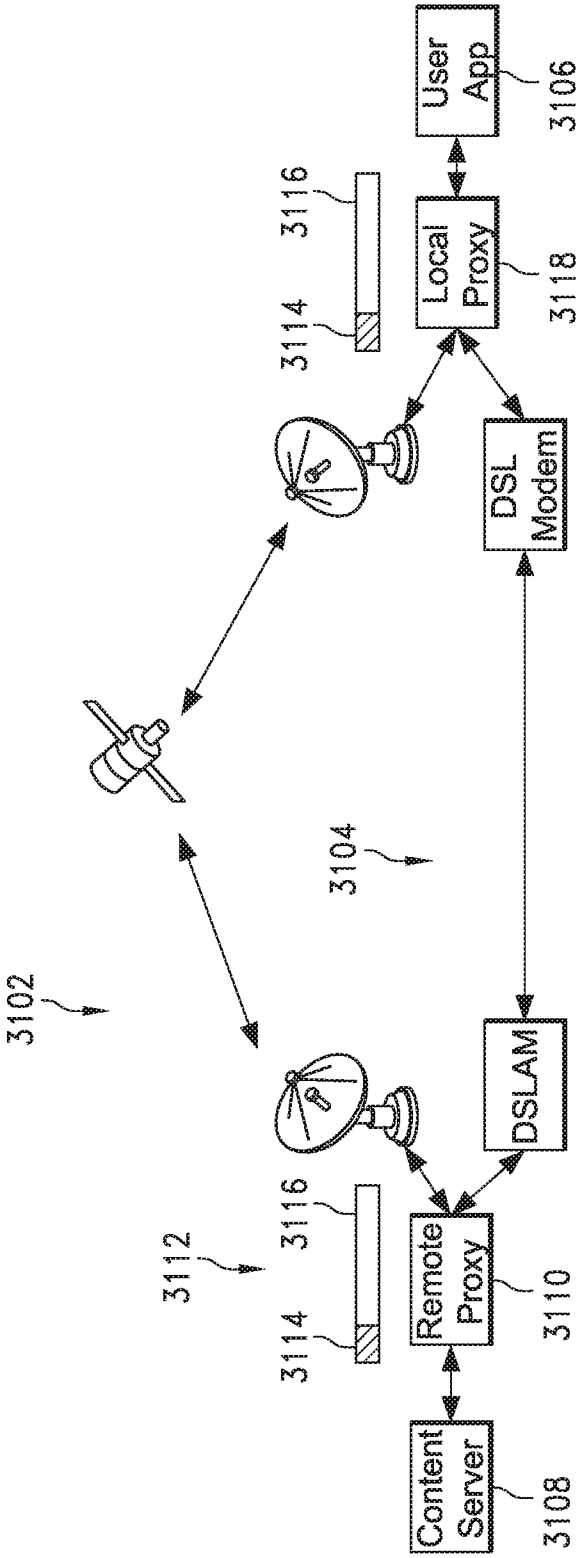
User App
3106
3116
Local Proxy
3118
3114
DSL Modem
3104
3102
DSLAM
3112
3116
Remote Proxy
3110
3114
Content Server
3108

FIG. 225

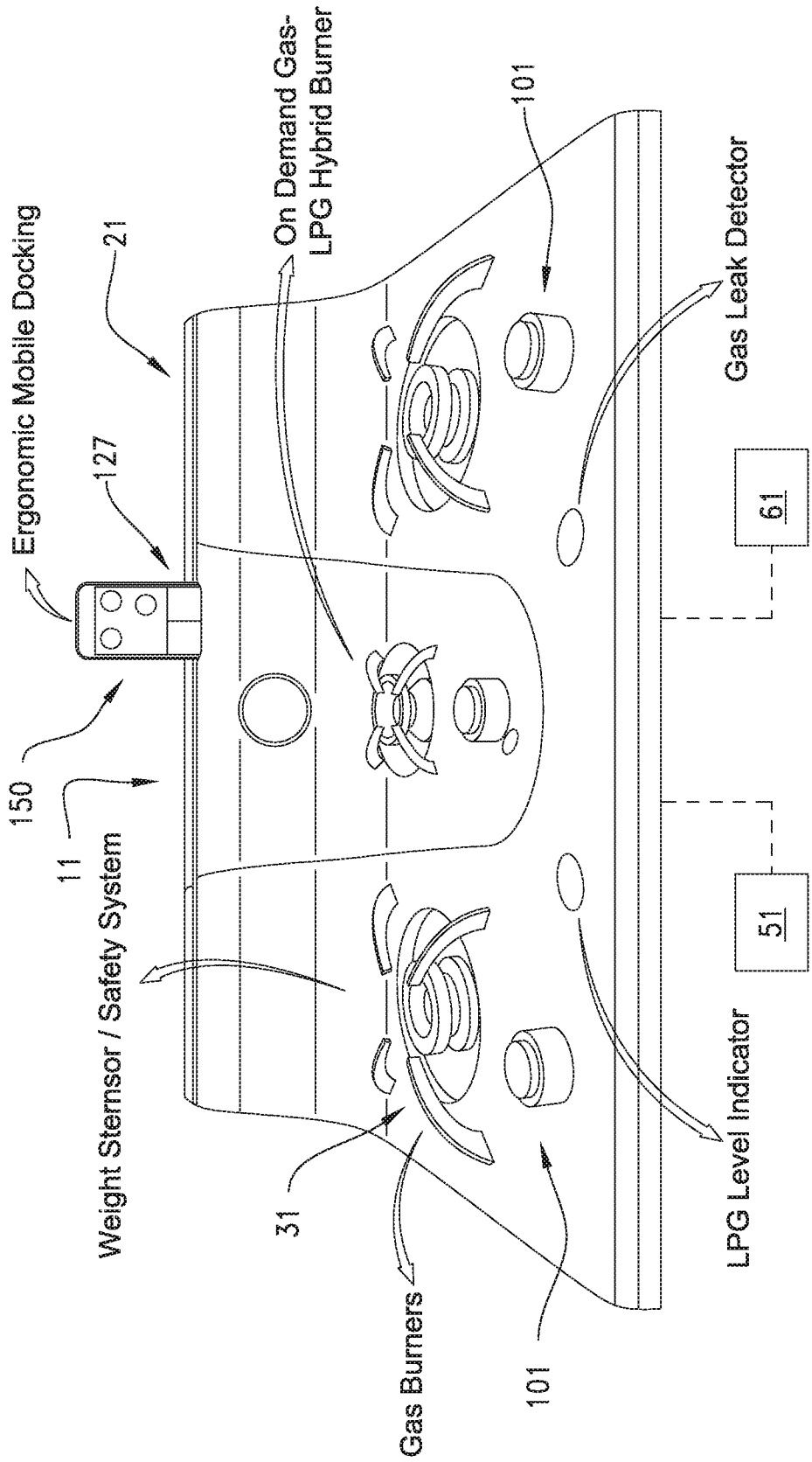
Ergonomic Mobile Docking
21
On Demand Gas-
LPG Hybrid Burner
101
Gas Leak Detector
127
61
150
11
Weight Sternsor / Safety System
51
31
LPG Level Indicator
Gas Burners
101

FIG. 226

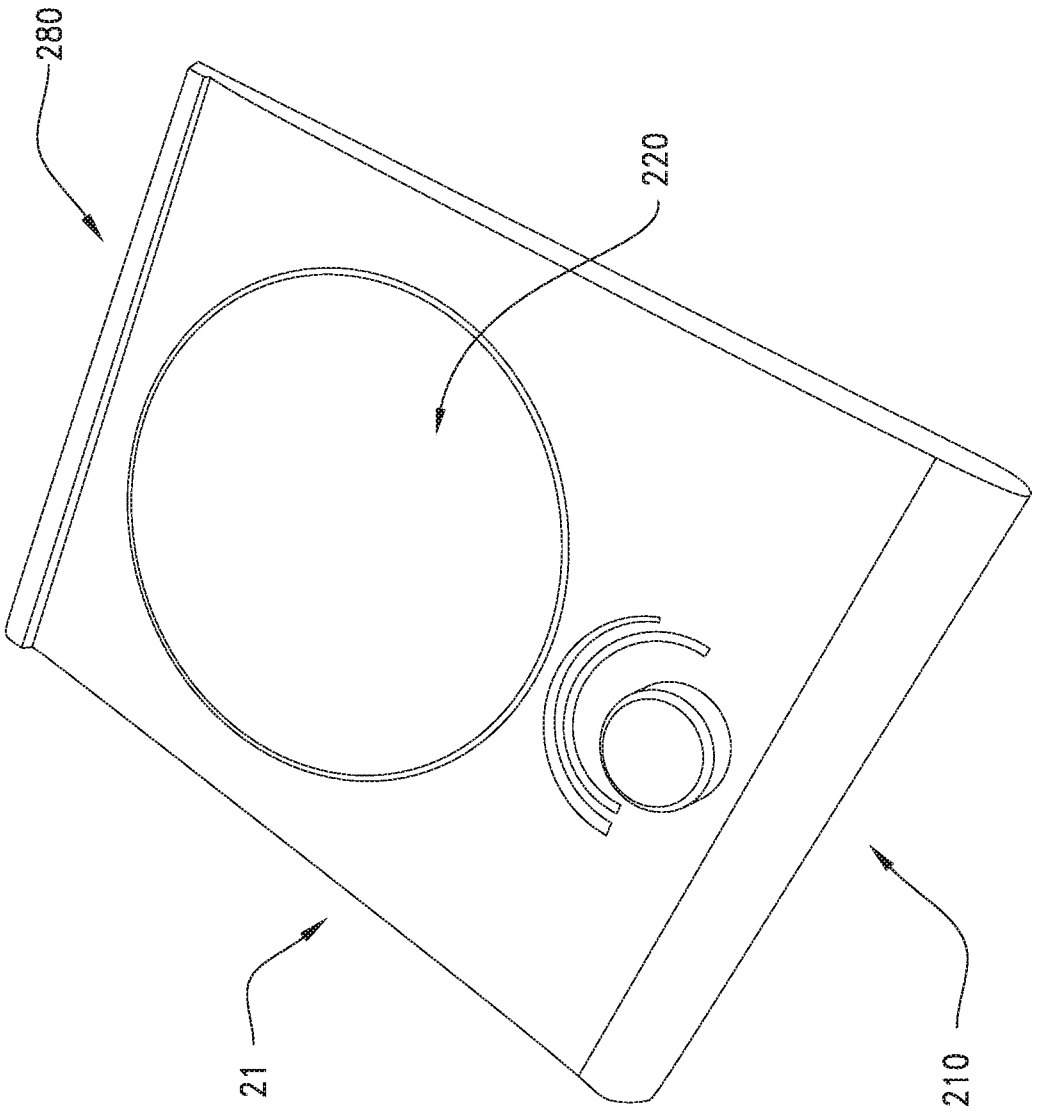

FIG. 227

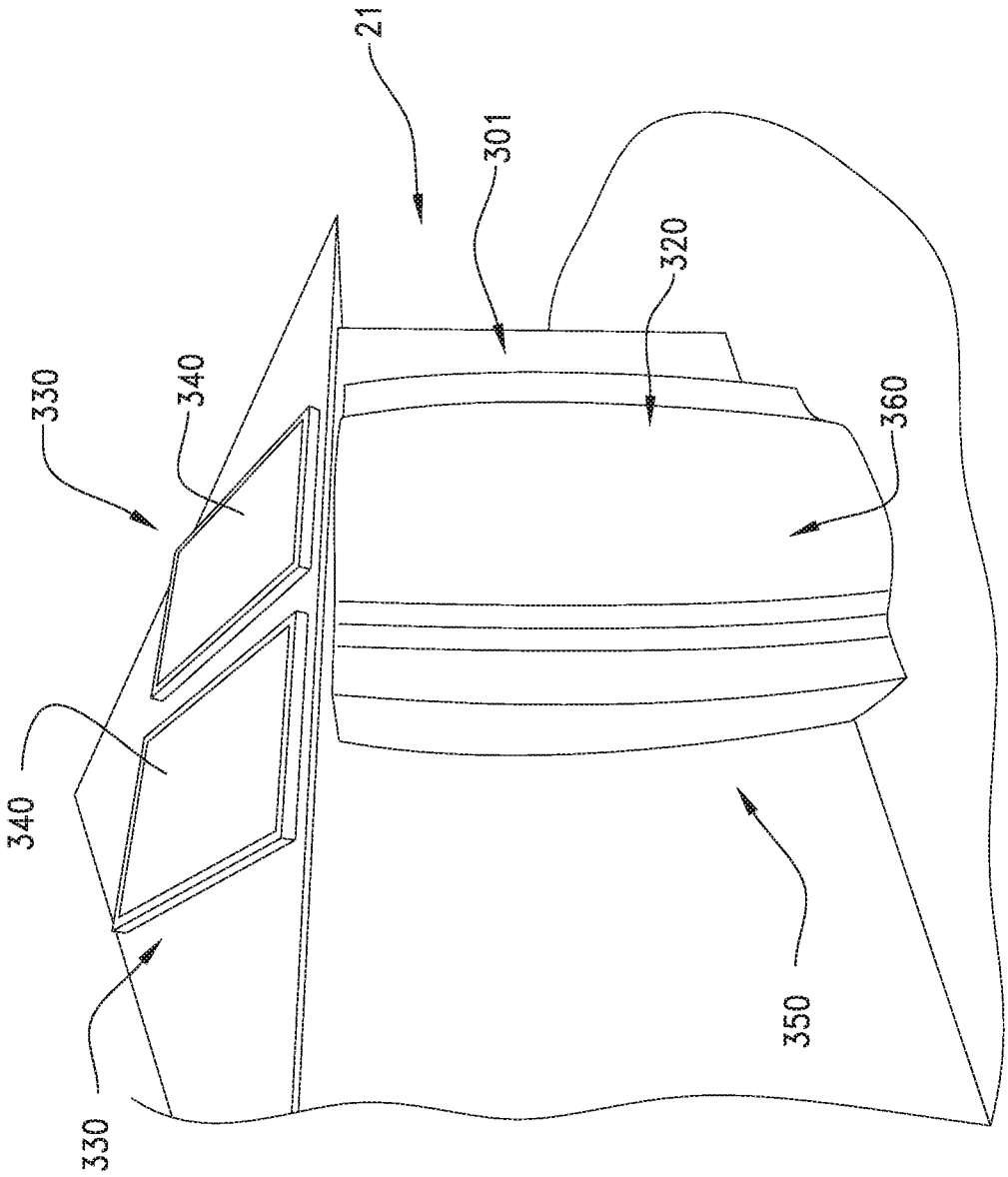

FIG. 228

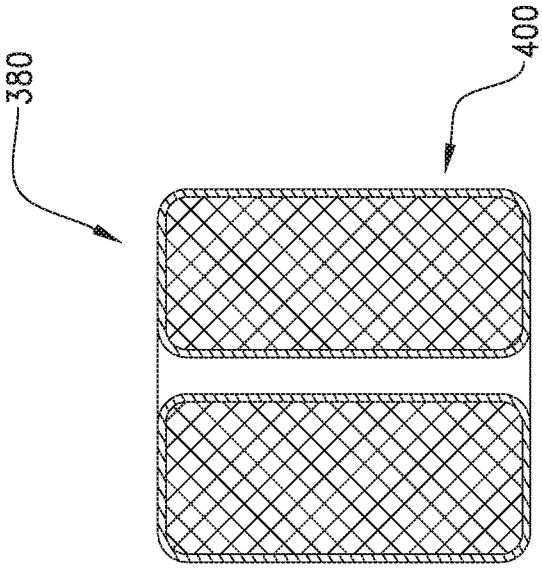

FIG. 230

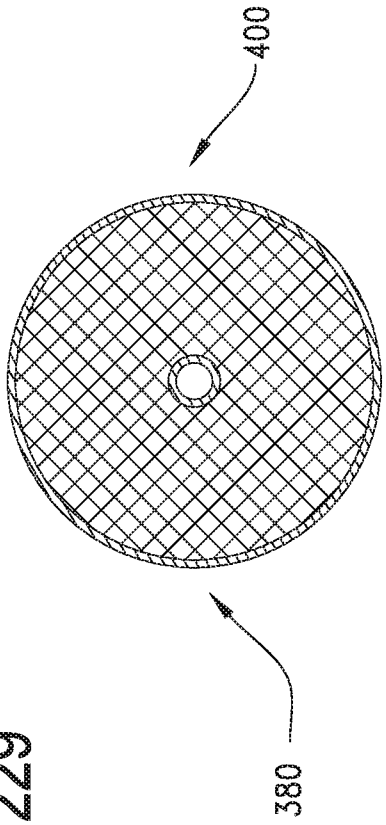

FIG. 231

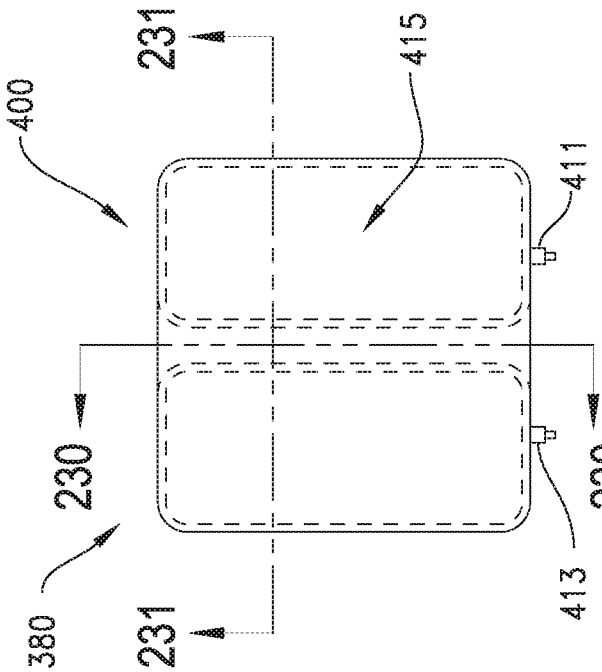

FIG. 229

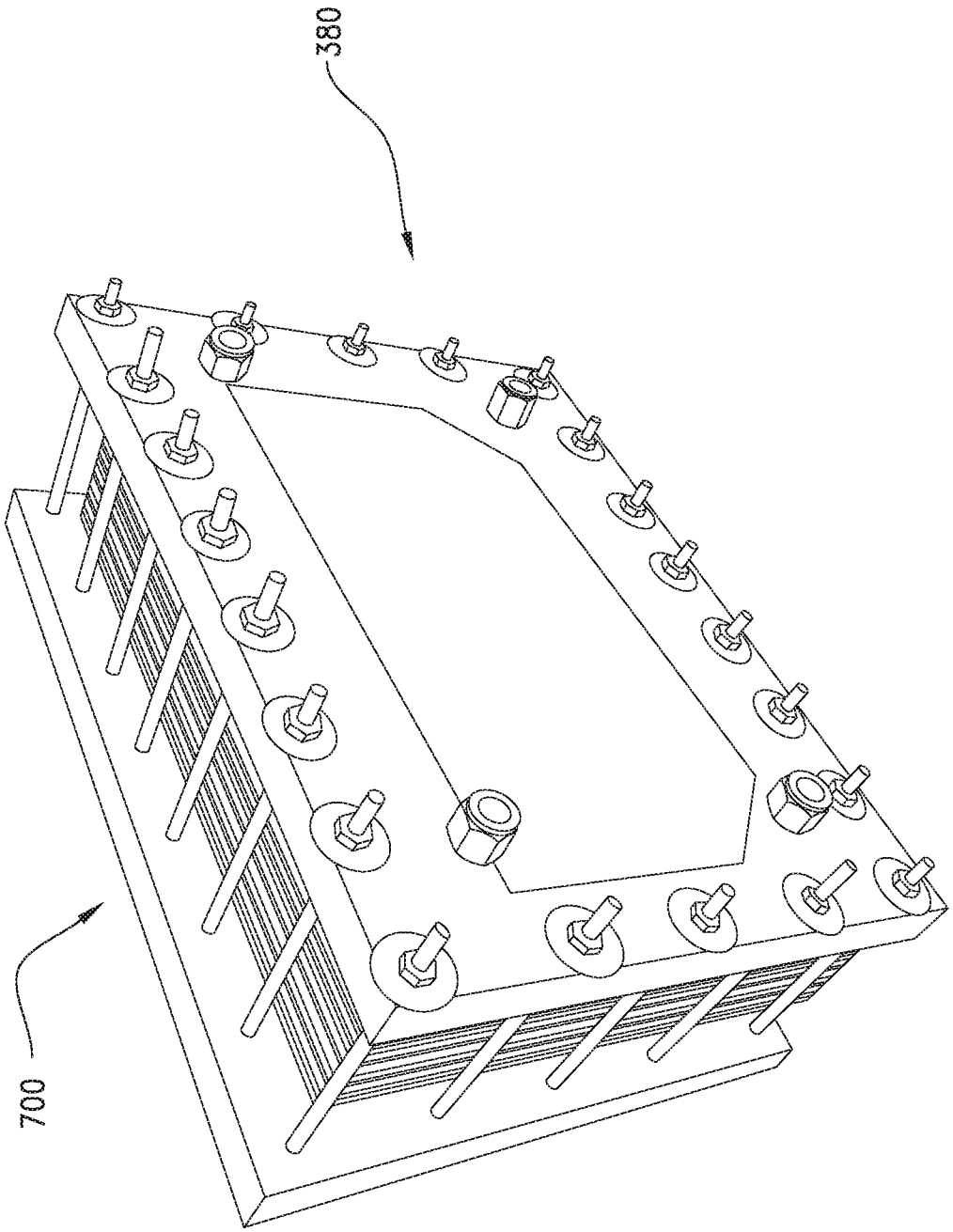

FIG. 232

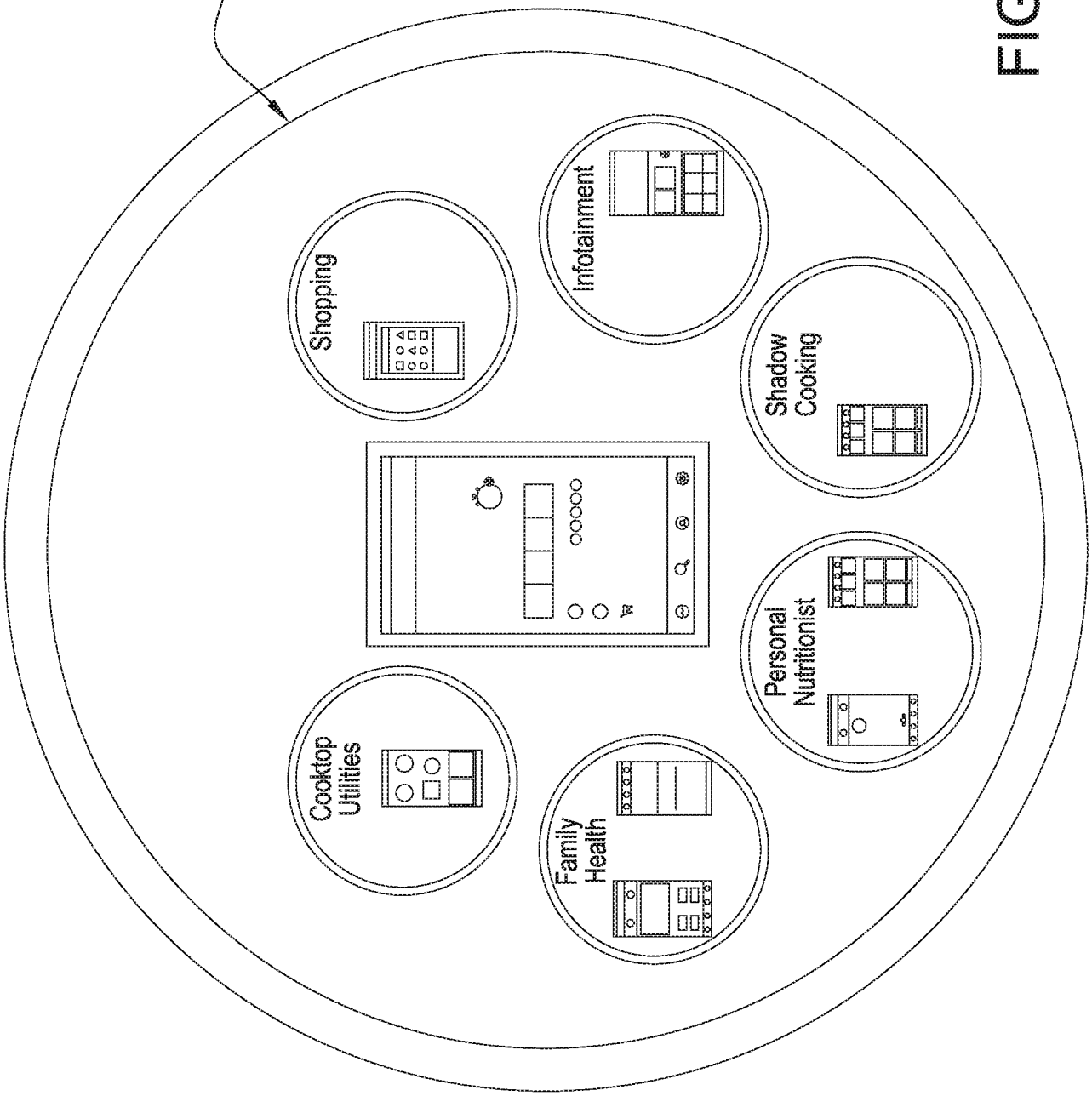
800
Shopping
Infotainment
Shadow Cooking
Personal Nutritionist
Cooktop Utilities
Family Health

FIG. 233

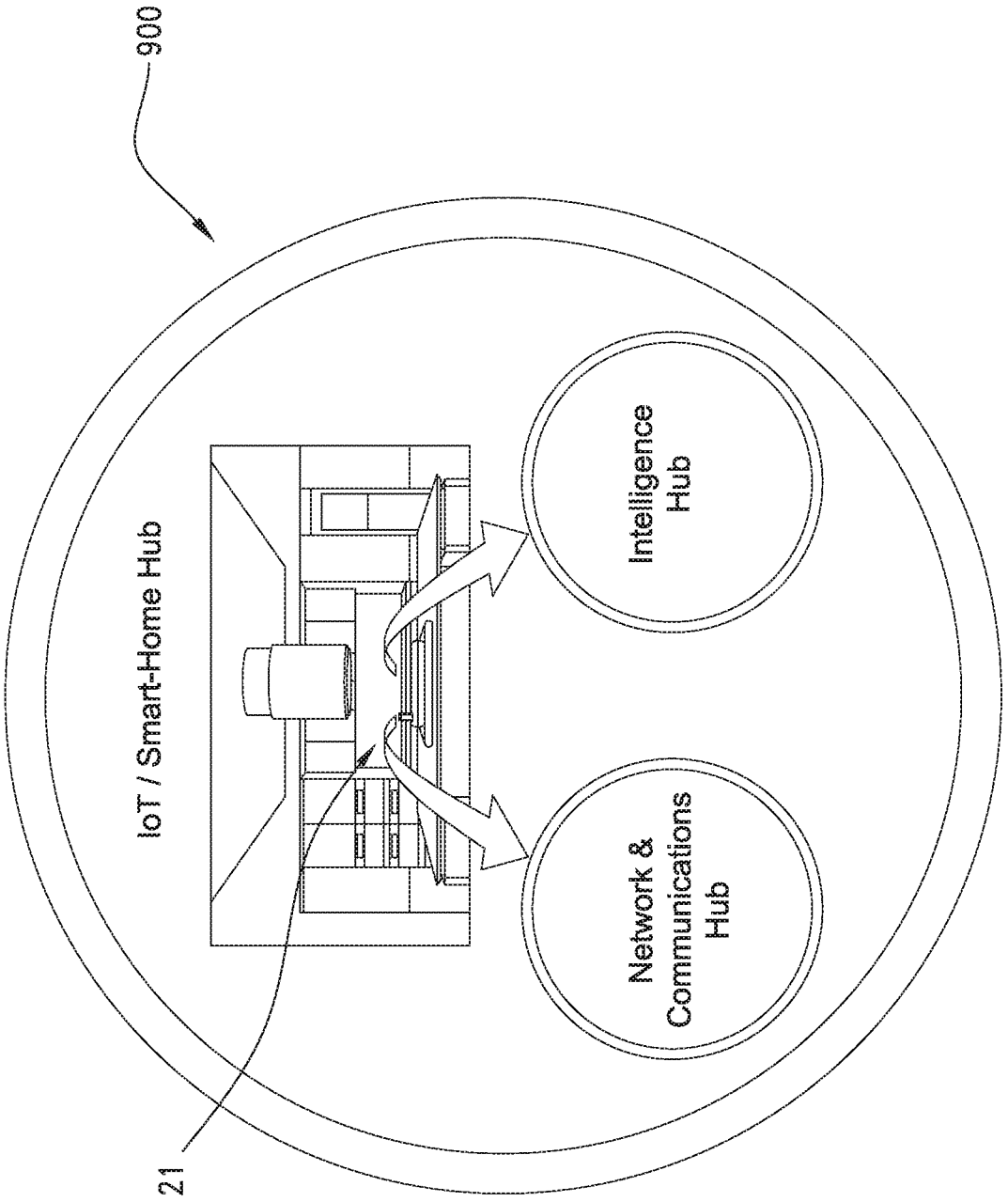
900
IoT / Smart-Home Hub
Intelligence Hub
Network & Communications Hub
21

FIG. 234

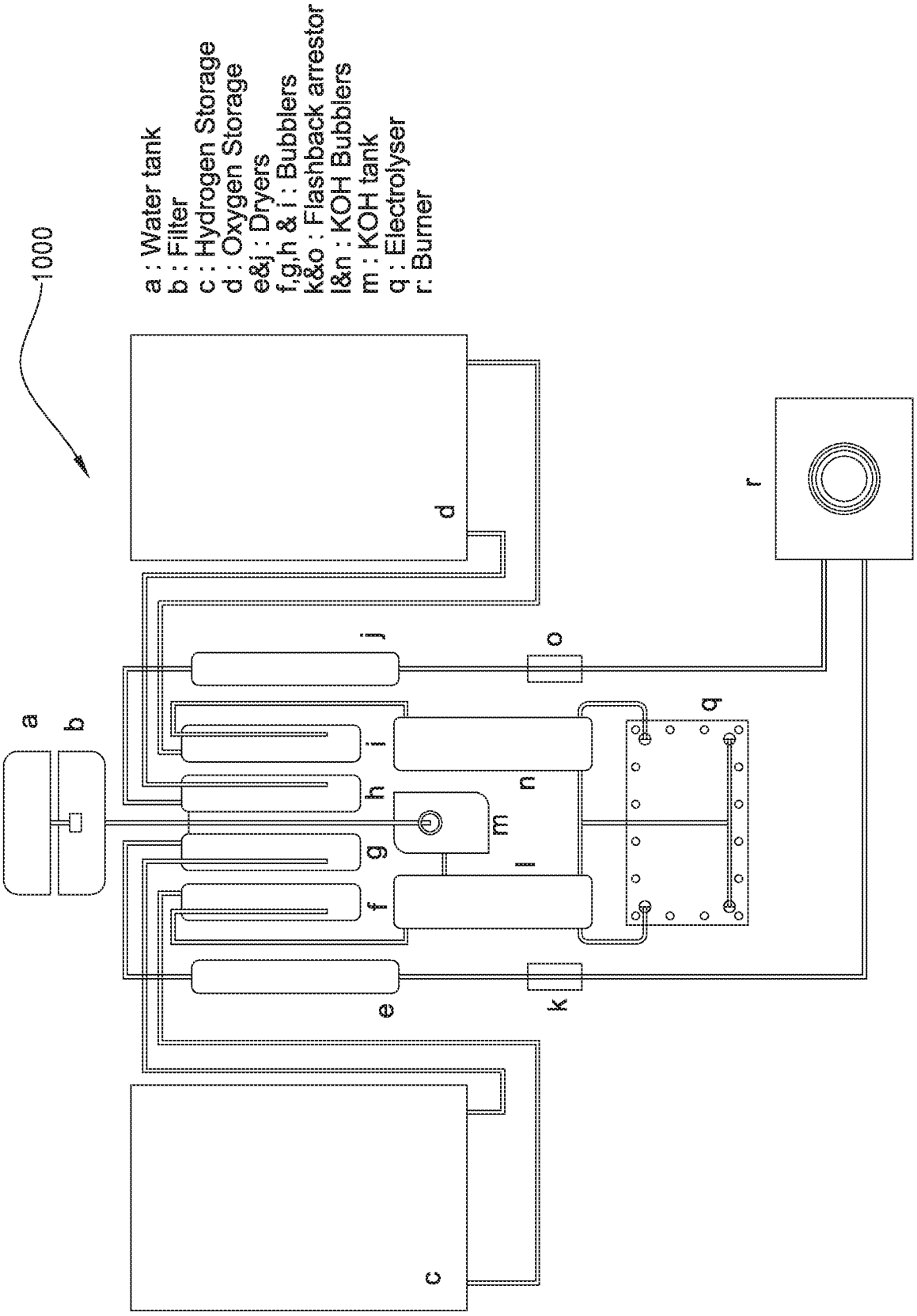
1000
a : Water tank
b : Filter
c : Hydrogen Storage
d : Oxygen Storage
e&j : Dryers
f,g,h & i : Bubblers
k&o : Flashback arrestor
l&n : KOH Bubblers
m : KOH tank
q : Electrolyser
r: Burner
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
q
r

FIG. 235

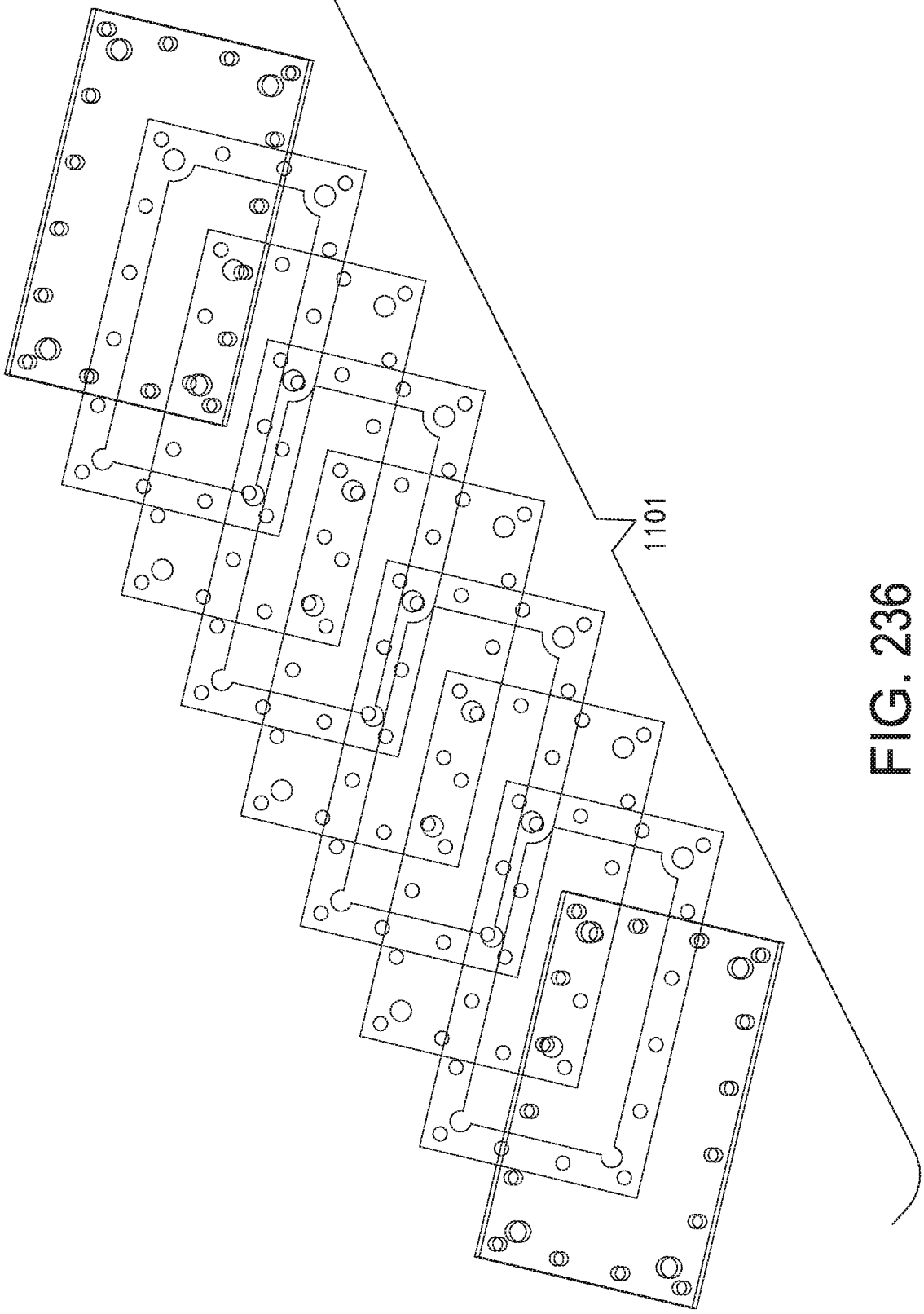

FIG. 236

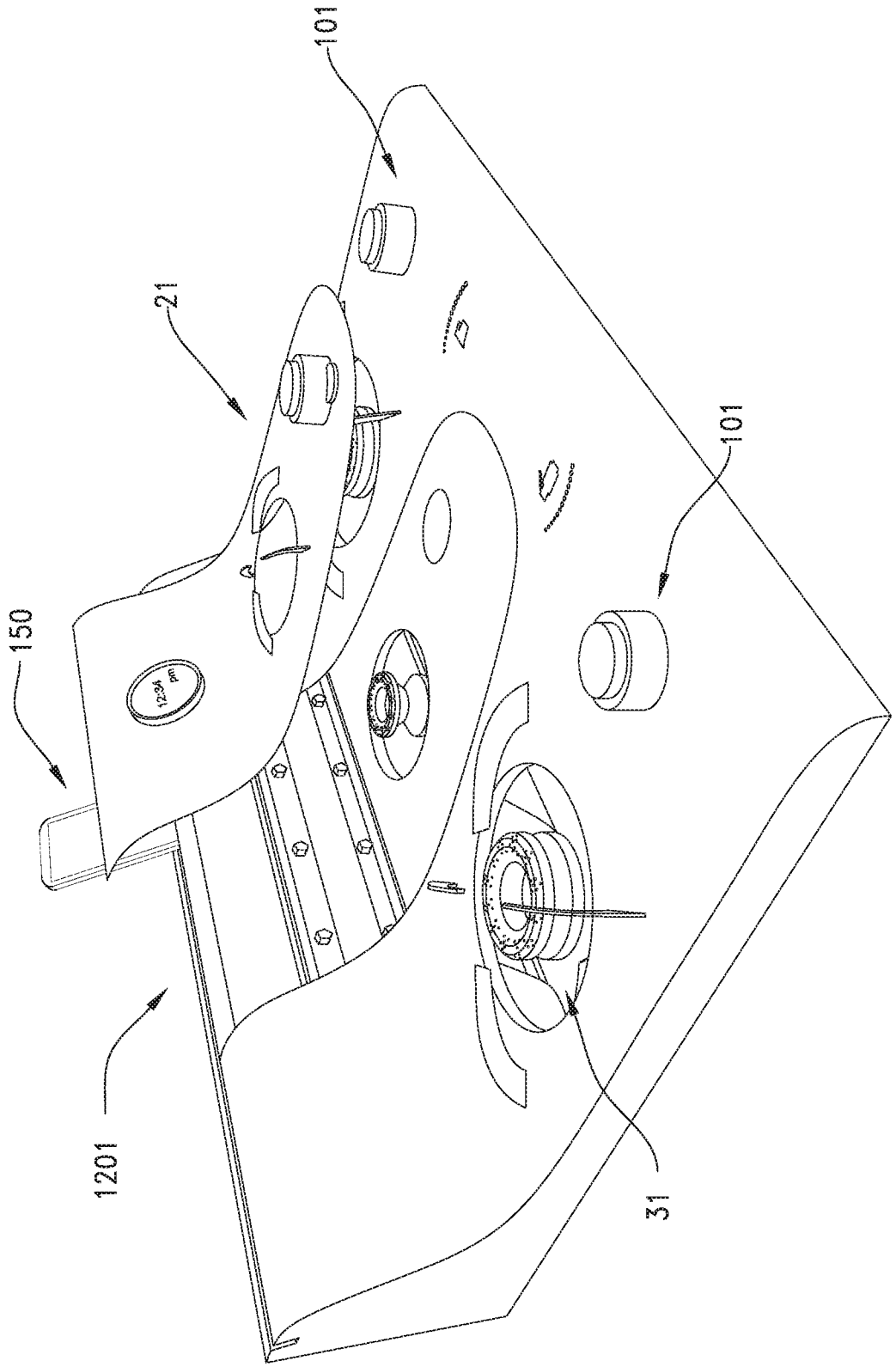

FIG. 237

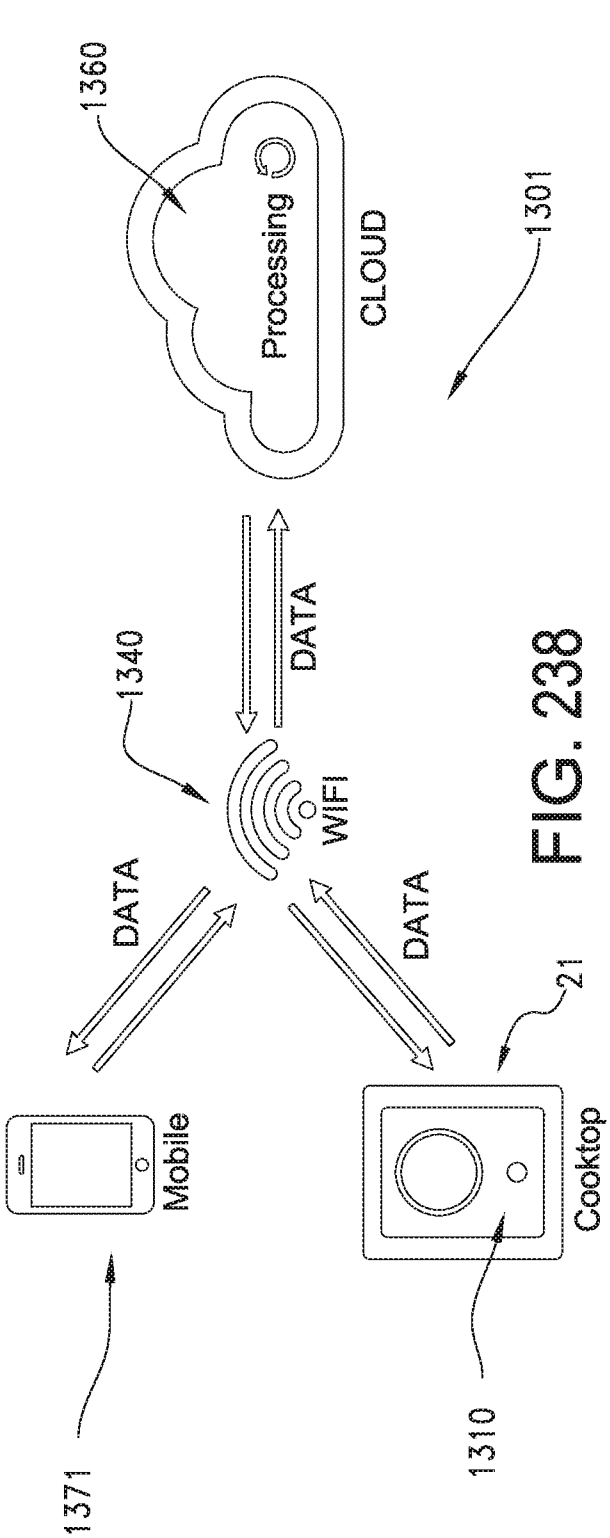

FIG. 238

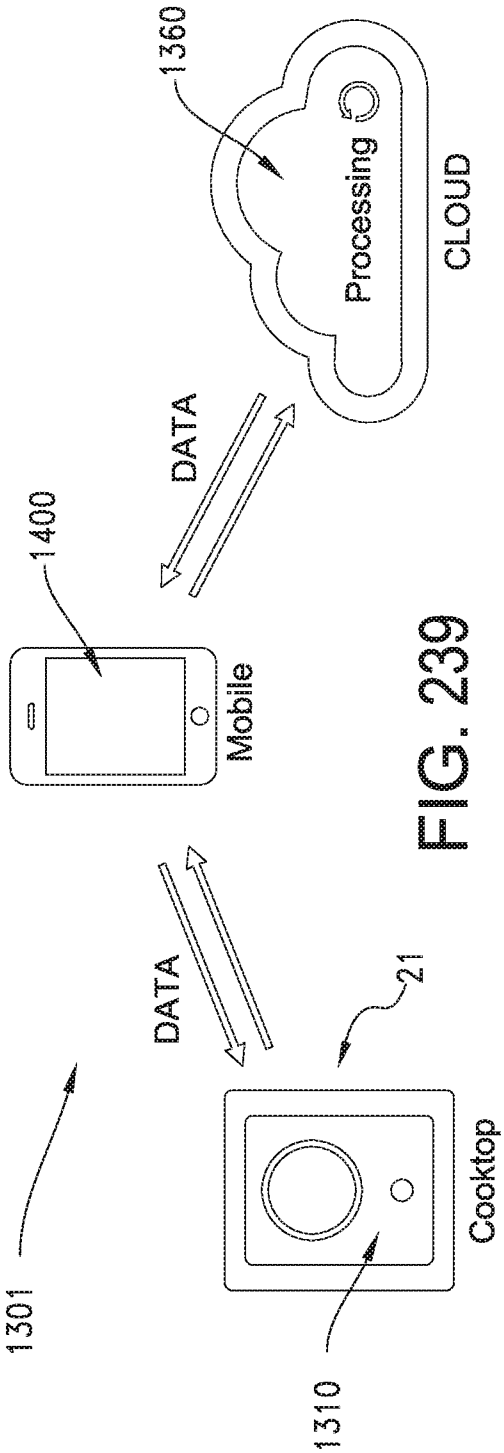

FIG. 239

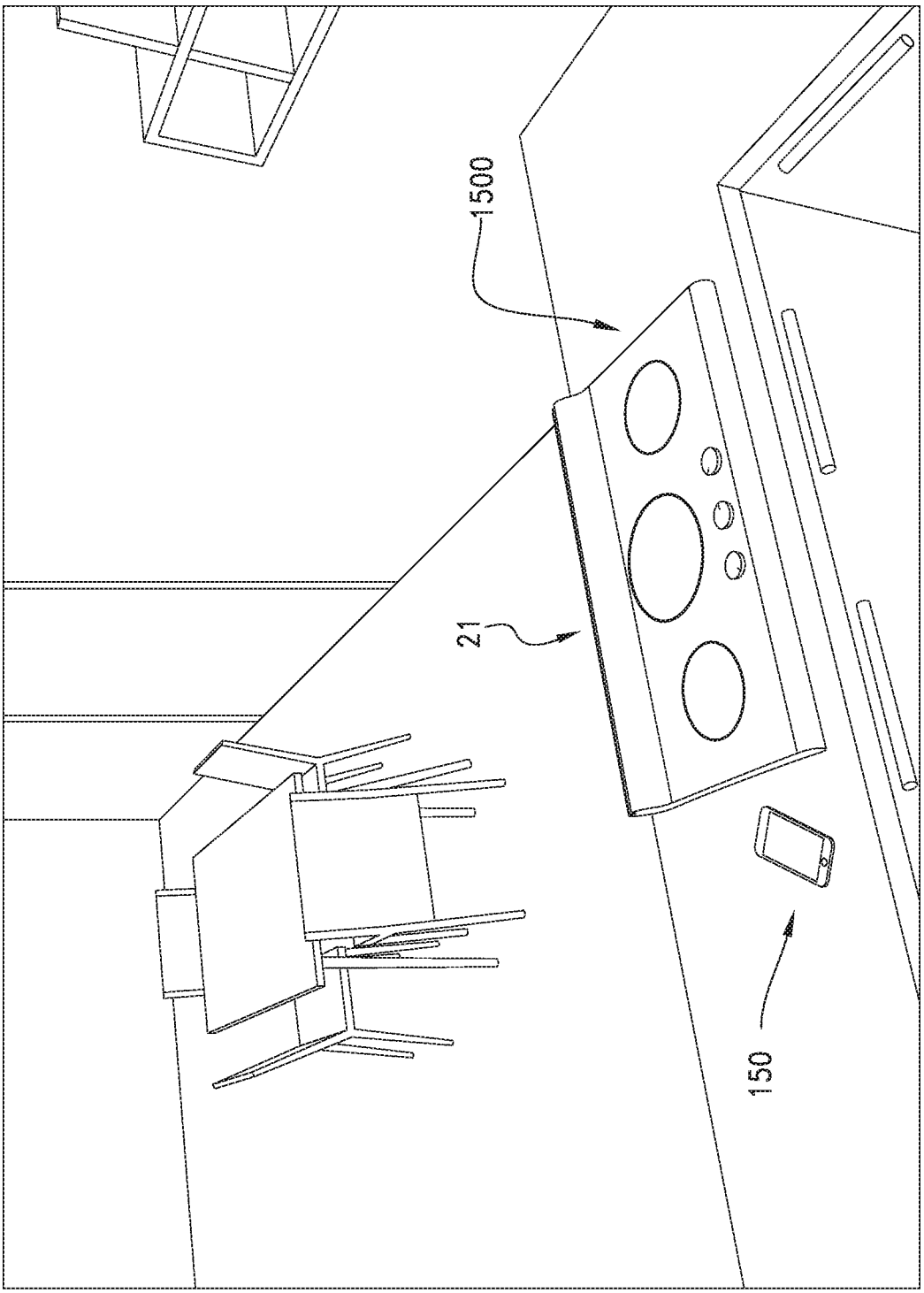

FIG. 240

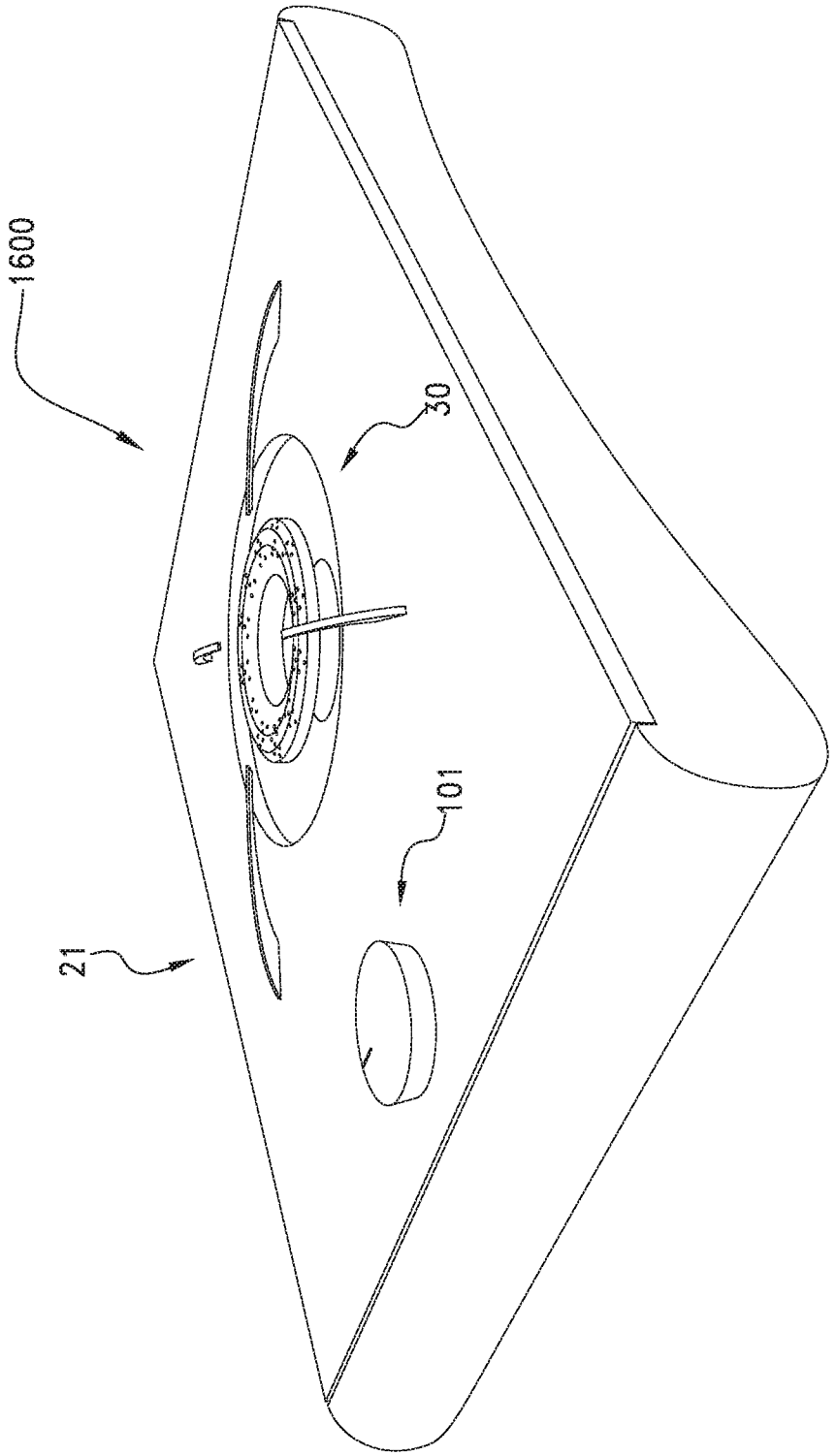

FIG. 241

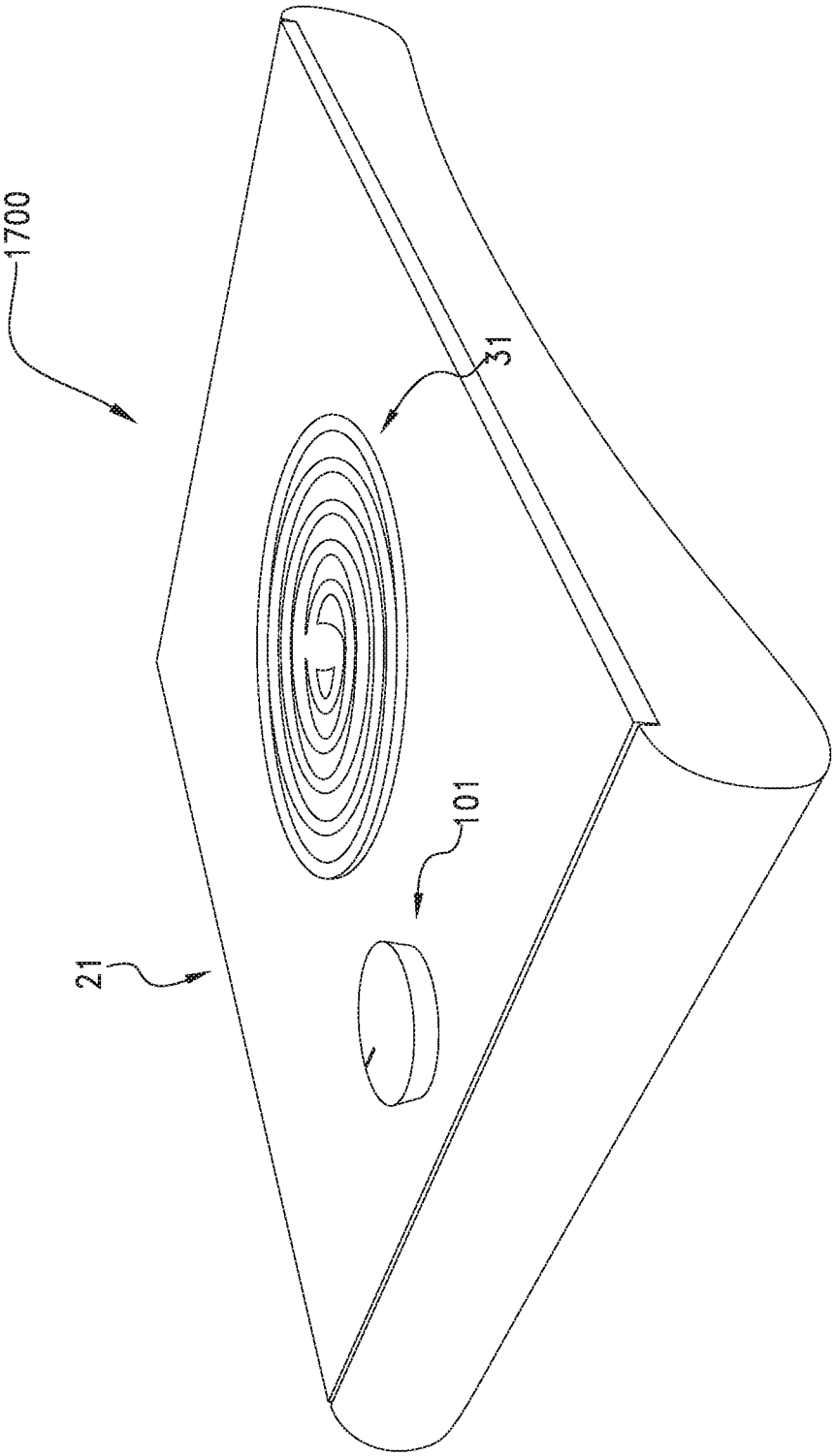

FIG. 242

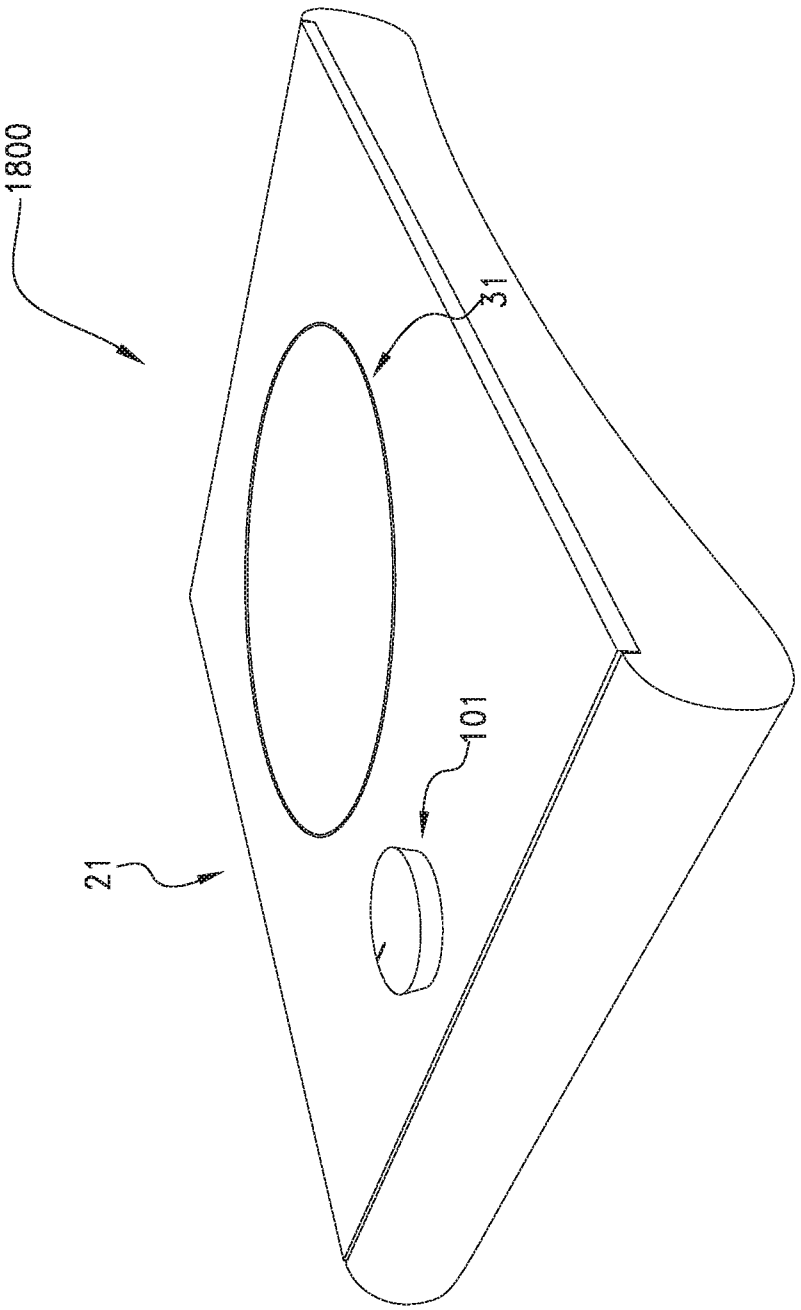

FIG. 243

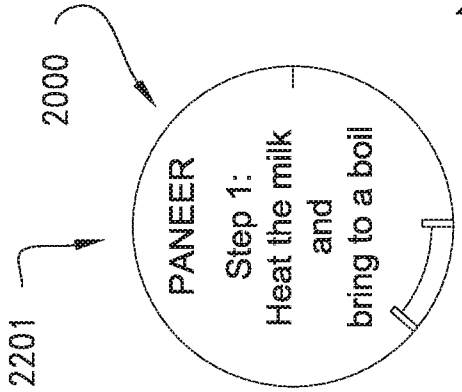

FIG. 247

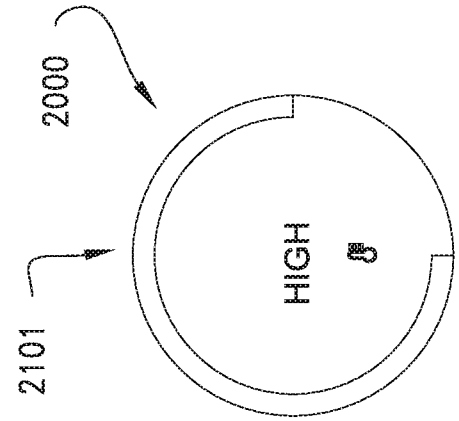

FIG. 246

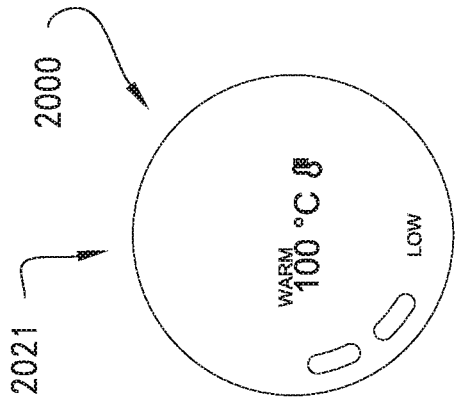

FIG. 245

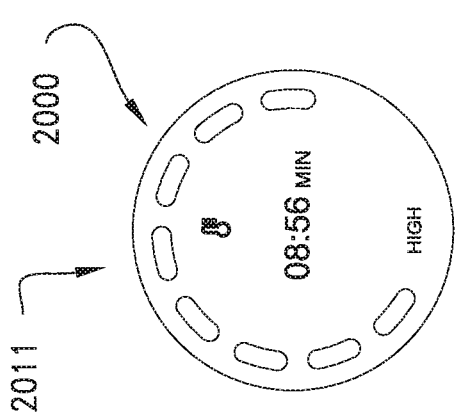

FIG. 244

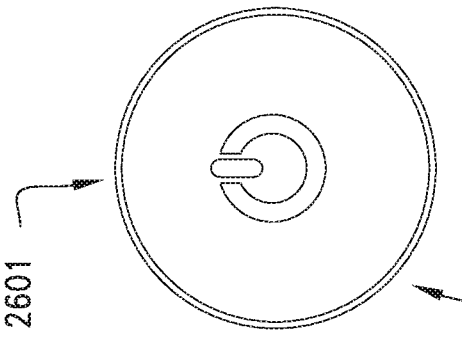

FIG. 251

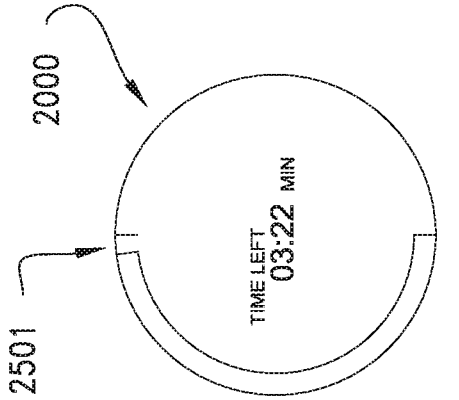

FIG. 250

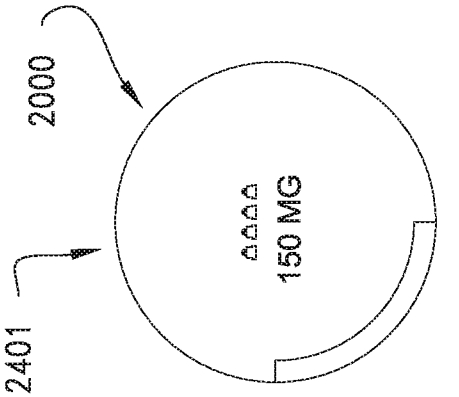

FIG. 249

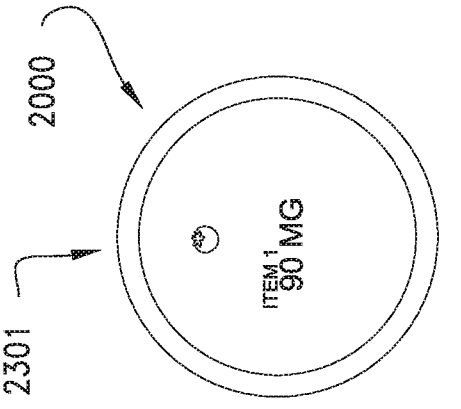

FIG. 248

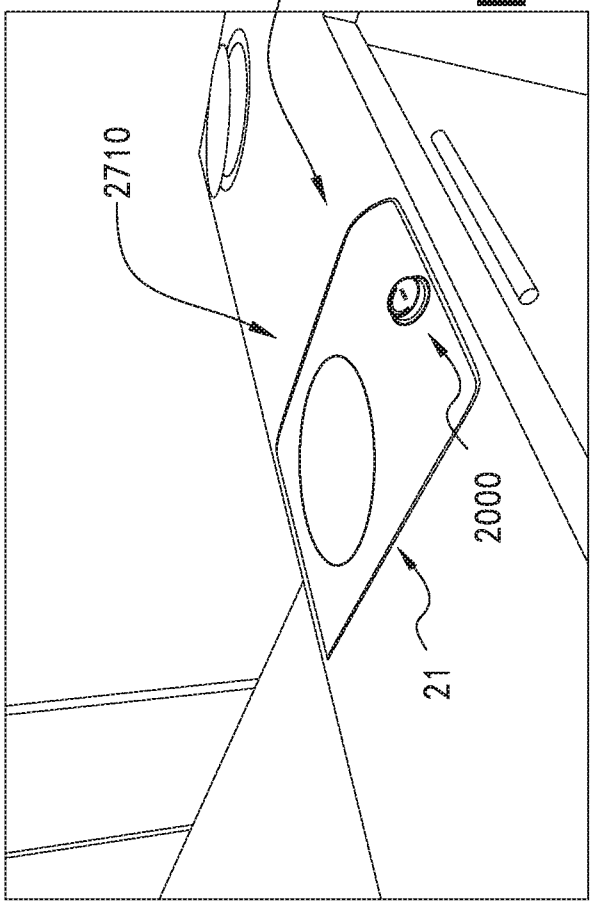

FIG. 252

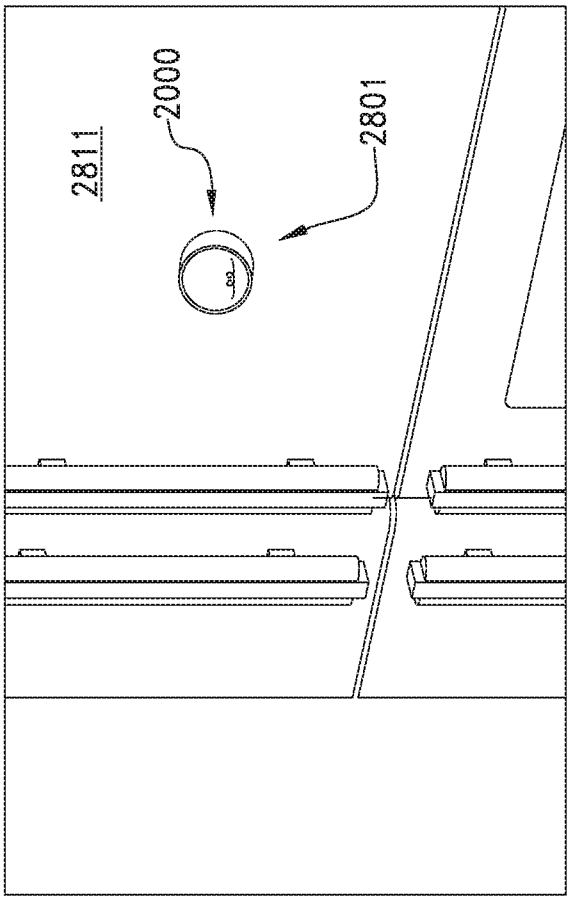

FIG. 253

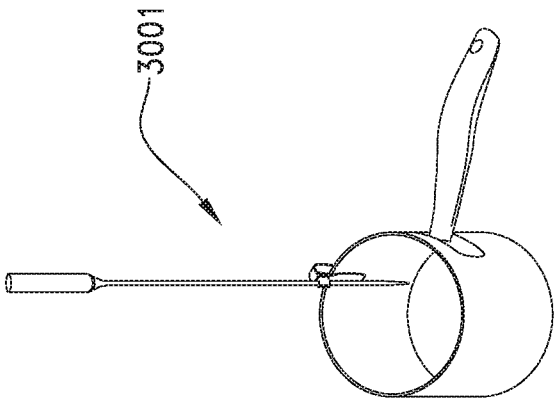

FIG. 255

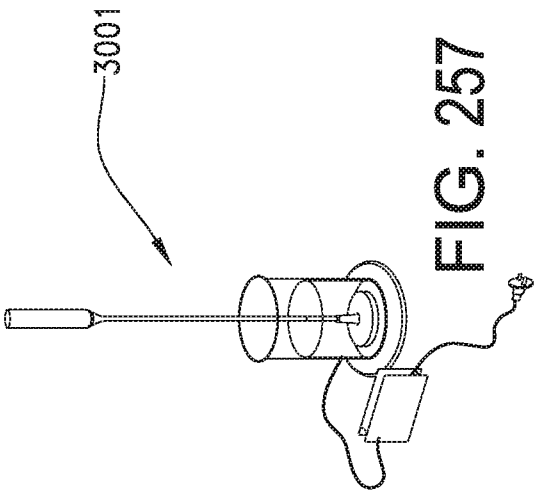

FIG. 257

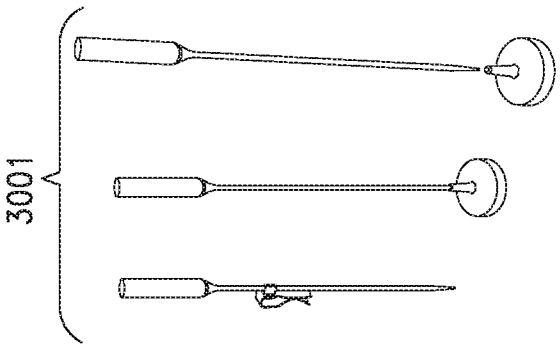

FIG. 254

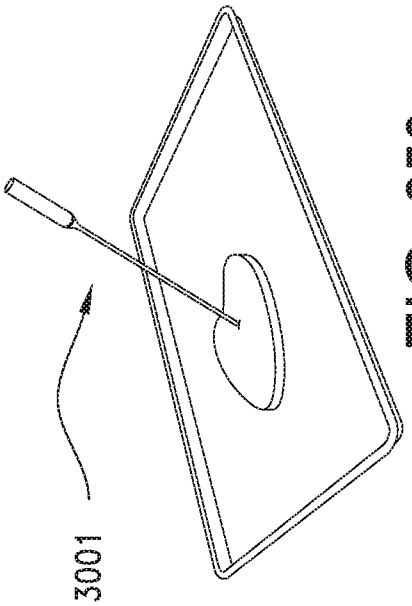

FIG. 256

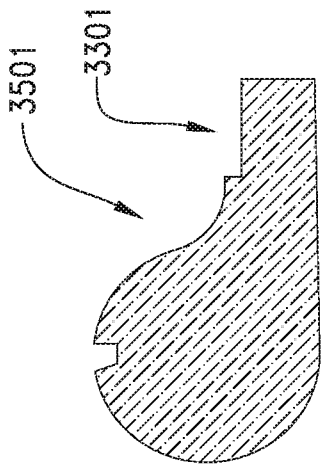

FIG. 260

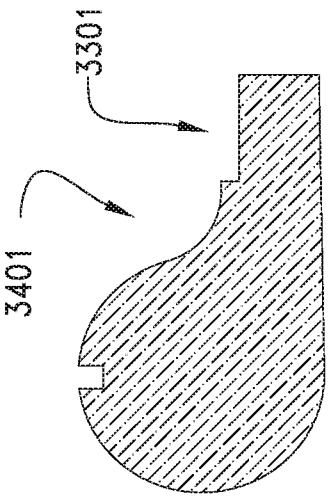

FIG. 259

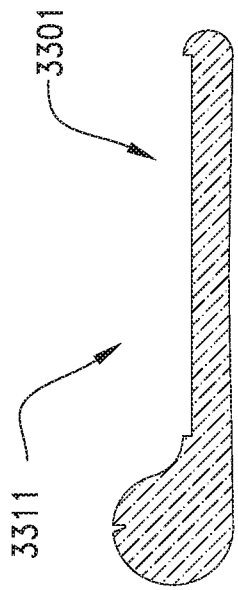

FIG. 258

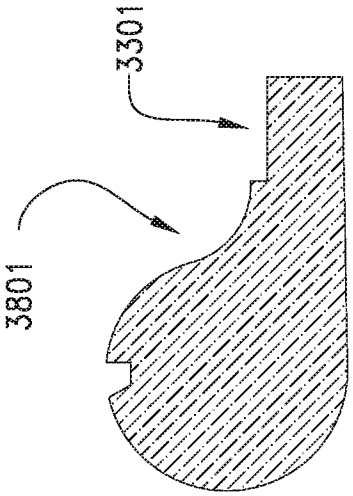

FIG. 263

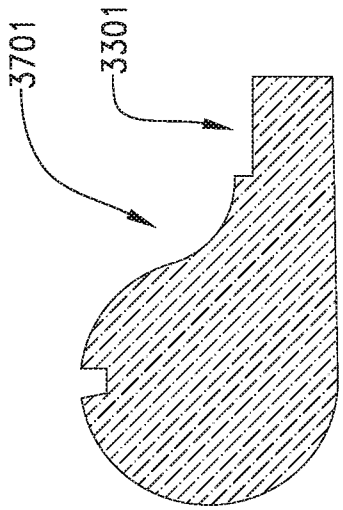

FIG. 262

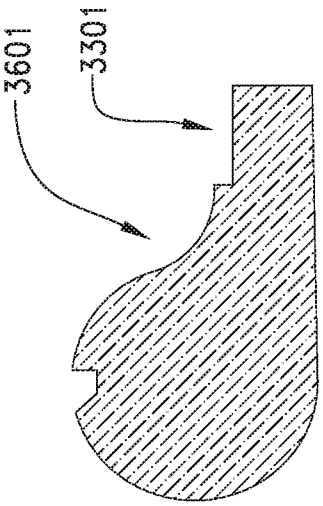

FIG. 261

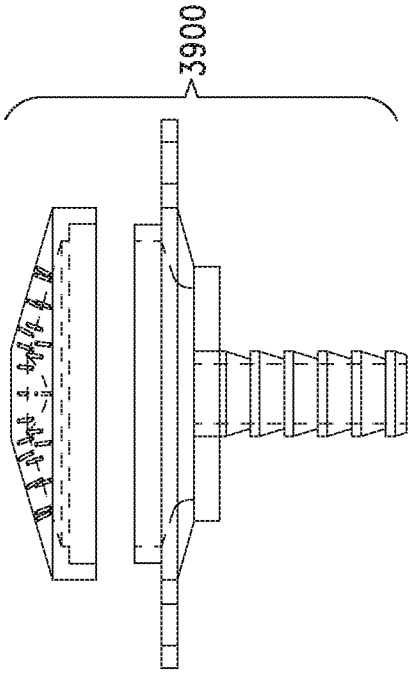

FIG. 266

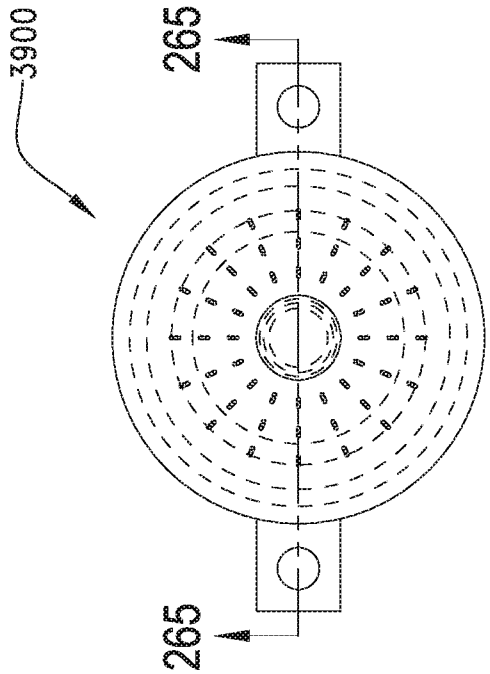

FIG. 264

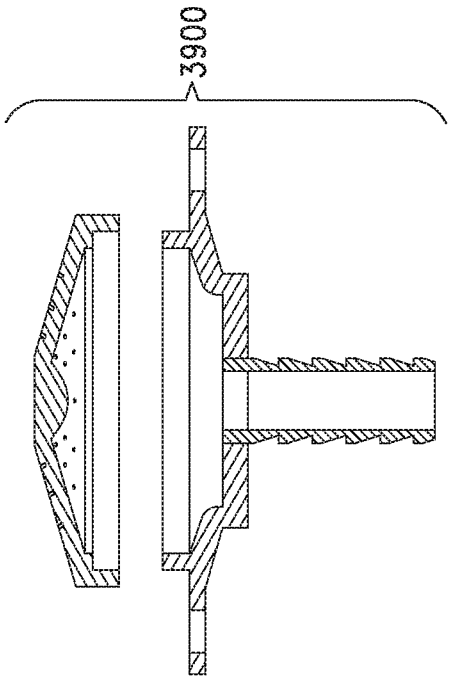

FIG. 265

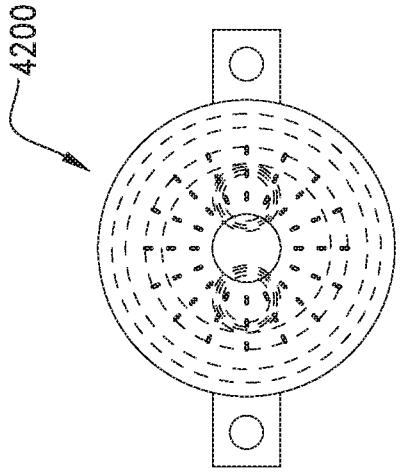

FIG. 271

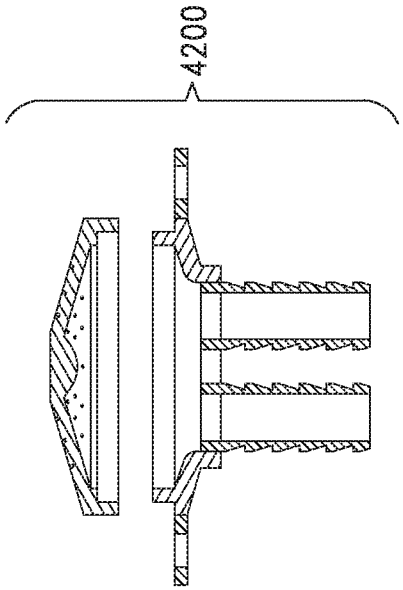

FIG. 268

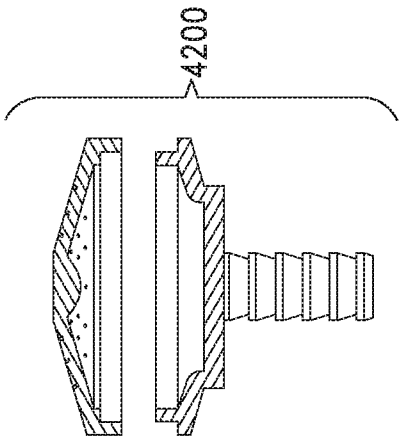

FIG. 270

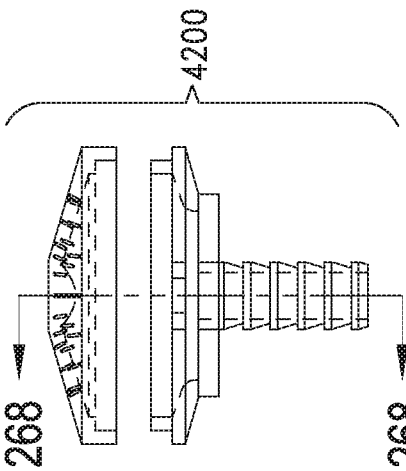

FIG. 267

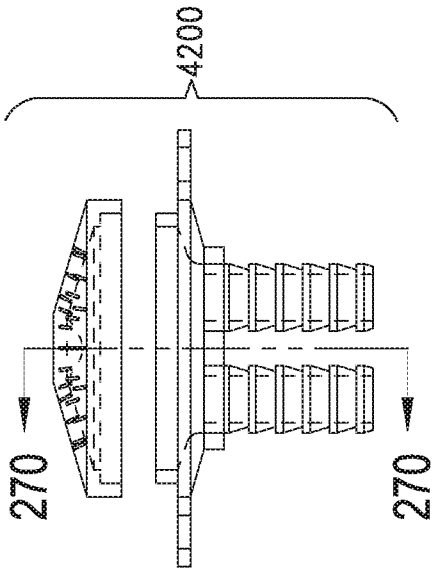

FIG. 269

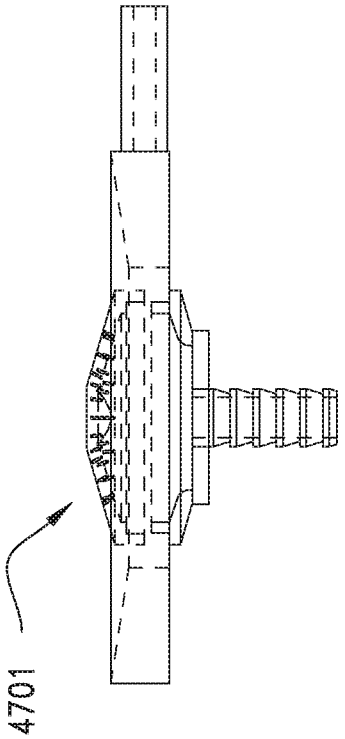

FIG. 273

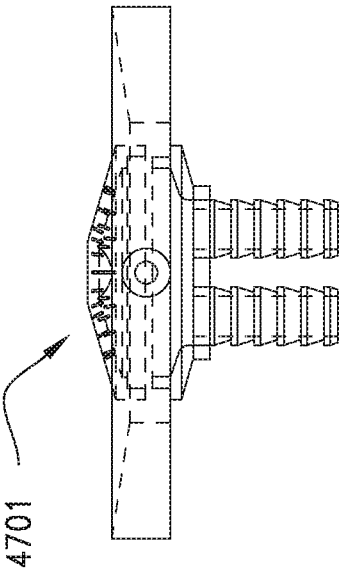

FIG. 272

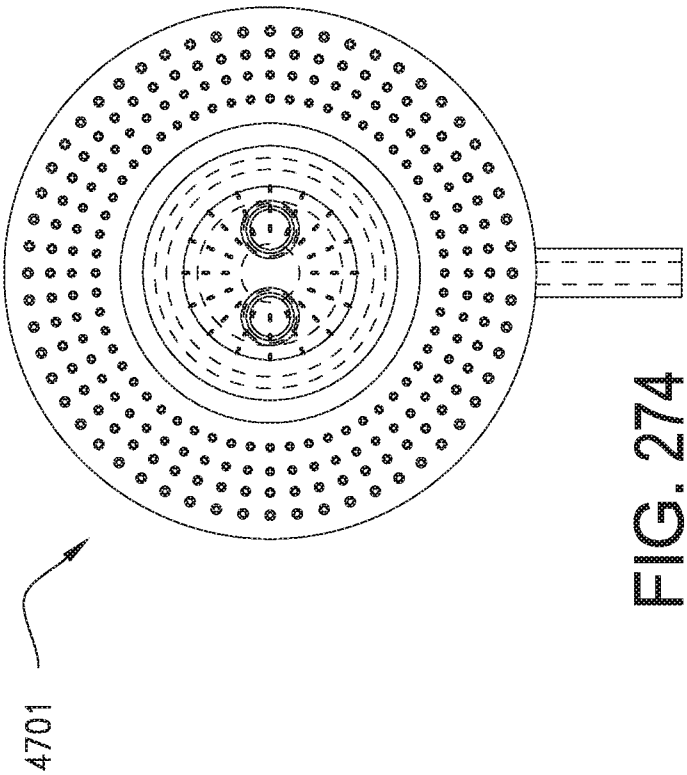

FIG. 274

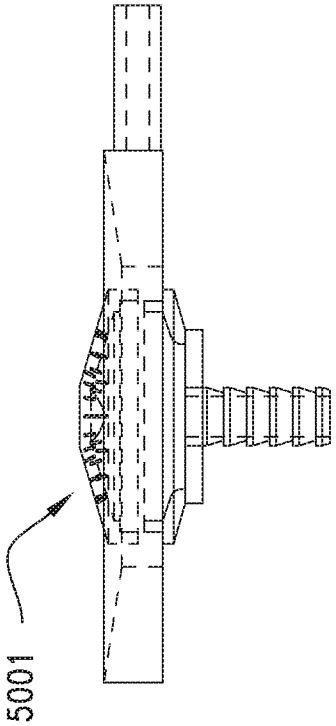

FIG. 276

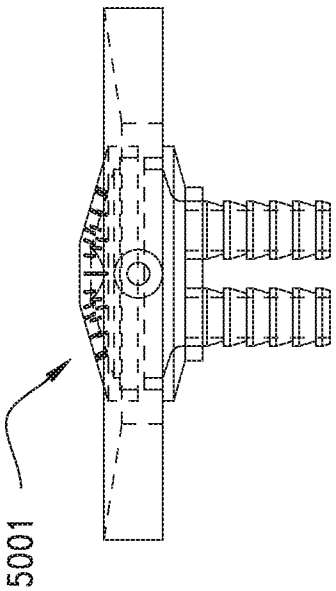

FIG. 275

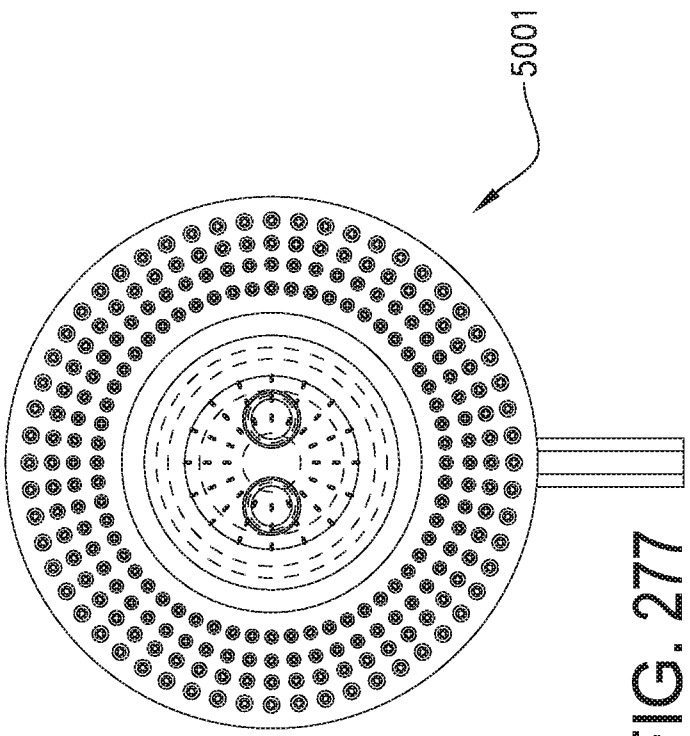

FIG. 277

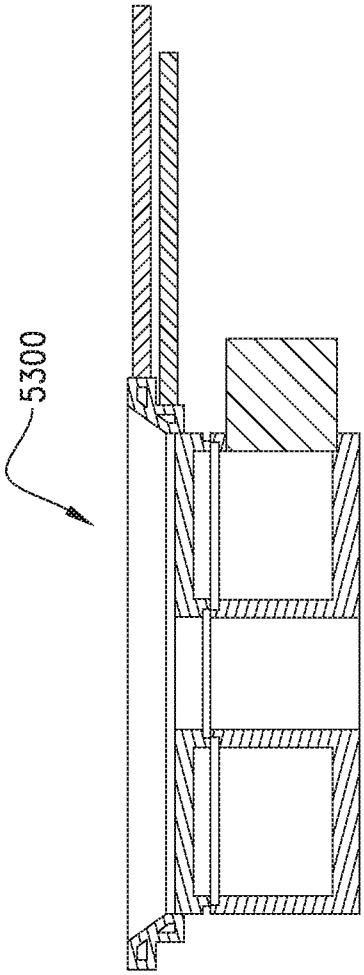

FIG. 279

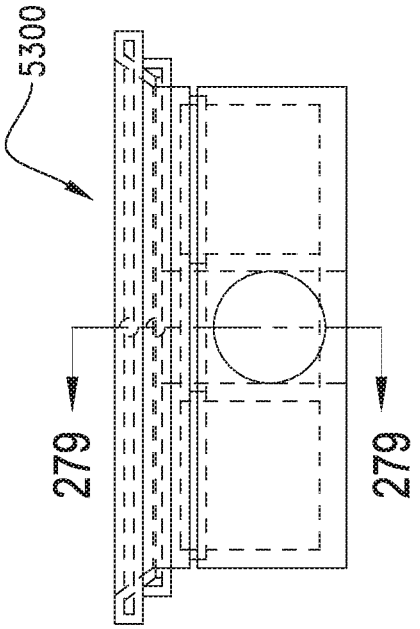

FIG. 278

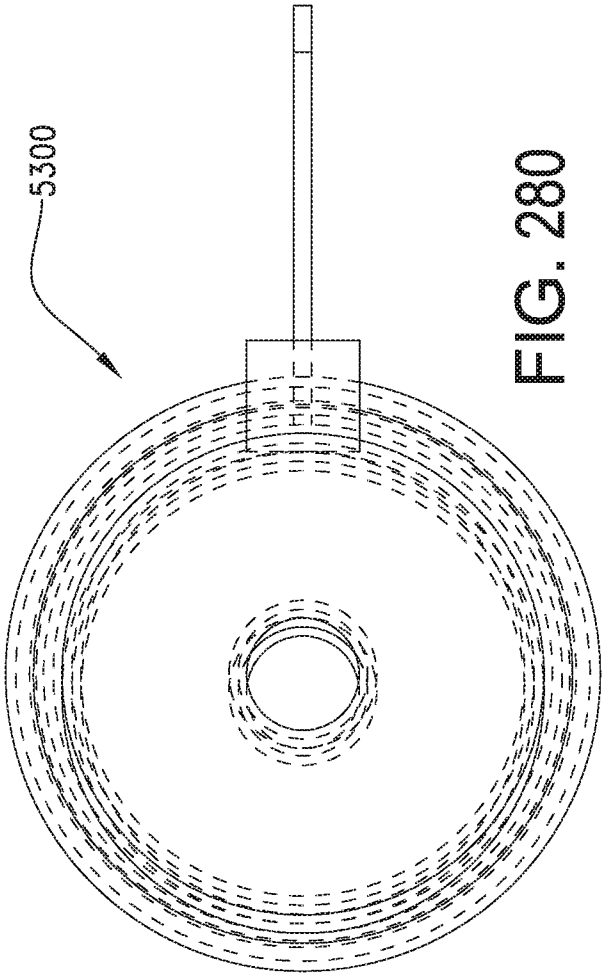

FIG. 280

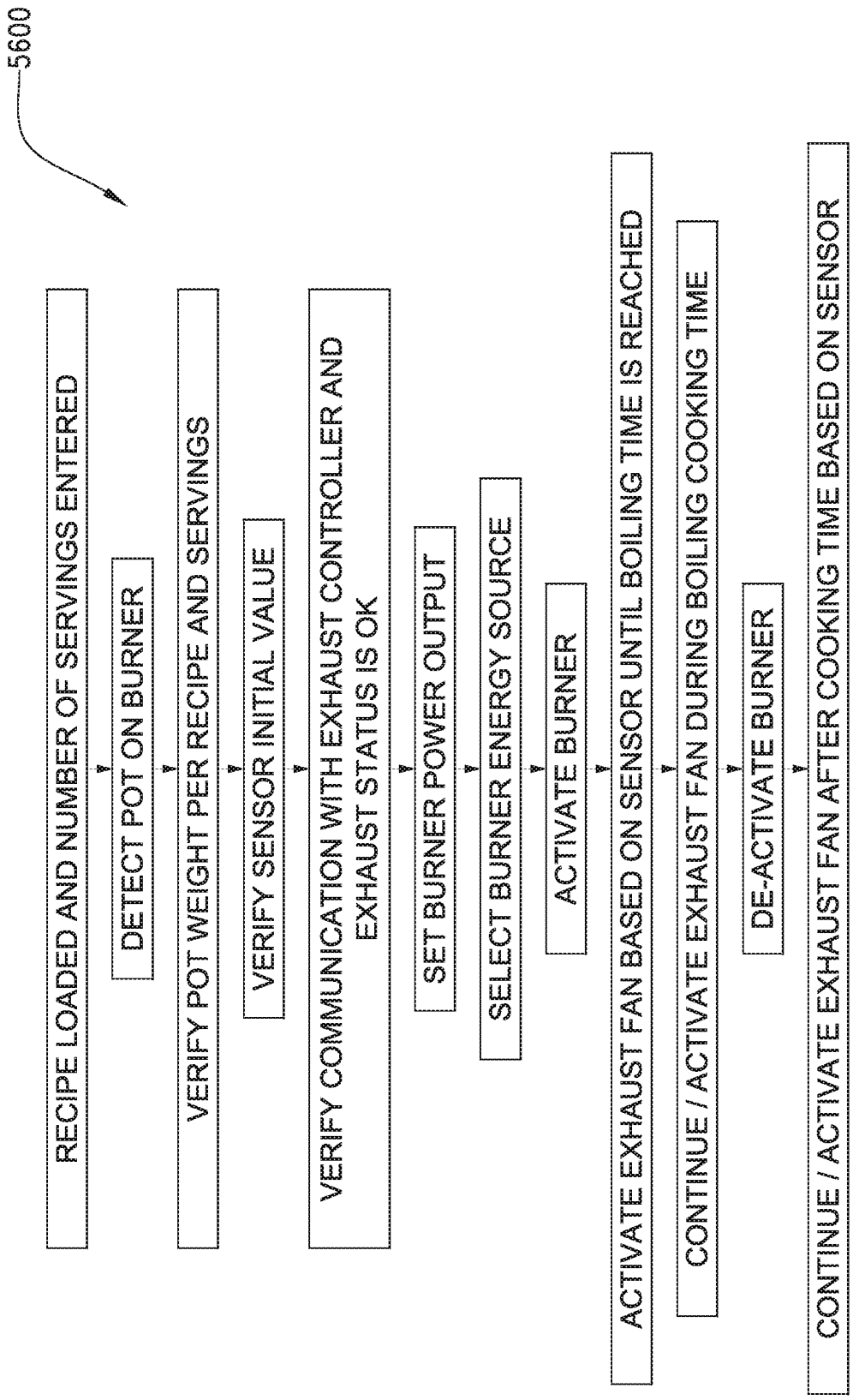
5600
RECIPE LOADED AND NUMBER OF SERVINGS ENTERED
DETECT POT ON BURNER
VERIFY POT WEIGHT PER RECIPE AND SERVINGS
VERIFY SENSOR INITIAL VALUE
VERIFY COMMUNICATION WITH EXHAUST CONTROLLER AND EXHAUST STATUS IS OK
SET BURNER POWER OUTPUT
SELECT BURNER ENERGY SOURCE
ACTIVATE BURNER
ACTIVATE EXHAUST FAN BASED ON SENSOR UNTIL BOILING TIME IS REACHED
CONTINUE / ACTIVATE EXHAUST FAN DURING BOILING COOKING TIME
DE-ACTIVATE BURNER
CONTINUE / ACTIVATE EXHAUST FAN AFTER COOKING TIME BASED ON SENSOR

FIG. 281

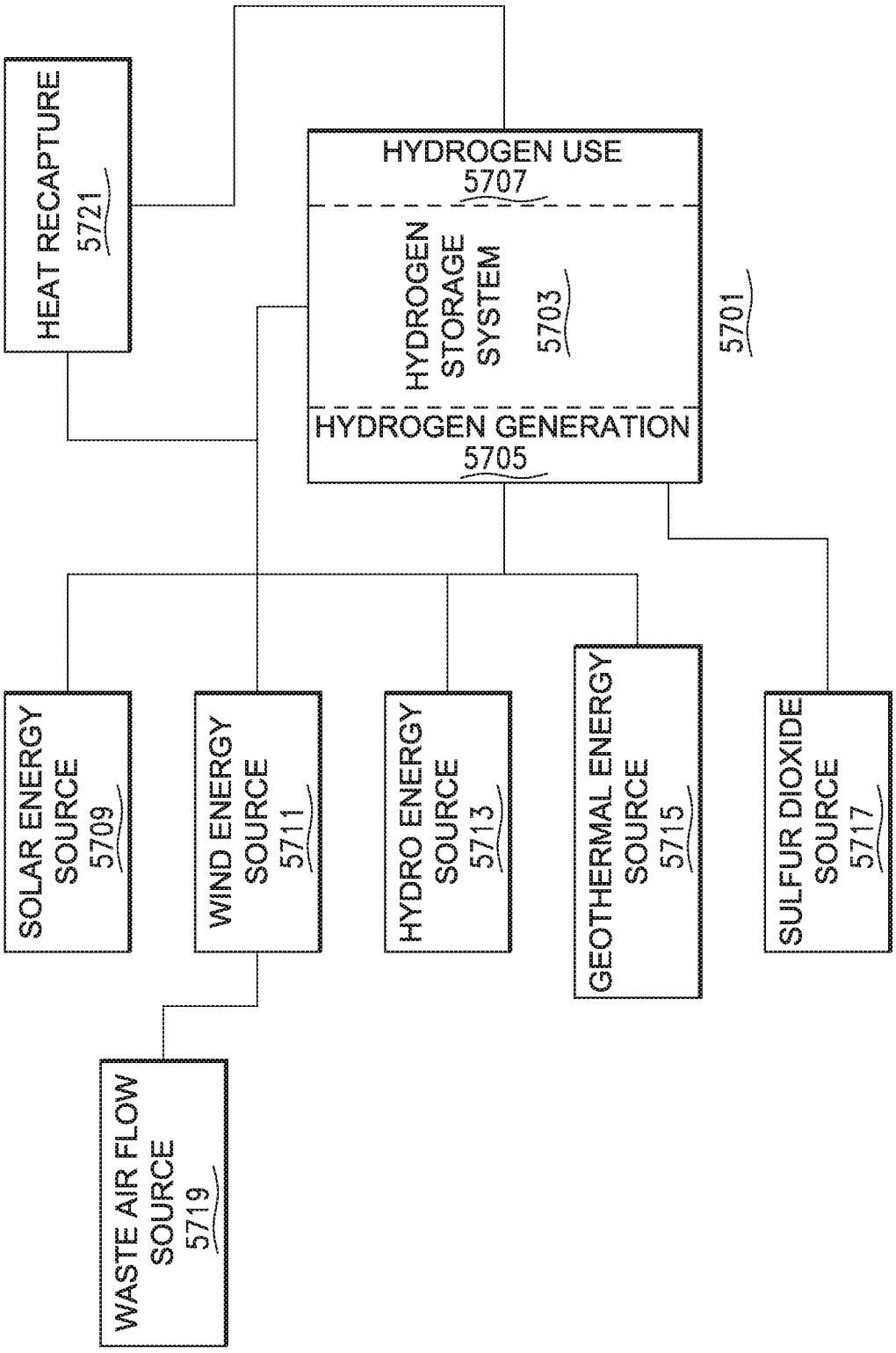
HEAT RECAPTURE
5721
HYDROGEN USE
5707
HYDROGEN STORAGE SYSTEM
5703
5701
HYDROGEN GENERATION
5705
SOLAR ENERGY SOURCE
5709
WIND ENERGY SOURCE
5711
HYDRO ENERGY SOURCE
5713
GEOTHERMAL ENERGY SOURCE
5715
SULFUR DIOXIDE SOURCE
5717
WASTE AIR FLOW SOURCE
5719

FIG. 282

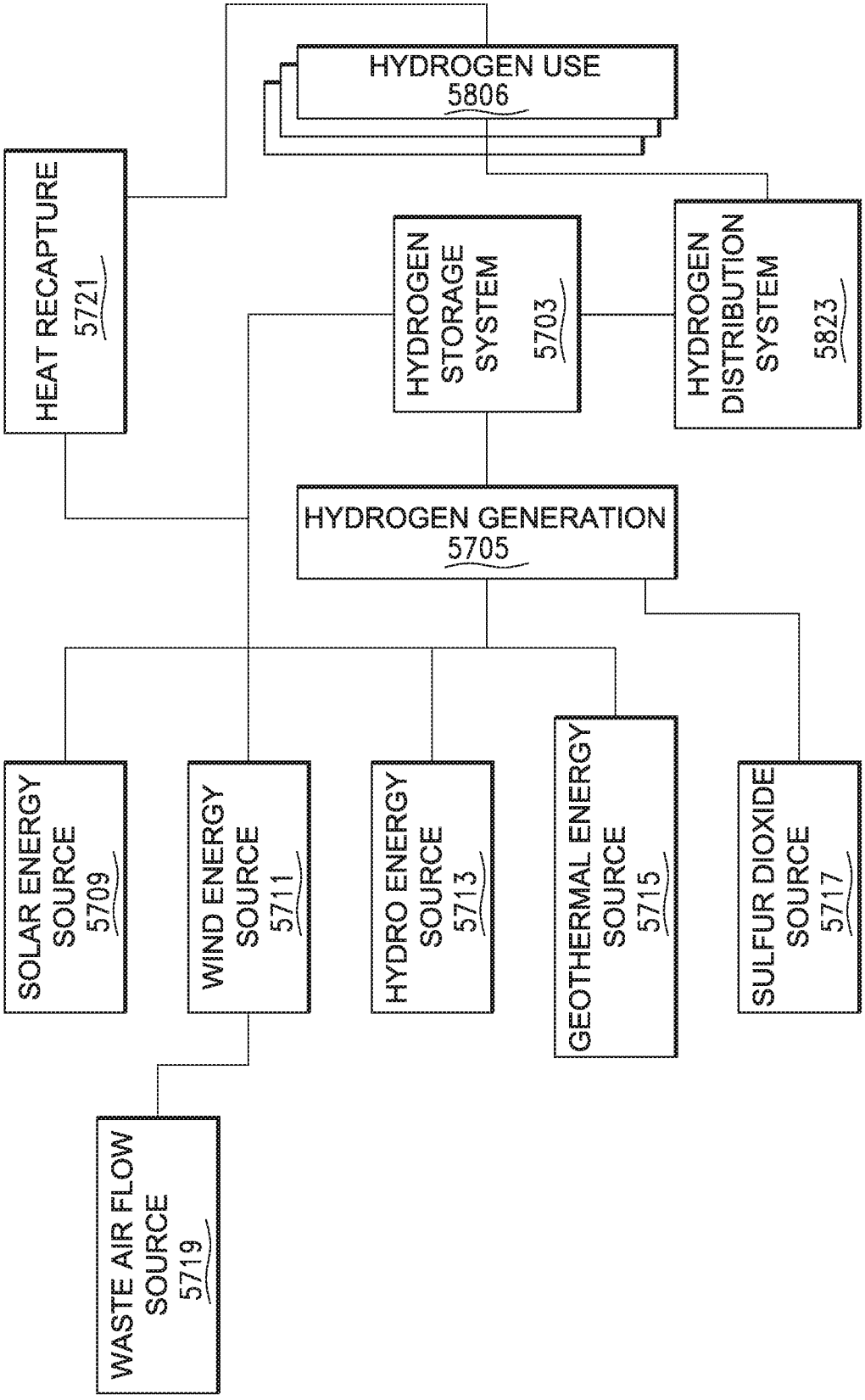
HYDROGEN USE
5806
HEAT RECAPTURE
5721
HYDROGEN STORAGE SYSTEM
5703
HYDROGEN DISTRIBUTION SYSTEM
5823
HYDROGEN GENERATION
5705
SOLAR ENERGY SOURCE
5709
WIND ENERGY SOURCE
5711
HYDRO ENERGY SOURCE
5713
GEOTHERMAL ENERGY SOURCE
5715
SULFUR DIOXIDE SOURCE
5717
WASTE AIR FLOW SOURCE
5719

FIG. 283

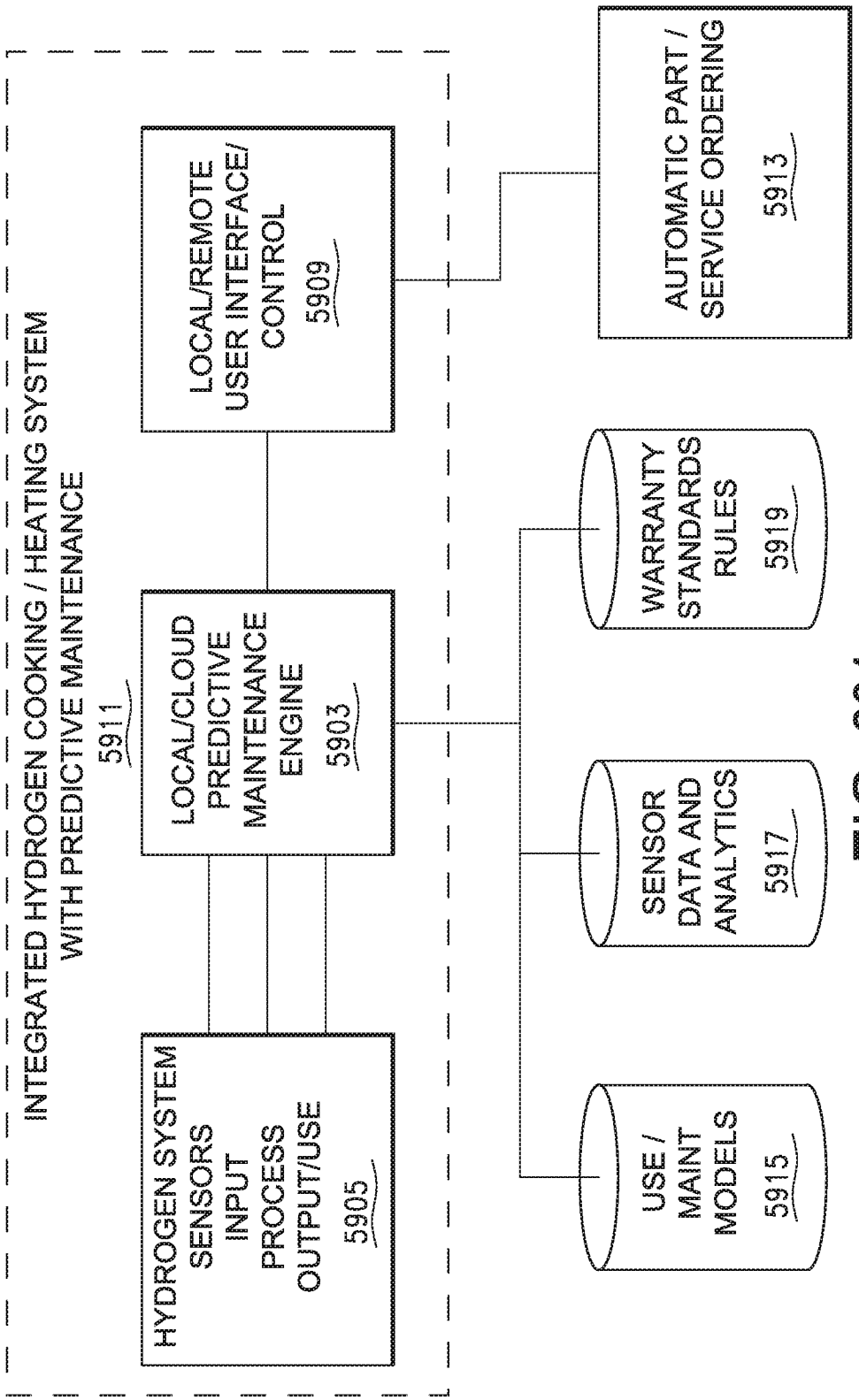
INTEGRATED HYDROGEN COOKING / HEATING SYSTEM WITH PREDICTIVE MAINTENANCE
5911
HYDROGEN SYSTEM SENSORS INPUT PROCESS OUTPUT/USE
5905
LOCAL/CLOUD PREDICTIVE MAINTENANCE ENGINE
5903
LOCAL/REMOTE USER INTERFACE/ CONTROL
5909
AUTOMATIC PART / SERVICE ORDERING
5913
WARRANTY STANDARDS RULES
5919
SENSOR DATA AND ANALYTICS
5917
USE / MAINT MODELS
5915

FIG. 284

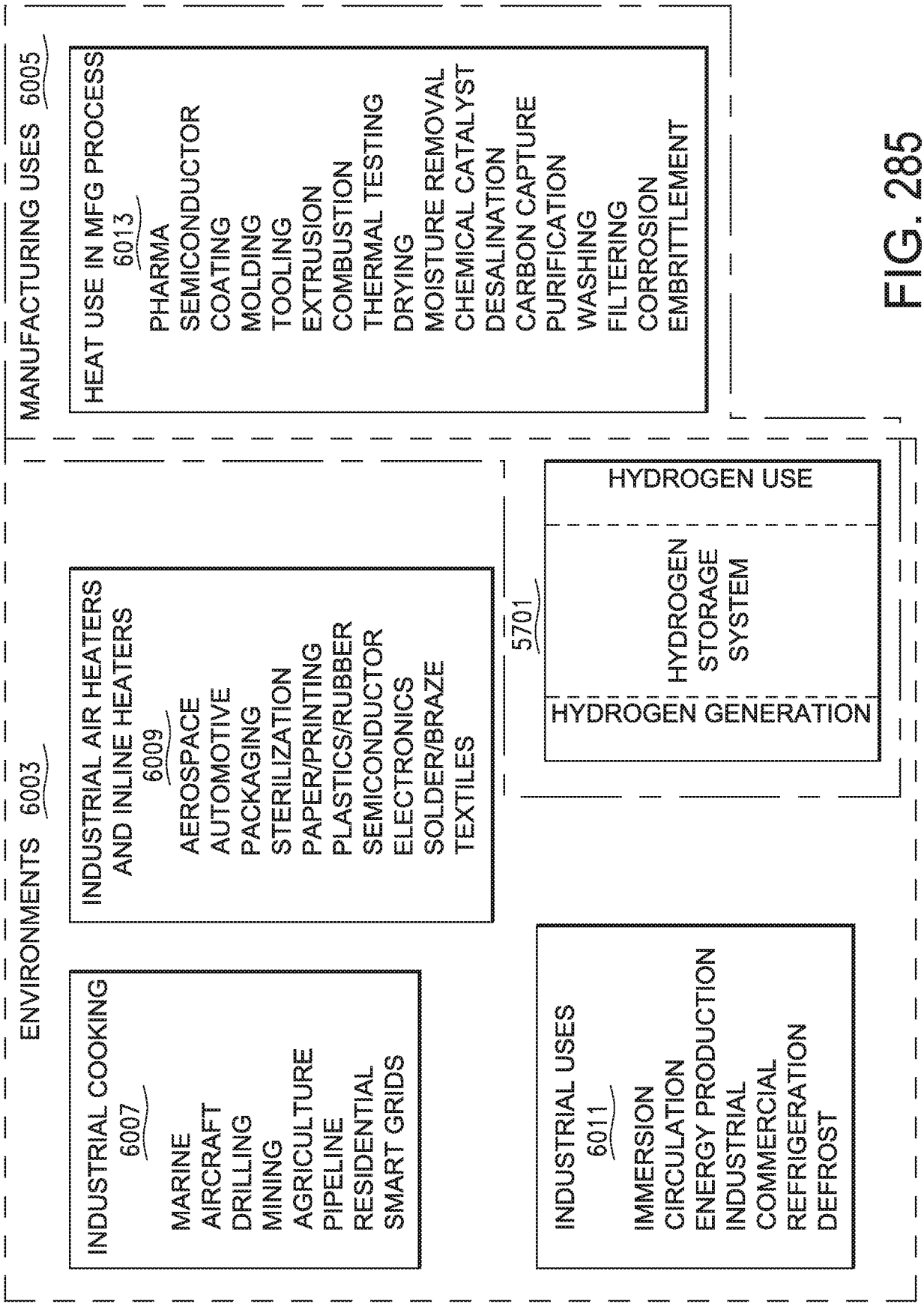
ENVIRONMENTS 6003
INDUSTRIAL COOKING 6007
MARINE
AIRCRAFT
DRILLING
MINING
AGRICULTURE
PIPELINE
RESIDENTIAL
SMART GRIDS
INDUSTRIAL AIR HEATERS AND INLINE HEATERS 6009
AEROSPACE
AUTOMOTIVE
PACKAGING
STERILIZATION
PAPER/PRINTING
PLASTICS/RUBBER
SEMICONDUCTOR
ELECTRONICS
SOLDER/BRAZE
TEXTILES
INDUSTRIAL USES 6011
IMMERSION
CIRCULATION
ENERGY PRODUCTION
INDUSTRIAL
COMMERCIAL
REFRIGERATION
DEFROST
5701
HYDROGEN USE
HYDROGEN GENERATION
HYDROGEN STORAGE SYSTEM
MANUFACTURING USES 6005
HEAT USE IN MFG PROCESS 6013
PHARMA
SEMICONDUCTOR
COATING
MOLDING
TOOLING
EXTRUSION
COMBUSTION
THERMAL TESTING
DRYING
MOISTURE REMOVAL
CHEMICAL CATALYST
DESALINATION
CARBON CAPTURE
PURIFICATION
WASHING
FILTERING
CORROSION
EMBRITTLEMENT

FIG. 285

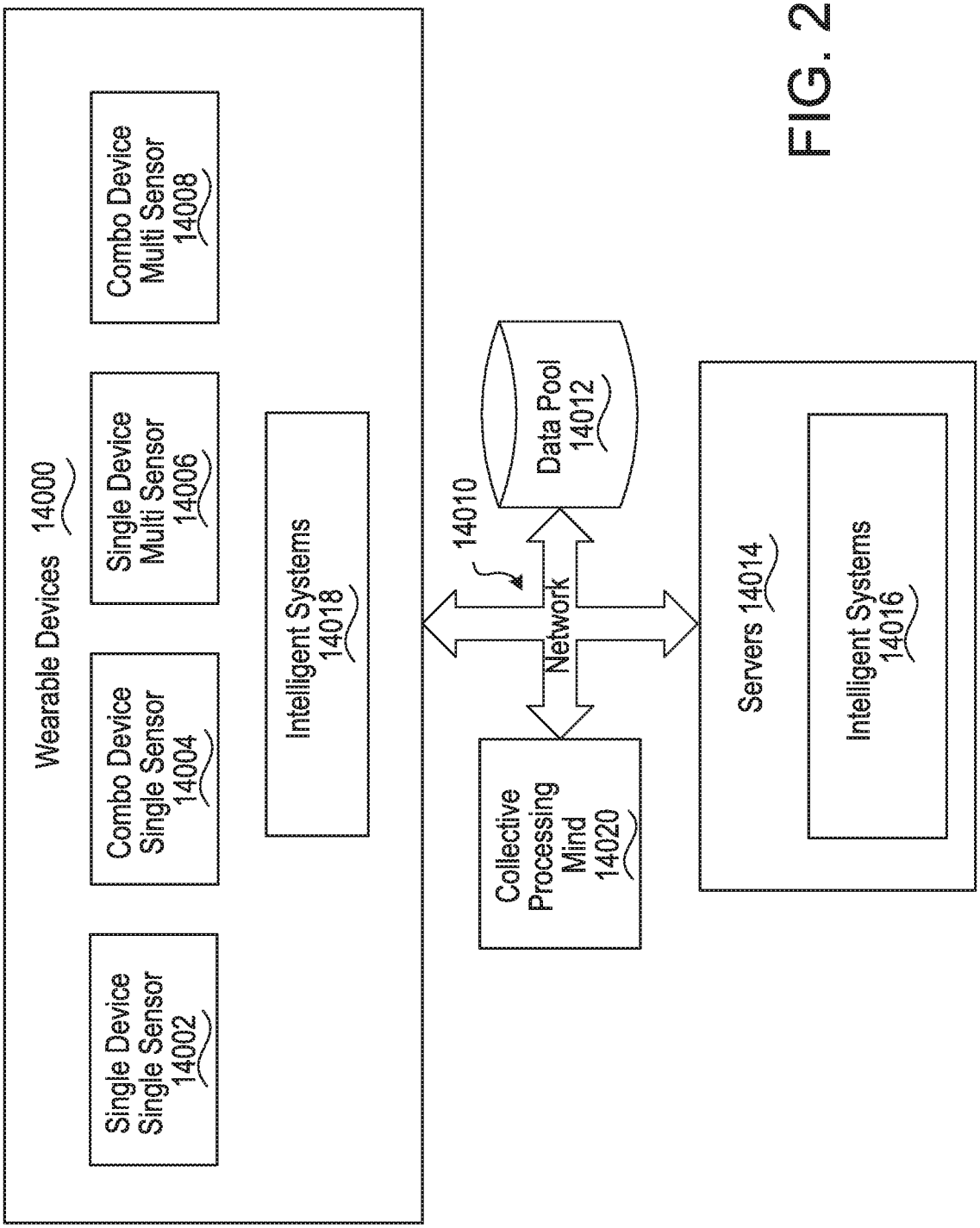
Wearable Devices 14000
Single Device Single Sensor 14002
Combo Device Single Sensor 14004
Single Device Multi Sensor 14006
Combo Device Multi Sensor 14008
Intelligent Systems 14018
14010
Network
Data Pool 14012
Collective Processing Mind 14020
Servers 14014
Intelligent Systems 14016

FIG. 286

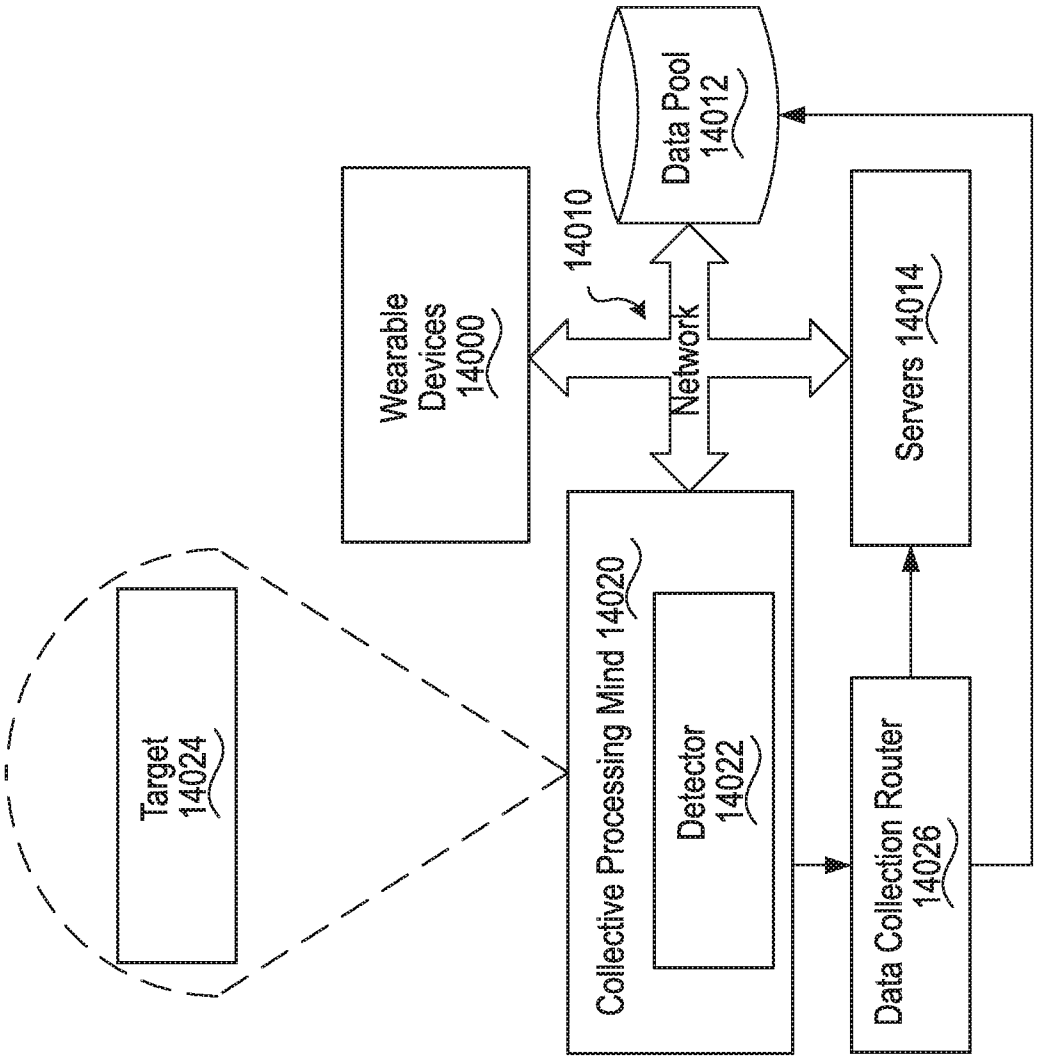
Data Pool
14012
14010
Wearable
Devices
14000
Network
Servers 14014
Target
14024
Collective Processing Mind 14020
Detector
14022
Data Collection Router
14026

FIG. 287

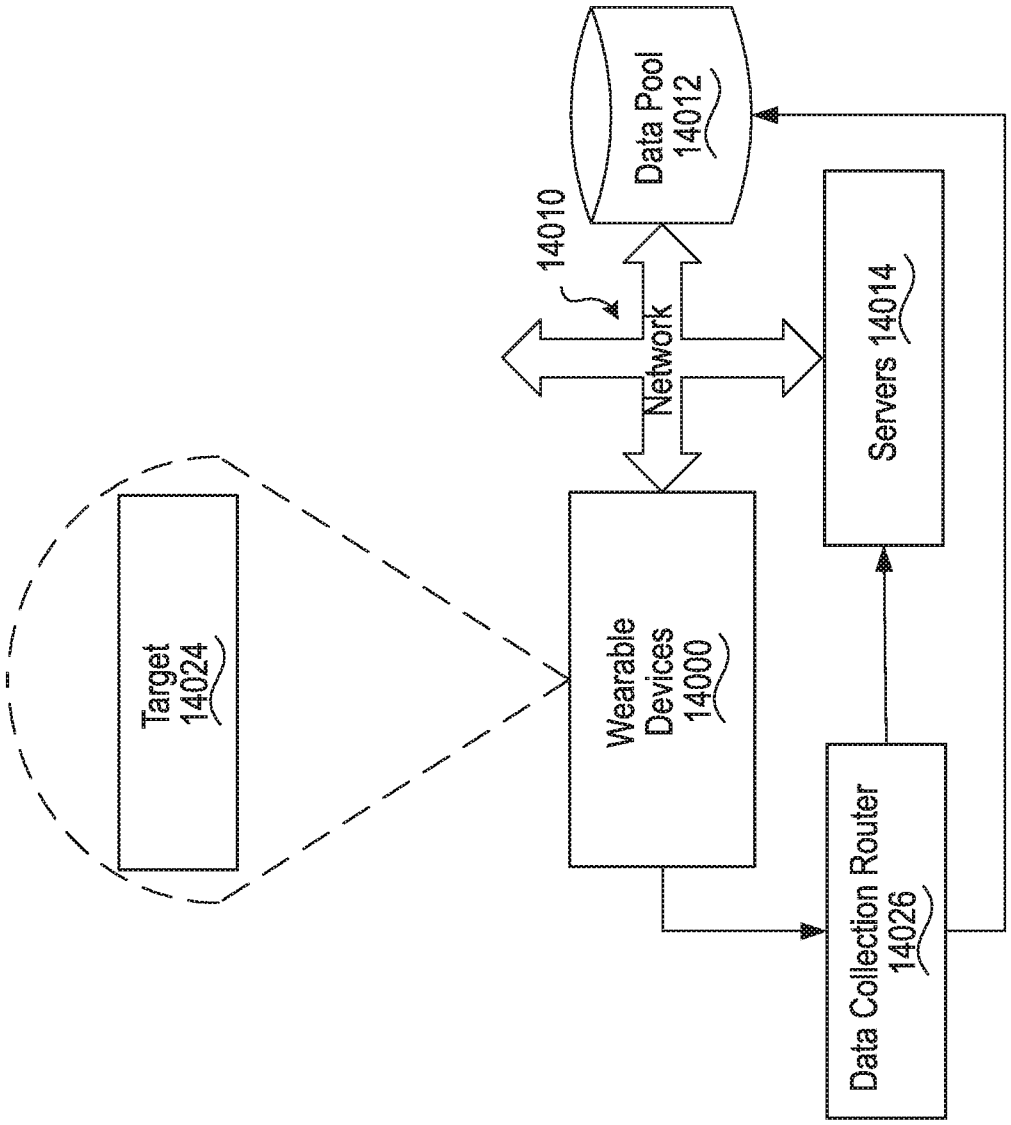
Data Pool
14012
14010
Network
Servers 14014
Target
14024
Wearable
Devices
14000
Data Collection Router
14026

FIG. 288

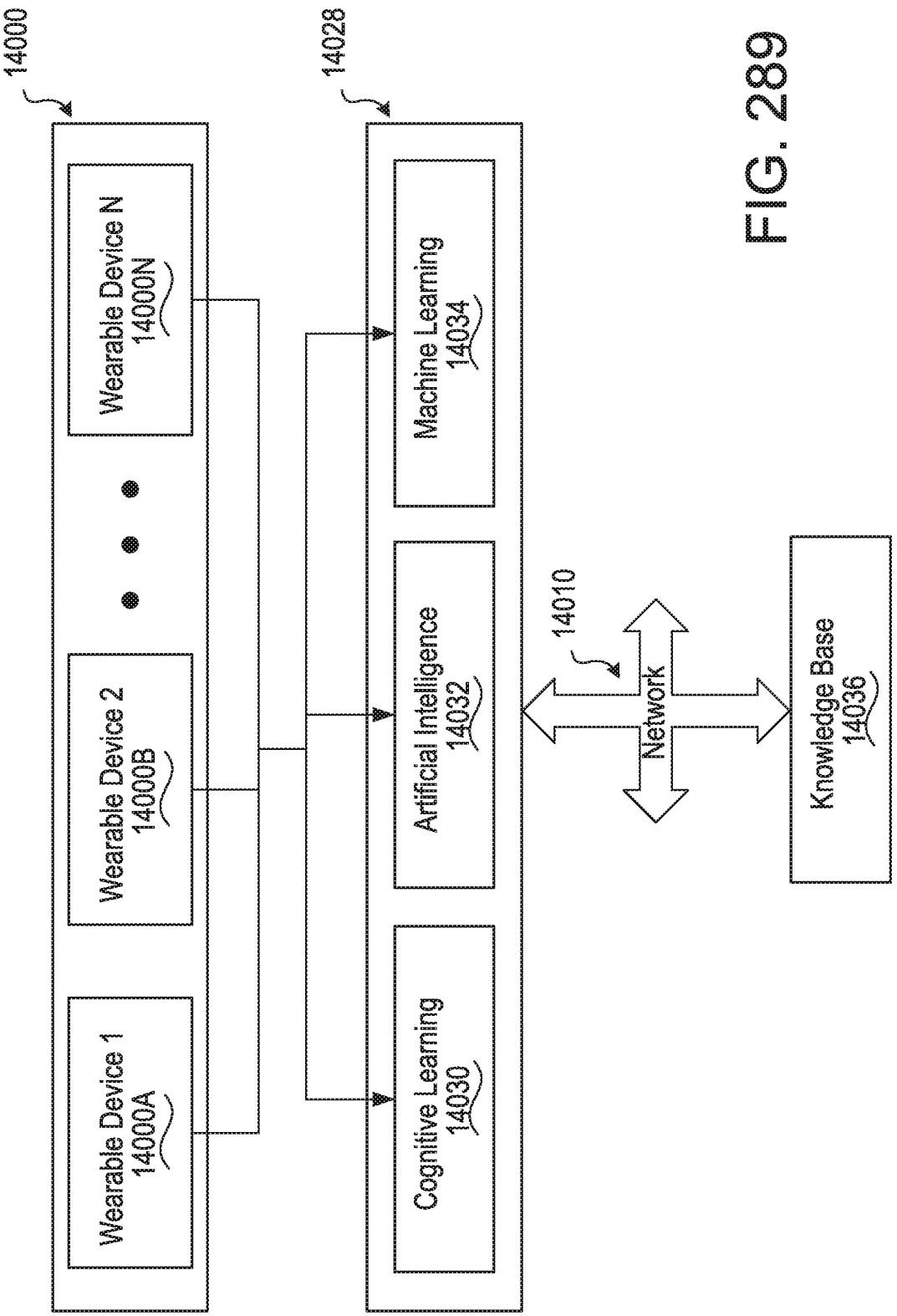
14000
Wearable Device 1
14000A
Wearable Device 2
14000B
Wearable Device N
14000N
14028
Cognitive Learning
14030
Artificial Intelligence
14032
Machine Learning
14034
14010
Network
Knowledge Base
14036

FIG. 289

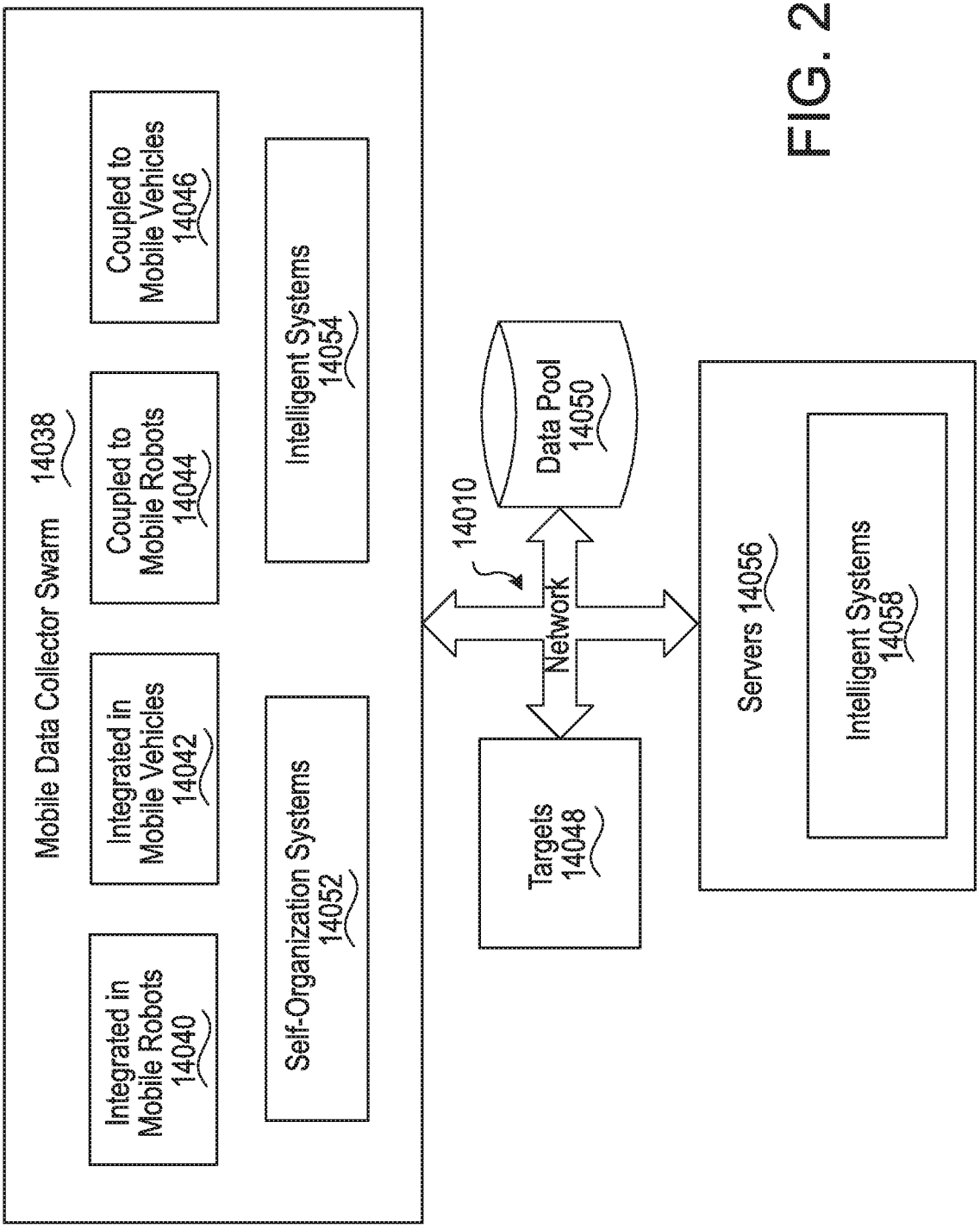
Mobile Data Collector Swarm 14038
Integrated in Mobile Robots 14040
Integrated in Mobile Vehicles 14042
Coupled to Mobile Robots 14044
Coupled to Mobile Vehicles 14046
Self-Organization Systems 14052
Intelligent Systems 14054
14010
Network
Data Pool 14050
Targets 14048
Servers 14056
Intelligent Systems 14058

FIG. 290

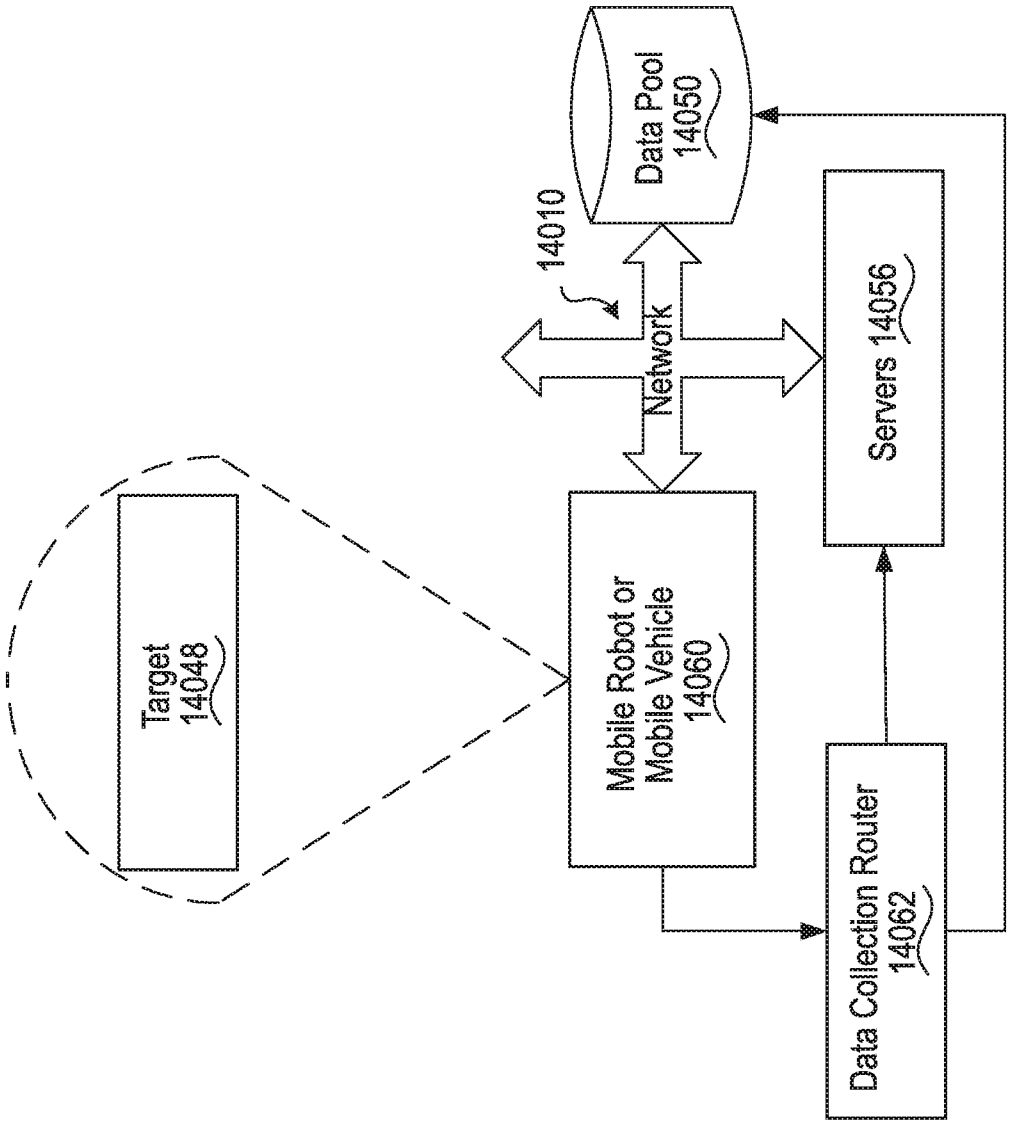
Data Pool
14050
14010
Network
Servers 14056
Target
14048
Mobile Robot or
Mobile Vehicle
14060
Data Collection Router
14062

FIG. 291

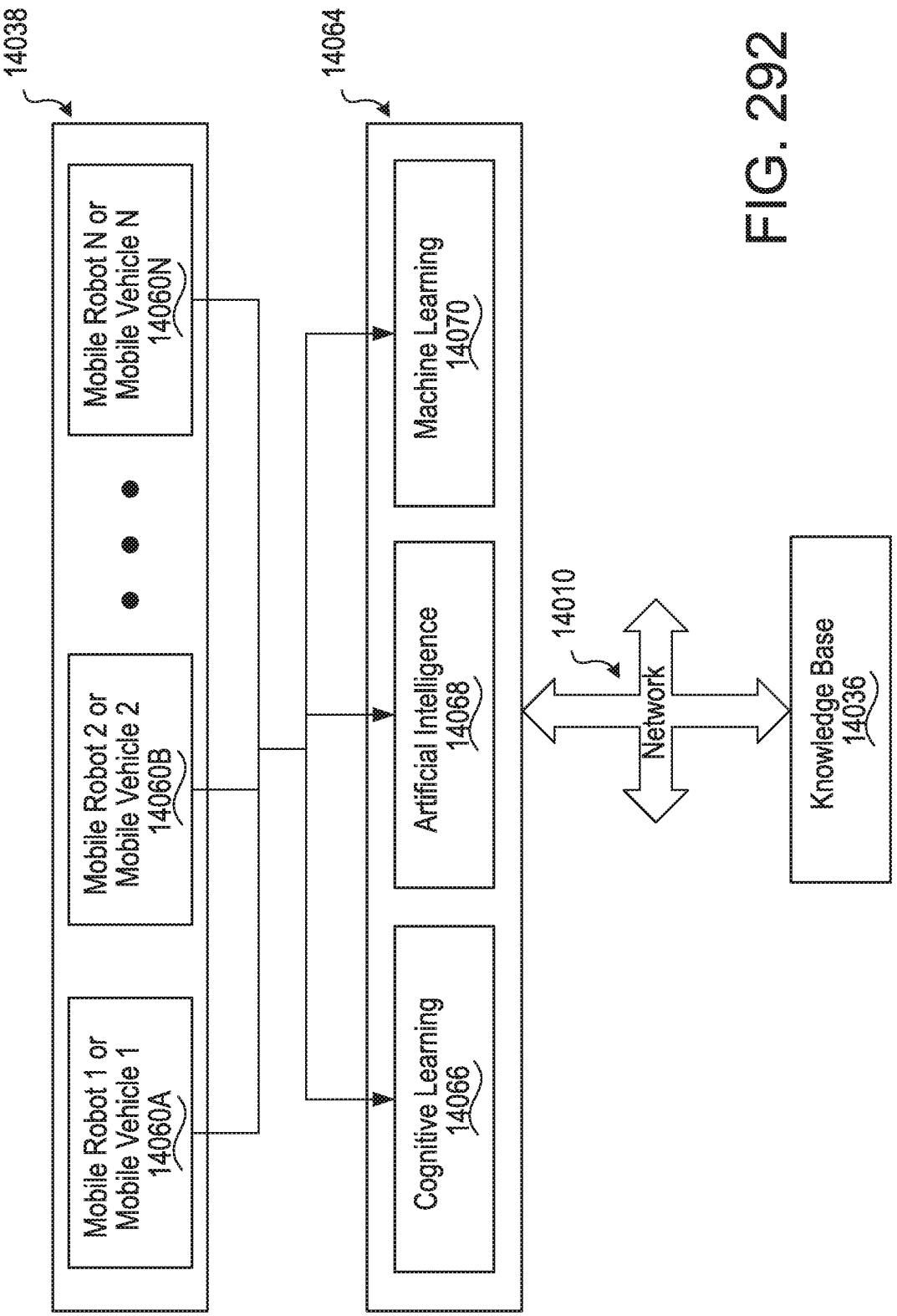
14038
Mobile Robot 1 or Mobile Vehicle 1 14060A
Mobile Robot 2 or Mobile Vehicle 2 14060B
Mobile Robot N or Mobile Vehicle N 14060N
14064
Cognitive Learning 14066
Artificial Intelligence 14068
Machine Learning 14070
14010
Network
Knowledge Base 14036

FIG. 292

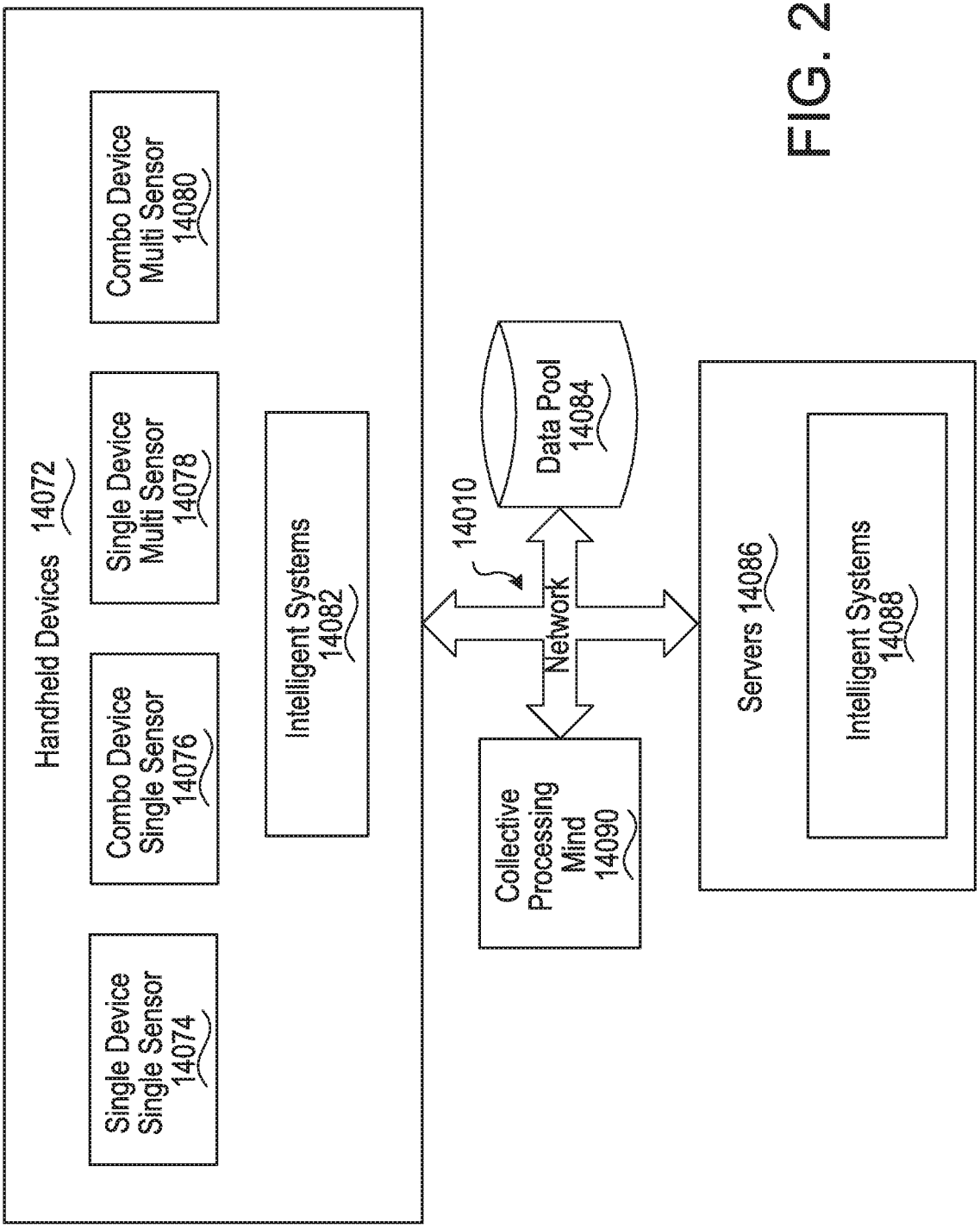
Handheld Devices 14072
Single Device Single Sensor 14074
Combo Device Single Sensor 14076
Single Device Multi Sensor 14078
Combo Device Multi Sensor 14080
Intelligent Systems 14082
14010
Network
Data Pool 14084
Collective Processing Mind 14090
Servers 14086
Intelligent Systems 14088

FIG. 293

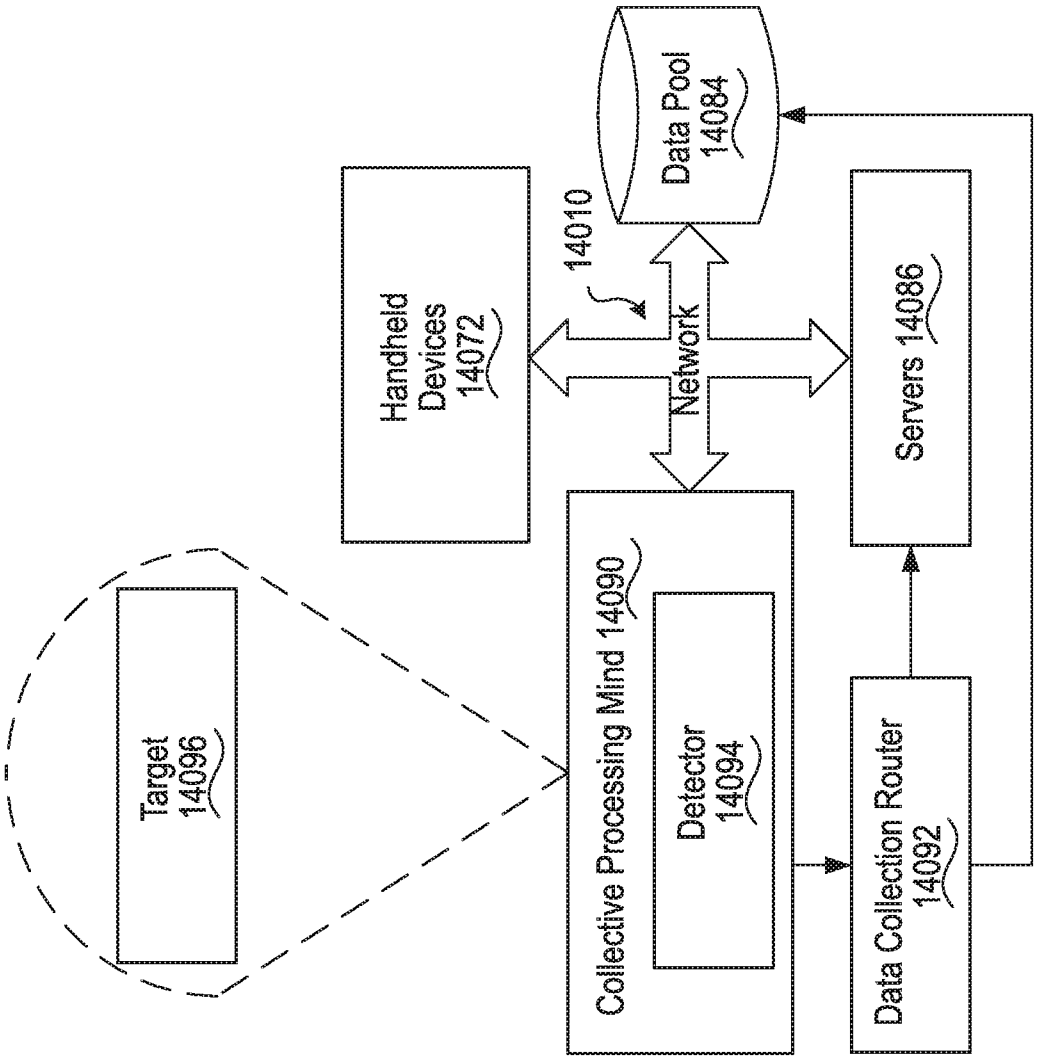
Data Pool
14084
14010
Handheld
Devices
14072
Network
Servers 14086
Target
14096
Collective Processing Mind 14090
Detector
14094
Data Collection Router
14092

FIG. 294

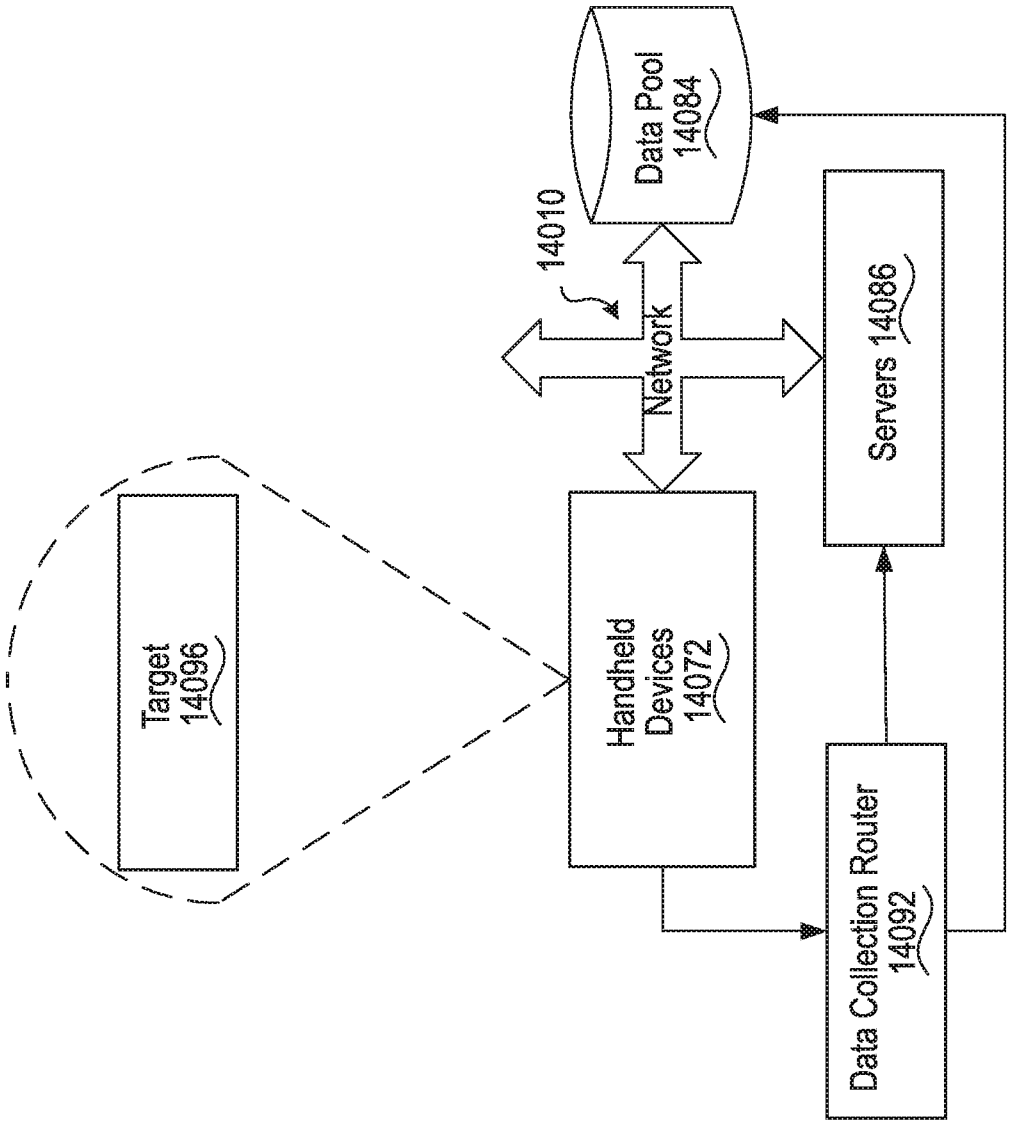
Data Pool
14084
14010
Network
Servers 14086
Target
14096
Handheld
Devices
14072
Data Collection Router
14092

FIG. 295

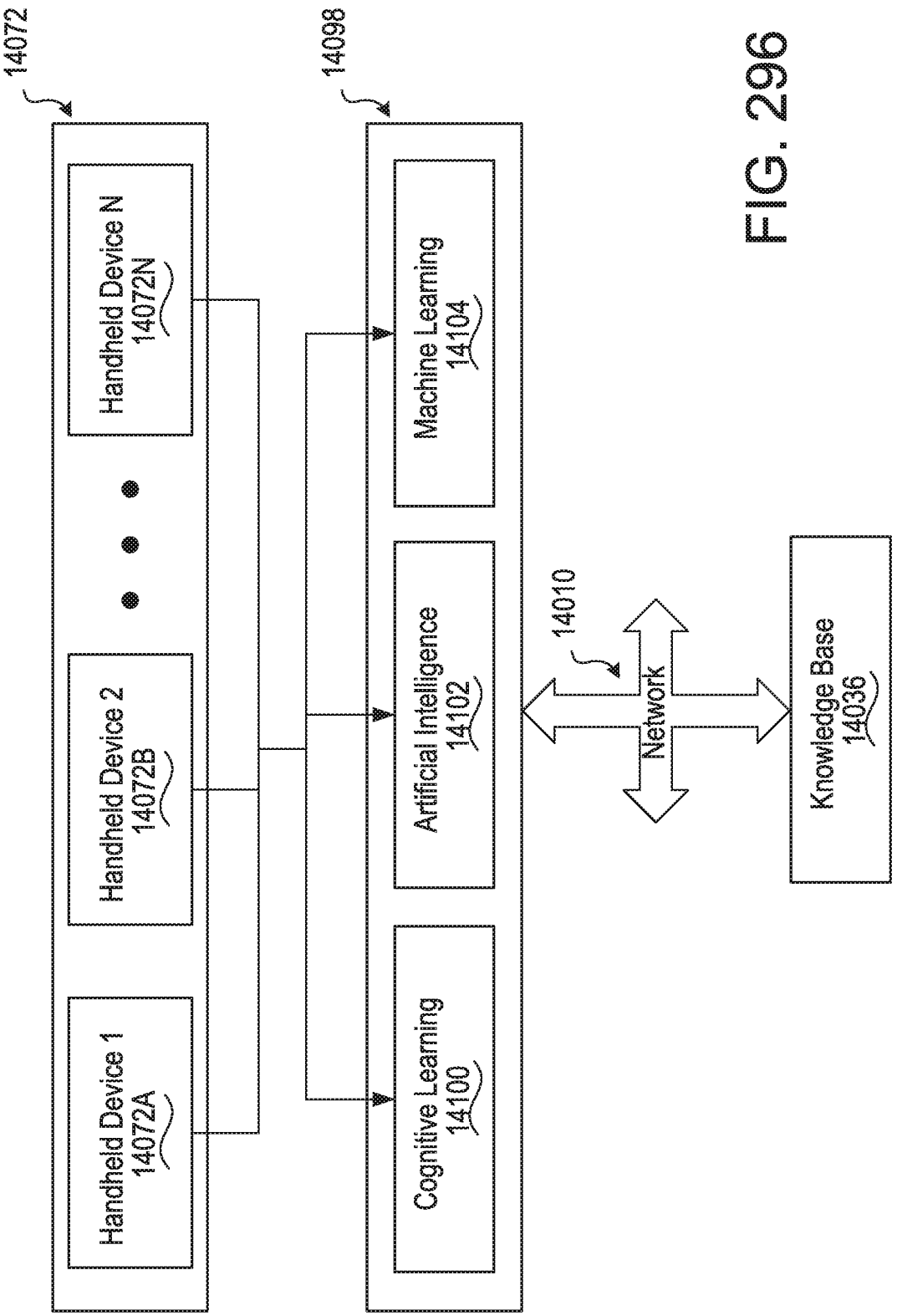
14072
Handheld Device 1
14072A
Handheld Device 2
14072B
Handheld Device N
14072N
14098
Cognitive Learning
14100
Artificial Intelligence
14102
Machine Learning
14104
14010
Network
Knowledge Base
14036

FIG. 296

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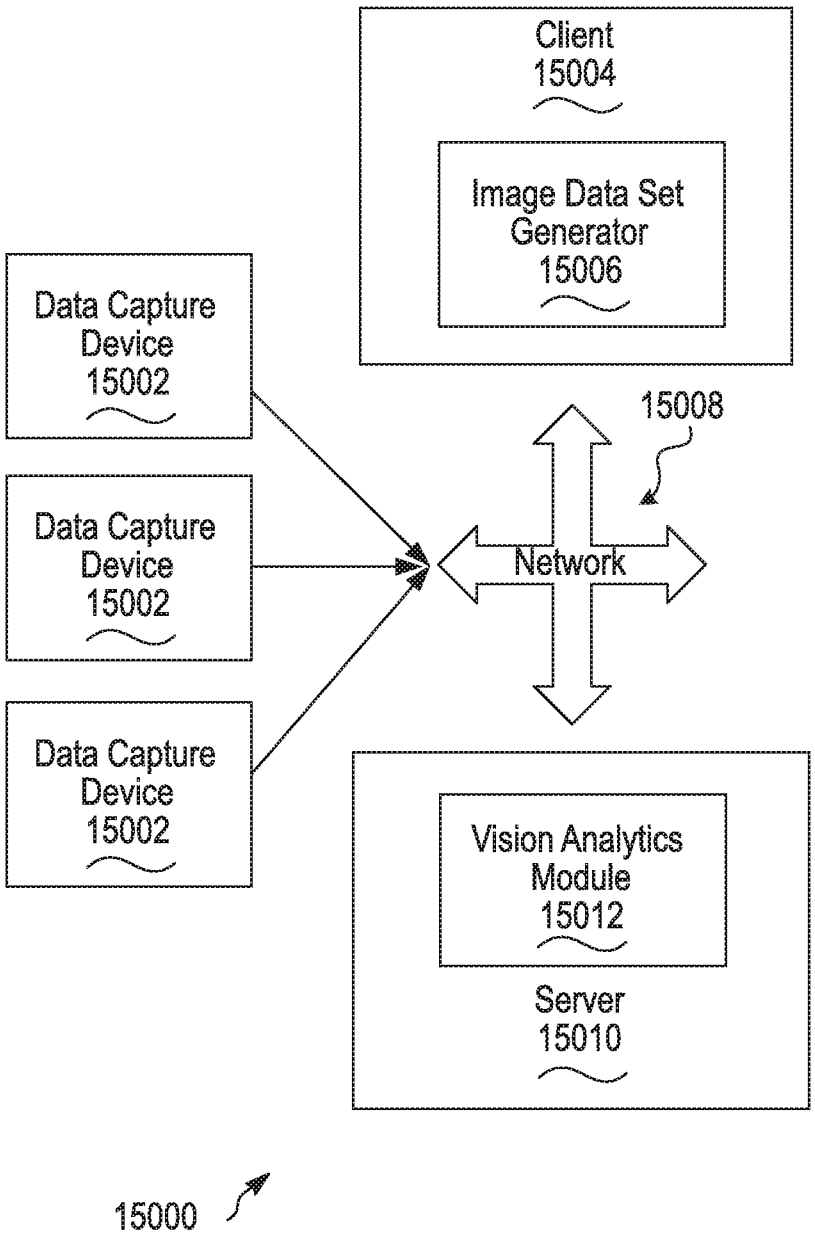

FIG. 297

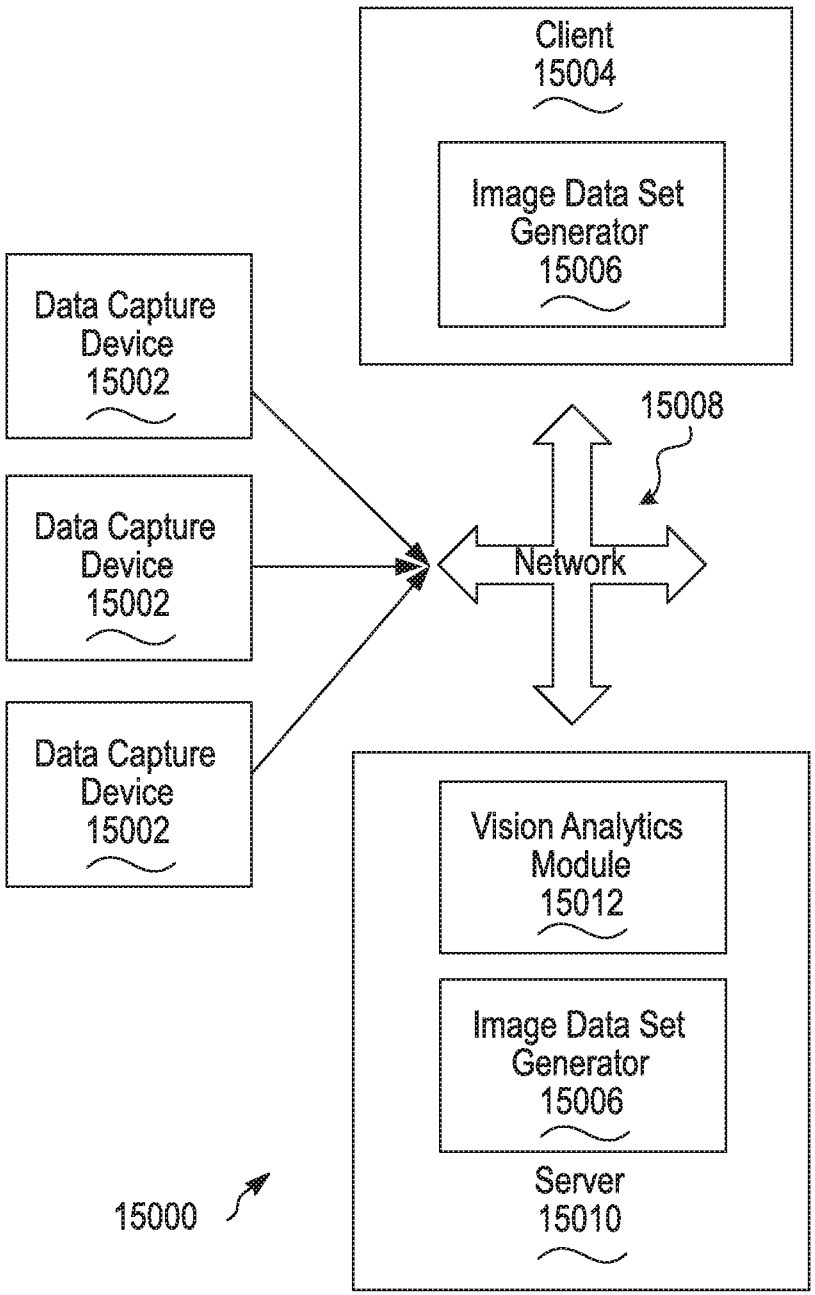
Client
15004
Image Data Set
Generator
15006
Data Capture
Device
15002
Data Capture
Device
15002
Data Capture
Device
15002
15008
Network
Vision Analytics
Module
15012
Image Data Set
Generator
15006
Server
15010
15000

FIG. 298

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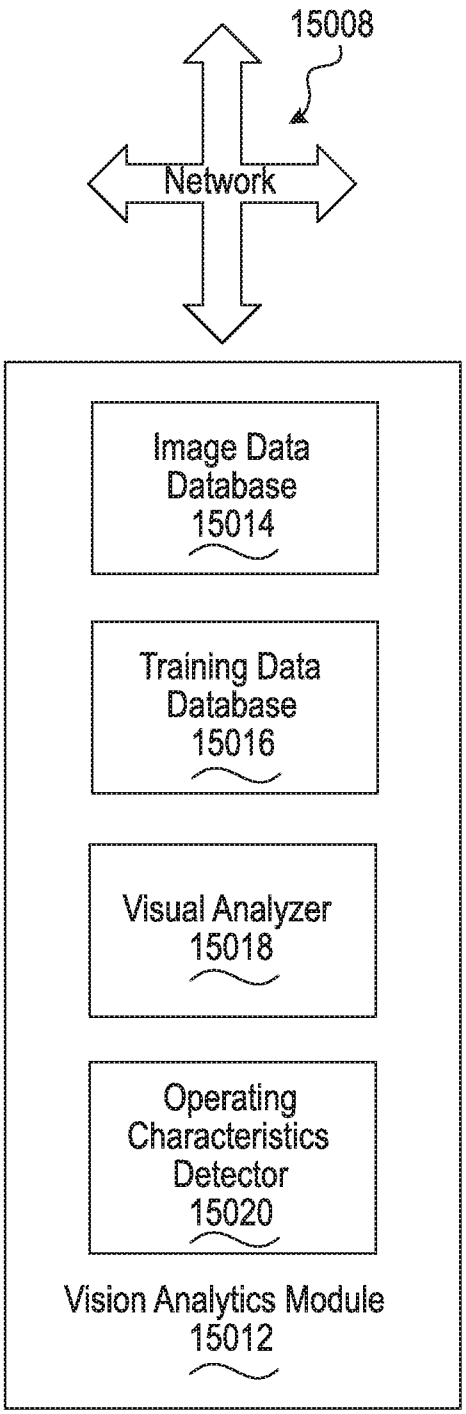


FIG. 299

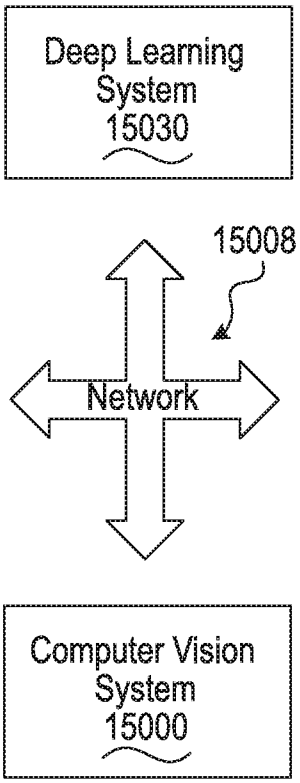

Deep Learning System 15030
15008
Network
Computer Vision System 15000

FIG. 300

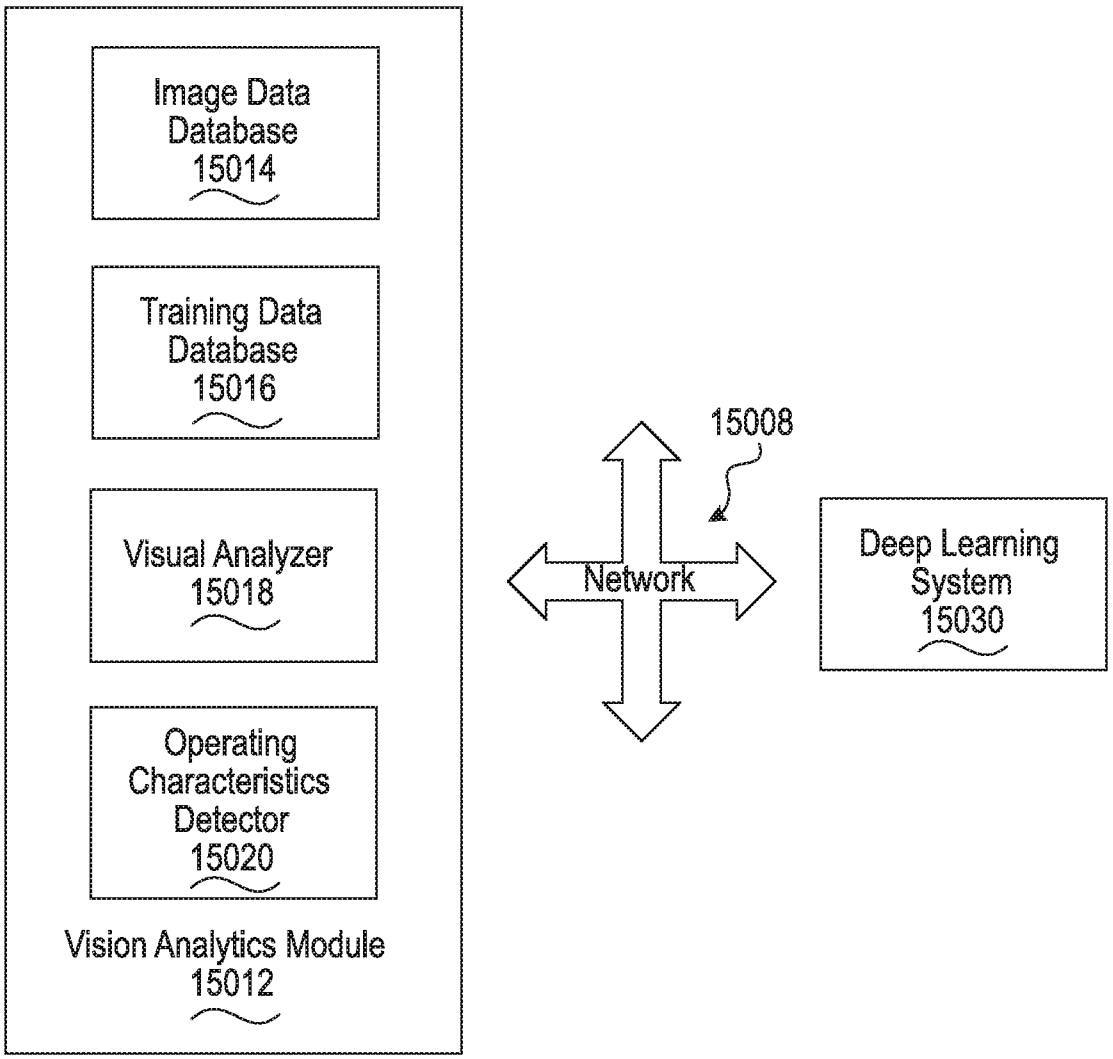


Image Data Database 15014
Training Data Database 15016
Visual Analyzer 15018
Operating Characteristics Detector 15020
Vision Analytics Module 15012
15008
Network
Deep Learning System 15030

FIG. 301

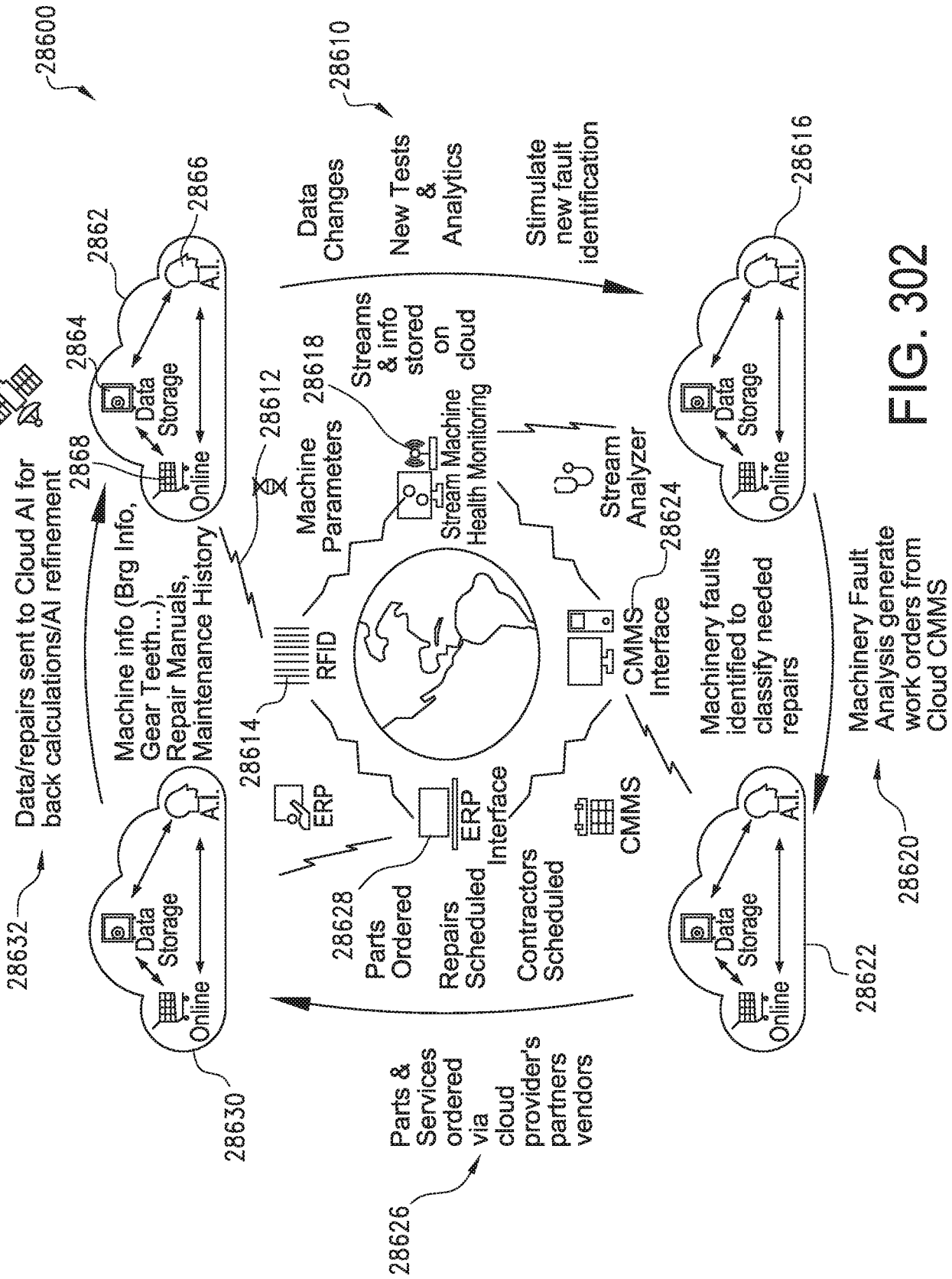

28600
28610
Data Changes
New Tests & Analytics
Stimulate new fault identification
2862
2866
A.I.
2864
Data Storage
2868
Online
28612
Machine Parameters
28618
Streams & info stored on cloud
Stream Machine Health Monitoring
Stream Analyzer
28624
28616
Data/repairs sent to Cloud AI for back calculations/AI refinement
Machine info (Brg Info, Gear Teeth...), Repair Manuals, Maintenance History
28614
RFID
CMMS Interface
Machinery faults identified to classify needed repairs
Machinery Fault Analysis generate work orders from Cloud CMMS
28632
ERP
ERP Interface
CMMS
28628
Parts Ordered
Repairs Scheduled
Contractors Scheduled
28620
28630
28622
Parts & Services ordered via cloud provider's partners vendors
28626

FIG. 302

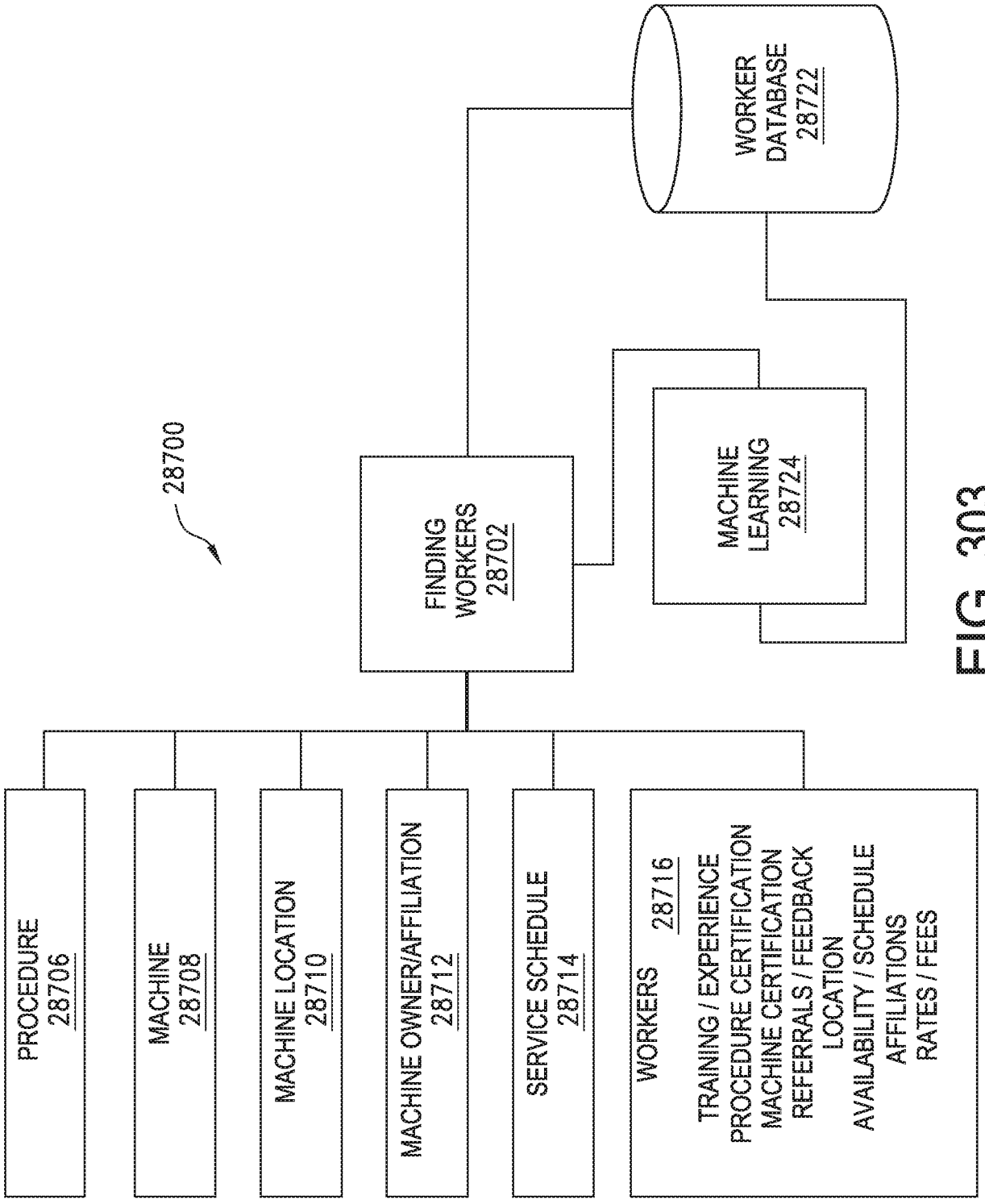

28700
WORKER DATABASE 28722
FINDING WORKERS 28702
MACHINE LEARNING 28724
PROCEDURE 28706
MACHINE 28708
MACHINE LOCATION 28710
MACHINE OWNER/AFFILIATION 28712
SERVICE SCHEDULE 28714
WORKERS 28716
TRAINING / EXPERIENCE
PROCEDURE CERTIFICATION
MACHINE CERTIFICATION
REFERRALS / FEEDBACK
LOCATION
AVAILABILITY / SCHEDULE
AFFILIATIONS
RATES / FEES

FIG. 303

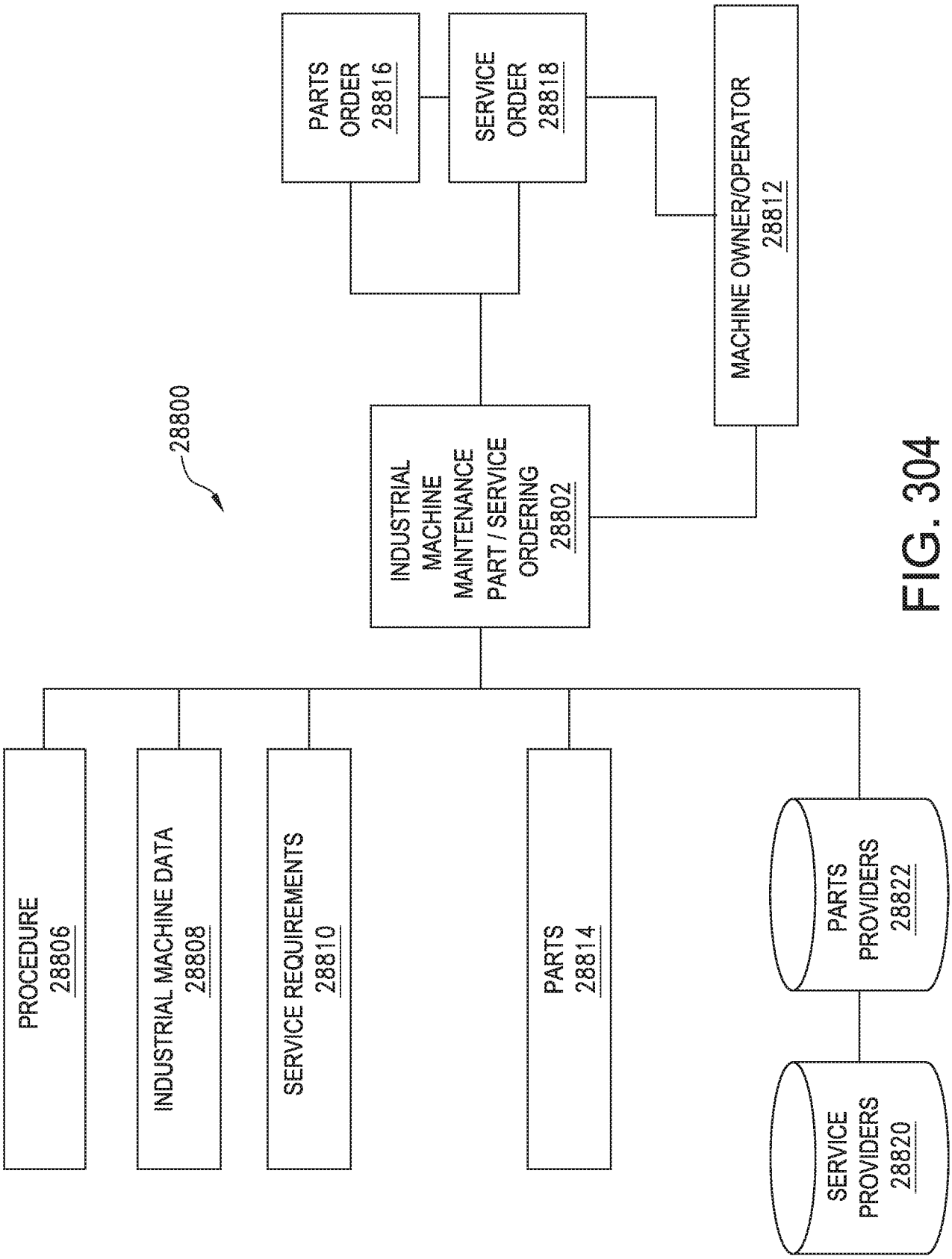

28800
INDUSTRIAL MACHINE MAINTENANCE PART / SERVICE ORDERING 28802
PARTS ORDER 28816
SERVICE ORDER 28818
MACHINE OWNER/OPERATOR 28812
PROCEDURE 28806
INDUSTRIAL MACHINE DATA 28808
SERVICE REQUIREMENTS 28810
PARTS 28814
PARTS PROVIDERS 28822
SERVICE PROVIDERS 28820

FIG. 304

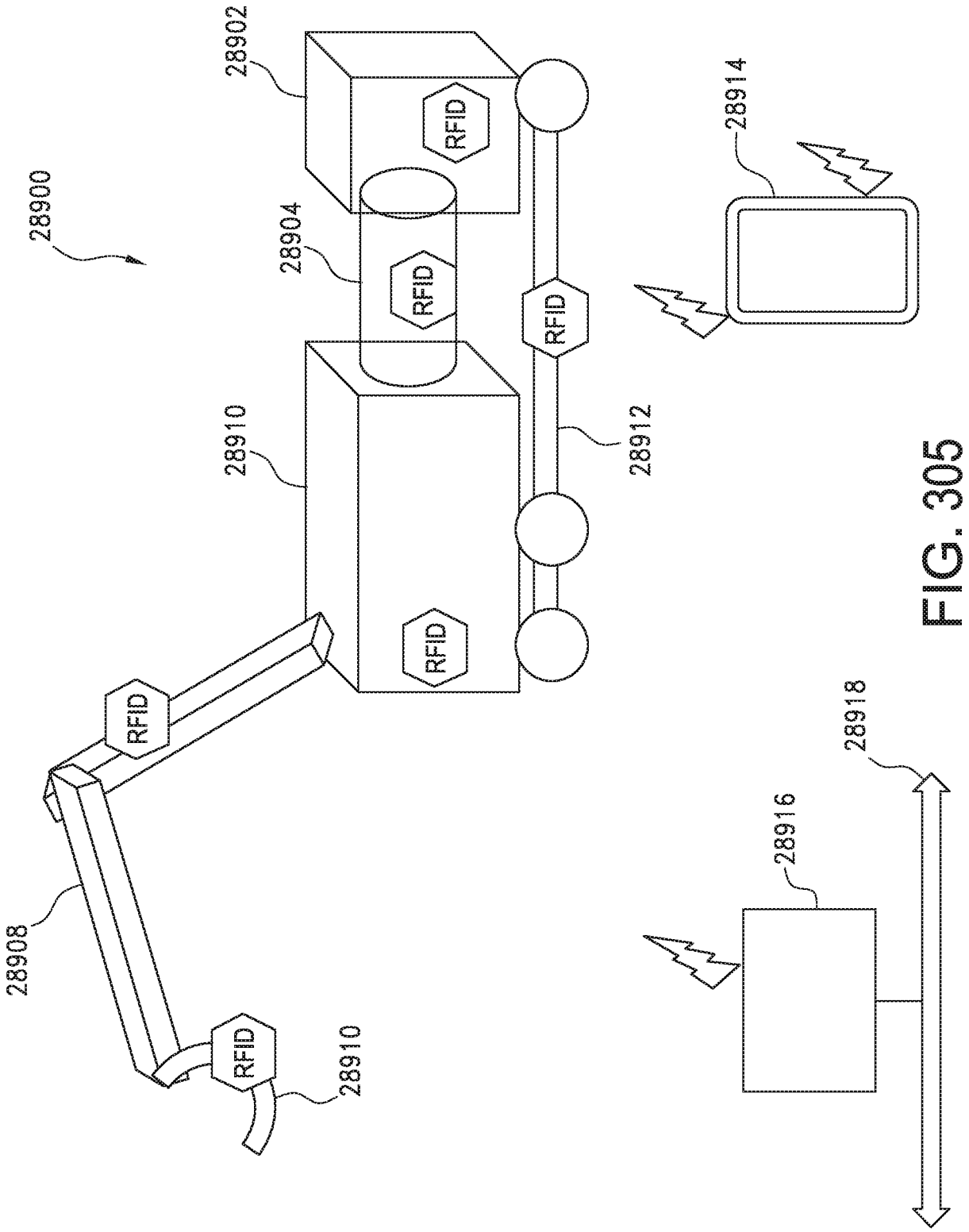


FIG. 305

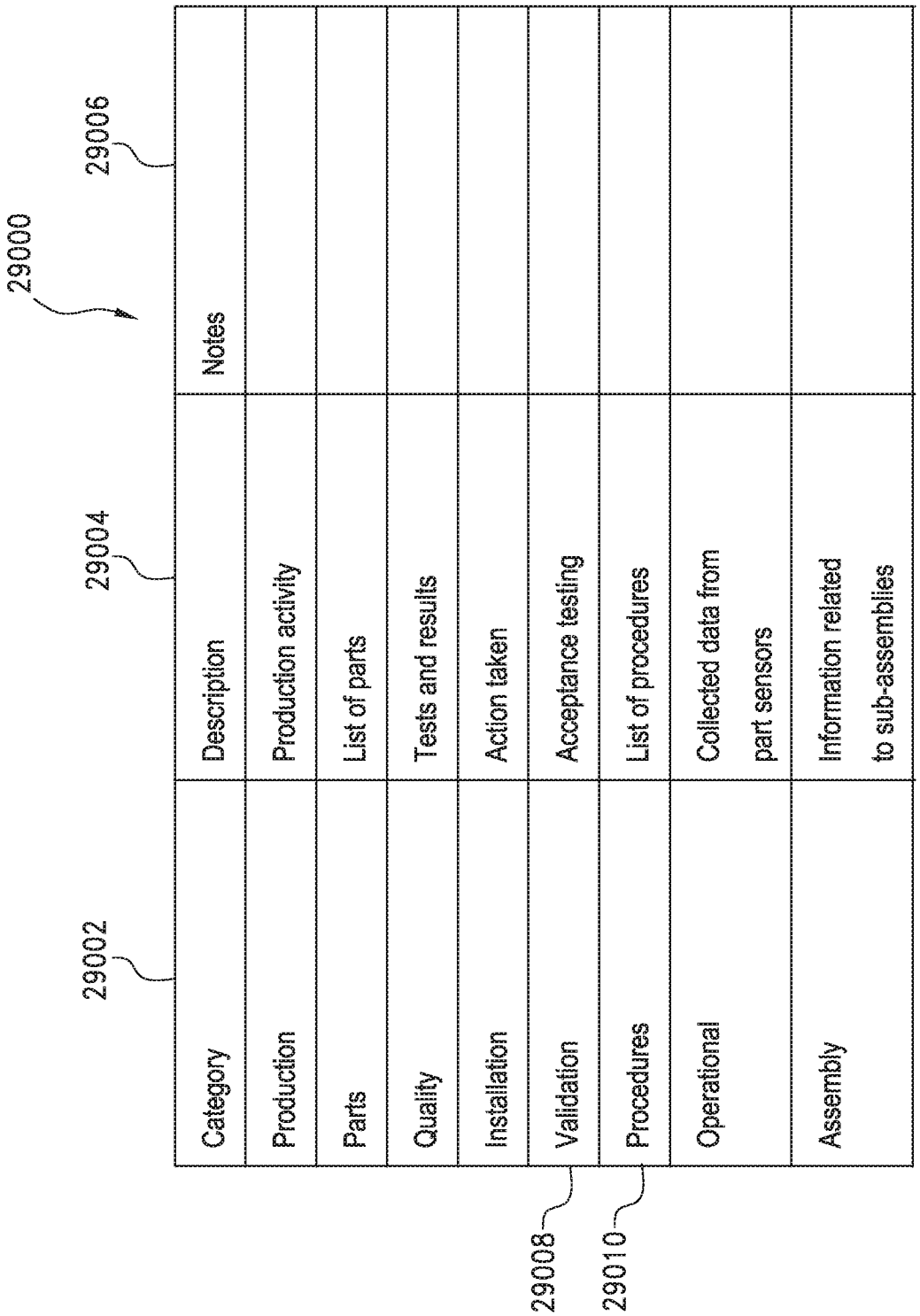

29000
29002
29004
29006
29008
29010
Category
Description
Notes
Production
Production activity
Parts
List of parts
Quality
Tests and results
Installation
Action taken
Validation
Acceptance testing
Procedures
List of procedures
Operational
Collected data from part sensors
Assembly
Information related to sub-assemblies

FIG. 306

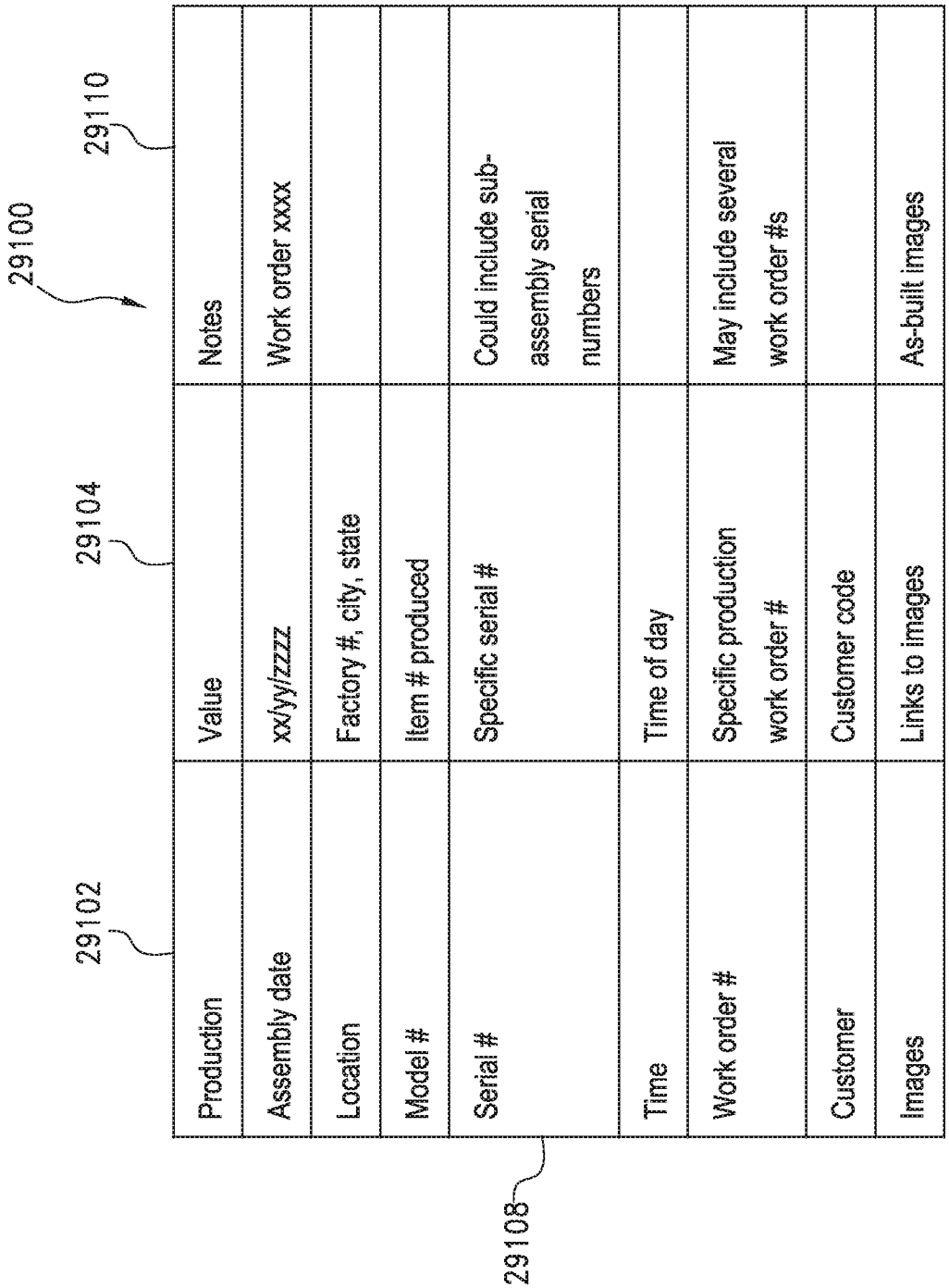

29100
29102
29104
29110
29108
Production
Value
Notes
Assembly date
xx/yy/zzzz
Work order xxxx
Location
Factory #, city, state
Model #
Item # produced
Serial #
Specific serial #
Could include sub-assembly serial numbers
Time
Time of day
Work order #
Specific production work order #
May include several work order #s
Customer
Customer code
Images
Links to images
As-built images

FIG. 307

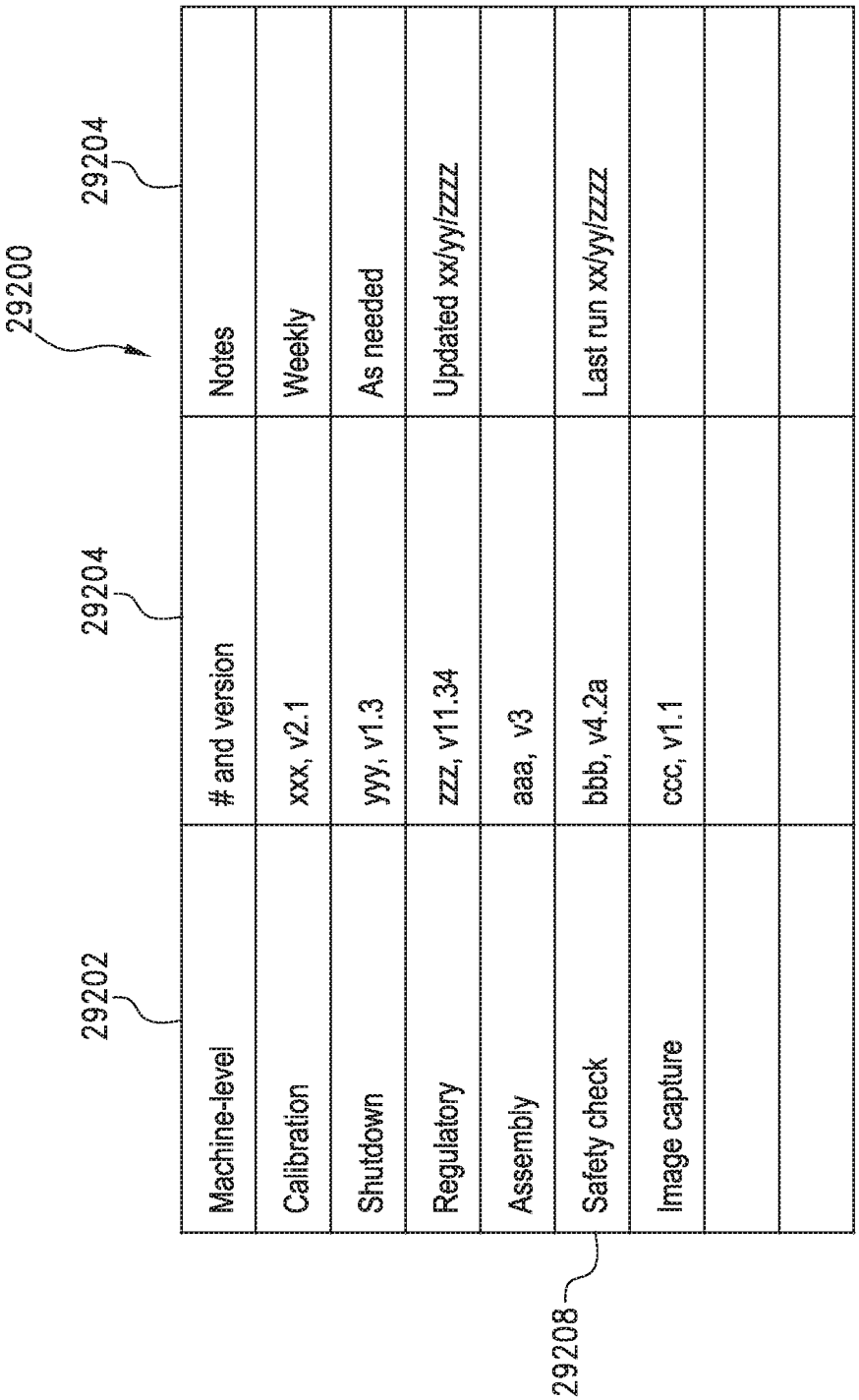

29200
29202
29204
29204
29208
Machine-level
and version
Notes
Calibration
xxx, v2.1
Weekly
Shutdown
yyy, v1.3
As needed
Regulatory
zzz, v11.34
Updated xx/yy/zzzz
Assembly
aaa, v3
Safety check
bbb, v4.2a
Last run xx/yy/zzzz
Image capture
ccc, v1.1

FIG. 308

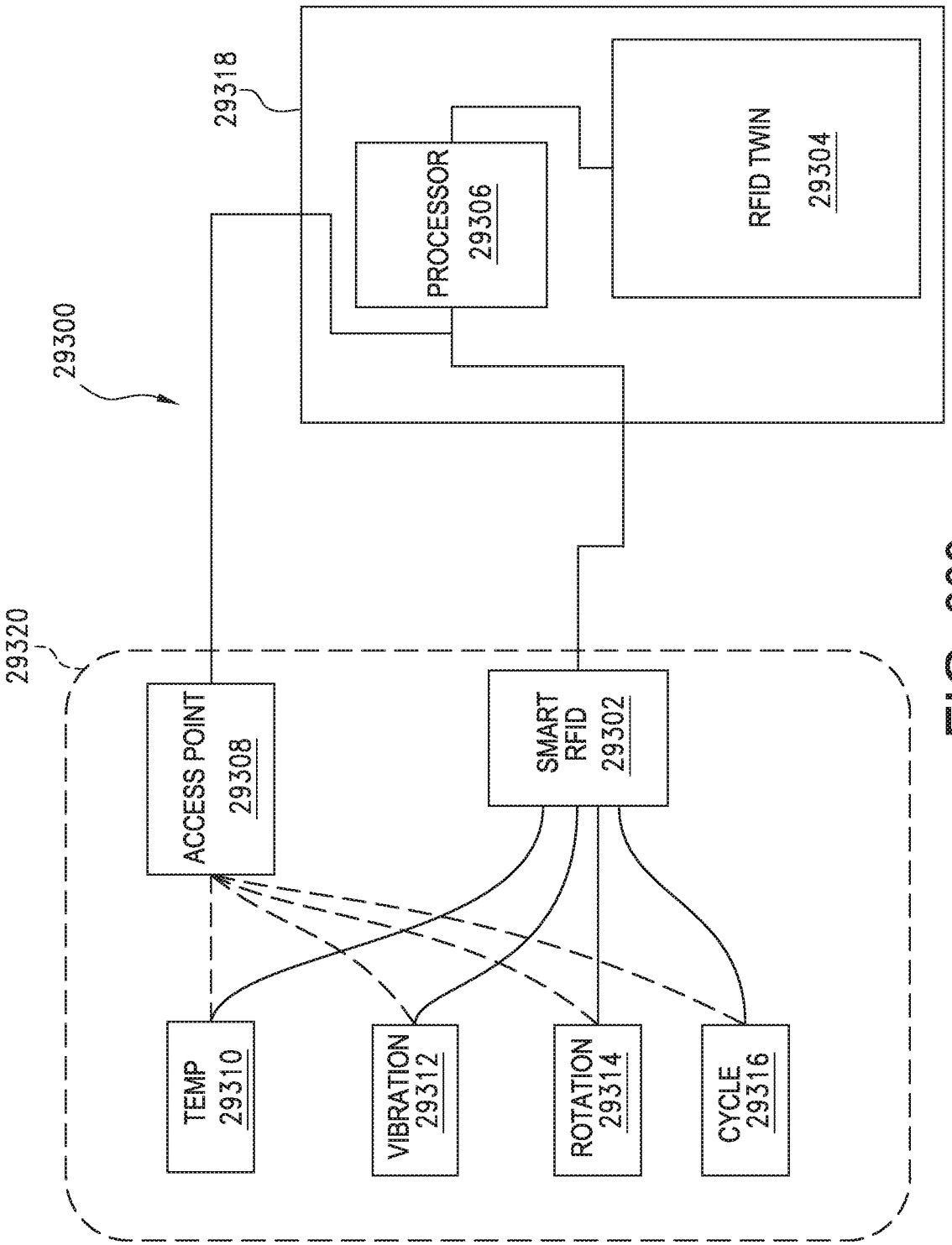

29318
PROCESSOR
29306
RFID TWIN
29304
29300
29320
ACCESS POINT
29308
SMART
RFID
29302
TEMP
29310
VIBRATION
29312
ROTATION
29314
CYCLE
29316

FIG. 309

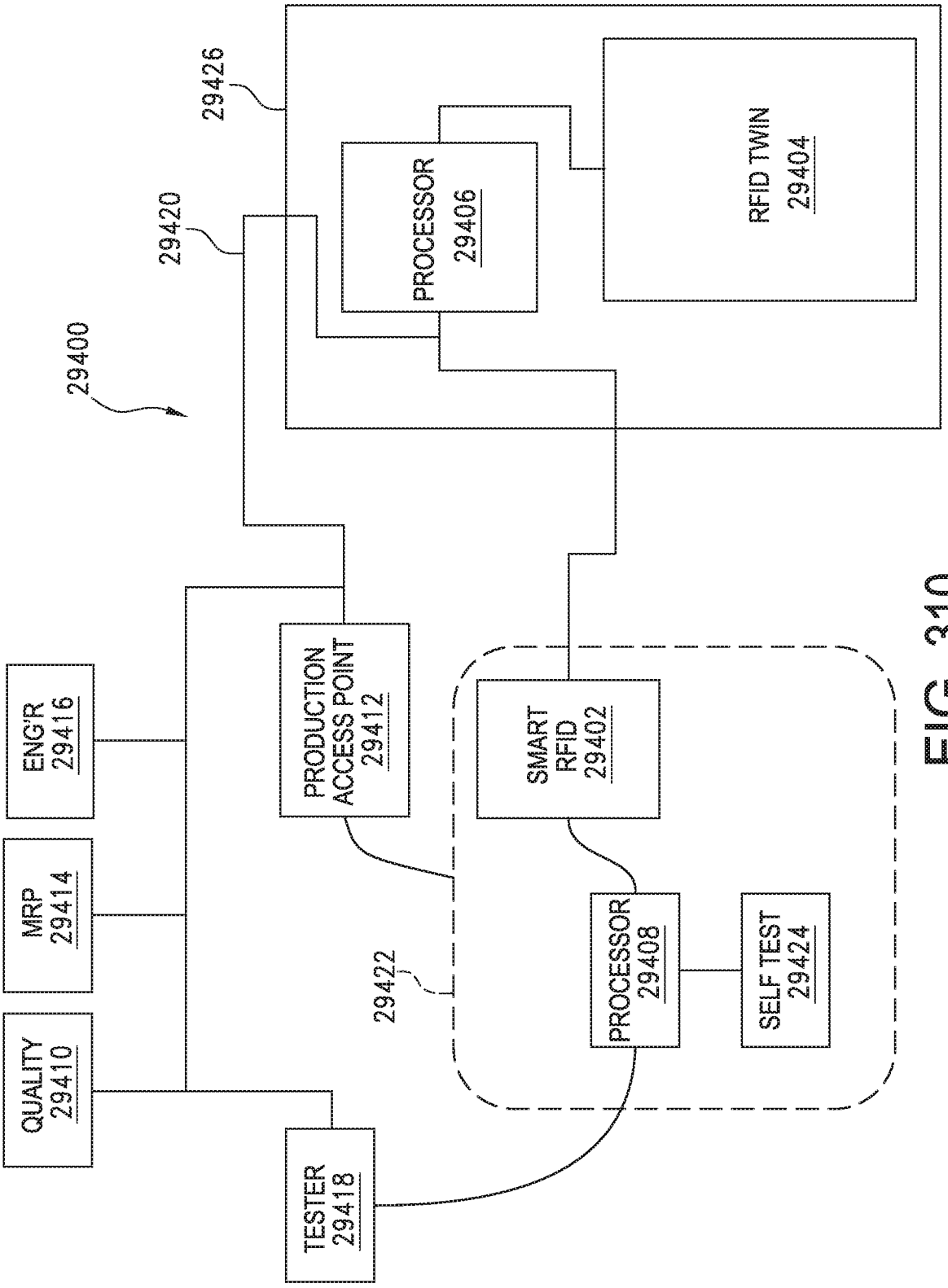

29400
29420
29426
PROCESSOR 29406
RFID TWIN 29404
PRODUCTION ACCESS POINT 29412
SMART RFID 29402
ENG'R 29416
MRP 29414
QUALITY 29410
TESTER 29418
29422
PROCESSOR 29408
SELF TEST 29424

FIG. 310

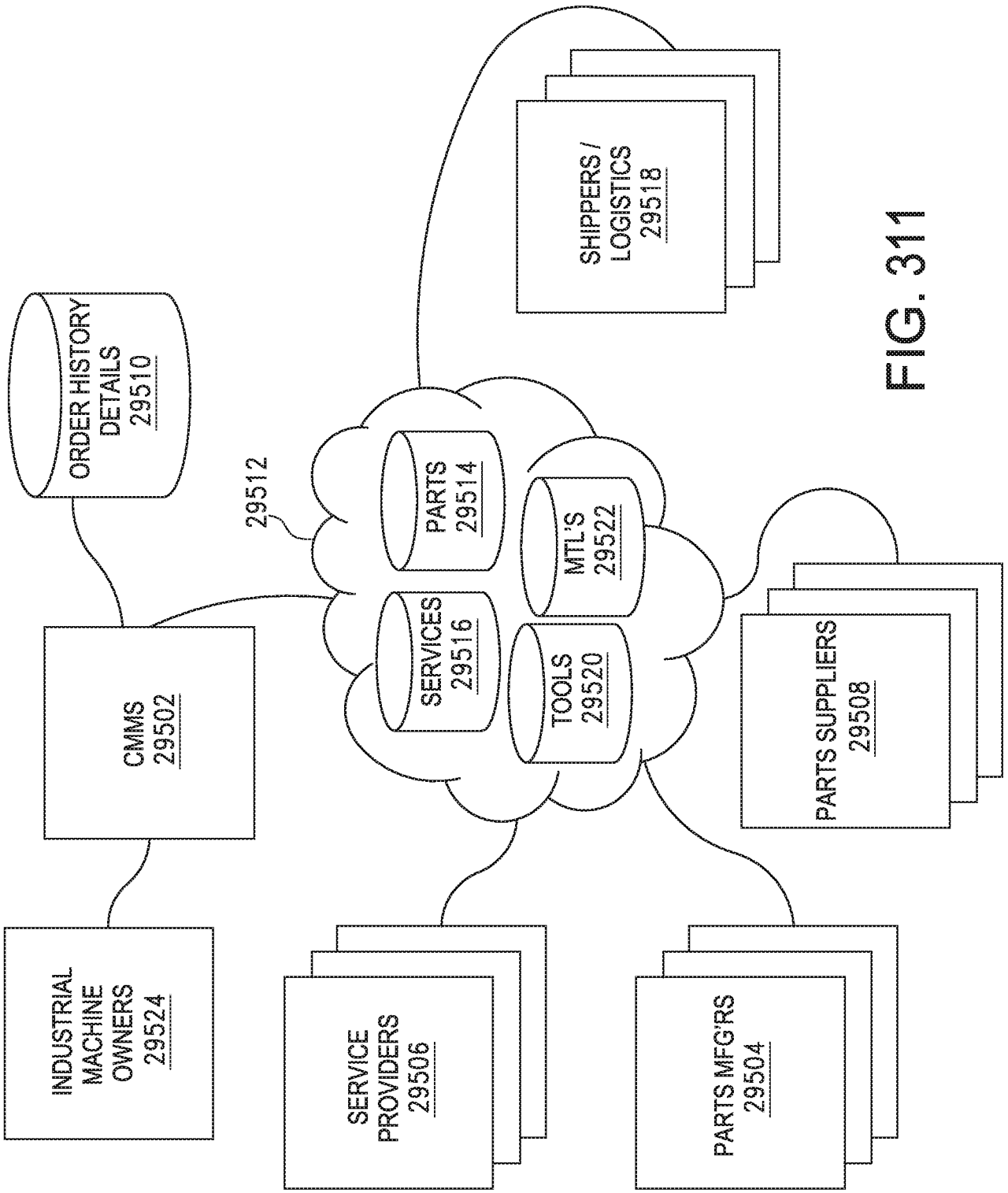
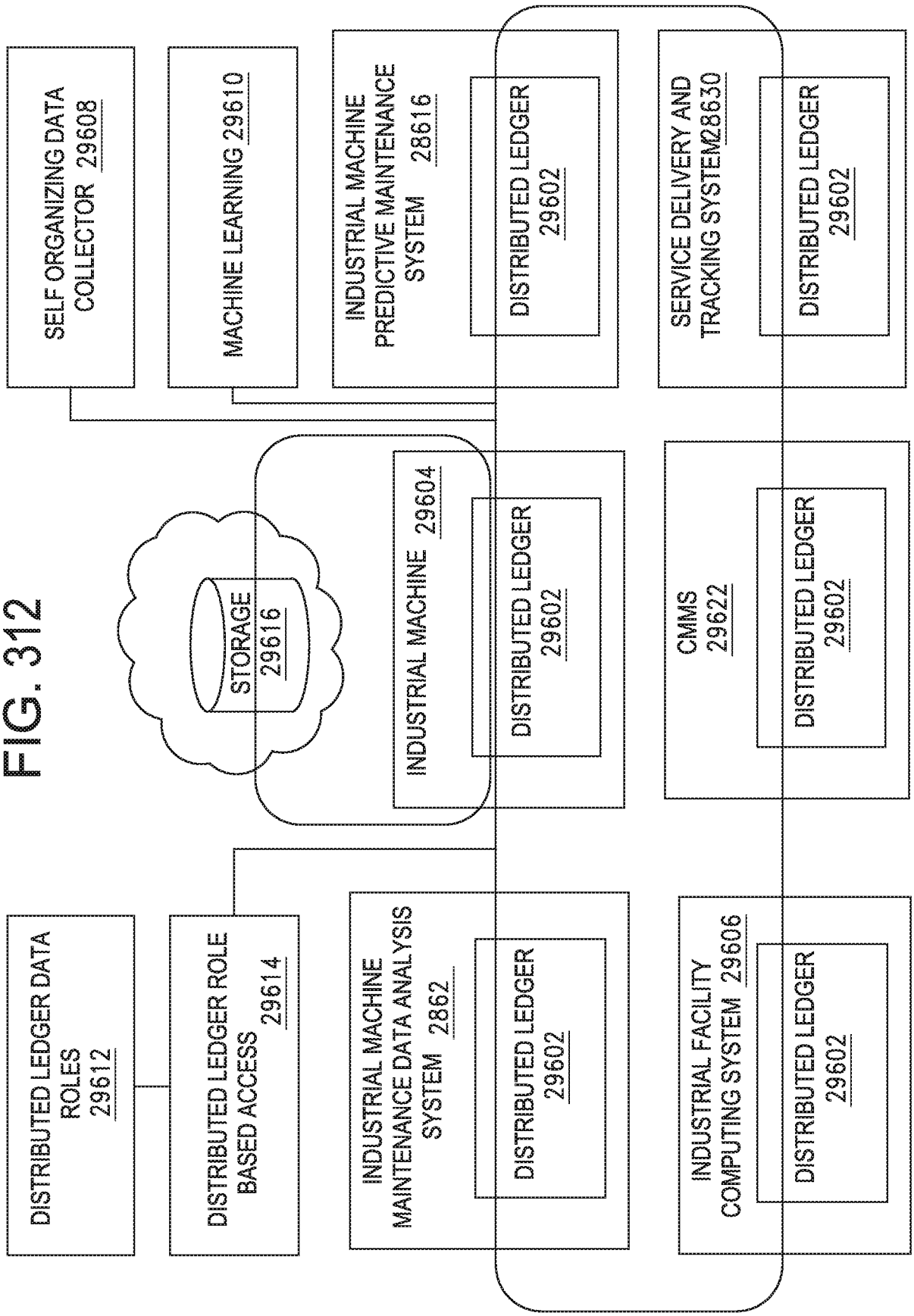

SHIPPERS / LOGISTICS 29518
ORDER HISTORY DETAILS 29510
29512
PARTS 29514
MTL'S 29522
SERVICES 29516
TOOLS 29520
CMMS 29502
PARTS SUPPLIERS 29508
INDUSTRIAL MACHINE OWNERS 29524
SERVICE PROVIDERS 29506
PARTS MFG'RS 29504

FIG. 311

FIG. 312


SELF ORGANIZING DATA COLLECTOR 29608
MACHINE LEARNING 29610
INDUSTRIAL MACHINE PREDICTIVE MAINTENANCE SYSTEM 28616
DISTRIBUTED LEDGER 29602
SERVICE DELIVERY AND TRACKING SYSTEM28630
DISTRIBUTED LEDGER 29602
STORAGE 29616
INDUSTRIAL MACHINE 29604
DISTRIBUTED LEDGER 29602
CMMS 29622
DISTRIBUTED LEDGER 29602
DISTRIBUTED LEDGER DATA ROLES 29612
DISTRIBUTED LEDGER ROLE BASED ACCESS 29614
INDUSTRIAL MACHINE MAINTENANCE DATA ANALYSIS SYSTEM 2862
DISTRIBUTED LEDGER 29602
INDUSTRIAL FACILITY COMPUTING SYSTEM 29606
DISTRIBUTED LEDGER 29602

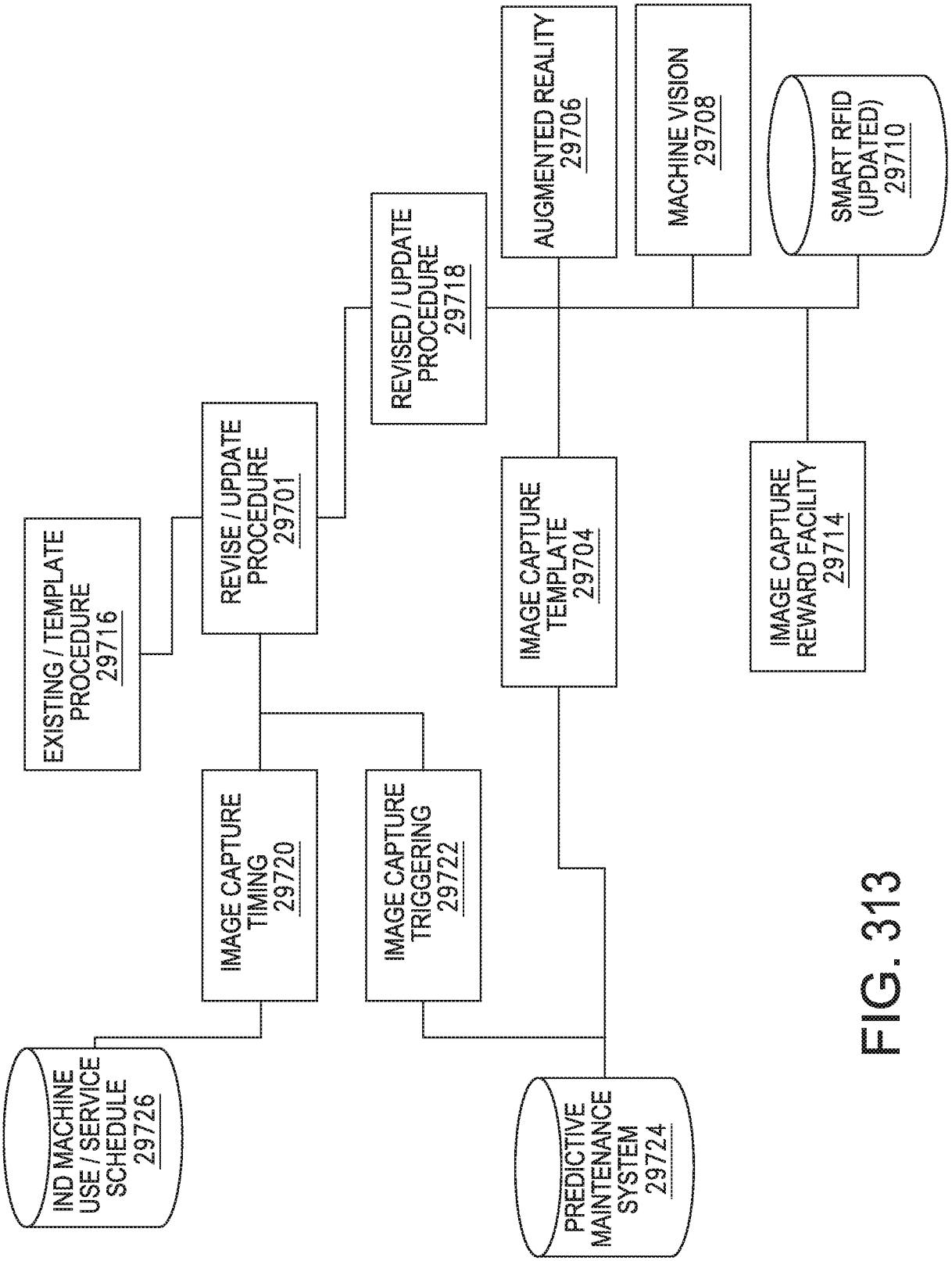

EXISTING / TEMPLATE PROCEDURE 29716
REVISE / UPDATE PROCEDURE 29701
REVISED / UPDATE PROCEDURE 29718
AUGMENTED REALITY 29706
MACHINE VISION 29708
SMART RFID (UPDATED) 29710
IMAGE CAPTURE TIMING 29720
IMAGE CAPTURE TRIGGERING 29722
IMAGE CAPTURE TEMPLATE 29704
IMAGE CAPTURE REWARD FACILITY 29714
IND MACHINE USE / SERVICE SCHEDULE 29726
PREDICTIVE MAINTENANCE SYSTEM 29724

FIG. 313

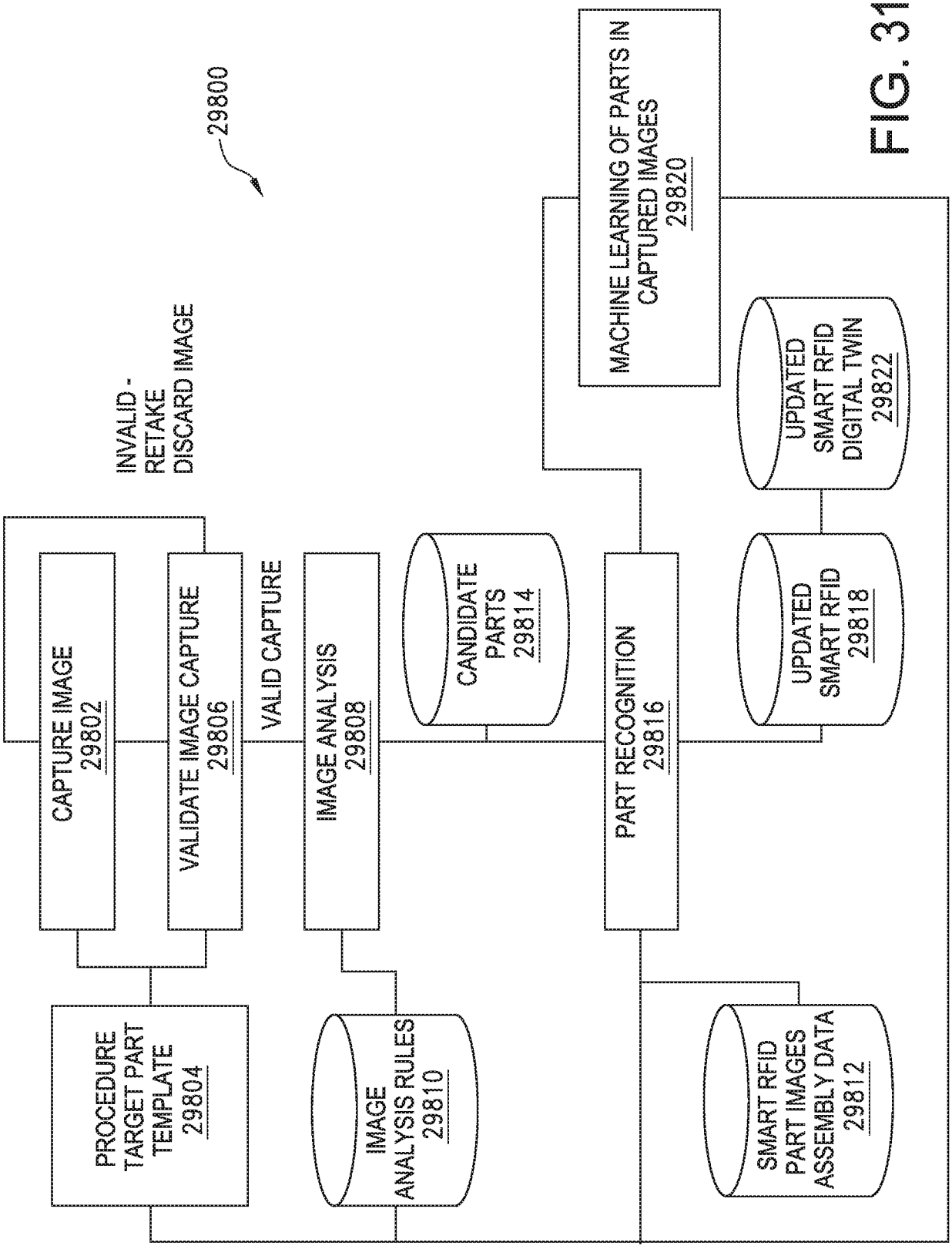

29800
INVALID - RETAKE DISCARD IMAGE
CAPTURE IMAGE 29802
VALIDATE IMAGE CAPTURE 29806
VALID CAPTURE
IMAGE ANALYSIS 29808
CANDIDATE PARTS 29814
PART RECOGNITION 29816
MACHINE LEARNING OF PARTS IN CAPTURED IMAGES 29820
UPDATED SMART RFID DIGITAL TWIN 29822
UPDATED SMART RFID 29818
PROCEDURE TARGET PART TEMPLATE 29804
IMAGE ANALYSIS RULES 29810
SMART RFID PART IMAGES ASSEMBLY DATA 29812

FIG. 314

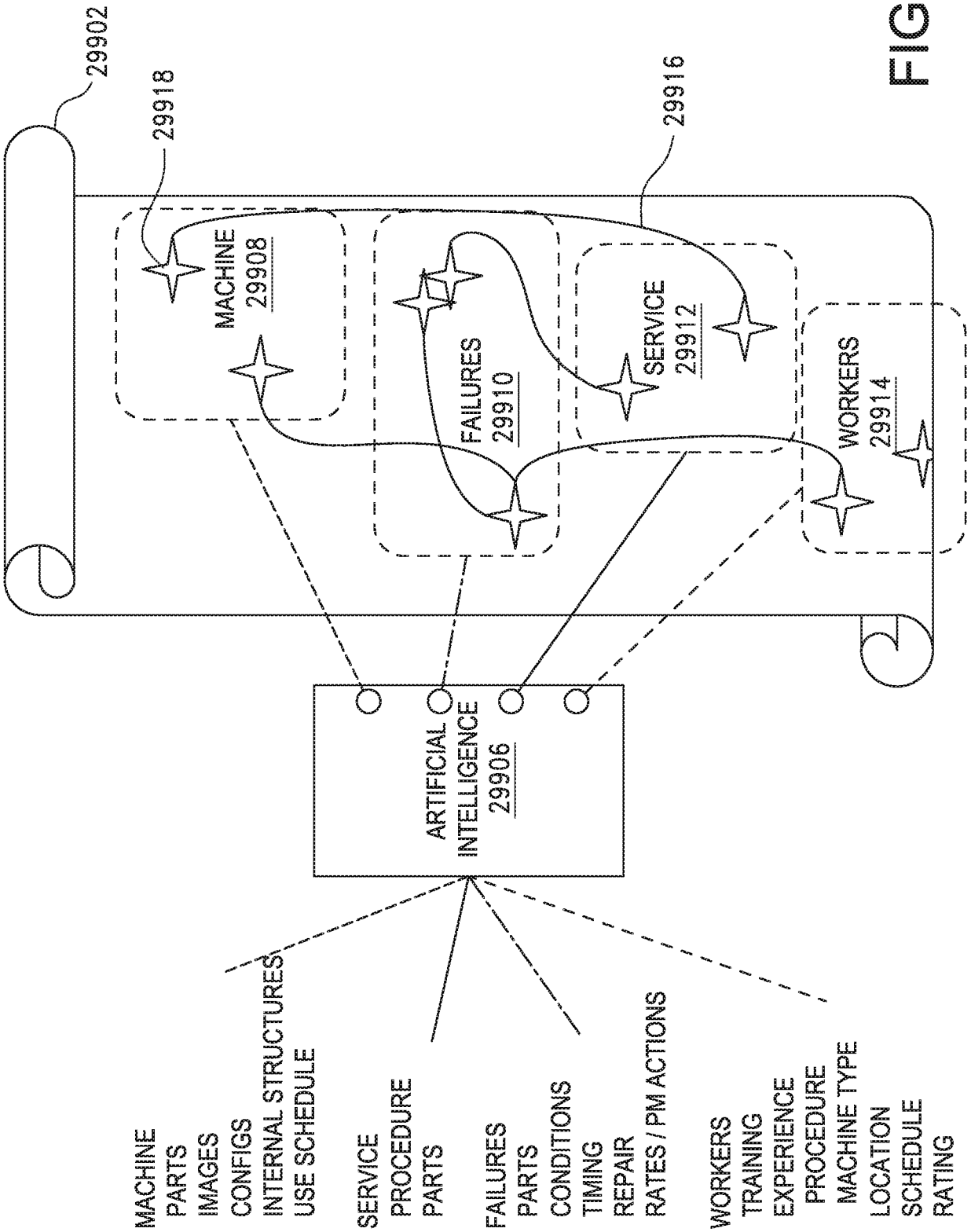

29902
29918
29916
MACHINE
29908
FAILURES
29910
SERVICE
29912
WORKERS
29914
ARTIFICIAL
INTELLIGENCE
29906
MACHINE
PARTS
IMAGES
CONFIGS
INTERNAL STRUCTURES
USE SCHEDULE
SERVICE
PROCEDURE
PARTS
FAILURES
PARTS
CONDITIONS
TIMING
REPAIR
RATES / PM ACTIONS
WORKERS
TRAINING
EXPERIENCE
PROCEDURE
MACHINE TYPE
LOCATION
SCHEDULE
RATING

FIG. 315

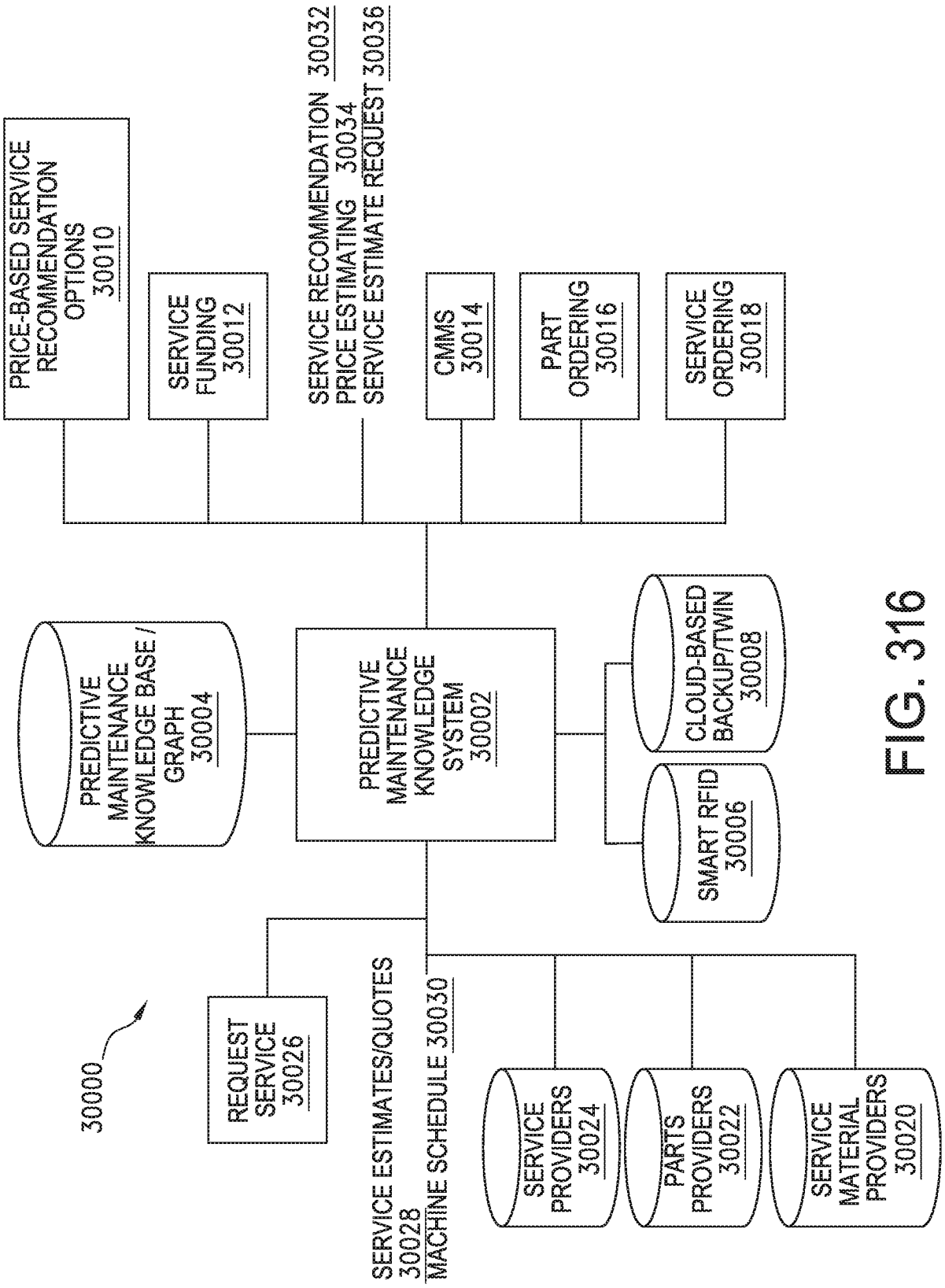

30000
REQUEST SERVICE 30026
SERVICE ESTIMATES/QUOTES 30028
MACHINE SCHEDULE 30030
SERVICE PROVIDERS 30024
PARTS PROVIDERS 30022
SERVICE MATERIAL PROVIDERS 30020
PREDICTIVE MAINTENANCE KNOWLEDGE BASE / GRAPH 30004
PREDICTIVE MAINTENANCE KNOWLEDGE SYSTEM 30002
CLOUD-BASED BACKUP/TWIN 30008
SMART RFID 30006
PRICE-BASED SERVICE RECOMMENDATION OPTIONS 30010
SERVICE FUNDING 30012
SERVICE RECOMMENDATION 30032
PRICE ESTIMATING 30034
SERVICE ESTIMATE REQUEST 30036
CMMS 30014
PART ORDERING 30016
SERVICE ORDERING 30018

FIG. 316

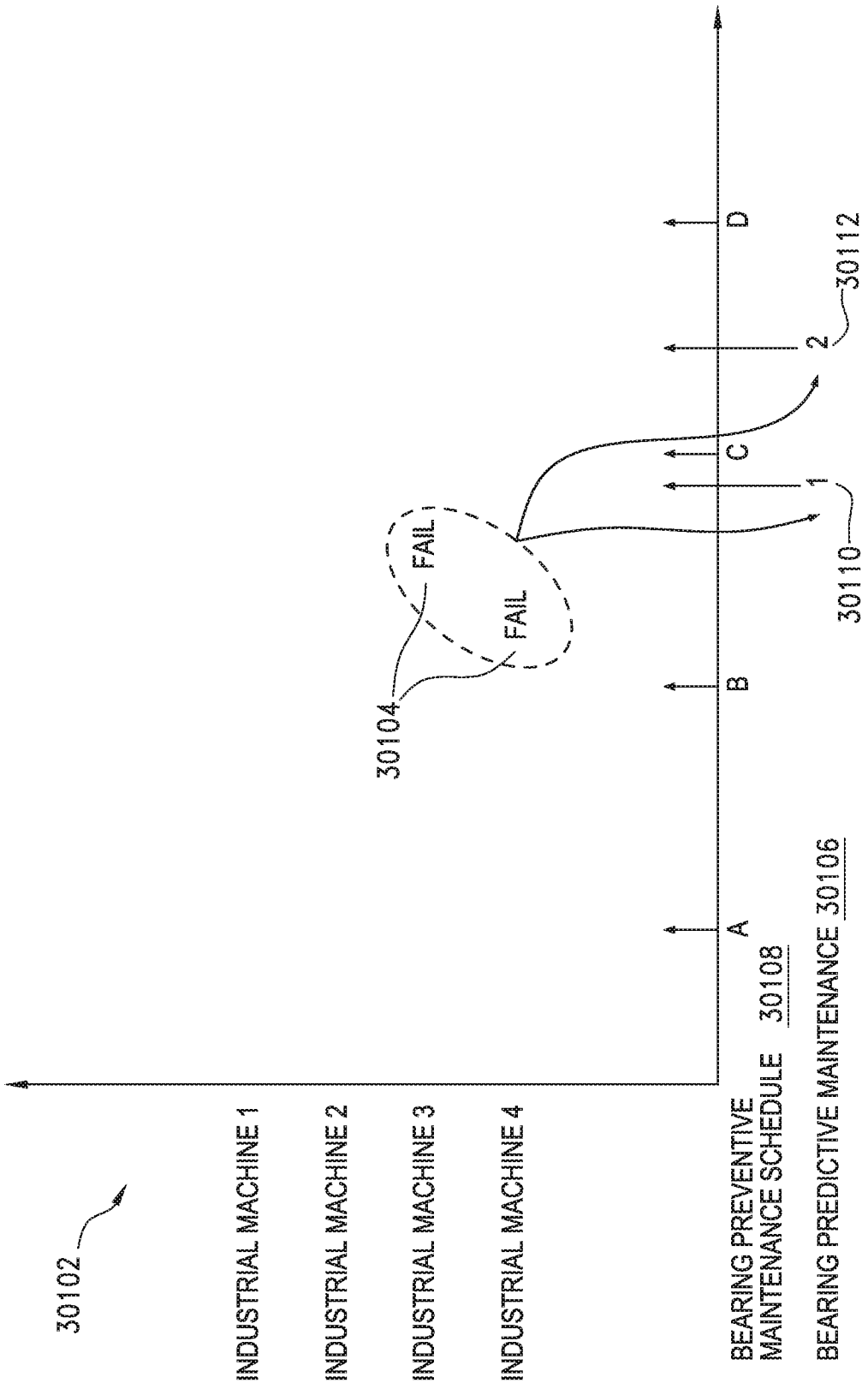

30102
INDUSTRIAL MACHINE 1
INDUSTRIAL MACHINE 2
INDUSTRIAL MACHINE 3
INDUSTRIAL MACHINE 4
BEARING PREVENTIVE MAINTENANCE SCHEDULE 30108
BEARING PREDICTIVE MAINTENANCE 30106
A
B
C
D
1
2
30110
30112
30104
FAIL
FAIL

FIG. 317

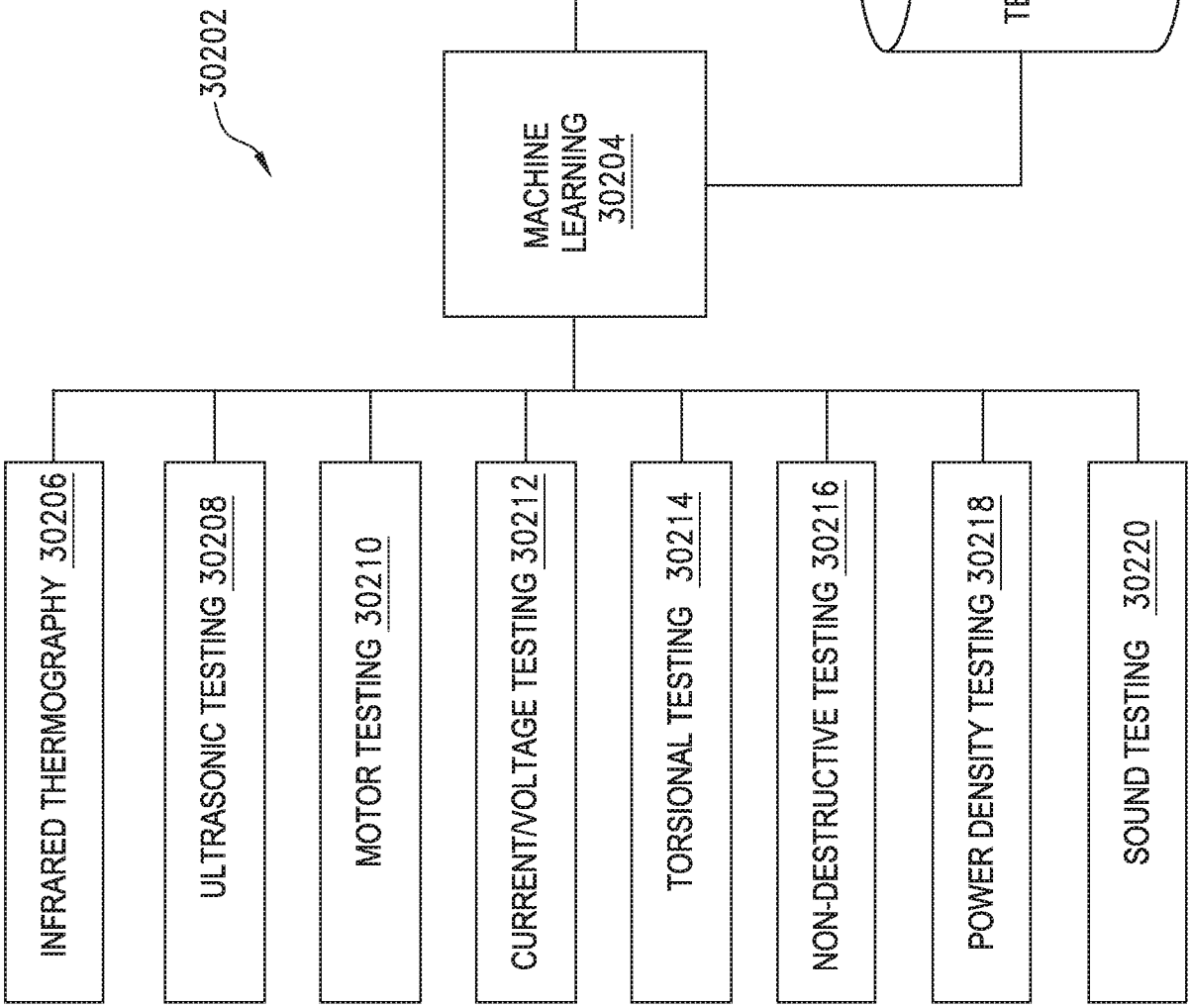

30202
MACHINE LEARNING 30204
TEST RESULTS 30222
INFRARED THERMOGRAPHY 30206
ULTRASONIC TESTING 30208
MOTOR TESTING 30210
CURRENT/VOLTAGE TESTING 30212
TORSIONAL TESTING 30214
NON-DESTRUCTIVE TESTING 30216
POWER DENSITY TESTING 30218
SOUND TESTING 30220

FIG. 318

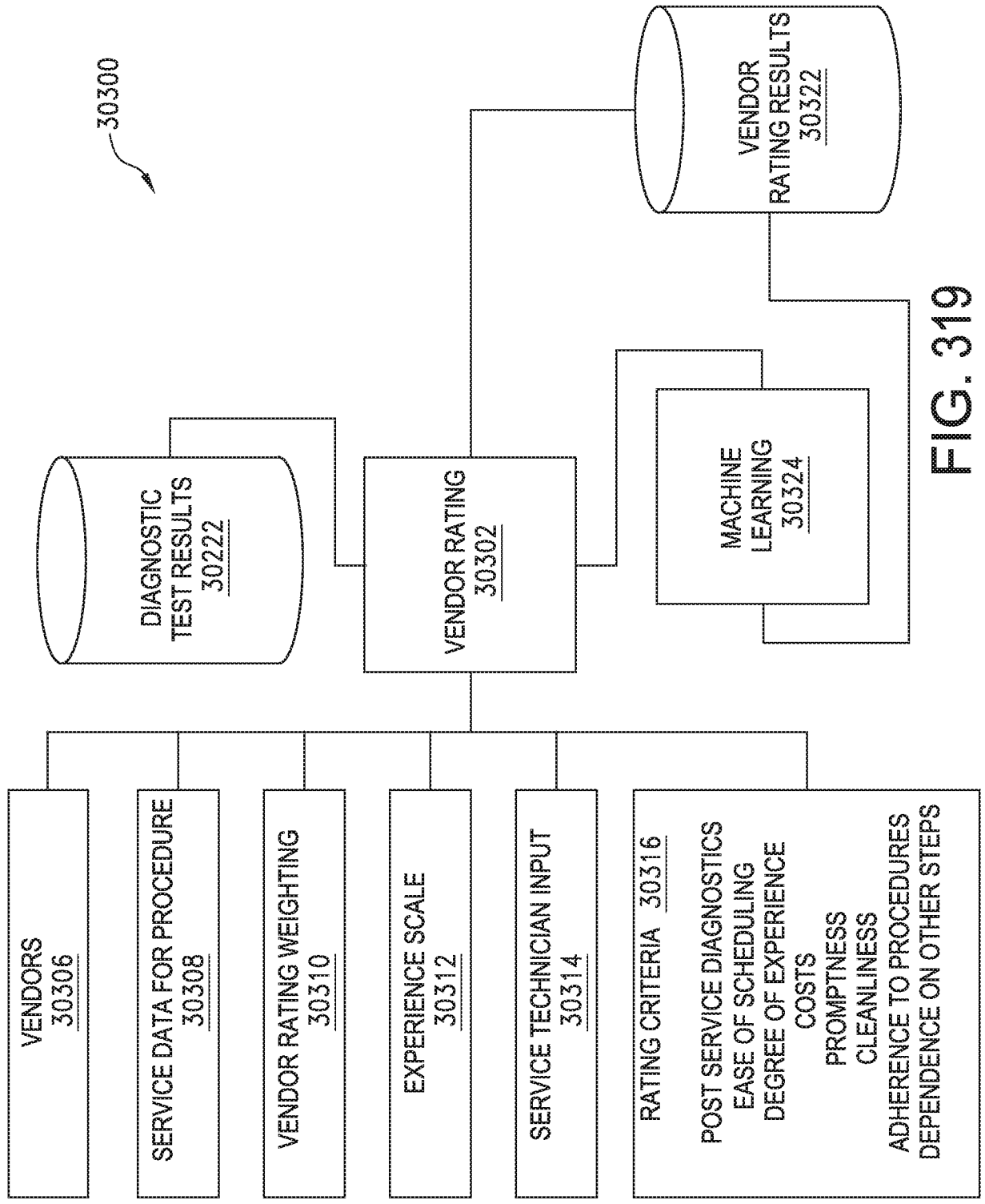

30300
VENDOR RATING RESULTS 30322
DIAGNOSTIC TEST RESULTS 30222
VENDOR RATING 30302
MACHINE LEARNING 30324
VENDORS 30306
SERVICE DATA FOR PROCEDURE 30308
VENDOR RATING WEIGHTING 30310
EXPERIENCE SCALE 30312
SERVICE TECHNICIAN INPUT 30314
RATING CRITERIA 30316
POST SERVICE DIAGNOSTICS
EASE OF SCHEDULING
DEGREE OF EXPERIENCE
COSTS
PROMPTNESS
CLEANLINESS
ADHERENCE TO PROCEDURES
DEPENDENCE ON OTHER STEPS

FIG. 319

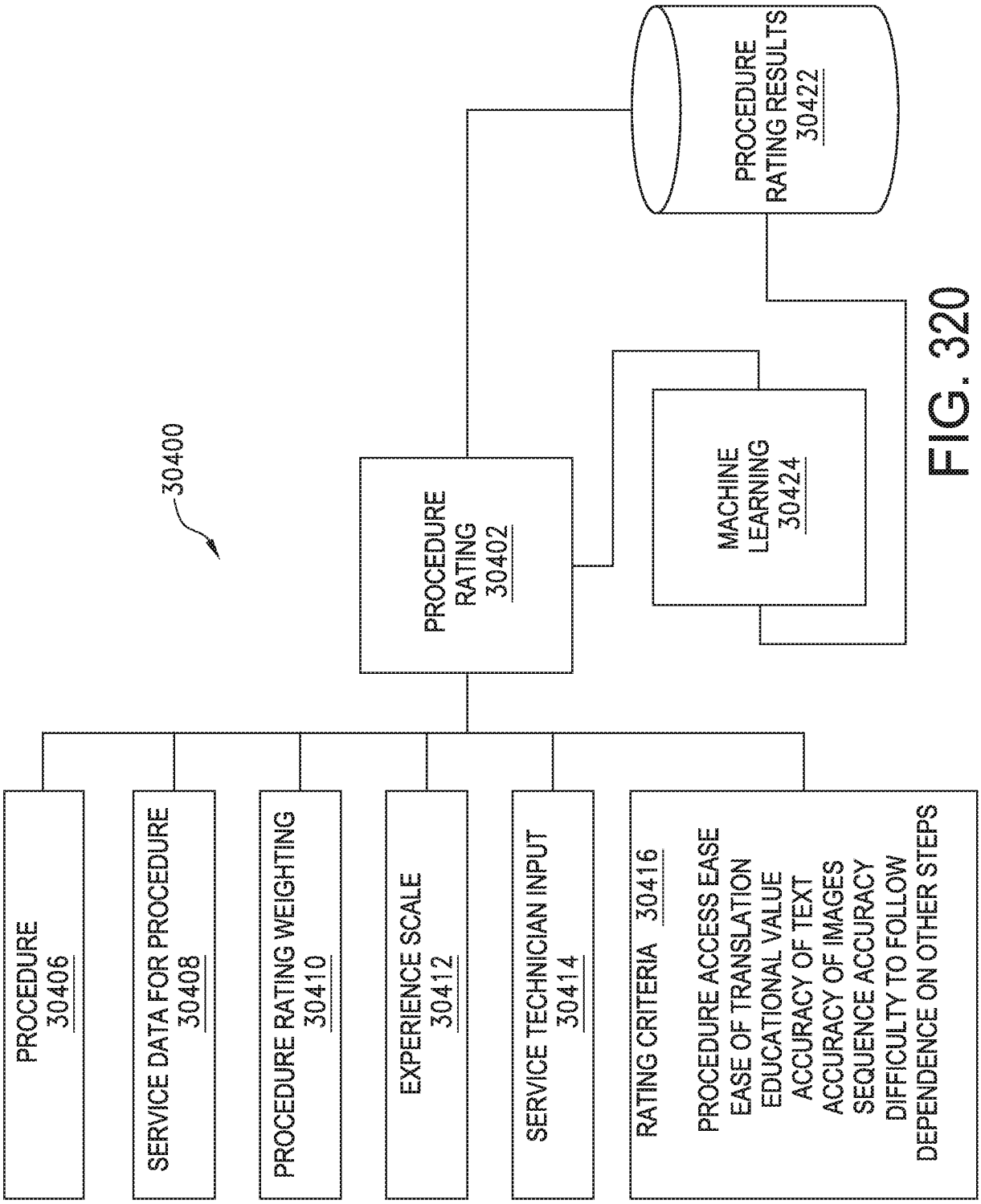

30400
PROCEDURE RATING RESULTS 30422
PROCEDURE RATING 30402
MACHINE LEARNING 30424
PROCEDURE 30406
SERVICE DATA FOR PROCEDURE 30408
PROCEDURE RATING WEIGHTING 30410
EXPERIENCE SCALE 30412
SERVICE TECHNICIAN INPUT 30414
RATING CRITERIA 30416
PROCEDURE ACCESS EASE
EASE OF TRANSLATION
EDUCATIONAL VALUE
ACCURACY OF TEXT
ACCURACY OF IMAGES
SEQUENCE ACCURACY
DIFFICULTY TO FOLLOW
DEPENDENCE ON OTHER STEPS

FIG. 320

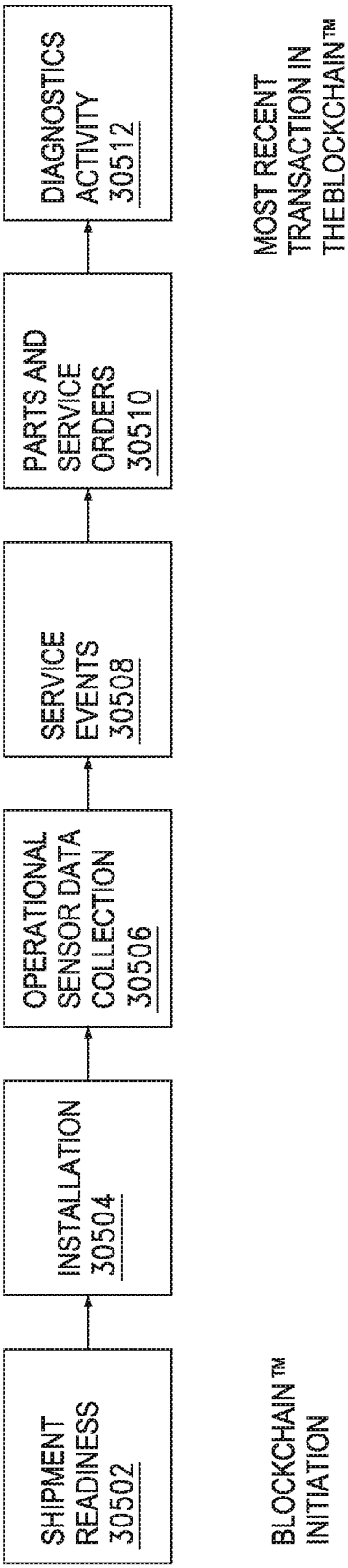

SHIPMENT READINESS 30502
INSTALLATION 30504
OPERATIONAL SENSOR DATA COLLECTION 30506
SERVICE EVENTS 30508
PARTS AND SERVICE ORDERS 30510
DIAGNOSTICS ACTIVITY 30512
BLOCKCHAIN™ INITIATION
MOST RECENT TRANSACTION IN THEBLOCKCHAIN™

FIG. 321

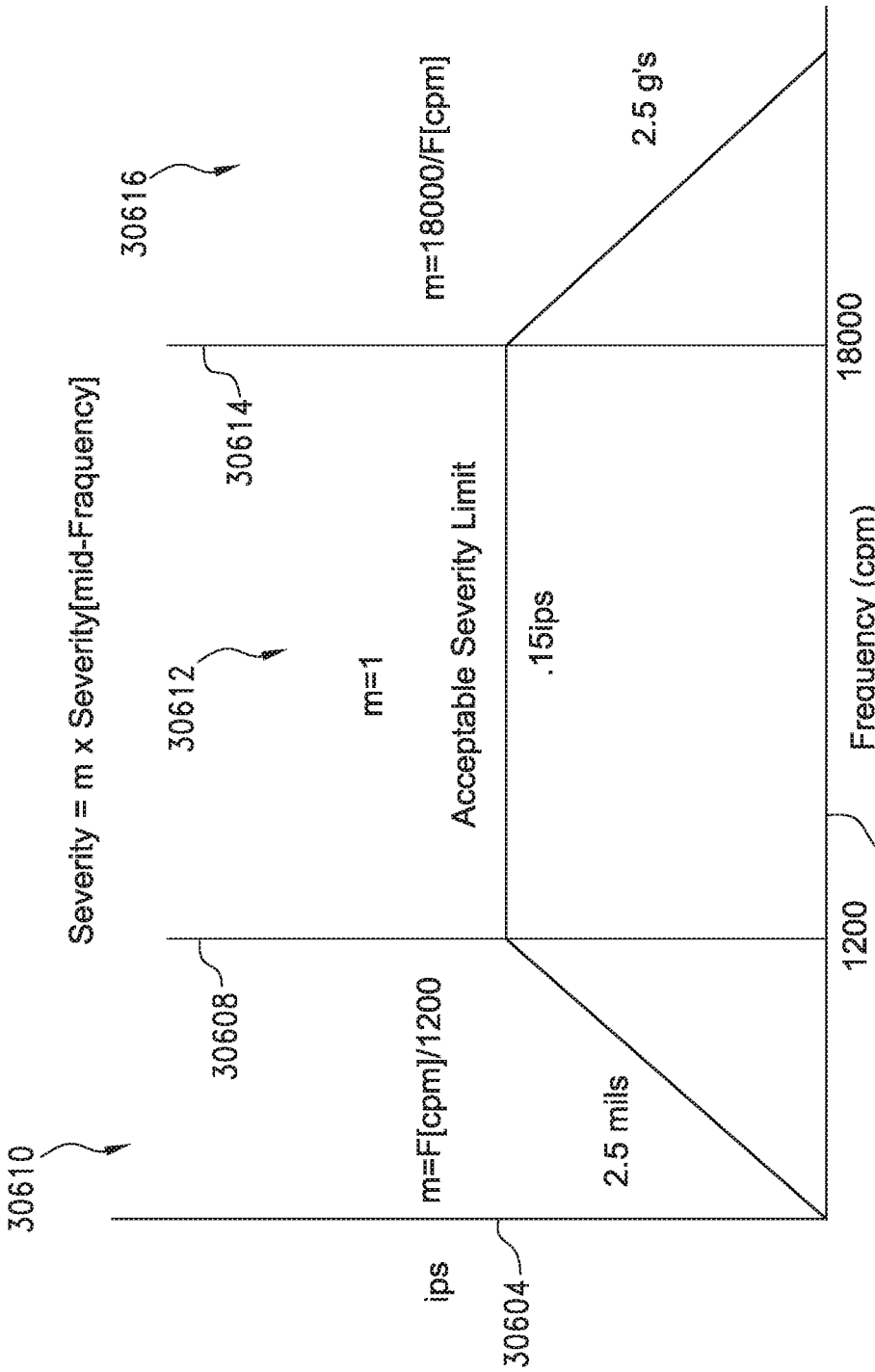

Severity = m x Severity[mid-Fraquency]
30610
30616
30614
30612
30608
30604
30606
m=18000/F[cpm]
2.5 g's
m=1
Acceptable Severity Limit
.15ips
m=F[cpm]/1200
2.5 mils
ips
1200
18000
Frequency (cpm)

FIG. 322

Spectal Peak Levels taken with Bearing Cap Mounted Accelerometer

Severity	Action	< 1200 cpm < 20 hz mils pk-to-pk	1200 cpm - 18000 cpm 20-300 hz ips pk (inches-per-sec peak)	>18500 cpm > 300hz g's pk
	Acceptable	< 2.5	Level < .15	< 2.5
*	Watch	2.5 < Level < 5.0	.15 < Level < .3	2.5 < Level < 5.0
**	Resurvey	5.0 < Level < 10.0	.3 < Level < .6	5.0 < Level < 10.0
***	Action Soon	10.0 < Level < 16.6	.6 < Level < 1.0	10.0 < Level < 16.6
****	Immediate	Level > 16.6	Level > 1.0	Level > 16.6

FIG. 323

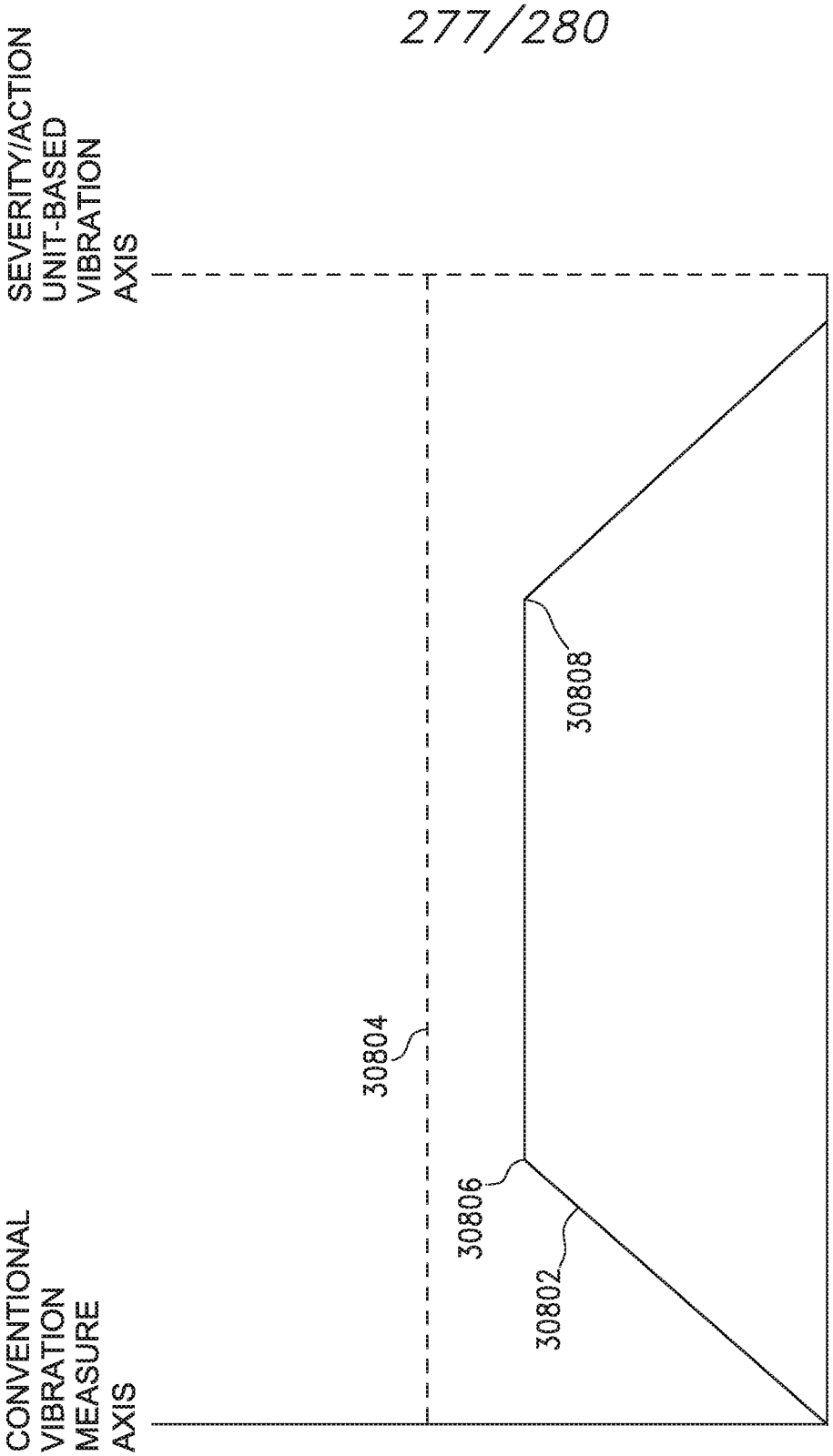

SEVERITY/ACTION UNIT-BASED VIBRATION AXIS
CONVENTIONAL VIBRATION MEASURE AXIS
30804
30806
30808
30802

FIG. 324

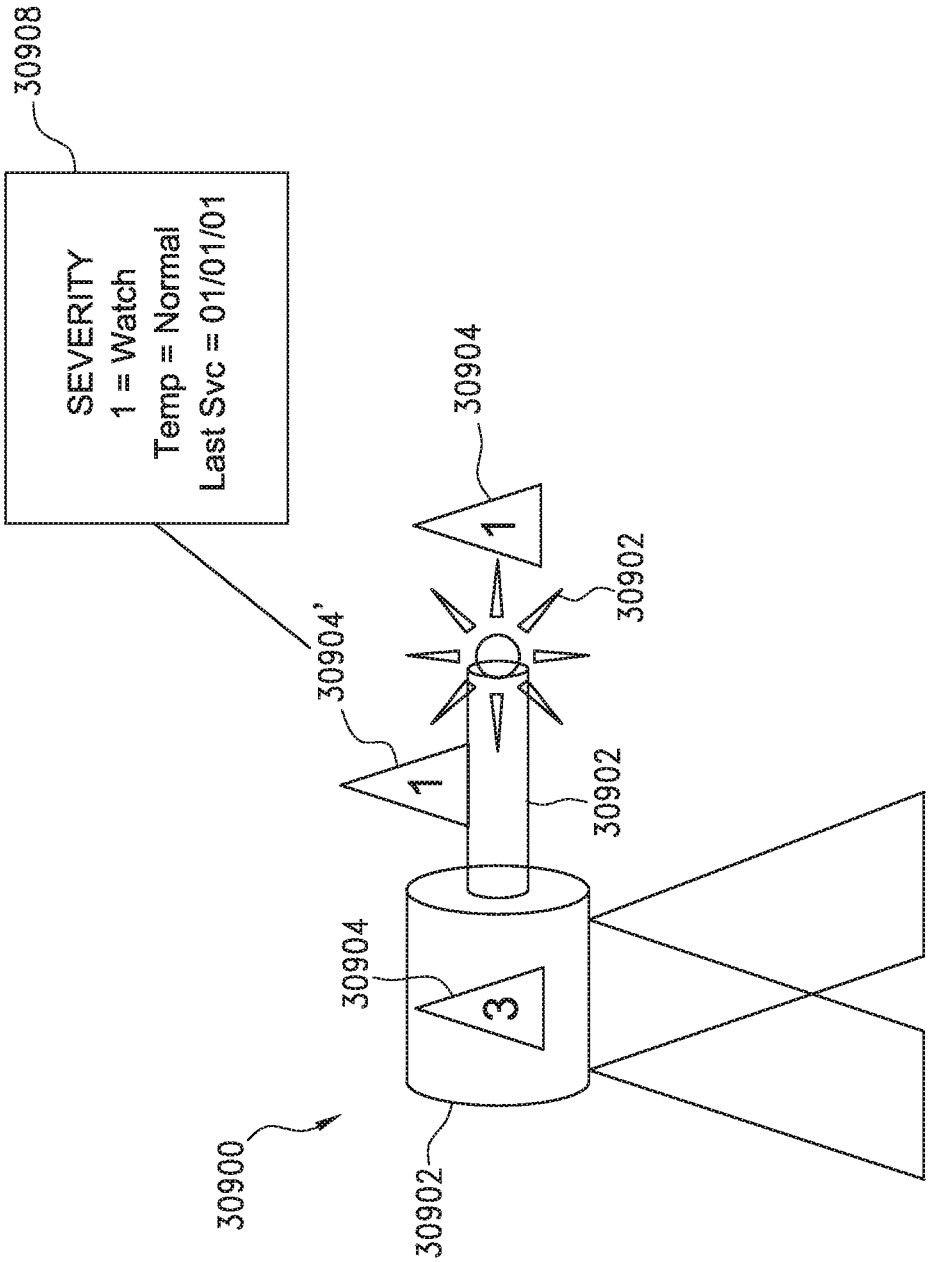
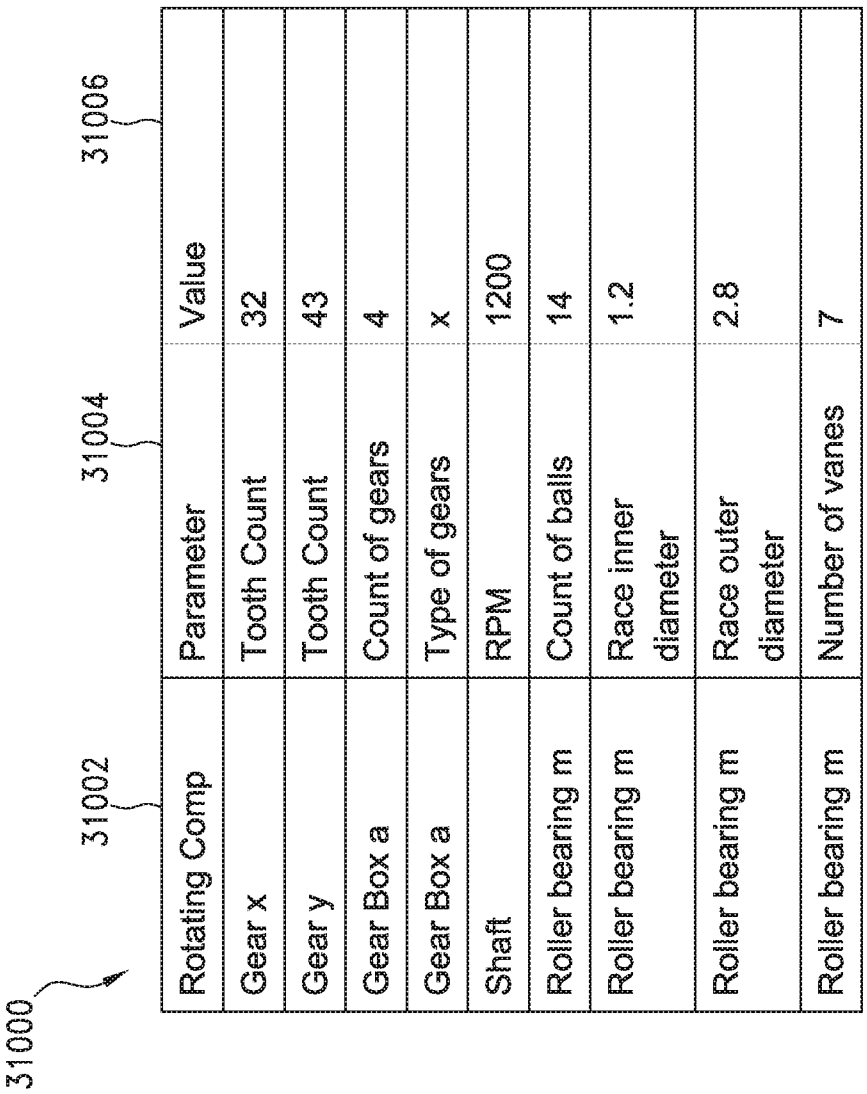

30908
SEVERITY
1 = Watch
Temp = Normal
Last Svc = 01/01/01
30904'
30904
30902
30902
30904
30900
30902
1
1
3

FIG. 325



Rotating Comp	Parameter	Value
Gear x	Tooth Count	32
Gear y	Tooth Count	43
Gear Box a	Count of gears	4
Gear Box a	Type of gears	x
Shaft	RPM	1200
Roller bearing m	Count of balls	14
Roller bearing m	Race inner diameter	1.2
Roller bearing m	Race outer diameter	2.8
Roller bearing m	Number of vanes	7

FIG. 326

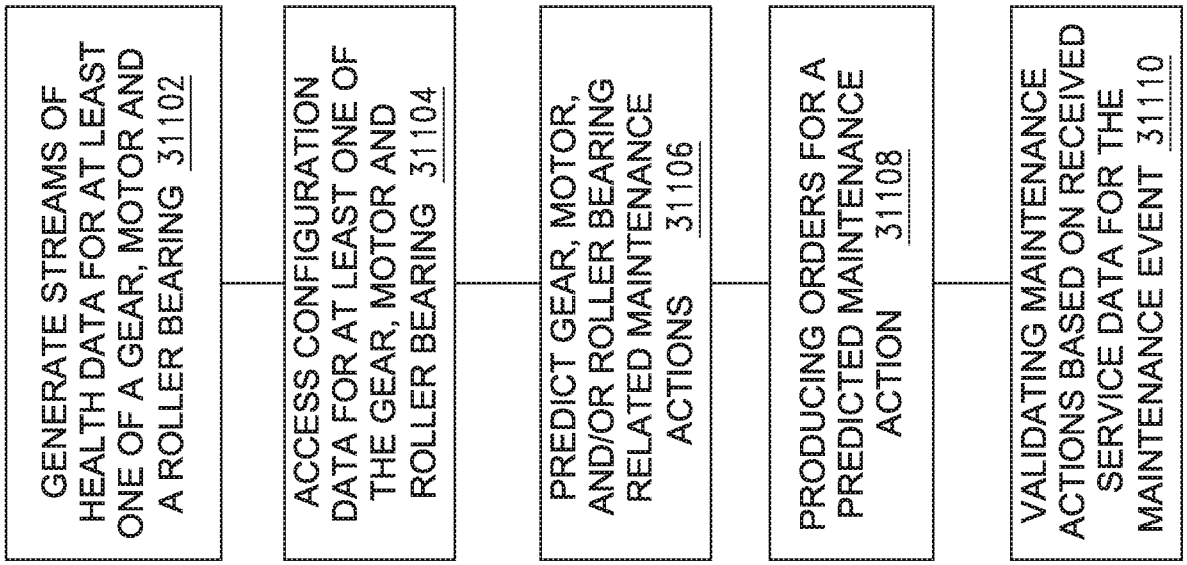

GENERATE STREAMS OF HEALTH DATA FOR AT LEAST ONE OF A GEAR, MOTOR AND A ROLLER BEARING 31102
ACCESS CONFIGURATION DATA FOR AT LEAST ONE OF THE GEAR, MOTOR AND ROLLER BEARING 31104
PREDICT GEAR, MOTOR, AND/OR ROLLER BEARING RELATED MAINTENANCE ACTIONS 31106
PRODUCING ORDERS FOR A PREDICTED MAINTENANCE ACTION 31108
VALIDATING MAINTENANCE ACTIONS BASED ON RECEIVED SERVICE DATA FOR THE MAINTENANCE EVENT 31110

FIG. 327

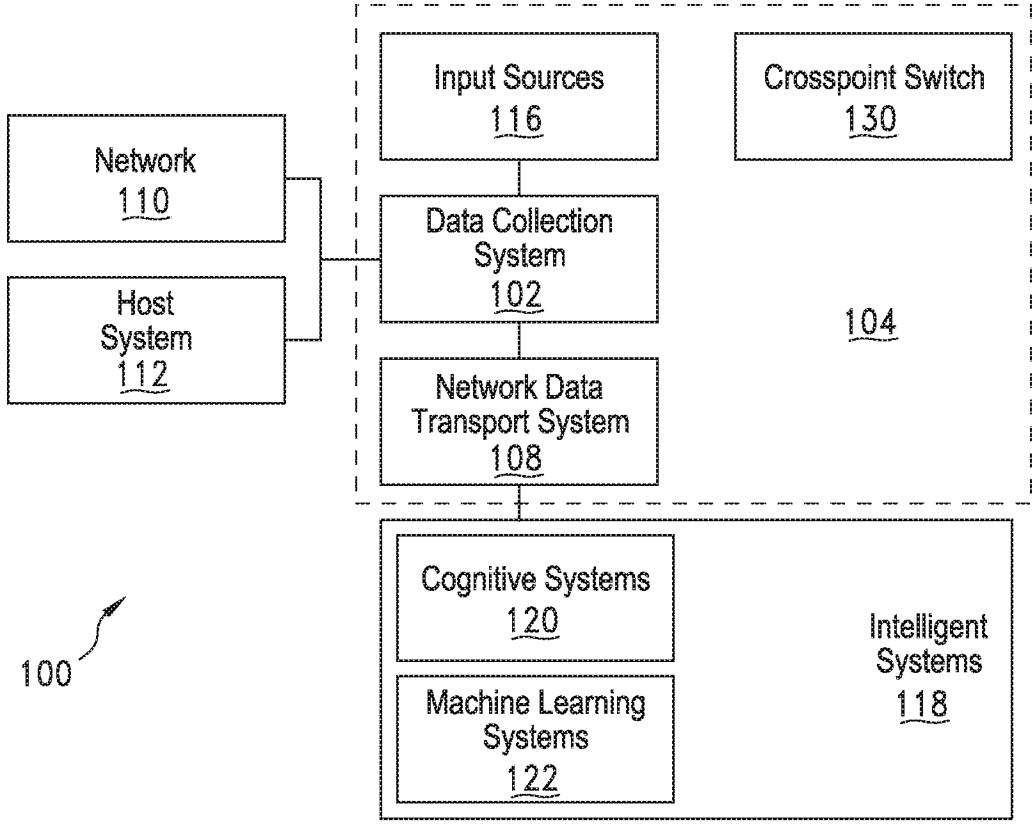

Input Sources
116
Crosspoint Switch
130
Network
110
Data Collection
System
102
Host
System
112
104
Network Data
Transport System
108
Cognitive Systems
120
Intelligent
Systems
118
Machine Learning
Systems
122
100

FIG. 6