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(54) **SYSTEM AND METHOD FOR AUTONOMOUS DYNAMIC PROVISIONING**

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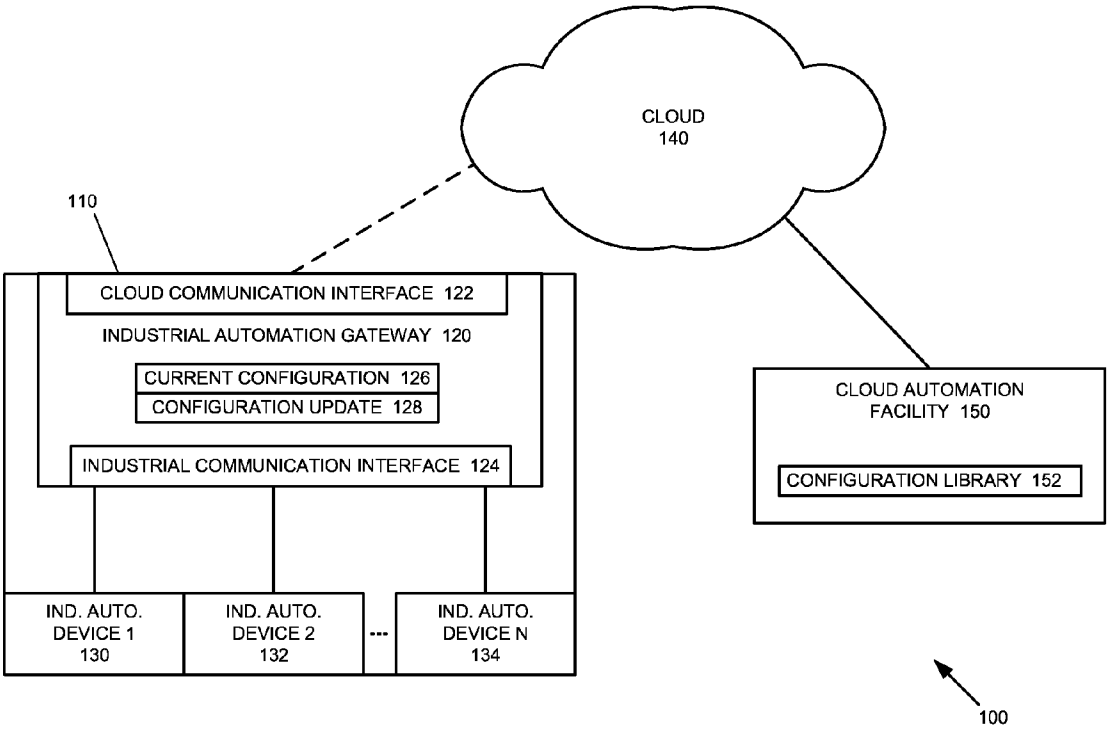
(52) **U.S. Cl.**

CPC ..... ***H04L 41/0813*** (2013.01); ***H04L 67/10*** (2013.01); ***H04L 67/125*** (2013.01)

(57) **ABSTRACT**

An industrial automation gateway for autonomous dynamic provisioning is provided. The industrial automation gateway includes a cloud communication interface coupled with, and configured for communication with, a cloud automation facility, and a processor coupled with the cloud communication interface. The processor is configured to determine a current configuration of the industrial automation gateway, and request a configuration update from the cloud automation facility through the cloud communication interface. The processor is also configured to receive the configuration update from the cloud automation facility through the cloud communication interface, and implement the configuration update within the industrial automation gateway.



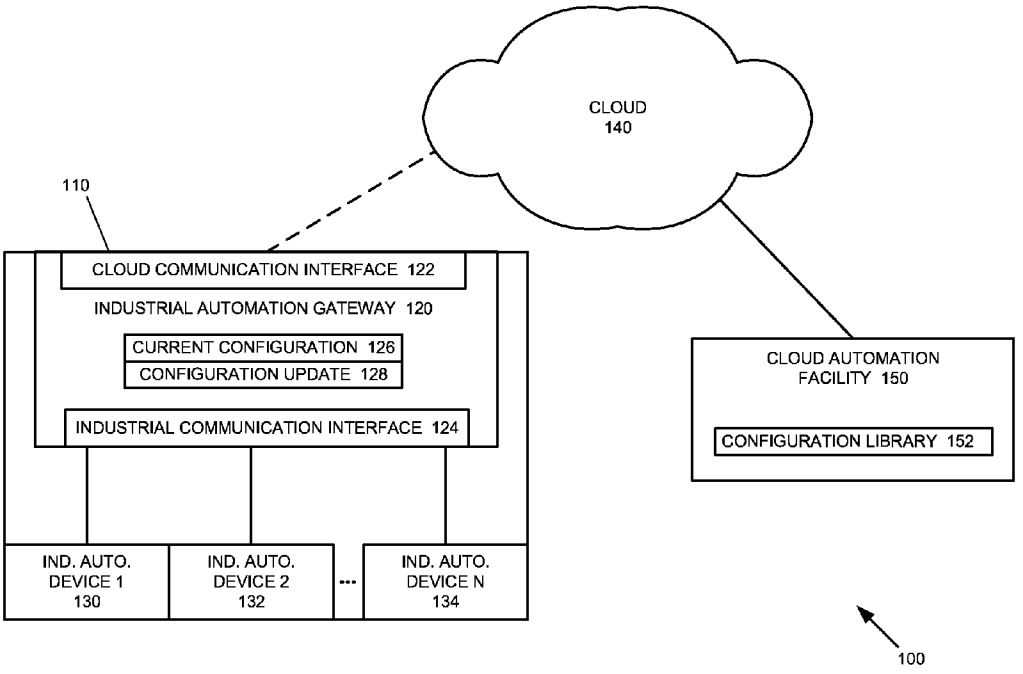

CLOUD
140
110
CLOUD COMMUNICATION INTERFACE 122
INDUSTRIAL AUTOMATION GATEWAY 120
CURRENT CONFIGURATION 126
CONFIGURATION UPDATE 128
INDUSTRIAL COMMUNICATION INTERFACE 124
CLOUD AUTOMATION FACILITY 150
CONFIGURATION LIBRARY 152
IND. AUTO. DEVICE 1 130
IND. AUTO. DEVICE 2 132
IND. AUTO. DEVICE N 134
100

**FIGURE 1**

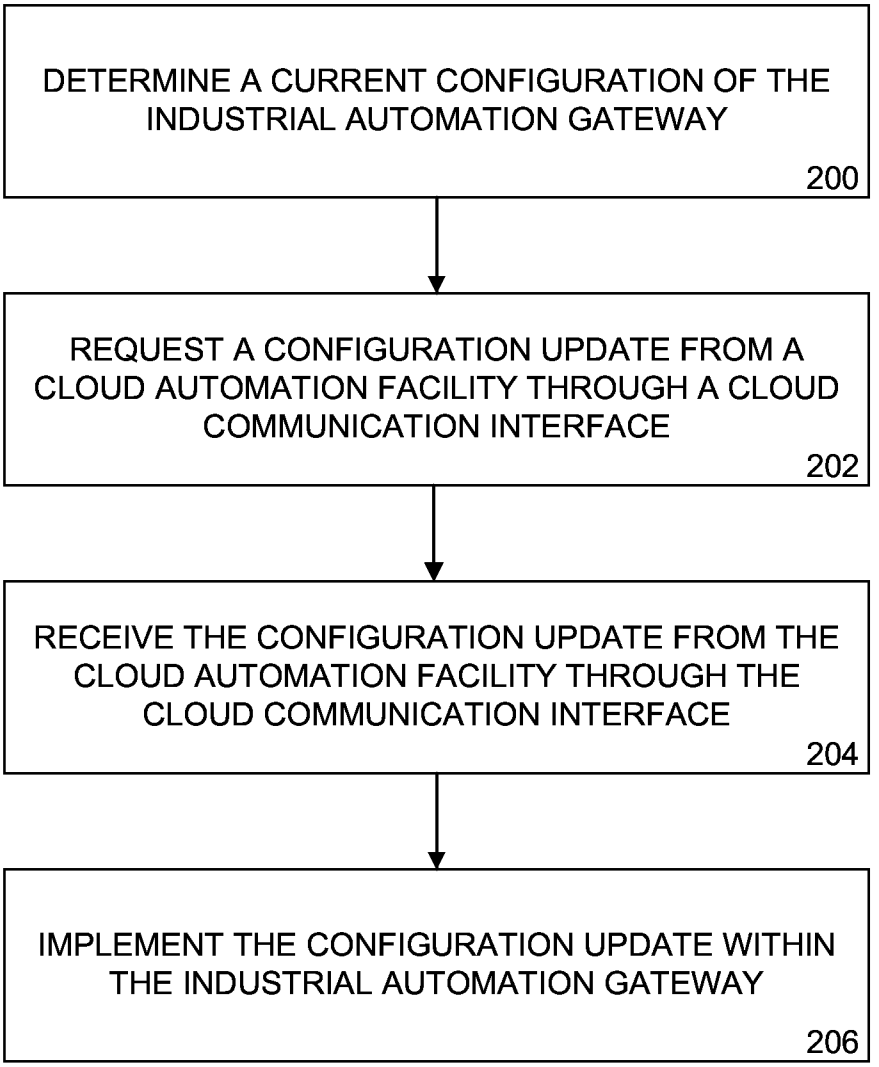

DETERMINE A CURRENT CONFIGURATION OF THE INDUSTRIAL AUTOMATION GATEWAY
200
REQUEST A CONFIGURATION UPDATE FROM A CLOUD AUTOMATION FACILITY THROUGH A CLOUD COMMUNICATION INTERFACE
202
RECEIVE THE CONFIGURATION UPDATE FROM THE CLOUD AUTOMATION FACILITY THROUGH THE CLOUD COMMUNICATION INTERFACE
204
IMPLEMENT THE CONFIGURATION UPDATE WITHIN THE INDUSTRIAL AUTOMATION GATEWAY
206

**FIGURE 2**

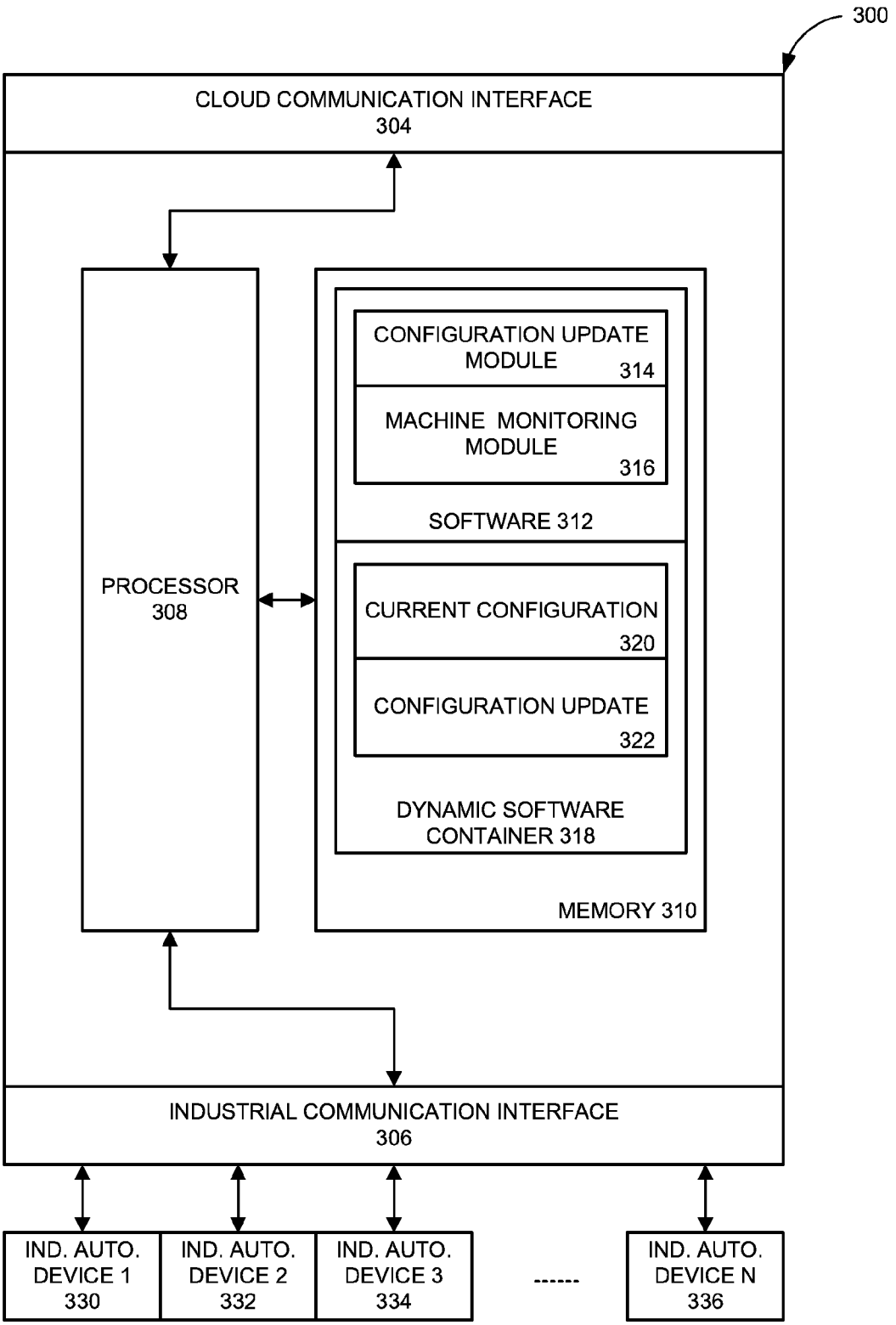

300
CLOUD COMMUNICATION INTERFACE
304
PROCESSOR
308
CONFIGURATION UPDATE
MODULE
314
MACHINE MONITORING
MODULE
316
SOFTWARE 312
CURRENT CONFIGURATION
320
CONFIGURATION UPDATE
322
DYNAMIC SOFTWARE
CONTAINER 318
MEMORY 310
INDUSTRIAL COMMUNICATION INTERFACE
306
IND. AUTO.
DEVICE 1
330
IND. AUTO.
DEVICE 2
332
IND. AUTO.
DEVICE 3
334
------
IND. AUTO.
DEVICE N
336

**FIGURE 3**

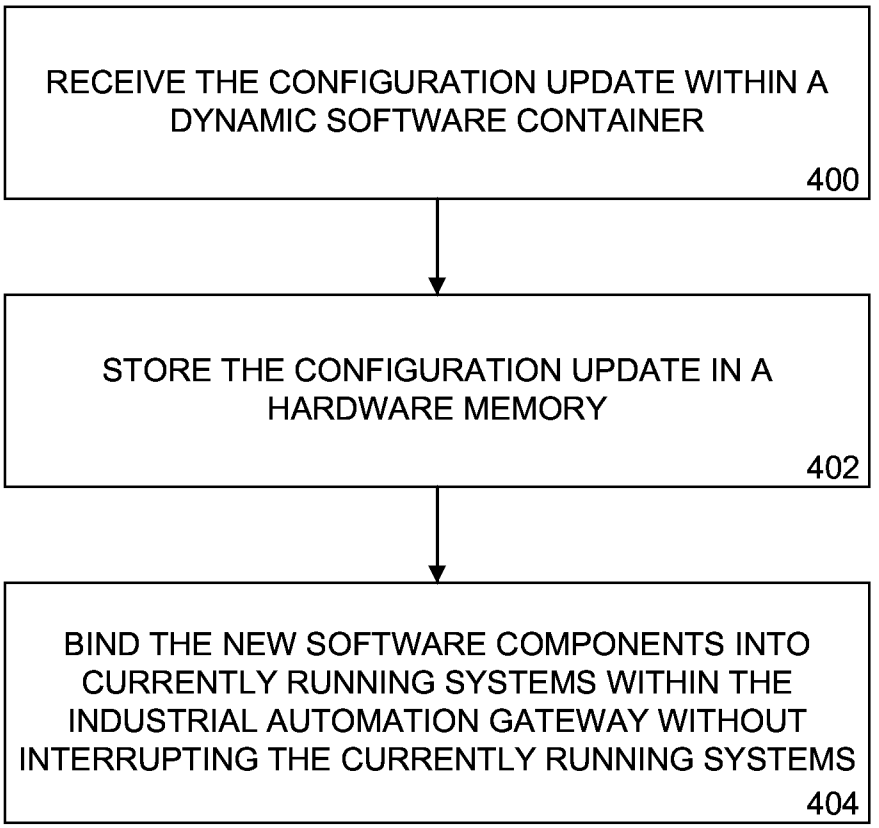

RECEIVE THE CONFIGURATION UPDATE WITHIN A DYNAMIC SOFTWARE CONTAINER
400
STORE THE CONFIGURATION UPDATE IN A HARDWARE MEMORY
402
BIND THE NEW SOFTWARE COMPONENTS INTO CURRENTLY RUNNING SYSTEMS WITHIN THE INDUSTRIAL AUTOMATION GATEWAY WITHOUT INTERRUPTING THE CURRENTLY RUNNING SYSTEMS
404

**FIGURE 4**

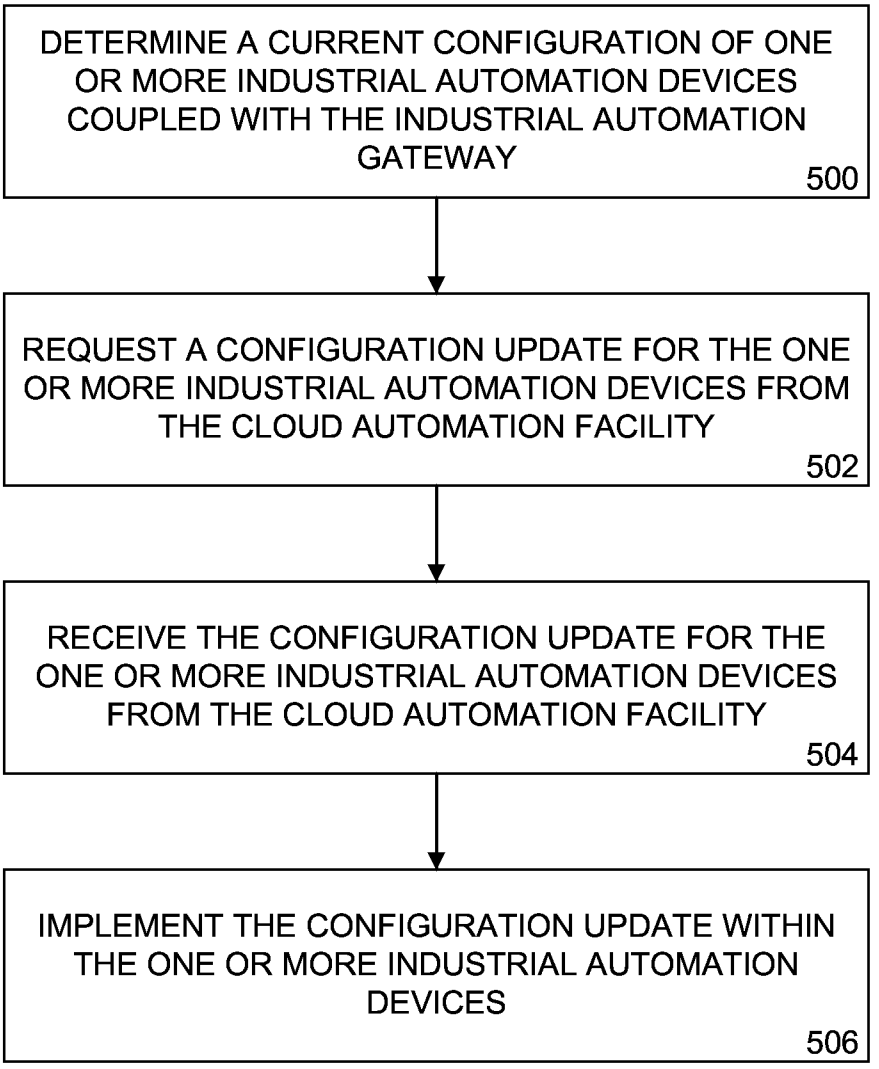

DETERMINE A CURRENT CONFIGURATION OF ONE OR MORE INDUSTRIAL AUTOMATION DEVICES COUPLED WITH THE INDUSTRIAL AUTOMATION GATEWAY
500
REQUEST A CONFIGURATION UPDATE FOR THE ONE OR MORE INDUSTRIAL AUTOMATION DEVICES FROM THE CLOUD AUTOMATION FACILITY
502
RECEIVE THE CONFIGURATION UPDATE FOR THE ONE OR MORE INDUSTRIAL AUTOMATION DEVICES FROM THE CLOUD AUTOMATION FACILITY
504
IMPLEMENT THE CONFIGURATION UPDATE WITHIN THE ONE OR MORE INDUSTRIAL AUTOMATION DEVICES
506

**FIGURE 5**

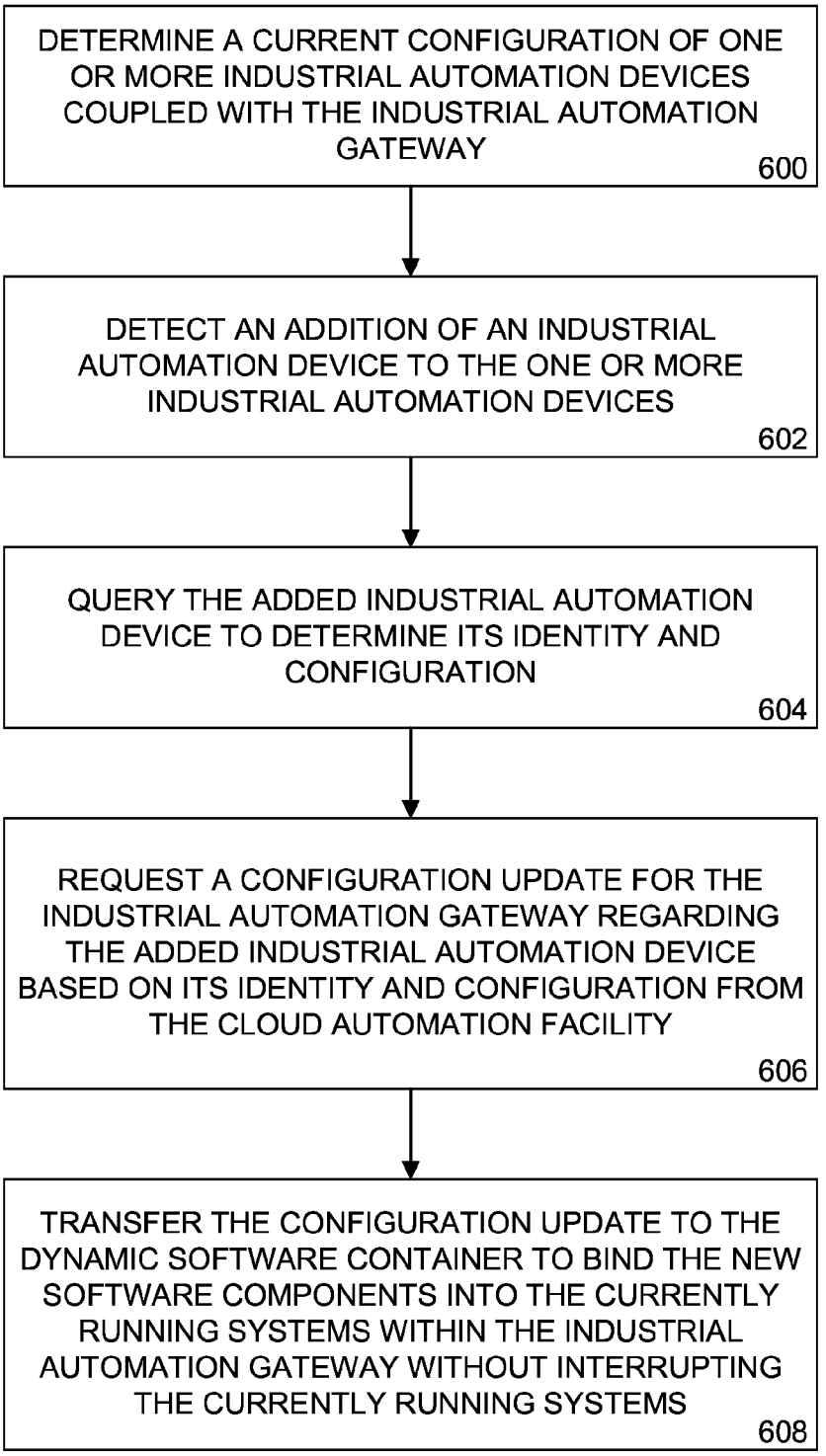

DETERMINE A CURRENT CONFIGURATION OF ONE OR MORE INDUSTRIAL AUTOMATION DEVICES COUPLED WITH THE INDUSTRIAL AUTOMATION GATEWAY
600
DETECT AN ADDITION OF AN INDUSTRIAL AUTOMATION DEVICE TO THE ONE OR MORE INDUSTRIAL AUTOMATION DEVICES
602
QUERY THE ADDED INDUSTRIAL AUTOMATION DEVICE TO DETERMINE ITS IDENTITY AND CONFIGURATION
604
REQUEST A CONFIGURATION UPDATE FOR THE INDUSTRIAL AUTOMATION GATEWAY REGARDING THE ADDED INDUSTRIAL AUTOMATION DEVICE BASED ON ITS IDENTITY AND CONFIGURATION FROM THE CLOUD AUTOMATION FACILITY
606
TRANSFER THE CONFIGURATION UPDATE TO THE DYNAMIC SOFTWARE CONTAINER TO BIND THE NEW SOFTWARE COMPONENTS INTO THE CURRENTLY RUNNING SYSTEMS WITHIN THE INDUSTRIAL AUTOMATION GATEWAY WITHOUT INTERRUPTING THE CURRENTLY RUNNING SYSTEMS
608

**FIGURE 6**

# SYSTEM AND METHOD FOR AUTONOMOUS DYNAMIC PROVISIONING

## RELATED APPLICATIONS

**[0001]** This application hereby claims the benefit of and priority to U.S. Provisional Patent Application No. 62/016,005, titled "INDUSTRIAL AUTOMATION NODE AND METHOD", filed on Jun. 23, 2014 and which is hereby incorporated by reference in its entirety.

## TECHNICAL BACKGROUND

**[0002]** Industrial automation is used to control machines and processes in manufacturing. Automated machines commonly control the handling of components, sub-components, and raw materials, perform fabrication processes, testing, product handling, packaging, and shipping. Industrial automation enables precise control of industrial processes, achievement of smaller tolerances and better quality products, higher production outputs, and increased worker safety and productivity.

**[0003]** Industrial automation installations comprise multiple computerized devices that control industrial machines and industrial processes. The components of an industrial automation installation must work together in a coordinated fashion, performing operations such as exchanging data, controlling the timing and scheduling of processes, providing information to operators or technicians, and receiving operator inputs.

**[0004]** Because of the large number of system variables that must be monitored and controlled, industrial automation systems often generate vast amounts of data. In addition to production statistics, data relating to machine health, alarm status, operator feedback, electrical or mechanical load, and the like are often monitored. The data is generated by the many industrial devices that can make up a given automation system, including industrial controllers and associated I/O, telemetry devices, motion control devices, valves, conveyors, raw material handling systems, product handling systems, visualization applications, traceability systems, and the like. Moreover, such industrial facilities can operate on a twenty-four hour basis, wherein automation systems can generate a vast amount of data.

**[0005]** In addition, industrial automation monitoring has evolved from monitoring devices in an industrial plant to include monitoring devices at remote sites, such as mobile or temporary facilities. Industrial automation monitoring can be used for drilling, mining, and other resource extraction operations. Industrial automation monitoring can be used in monitoring water treatment facilities or in monitoring of environmental conditions. Industrial automation monitoring can be used to monitor the health and operation of industrial automation devices including field equipment.

**[0006]** Industrial automation devices can generate industrial automation data at multiple, geographically disparate locations. The industrial automation data can be collected via the cloud, wherein industrial automation data can be accumulated and made available to a user or users via the cloud. Where the industrial automation devices are distributed geographically, the cloud advantageously provides a facility for accessing data from multiple, distributed industrial automation devices.

## Overview

**[0007]** In an embodiment, an industrial automation gateway for autonomous dynamic provisioning is provided. The industrial automation gateway includes a cloud communication interface coupled with, and configured for communication with, a cloud automation facility, and a processor coupled with the cloud communication interface. The processor is configured to determine a current configuration of the industrial automation gateway, and request a configuration update from the cloud automation facility through the cloud communication interface. The processor is also configured to receive the configuration update from the cloud automation facility through the cloud communication interface, and implement the configuration update within the industrial automation gateway.

**[0008]** In another embodiment, a method for autonomous dynamic provisioning within an industrial automation gateway is provided. The method includes determining a current configuration of the industrial automation gateway, and requesting a configuration update from a cloud automation facility through a cloud communication interface. The method also includes receiving the configuration update from the cloud automation facility through the cloud communication interface, and implementing the configuration update within the industrial automation gateway.

**[0009]** In a further embodiment, one or more non-transitory computer-readable media having stored thereon program instructions to facilitate autonomous dynamic provisioning within an industrial automation gateway is provided. The program instructions, when executed by a computing system, direct the computing system to at least determine a current configuration of the industrial automation gateway, and request a configuration update from a cloud automation facility through a cloud communication interface. The program instructions also direct the computing system to receive the configuration update from the cloud automation facility through the cloud communication interface, and implement the configuration update within the industrial automation gateway.

**[0010]** This Overview is provided to introduce a selection of concepts in a simplified form that are further described below in the Technical Disclosure. It should be understood that this Overview is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** FIG. **1** illustrates an exemplary industrial automation system.

**[0012]** FIG. **2** illustrates an exemplary flowchart for the operation of an industrial automation gateway.

**[0013]** FIG. **3** illustrates a block diagram of a computer system configured to operate as an industrial automation gateway.

**[0014]** FIG. **4** illustrates an exemplary flowchart for the operation of an industrial automation gateway in another example.

**[0015]** FIG. **5** illustrates an exemplary flowchart for the operation of an industrial automation gateway in further example.

**[0016]** FIG. **6** illustrates an exemplary flowchart for the operation of an industrial automation gateway in still another example.

## DETAILED DESCRIPTION

**[0017]** The following description and associated drawings teach the best mode of the invention. For the purpose of teaching inventive principles, some conventional aspects of the best mode may be simplified or omitted. The following claims specify the scope of the invention. Some aspects of the best mode may not fall within the scope of the invention as specified by the claims. Thus, those skilled in the art will appreciate variations from the best mode that fall within the scope of the invention. Those skilled in the art will appreciate that the features described below can be combined in various ways to form multiple variations of the invention. As a result, the invention is not limited to the specific examples described below, but only by claims and their equivalents.

**[0018]** FIG. **1** shows an exemplary industrial automation node **110**. Industrial automation node **110** is part of an industrial automation system **100**, with the industrial automation system **100** further including cloud **140** and cloud automation facility **150**. Industrial automation node **110** is in communication with cloud **140**. Industrial automation node **110** communicates continuously, periodically, or intermittently with cloud **140**. Industrial automation node **110** communicates with cloud **140** via a wired or wireless communication channel. Industrial automation node **110** in some examples communicates with cloud **140** via a cellular communication link and exchanges communications with cloud **140** via a cellular telephone communication protocol. In such an example, industrial automation node **110** has an account with a cellular provider.

**[0019]** Industrial automation node **110** in some examples is located in a manufacturing plant or other industrial facility. Alternatively, in other examples industrial automation node **110** is remotely located and comprises a small facility, a temporary facility, a mobile facility, or other self-contained facility. In other examples, industrial automation node **110** is substantially stationary or is fixed in location.

**[0020]** Industrial automation node **110** performs some manner of industrial automation operation or operations. Industrial automation node **110** generates and/or gathers industrial automation data. Industrial automation data can include timestamps that indicate when data portions were generated or collected. Industrial automation node **110** transfers the industrial automation data to cloud **140** for storage, analysis, and other uses. Industrial automation node **110** further transfers operational information to cloud **140** in some examples, including operational status and operational characteristic. Industrial automation node **110** in some examples receives information from cloud **140**, including programming, measurement values or other information needed for operation of industrial automation node **110**, requests for operational status and operational characteristics from industrial automation node **110**, and other information.

**[0021]** Industrial automation node **110** relays industrial automation data to cloud automation facility **150**. Industrial automation node **110** may also accumulate, process, filter, compress, or otherwise modify the industrial automation data before relaying it to cloud automation facility **150**. In addition, industrial automation node **110** may periodically transfer a heartbeat message to cloud automation facility **150**.

**[0022]** Cloud **140** comprises a network or association of connected computer devices and digital electronic resources that can be used to perform processing and to relay communications. The term "cloud" is a shorthand reference to cloud computing infrastructure. The cloud includes one or more communication networks, such as the Internet, for example, and can further include portions of an industrial communications network, such as a local area network (LAN) or a wide area network (WAN). In cloud computing, a computing process may run on one or many connected cloud computers at the same time. In cloud computing, the cloud can host and run an application anywhere in the world. Further, cloud **140** enables access to the application from anywhere.

**[0023]** Cloud **140** includes one or more data storage facilities for storing received industrial automation data in some examples. Cloud **140** receives industrial automation data from industrial automation node **110** and accumulates and stores the industrial automation data. Cloud **140** in some examples processes and/or analyzes the industrial automation data.

**[0024]** Cloud automation facility **150** is configured to communicate with industrial automation node **110** via cloud **140** and provide cloud services to industrial automation node **110**. Cloud services can include, but are not limited to, data storage, data analysis, control applications, visualization applications such as cloud-based Human-Machine Interfaces (HMIs), reporting applications, Enterprise Resource Planning (ERP) applications, notification services, or other such applications.

**[0025]** Cloud automation facility **150** is configured to obtain industrial automation data of industrial automation node **110** via cloud **140**. In addition, cloud automation facility **150** stores and provides configuration information to industrial automation node **110**. Cloud automation facility **150** includes configuration library **152** that stores configuration information for one or more industrial automation nodes **110**. Configuration library **152** is used to configure industrial automation nodes **110**. Configuration library **152** can be used to configure a large variety of industrial automation devices **130-134**. Configuration library **152** in some examples stores configuration information for each industrial automation device **130-134** of industrial automation node **110**. Alternatively, in other examples configuration library **152** stores configuration information for all possible industrial automation devices **130-134** that could be used by industrial automation node **110**. Configuration library **152** stores multiple versions of each configuration information item in some examples. Configuration library **152** receives updates of configuration information and provides the updated configuration information to industrial automation nodes **110**.

**[0026]** Industrial automation node **110** in the example shown includes one or more industrial automation devices **130-134** and industrial automation gateway **120** coupled to the one or more industrial automation devices **130-134**. The one or more industrial automation devices **130-134** perform industrial automation operations. The one or more industrial automation devices **130-134** can be selected and included in industrial automation node **110** to perform specific automation tasks.

**[0027]** Industrial automation node **110** interacts with cloud-based computing services that are hosted by cloud **140**. The cloud platform comprises infrastructure that allows shared computing services to be accessed and utilized by cloud-capable devices. The cloud platform can be a public

cloud that is accessible via the Internet by devices having Internet connectivity and appropriate authorizations to utilize commercially-available communication services. In some examples, access to the cloud platform and associated services can be provided to customers as subscription services.

**[0028]** Providing the one or more industrial automation devices **130-134** with cloud capability can offer a number of advantages. Cloud-based storage can be easily scaled to accommodate the large quantities of data that can be generated daily by an industrial automation enterprise. Moreover, multiple industrial automation facilities at different geographical locations can migrate their respective automation data to the cloud **140** for aggregation, collation, collective analysis, and enterprise-level reporting without the need to establish a private network between the facilities.

**[0029]** Cloud-based diagnostic applications can monitor the health of respective automation systems or their associated industrial devices across an entire plant, or across multiple industrial automation facilities. Cloud-based control applications can be used to track a unit of product (or a unit or units of raw materials) through stages of production, collecting data for each unit at each stage.

**[0030]** Industrial automation node **110** can accept a number of and variety of industrial automation devices **130-134**. The one or more industrial automation devices **130-134** can be installed to and removed from industrial automation node **110** in some examples. The one or more industrial automation devices **130-134** in some examples comprise batch control systems, continuous control systems, or discrete control systems. The one or more industrial automation devices **130-134** can include devices such as industrial controllers (e.g., programmable logic controllers or other types of programmable automation controllers), field devices such as sensors, meters, valves, motor drives, actuators, HMIs, industrial robots, barcode markers and readers, vision system devices, welders, or other such industrial devices.

**[0031]** Industrial automation gateway **120** includes cloud communication interface **122** and industrial communication interface **124**. Cloud communication interface **122** is configured to communicate with cloud **140**. Industrial communication interface **124** is configured to communicate with the one or more industrial automation devices **130-134**.

**[0032]** Industrial communication interface **124** facilitates monitoring and control of a process or processes. Industrial communication interface **124** exchanges data with the one or more industrial automation devices **130-134** using a communication system such as native hardwired I/O or via a plant network such as Ethernet/IP, Data Highway Plus, ControlNet, Devicenet, or the like. Industrial communication interface **124** typically receives any combination of digital or analog signals from the one or more industrial automation devices **130-134** indicating a current state of the one or more industrial automation devices **130-134** and associated processes.

**[0033]** Cloud communication interface **122** comprises a communication interface that exchanges communications with cloud **140**. Cloud communication interface **122** uses any suitable communication protocol. Cloud communication interface **122** performs wired and/or wireless communications with cloud **140**, as needed. Cloud communication interface **122** can employ one or more different types of communications modules to connect with mobile-phone carriers, Wi-Fi providers, and other communications-services providers from locations in which wireless service can be obtained. Cloud communication interface **122** in some examples performs wireless communications with cloud **140** using a cellular communications protocol, including cellular communications protocols such as 2G (second generation)/CDMA, 3G/LTE, 4G, 5G, or any other suitable cellular telephone communication protocol. Alternatively, cloud communication interface **122** uses other suitable wireless communication protocols. By employing cloud communication interface **122**, cloud-computing services can be extended into many different, geographically dispersed areas and to a variety of technologies and uses for which traditional wireless-service subscriptions would not be economically feasible.

**[0034]** Industrial automation gateway **120** can transfer substantially real-time industrial automation data to cloud **140**. However, if industrial automation gateway **120** determines that communications are not possible, or if industrial automation gateway **120** determines that it is not time for an industrial automation data upload, industrial automation gateway **120** can transfer bulk industrial automation data to cloud **140**. In such a situation, industrial automation gateway **120** enters a store-and-forward mode, wherein industrial automation node **110** accumulates industrial automation data and transfers the accumulated industrial automation data to cloud **140** at predetermined time periods.

**[0035]** Industrial automation gateway **120** in some examples includes multiple communication ports. Industrial automation gateway **120** in some examples includes wired and wireless communication ports. Consequently, industrial automation gateway **120** may be able to communicate with cloud **140** in various ways and using more than one communication protocol or scheme.

**[0036]** In some examples, industrial automation gateway **120** provides security. Industrial automation gateway **120** can provide access control, screening or limiting communications. Industrial automation gateway **120** can encrypt the industrial automation data being transferred to cloud **140**.

**[0037]** Industrial automation gateway **120** in some examples is a small footprint device, such as the netbiter™ remote communication gateway, available from HMS Industrial Networks. The netbiter™ remote communication gateway includes GSM/GPRS cellular communication capability and includes Ethernet wired communication capability. Industrial automation gateway **120** in some examples has a small physical size, uses a low amount of electrical energy, performs as little processing or communicating as needed, adds minimal latency to data transfers or operations in industrial automation node **110**, or a combination of these factors, for example.

**[0038]** Industrial automation gateway **120** comprises a fixed hardware and software in some examples. Alternatively, industrial automation gateway **120** comprises a communication card or other communication device that can be installed into and removed from industrial automation node **110**. Corresponding gateway software can be obtained by industrial automation node **110** for a current gateway device or for a current gateway device format/protocol.

**[0039]** In some examples, the software for industrial automation gateway **120** is configurable, such as by cloud **140** or by cloud automation facility **150**. Further, the gateway software can be dynamically updated or modified.

**[0040]** Industrial automation gateway **120** obtains and loads suitable data plug-ins or configurations for the one or more industrial automation devices **130-134**. The data plug-ins or configurations comprise plug-ins for receiving industrial automation data from the one or more industrial automa-

tion devices **130-134**. Industrial automation gateway **120** may acquire one or more data plug-in or configuration for each industrial automation device **130-134**. The data plug-ins or configurations operate to receive the industrial automation data in a format of the corresponding industrial automation device **130-134**. The data plug-ins can process or condition the industrial automation data. The data plug-ins can transform the industrial automation data. Other uses for the data plug-ins are contemplated and are within the scope of the description and claims. However, the data plug-ins do not generate the industrial automation data.

**[0041]** Industrial automation gateway **120** in some examples stores a set, subset, or sets of plug-ins or configurations that are anticipated to be needed in industrial automation node **110**. Industrial automation gateway **120** may store more plug-ins and configurations than needed, including plug-ins and configurations that may be needed for future devices or future operations. Alternatively, in other examples, industrial automation gateway **120** obtains and installs only the needed data plug-ins and configurations, wherein unneeded data plug-ins and configurations are not present in industrial automation node **110**.

**[0042]** Industrial automation gateway **120** in some examples includes configuration information in messages or data that is sent to cloud **140**. Further, cloud **140** (or cloud automation facility **150**) in some examples sends available configuration version information to industrial automation gateway **120**. As a result, industrial automation gateway **120** can determine that a newer configuration version is available and can subsequently request the newer configuration version from cloud **140** or from cloud automation facility **150**.

**[0043]** In some examples, industrial automation gateway **120** is configured to request a configuration update from cloud **140** or cloud automation facility **150**, with the request including information including a current configuration **126** (and can include other information such as information about the one or more installed industrial automation devices **130-134**), receive a configuration update **128** in response, if a configuration update **128** is needed or warranted, and implement the received configuration update **128**.

**[0044]** In some examples, industrial automation node **110** comprises one or more industrial automation devices **130-134** configured to generate industrial automation and an industrial automation gateway **120** in communication with the one or more industrial automation devices **130-134** and in communication with a cloud automation facility **150**, with industrial automation gateway **120** configured to determine a current configuration **126** of the gateway **120**, transfer the current configuration **126** to cloud automation facility **150**, and receive and implement a configuration update **128** from cloud automation facility **150**. In some examples, industrial automation node **110** performs a configuration update without any operator inputs.

**[0045]** In some examples, the configuration information comprises communication parameters, data collection parameters, and data conditioning parameters. The communication parameters define communications characteristics for industrial automation node **110**, such as communication times/intervals, communication types/protocols, a number of stored messages per upload package, a maximum upload frequency and/or bandwidth limits, and a size or time limit for storing industrial automation data in a disconnected state, for example. The data collection parameters define data collection parameters for the one or more industrial automation devices **130-134** of industrial automation node **110**, such as data to be collected and tags or alarms to be collected from specific industrial automation devices **130-134**, and how often data is to be collected, for example. The data conditioning parameters define data conditioning operations to be performed, such as filtering, compression, transformation, etc. It should be understood that additional communication parameters, data collection parameters, and data conditioning parameters are contemplated and are within the scope of the description and claims.

**[0046]** FIG. **2** illustrates an exemplary flowchart for the operation of industrial automation gateway **120**. In this example, industrial automation gateway **120** determines a current configuration **126** of industrial automation gateway **120**, (operation **200**). Industrial automation gateway **120** then requests a configuration update from cloud automation facility **150** through cloud communication interface **122** and the cloud **140**, (operation **202**).

**[0047]** Industrial automation gateway **120** receives configuration update **128** from cloud automation facility **150** through the cloud **140** and cloud communication interface **122**, (operation **204**). Industrial automation gateway **120** implements configuration update **128** within industrial automation gateway **120**, (operation **206**).

**[0048]** FIG. **3** illustrates a block diagram of a computer system configured to operate as an industrial automation gateway **300**, such as industrial automation gateway **120** from FIG. **1**.

**[0049]** Industrial automation node **300** includes cloud communication interface **304**, industrial communication interface **306**, processor **308** coupled to cloud communication interface **304** and to industrial communication interface **306**, and a hardware memory **310** coupled to processor **308**. Memory **310** can be separate from or included in processor **308**.

**[0050]** The hardware memory **310** in the example shown includes software **312**. In some examples, software **312** comprises operating instructions that configure the industrial automation gateway **300**, when executed by the industrial automation gateway **300** in general or processor **308** in particular, to direct industrial automation gateway **300** to perform industrial automation node operations. Other data, such as operational data, may also be stored in hardware memory **310**. The software **312** in one example comprises at least a configuration update module **314** and a configuration monitoring module **316**. The configuration update module **314** performs configuration updates of the industrial automation gateway **300** in some examples. The configuration monitoring module performs event monitoring in the industrial automation devices **330-336** in some examples.

**[0051]** Processor **308** may comprise a microprocessor and other circuitry that retrieves and executes software **312** from hardware memory **310**. Processor **308** may be implemented within a single processing device, but may also be distributed across multiple processing devices or sub-systems that cooperate in executing program instructions. Examples of processor **308** include general purpose central processing units, application specific processors, and logic devices, as well as any other type of processing device, combinations, or variations.

**[0052]** Hardware memory **310** may comprise any computer readable storage media readable by processor **308** and capable of storing software **312**. Hardware memory **310** may include volatile and nonvolatile, removable and non-removable media implemented in any method or technology for

storage of information, such as computer readable instructions, data structures, program modules, or other data. Hardware memory **310** may be independent from or integrated into processor **308**. Hardware memory **310** can comprise additional elements, such as a memory controller, capable of communicating with processor **308**. Examples of storage media include random access memory, read only memory, magnetic disks, optical disks, flash memory, virtual memory and non-virtual memory, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other suitable storage media. In no case is the storage media a propagated signal.

**[0053]** In addition to storage media, in some implementations hardware memory **310** may also include communication media over which software **312** may be communicated internally or externally. Hardware memory **310** may be implemented as a single storage device but may also be implemented across multiple storage devices or sub-systems co-located or distributed relative to each other. Hardware memory **310** may comprise additional elements capable of communicating with processor **308** or possibly other systems.

**[0054]** Software **312** may be implemented in program instructions and among other functions and may, when executed by processor **308**, direct processor **308** to operate as described herein. In particular, the program instructions may include various components or modules that cooperate or otherwise interact to implement at least a portion of industrial automation gateway **300**. The various components or modules may be embodied in compiled or interpreted instructions or in some other variation or combination of instructions. The various components or modules may be executed in a synchronous or asynchronous manner, in a serial or in parallel, in a single threaded environment or multi-threaded, or in accordance with any other suitable execution paradigm, variation, or combination thereof. Software **312** in the examples comprises computer programs, firmware, or some other form of machine-readable processing instructions. Software **312** may include an operating system, utilities, drivers, network interfaces, applications, virtual machines, or some other type of software. Software **312** may include additional processes, programs, or components, such as operating system software or other application software. Software **312** may also comprise firmware or some other form of machine-readable processing instructions executable by processor **308**.

**[0055]** In general, software **312**, when loaded into processor **308** and executed, may transform a suitable apparatus, system, or device from a general-purpose computing system into a special-purpose computing system customized to perform a configuration update or perform event monitoring, among other operations. Indeed, encoding software **312** on the memory **310** may transform the physical structure of the memory **310**. The specific transformation of the physical structure may depend on various factors in different implementations of this description. Examples of such factors may include, but are not limited to the technology used to implement the storage media of the memory **310** and whether the computer-storage media are characterized as primary or secondary storage, as well as other factors.

**[0056]** In addition to software **312**, memory **310** comprises dynamic software container **318** that allows new software components with additional functionality to be downloaded when the cloud application detects a new configuration. Operation of dynamic software container **318** is further illustrated by the flowchart of FIG. **4**. These new gateway components are bound into the currently running system so as to dynamically enhance its operation without interruption. In this way, industrial automation gateway **300** can automatically extend its capabilities to speak new protocols and connect new industrial automation devices **330-336** added by the industrial customer on premises. This operation of industrial automation gateway **300** is further illustrated by the flowchart of FIG. **6**.

**[0057]** Industrial automation gateway **300** can be configured to wake up and discover any industrial automation devices **330-336** located on its local LAN network. In this way, devices may not only be discovered, but by using CIP messages industrial automation gateway **300** can query the exact product identification and its configuration. This map of local devices **330-336** and their configuration can then be communicated by industrial automation gateway **300** to cloud automation facility **150** to update the cloud model for these devices **330-336**. This model is then used to construct dashboards, reports, and analytics that will consume real-time operational data conveyed from these devices **330-336** to the cloud **140** by industrial automation gateway **300**.

**[0058]** In the same way, periodic checks of local devices **330-336** can discover newly deployed devices **330-336** and their configuration, and update the cloud model automatically. Cloud service users are then notified of model changes so that they can update dashboards, reports, and analytics as required. This operation of industrial automation gateway **300** is further illustrated by the flowchart of FIG. **5**.

**[0059]** Cloud communication interface **304** may include communication connections and devices that allow for communication with other computing systems over a communication network or collection of networks. Cloud communication interface **304** may include user input and output devices for being controlled by a user.

**[0060]** Cloud communication interface **304** comprises a network card, network interface, port, or interface circuitry that allows industrial automation gateway **300** to communicate over a network or networks. Cloud communication interface **304** may also include a memory device, software, processing circuitry, or some other device. Cloud communication interface **304** can use any suitable communication protocol to exchange communications.

**[0061]** Cloud communication interface **304** may include components that communicate over communication links, such as network cards, ports, RF transceivers, processing circuitry and software, or other communication components. Cloud communication interface **304** may be configured to communicate over electrically conductive, wireless, optical, or other links.

**[0062]** Cloud communication interface **304** can further include components that interact with a user to receive user inputs and user communications and to present media and/or information. These components typically include a keyboard, display, indicator lights, speakers, touch pads, microphone, buttons, mouse, or other user input/output apparatus, including combinations thereof.

**[0063]** Industrial communication interface **306** may include communication connections and devices that allow for communication with other computing systems over a communication network or collection of networks. Industrial communication interface **306** may include user input and output devices for being controlled by a user.

**[0064]** Industrial communication interface **306** comprises a network card, network interface, port, or interface circuitry that allows industrial automation gateway **300** to communicate over a network or networks. Industrial communication interface **306** may also include a memory device, software, processing circuitry, or some other device. Industrial communication interface **306** can use any suitable communication protocol to exchange communications.

**[0065]** Industrial communication interface **306** may include components that communicate over communication links, such as network cards, ports, RF transceivers, processing circuitry and software, or other communication components. Industrial communication interface **306** may be configured to communicate over electrically conductive, wireless, optical, or other links.

**[0066]** Industrial communication interface **306** can further include components that interact with a user to receive user inputs and user communications and to present media and/or information. These components typically include a keyboard, display, indicator lights, speakers, touch pads, microphone, buttons, mouse, or other user input/output apparatus, including combinations thereof.

**[0067]** FIG. **4** illustrates an exemplary flowchart for the operation of industrial automation gateway **300** in another example. In this example, industrial automation gateway **300** receives configuration update **322** within dynamic software container **318**, (operation **400**). Dynamic software container **318** stores configuration update **322** within hardware memory **310** (operation **402**). Dynamic software container **318** binds the new software components into currently running systems within industrial automation gateway **300** without interrupting the currently running systems, (operation **404**).

**[0068]** FIG. **5** illustrates an exemplary flowchart for the operation of industrial automation gateway **300** in further example. In this example, industrial automation gateway **300** determines a current configuration of one or more industrial automation devices **330-336** coupled with industrial automation gateway **300** through industrial communication interface **306**, (operation **500**).

**[0069]** Industrial automation gateway **300** requests a configuration update for the one or more industrial automation devices **330-336** from cloud automation facility **150**, (operation **502**). Industrial automation gateway **300** receives the configuration update for the one or more industrial automation devices **330-336** from cloud automation facility **150**, (operation **504**). Industrial automation gateway **300** implements the configuration update within the one or more industrial automation devices **330-336**, (operation **506**).

**[0070]** FIG. **6** illustrates an exemplary flowchart for the operation of industrial automation gateway **300** in still another example. In this example, industrial automation gateway **300** determines a current configuration of one or more industrial automation devices **330-336** coupled with industrial automation gateway **300** through industrial communication interface **306**, (operation **600**).

**[0071]** Industrial automation gateway **300** detects the addition of an industrial automation device **330-336** to the one or more industrial automation devices **330-336**, (operation **602**). Industrial automation gateway **300** queries the added industrial automation device **330-336** to determine its identity and configuration, (operation **604**).

**[0072]** Industrial automation gateway **300** requests a configuration update for industrial automation gateway **300** regarding the added industrial automation device based on its identity and configuration from cloud automation facility **150**, (operation **606**). Industrial automation gateway **300** then transfers configuration update **322** to dynamic software container **318** to bind the new software components into the currently running systems within industrial automation gateway **300** without interrupting the currently running systems, (operation **608**).

**[0073]** The above description and associated figures teach the best mode of the invention. The following claims specify the scope of the invention. Note that some aspects of the best mode may not fall within the scope of the invention as specified by the claims. Those skilled in the art will appreciate that the features described above can be combined in various ways to form multiple variations of the invention. As a result, the invention is not limited to the specific embodiments described above, but only by the following claims and their equivalents.

What is claimed is:

**1**. An industrial automation gateway for autonomous dynamic provisioning comprising:
- a cloud communication interface coupled with, and configured for communication with, a cloud automation facility; and
- a processor coupled with the cloud communication interface, configured to:
  - determine a current configuration of the industrial automation gateway;
  - request a configuration update from the cloud automation facility through the cloud communication interface;
  - receive the configuration update from the cloud automation facility through the cloud communication interface; and
  - implement the configuration update within the industrial automation gateway.

**2**. The industrial automation gateway of claim **1**, further comprising:
- a dynamic software container coupled with the processor, configured to:
  - receive the configuration update, wherein the configuration update comprises new software components with additional functionality for the industrial automation gateway;
  - store the configuration update in a memory; and
  - bind the new software components into currently running systems within the industrial automation gateway without interruption of the currently running systems.

**3**. The industrial automation gateway of claim **2**, further comprising:
- an industrial communication interface coupled with, and configured for communication with, one or more industrial automation devices.

**4**. The industrial automation gateway of claim **3**, wherein the processor is further configured to:
- determine a current configuration of the one or more industrial automation devices;
- detect an addition of an industrial automation device to the one or more industrial automation devices;
- query the added industrial automation device to determine its identity and configuration;
- request a configuration update for the industrial automation gateway regarding the added industrial automation device based on its identity and configuration from the cloud automation facility through the cloud communi-

cation interface, the configuration update comprising new software components with additional functionality to allow the industrial automation gateway to communicate with, and control, the added industrial automation device; and

transfer the configuration update to the dynamic software container to bind the new software components into the currently running systems within the industrial automation gateway without interruption of the currently running systems.

**5**. The industrial automation gateway of claim **4**, wherein the processor is further configured to:

transfer the identity and configuration of the added industrial automation device to the cloud automation facility through the cloud communication interface to update cloud service users with information about the added industrial automation device.

**6**. The industrial automation gateway of claim **4**, wherein the configuration update comprises one or more of: communication parameters, data collection parameters, or data conditioning parameters.

**7**. The industrial automation gateway of claim **1**, further comprising:

an industrial communication interface coupled with, and configured for communication with, one or more industrial automation devices.

**8**. The industrial automation gateway of claim **7**, wherein the processor is further configured to:

determine a current configuration of at least one of the one or more industrial automation devices;

request a configuration update for the at least one of the one or more industrial automation devices from the cloud automation facility through the cloud communication interface;

receive the configuration update for the at least one of the one or more industrial automation devices from the cloud automation facility through the cloud communication interface; and

implement the configuration update within the at least one of the one or more industrial automation devices through the industrial communication interface.

**9**. A method for autonomous dynamic provisioning within an industrial automation gateway comprising:

determining a current configuration of the industrial automation gateway;

requesting a configuration update from a cloud automation facility through a cloud communication interface;

receiving the configuration update from the cloud automation facility through the cloud communication interface; and

implementing the configuration update within the industrial automation gateway.

**10**. The method of claim **9**, further comprising:

receiving the configuration update within a dynamic software container, wherein the configuration update comprises new software components with additional functionality for the industrial automation gateway;

storing the configuration update in a hardware memory; and

binding the new software components into currently running systems within the industrial automation gateway without interrupting the currently running systems.

**11**. The method of claim **10**, further comprising:

determining a current configuration of one or more industrial automation devices coupled with the industrial automation gateway through an industrial communication interface;

detecting an addition of an industrial automation device to the one or more industrial automation devices;

querying the added industrial automation device to determine its identity and configuration;

requesting a configuration update for the industrial automation gateway regarding the added industrial automation device based on its identity and configuration from the cloud automation facility through the cloud communication interface, the configuration update comprising new software components with additional functionality to allow the industrial automation gateway to communicate with, and control, the added industrial automation device; and

transferring the configuration update to the dynamic software container to bind the new software components into the currently running systems within the industrial automation gateway without interrupting the currently running systems.

**12**. The method of claim **11**, further comprising:

transferring the identity and configuration of the added industrial automation device to the cloud automation facility through the cloud communication interface to update cloud service users with information about the added industrial automation device.

**13**. The method of claim **11**, wherein the configuration update comprises one or more of:

communication parameters, data collection parameters, or data conditioning parameters.

**14**. The method of claim **9**, further comprising:

determining a current configuration of one or more industrial automation devices coupled with the industrial automation gateway through an industrial communication interface;

requesting a configuration update for the one or more industrial automation devices from the cloud automation facility through the cloud communication interface;

receiving the configuration update for the one or more industrial automation devices from the cloud automation facility through the cloud communication interface; and

implementing the configuration update within the one or more industrial automation devices through the industrial communication interface.

**15**. One or more non-transitory computer-readable media having stored thereon program instructions to facilitate autonomous dynamic provisioning within an industrial automation gateway, wherein the program instructions, when executed by a computing system, direct the computing system to at least:

determine a current configuration of the industrial automation gateway;

request a configuration update from a cloud automation facility through a cloud communication interface;

receive the configuration update from the cloud automation facility through the cloud communication interface; and

implement the configuration update within the industrial automation gateway.

**16**. The one or more non-transitory computer-readable media of claim **15**, further comprising program instructions, which when executed by the computing system, direct the computing system to at least:

receive the configuration update within a dynamic software container, wherein the configuration update comprises new software components with additional functionality for the industrial automation gateway;

store the configuration update in a hardware memory; and

bind the new software components into currently running systems within the industrial automation system without interruption of the currently running systems.

**17**. The one or more non-transitory computer-readable media of claim **16**, further comprising program instructions, which when executed by the computing system, direct the computing system to at least:

determine a current configuration of one or more industrial automation devices coupled with the industrial automation gateway through an industrial communication interface;

detect an addition of an industrial automation device to the one or more industrial automation devices;

query the added industrial automation device to determine its identity and configuration;

request a configuration update for the industrial automation gateway regarding the added industrial automation device based on its identity and configuration from the cloud automation facility through the cloud communication interface, the configuration update comprising new software components with additional functionality to allow the industrial automation gateway to communicate with, and control, the added industrial automation device; and

transfer the configuration update to the dynamic software container to bind the new software components into the currently running systems within the industrial automation gateway without interruption of the currently running systems.

**18**. The one or more non-transitory computer-readable media of claim **17**, further comprising program instructions, which when executed by the computing system, direct the computing system to at least:

transfer the identity and configuration of the added industrial automation device to the cloud automation facility through the cloud communication interface to update cloud service users with information about the added industrial automation device.

**19**. The one or more non-transitory computer-readable media of claim **17**, wherein the configuration update comprises one or more of: communication parameters, data collection parameters, or data conditioning parameters.

**20**. The one or more non-transitory computer-readable media of claim **15**, further comprising program instructions, which when executed by the computing system, direct the computing system to at least:

determine a current configuration of one or more industrial automation devices coupled with the industrial automation gateway through an industrial communication interface;

request a configuration update for the one or more industrial automation devices from the cloud automation facility through the cloud communication interface;

receive the configuration update for the one or more industrial automation devices from the cloud automation facility through the cloud communication interface; and

implement the configuration update within the one or more industrial automation devices through the industrial communication interface.

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