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(54) Title: SYSTEM AND METHOD FOR PROVIDING MONITORING AND CONTROL OF A SUPPLY IN A CYBER-PHYSICAL ENVIRONMENT

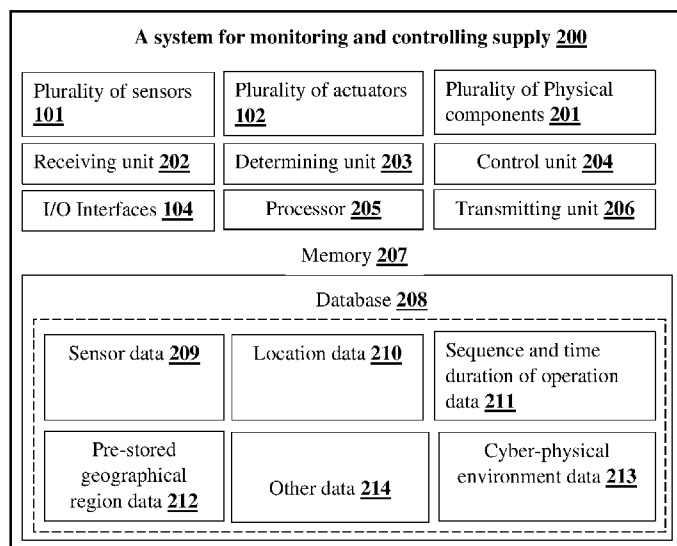


Figure 2

(57) Abstract: A system for monitoring and controlling supply in a cyber-physical environment is disclosed. The system provided with a plurality of sensors and plurality of actuators is configured to enable the control operation of plurality of control elements (valves, pumps) to provide supply to a plurality of supply locations. The system disclosed in the present disclosure enables equitable supply to supply locations in a cyber-physical environment irrespective of the varying terrain parameters in the selected geographical region. The disclosure provides a cost-effective solution for efficient monitoring and optimal control by achieving performance targets or metrics e.g., operation and maintenance costs, energy utilization, disparity in resource utilization across different components of the CPS and users.



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SYSTEM AND METHOD FOR PROVIDING MONITORING AND CONTROL OF A SUPPLY IN A CYBER-PHYSICAL ENVIRONMENT

Field of the Invention

- 5 The present disclosure relates to a field of cyber-physical environment, and more particularly, to a system and method for providing monitoring and control of a supply in a cyber-physical environment.

Background of the Invention

- 10 Cyber-Physical Systems (CPS) are systems whose operations are monitored, controlled and integrated using computing, communication and control systems. Distributed Cyber physical system/environment (CPS) are geographically distributed and have several different functional characteristics. Some examples of the distributed CPS include water distribution networks, gas distribution networks,
15 power distribution networks, automated traffic congestion control, among others. For optimal resource utilization of any distributed CPS at minimum operational costs, monitoring and control of plurality of its entities are essential. These entities, usually large in numbers and distributed over wide geographic regions, makes monitoring and control of CPS challenging. Though wireless communication technologies such as Wi-Fi, Bluetooth and cellular technologies are available, their use is limited due to
20 high power consumption and/or high Operations and Maintenance (O&M) cost, limited network coverage etc. In the distributed CPS, since the geographical distribution is of the order of 10s-100s of kilometres, emerging technologies such as long range (LoRa), NarrowBand-Internet of Things (NB-IoT) and Sigfox are more appropriate.
25

- For example, water supply in most of the developing countries are intermittent with poor levels of quality of service. The poor service levels can be attributed to constraints on available water and infrastructure, limited instrumentation, improper
30 operation of the system and poor maintenance of the water distribution network. As per the international benchmarks for water and sanitation utilities, the average figure for non-revenue water levels in developing countries are around 35 per cent. The main cause of non-revenue water is attributed to the ageing of pipeline infrastructure. To mitigate this, the service providers require accurate leak detection and
35 localization techniques through monitoring & decision support systems, to repair the

5 piping system quickly and minimize the amount of non-revenue water. Another major reason for water utilities to consider online monitoring and control is to reduce of the electrical energy consumption. Energy is required in all stages of the system, water treatment, pumping & storage and transportation. Energy cost represents 25-30 % of the water utilities total operational and maintenance cost. Even small improvements in this, therefore, can give significant savings.

10 At the same time, real-time monitoring and control of pressure and flow rates are necessary to meet customer demands. Further, in scenarios of insufficient supply or poor infrastructure availability, ensuring equitable distribution is important. However, currently water networks are largely operated manually with limited data resulting in inequitable supply and inefficient operation. To monitor and control these geographically distributed networks, sensors should be placed in appropriate locations and manual valves should be automated and appropriate communication between the devices are to be enabled. But mere replacement of manual valves with remote controllable valves over a large geographical area can lead to complete renovation of the cyber-physical environment which may not only be expensive, but also may disturb the supply to a geographical region for a long period of time.

20 Further, monitoring and control of geographically distributed networks require long distance communication technology. Cellular communication (3G/4G) is one possible solution but is associated with high cost and requires more power. It is not suitable for battery powered devices.

25 So, there is need for system for monitoring and controlling that achieves energy reduction, optimal resource scheduling and utilization by developing customized sensor, actuator & gateway nodes enabled with appropriate wireless technologies and data communication protocols which may be implemented over an existing distributed CPS as well without disturbing or interrupting supply to the supply locations even during installation.

30 The information disclosed in this background of the disclosure section is only for enhancement of understanding of the general background of the invention and should not be taken as an acknowledgement or any form of suggestion that this information forms the prior art already known to a person skilled in the art.

Objects of the Invention

35 An object of the present disclosure is to provide a method that overcomes the lack of control and monitoring in a cyber-physical environment/system distributed over a geographical region.

Another object of the present disclosure is to provide a system as a cost-effective solution for efficient monitoring and optimal control by achieving performance targets or metrics e.g., operation and maintenance costs, energy utilization, disparity in resource utilization across different components of the CPS and users.

5 **Summary of the Invention**

The present disclosure overcomes one or more shortcomings of the prior art and provides additional advantages discussed throughout the present disclosure. Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail
10 herein and are considered a part of the claimed disclosure.

In a non-limiting embodiment of the present disclosure, a system for providing monitoring and control capabilities, pertaining to a supply in a cyber-physical environment is disclosed. The system comprises a plurality of sensors for sensing at
15 corresponding plurality of physical components present in the cyber physical environment. The system further comprises a plurality of actuators for controlling a plurality of control elements (such as valves, pumps etc.,) connected with the plurality of physical components. Further, the system comprises a receiving unit to receive a plurality of sensor data, from the plurality of sensors, indicating functioning of the plurality of physical components responsible for providing the supply at a
20 plurality of supply locations distributed over a geographical region. The plurality of location data, corresponding to plurality of supply locations depending upon the geographical region is stored in the memory. The system further comprises a determining unit to determine a plurality of supply parameters based on hydraulic model required for adequately supplying the supply to each of the plurality of supply
25 locations. The supply parameters comprise at least one of pressure, flowrate, quantity of supply. The system further comprises a control unit to enable the plurality of actuators to control operations of the plurality of control elements, based on the plurality of supply parameters, to provide the supply to the plurality of supply locations.

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In one non-limiting embodiment of the present disclosure, a method of monitoring and controlling supply in a cyber-physical environment is disclosed. The method comprises providing a plurality of sensors for sensing at corresponding plurality of physical components present in the cyber physical environment. The method further
35 comprises providing a plurality of actuators for controlling a plurality of control elements connected with the plurality of physical components. The method further comprises receiving a plurality of sensor data, from the plurality of sensors, indicating functioning of the plurality of physical components responsible for providing the supply at a plurality of supply locations distributed over a geographical

- region. A plurality of location data, corresponding to plurality of supply locations depending upon the geographical region is stored in the memory. The method further comprises, determining a plurality of supply parameters based on hydraulic model required for adequately supplying the supply to each of the plurality of supply
- 5 locations. The supply parameters comprise at least one of pressure, flowrate, and quantity of supply. Further the method comprises controlling through the plurality of actuators operation of the plurality of control elements, based on the plurality of supply parameters, to provide the supply to the plurality of supply locations.

10 **Brief Description of the Drawings**

The embodiments of the disclosure itself, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings as listed below:

- 15 **Figure 1** depicts the architecture of the system for monitoring and supply in a Cyber-physical environment 100, in accordance with some embodiments of the present disclosure.

Figure 2 depicts the block diagram of the system for monitoring and controlling supply 200, in accordance with some embodiments of the present disclosure;

- 20 **Figure 3** depicts a flowchart **300** of a method of monitoring and controlling supply in a cyber-physical environment in accordance with an embodiment of the present disclosure;

Figure 4 depicts the block diagram of a sensor, in accordance with an exemplified embodiment of the present disclosure;

- 25 **Figure 5** depicts the block diagram of an actuator, in accordance with an exemplified embodiment of the present disclosure; and

Figure 6 depicts the block diagram of a gateway, in accordance with an exemplified embodiment of the present disclosure;

Figure 7 depicts an example of location data of a few point in a geographical region;

- 30 **Figure 8** depicts an example of a typical wireless network, in accordance with an embodiment of the present disclosure;

Figure 9 depicts an exemplified elevation profile generated between the selected two in accordance with an embodiment of the present disclosure;

Figure 10 depicts an exemplified repeater locator, in accordance with an embodiment of the present disclosure;

- 5 **Figure 11(a)** depicts a graph with selected sensor nodes of the plurality of sensors and plurality of actuators with corresponding edge weight value;

Figure 11(b) depicting a graph of a minimum weighted spanning tree constructed for the optimal network, in accordance with an embodiment of the present disclosure; and

- 10 **Figure 12** illustrates schematic diagram illustrating surge protection in pipeline and dry run prevention of pump, in accordance with an embodiment of the present disclosure.

Detailed Description

- 15 The foregoing has broadly outlined the features and technical advantages of the present disclosure in order that the detailed description of the disclosure that follows may be better understood. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present disclosure.

- 20 The novel features which are believed to be characteristic of the disclosure, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and
25 description only and is not intended as a definition of the limits of the present disclosure.

- Disclosed herein is a system for monitoring and controlling supply in a cyber - physical environment. The system comprises a plurality of sensors and plurality of actuators connected to a plurality of control elements (such as valves, pumps) in a
30 cyber physical system with supply locations distributed over a geographical region. The system is configured to provide supply to supply locations. The supply can be automated or monitored and controlled by a user remotely. In an embodiment, the method of monitoring and controlling comprises mainly steps of determining plurality of supply parameters required for adequately supplying the supply to supply
35 locations. According to an embodiment, the supply parameters may be based on

based on the optimizer output which may again depend on sensor data or hydraulic model associated with cyber-physical environment. Further, plurality of location data of the geographical region with the supply locations may also be used for identifying an optimal network topology for wireless communication in cyber-physical environment.

Figure 1 shows the architecture of a system for monitoring and controlling in a Cyber-physical environment 100, in accordance with some embodiments of the present disclosure.

The architecture includes a plurality of sensors and a plurality of actuators, one or more gateways, a system for controlling and monitoring supply, input/output interface and one or more users. For the purposes of illustration and simplification only one gateway and one user are depicted. The user for the purpose of this disclosure may be a person who accesses the input/output interface of the system to monitor or control the system. The user may be authorized personnel to access the system. The plurality of sensors and the plurality of actuators are communicatively connected to a system for monitoring and controlling supply in a cyber-physical environment. The plurality of sensors is placed for sensing at corresponding plurality of physical components present in the cyber physical environment. For example, the plurality of physical components comprises at least one of a reservoir, a pipelines, over-head tanks, sump, pump, power panels and the like. The plurality of actuators for controlling a plurality of control elements (valves, pumps) is connected with the plurality of physical components. In an embodiment of the disclosure, the plurality of sensors and the plurality of actuators are communicatively connected to the system through one or more gateways. In an embodiment of the disclosure, the plurality of sensors and the plurality of actuators are communicatively connected with each other to exchange information. The system is further connected to a web-based and/or mobile based interface. In an exemplified embodiment of the disclosure, the system receives a sensor data from a plurality of sensors in the system. For example, in one embodiment, one or more gateways may receive the sensor data from plurality of sensors. The system in accordance with the exemplified disclosure obtains the sensor data from the gateways.

The plurality of sensors can be operated in the following modes to meet different application needs:

1. Periodic transmission

In this mode, the plurality of sensors periodically transmit data to the gateway. Transmission interval is predefined in the plurality of sensors.

2. Send on change

In this mode, at least one sensor of the plurality of sensors transmits data only if there is a change in the parameter being measured. This will help to reduce power consumption of sensor node.

5 3. Send on trend

In this mode, the time series is parameterized using a family of functions (e.g., piecewise constant, piecewise linear, quadratic etc.) The at least one of the plurality of sensors transmits the function parameters.

4. Request-based

- 10 In this mode, the plurality of sensors is always in receive mode. It transmits data only if there is a request from the gateway.

5. Request with a history of data

- 15 This is similar to request-based mode, but the plurality of sensors is configured to store the time series data locally for a certain time interval. When the gateway requests the data, it transmits all the data and clears the memory.

Figure 2 depicts the block diagram of the system for monitoring and controlling supply 200, in accordance with some embodiments of the present disclosure;

- 20 In some implementations, the system for monitoring and controlling supply in a cyber physical environment includes a plurality of sensors(101), a plurality of actuators (102), a plurality of physical components (201), receiving unit (202), determining unit (203), control unit (204), transmitting unit (206), I/O interfaces (104), processor (205), memory (207) and data (208). As an example, the data is stored in the memory as shown in **Figure 2**.

- 25 In some embodiments, the data is stored in the memory in the form of various data structures. In an embodiment, the data includes sensor data, location data, prestored geographical data, cyber-physical environment data, sequence and time duration of operation data and other data.

- 30 In some embodiments, the data stored in the memory is processed by various units in the system. The receiving unit (202) is configured to receive a plurality of sensor data (209) from the plurality of sensors (101), indicating functioning of the plurality of physical components (201) responsible for providing the supply at a plurality of supply locations distributed over a geographical region. The plurality of location data (210) corresponding to plurality of supply locations depending upon the geographical

region is stored in the memory (207). For example, the location data comprise one or more of latitudinal data, longitudinal data and elevation data location points. In an embodiment of the disclosure, the receiving unit (202) is configured to receive the sensor data (209) from one or more gateways associated with the cyber-physical environment. The receiving unit (202) is further configured to store the received sensor data (209) in the memory (207).

The determining unit (203) is configured to determine a plurality of supply parameters required for adequately supplying the supply to each of the plurality of supply locations. The supply parameters comprise at least one of pressure, flow rate, and quantity of supply. In an exemplified embodiment of the disclosure, the determining unit (203) is further configured to determine demand and supply information for at least one of the plurality of supply locations based on the plurality of sensor data (209). The demand and supply information indicates an amount of supply available from the at least one of the plurality of physical components (201). In an embodiment the demand and supply information are determined by the number of supply locations, however according to another embodiment the demand and supply information is determined from usage data of the user provided to the system. For example, in another embodiment, user defined supply amount is provided to each of the supply location. To ensure the availability of the supply, the determining unit (203) is configured to obtain the sensor data (209) to verify the amount of supply in the supply storage to provide the supply to corresponding supply locations, For example, in a water distribution system, the determining unit determines from the level of water in a reservoir if a sufficient amount of water is available for supplying or not before operating the system.

The control unit (204) is configured to enable the plurality of actuators (102) to control operations of the plurality of control elements (valves, pumps) based on the plurality of supply parameters to provide the supply to the plurality of supply locations. In an exemplified embodiment, the plurality of actuators (102) is retrofitted over an established physical system to update the physical system into a cyber physical system. In another embodiment, the control unit (204) is configured to determine a sequence and time duration for operating one or more valves of plurality of valves to provide the supply to the plurality of supply locations.

For a system with automated valves, equitable supply can be realized by operating the valves in specific combinations for specific time intervals, determined from the disclosed method based one or more of plurality of sensor, actuator and location data. . Systematic operation of the valves can also reduce the power consumed in pumping. The duration for which each valve has to be opened is dependent on the other valves that are opened along with it. The system of the present disclosure decides the valves that have to be opened simultaneously and the time for which they

have to be kept open. Two input choices are available for finding this schedule for the operation of valves. In one, the user can provide a hydraulic model of the system. In the other case, measurements from the real network which may be stored as cyber-physical environment data can be used for identifying the schedule for valves. The technical advantage is achieved by the development of cost-effective and low power, long-range ad-hoc wireless sensor and actuator network, user interface and optimizer for monitoring and control of supply in a cyber-physical environment.

Figure 3 depicts a flowchart **300** of a method of monitoring and controlling supply in a cyber-physical environment, in accordance with an embodiment of the present disclosure.

The order in which the method **300** is described is not intended to be construed as a limitation, and any number of the described method blocks can be combined in any order to implement the method. Additionally, individual blocks may be deleted from the methods without departing from the spirit and scope of the subject matter described herein.

At block **301**, the method may include receiving, a plurality of sensor data, from the plurality of sensors, indicating functioning of the plurality of physical components responsible for providing the supply at a plurality of supply locations distributed over a geographical region. The plurality of location data, corresponding to plurality of supply locations depending upon the geographical region is stored in the memory. The location data comprise one or more of latitudinal data, longitudinal data and elevation data. The plurality of physical components comprises at least one of reservoir, pipeline, over-head tank, sump, pump, power panel and the like.

At block **302**, the method may include determining a plurality of supply parameters based on hydraulic model required for adequately supplying the supply to each of the plurality of supply locations. The supply parameters comprise at least one of pressure, flowrate, and quantity of supply;

At block **303**, the method may include controlling through the plurality of actuators operation of the plurality of control elements (valves, pumps), based on the plurality of supply parameters, to provide the supply to the plurality of supply locations. The controlling further comprises determining a sequence and a time duration for operating one or more of valves of the plurality of valves to provide the supply to the plurality of supply locations.

Figure 4 depicts the block diagram of an embodiment of plurality of sensors.

Considering the example of the water distribution, the plurality of sensors is used to monitor the real time water level in reservoirs like sumps and overhead tanks. However, they also have the provision to interface flow and pressure sensors. The main component of the plurality of sensor or sensor node is a microcontroller (5) with Long-Range (LoRa) transceiver (6). Weatherproof ultrasonic sensor (7) is used for measuring water level in reservoirs. Power supply unit (8) consist of switch mode power supply (SMPS) (9), a Voltage regulator (10) and rechargeable lithium ion battery (11). The plurality of sensors can be powered from 230 V AC supply or Solar panel or from inbuilt lithium ion rechargeable battery or combination of any two. The module is having a charge controller to recharge the lithium-ion battery. IP65 box is used to protect the printed circuit board from bad weather conditions. Each of the plurality of sensors may also have a sensor (12) to measure the temperature and humidity inside the IP65 box (13).

In an exemplified embodiment, a plurality of actuators/ actuator nodes is installed in electrical actuators to operate the valve remotely. The existing valves in most of the water distribution networks are manually operated using T pipes which is labour intensive. To implement complex operating schedules, the existing manual valves should be replaced with control valves. Installing a new valve will interrupt the service and cost of the new valve is high. In an exemplified embodiment in accordance with the present disclosure the existing manual valves are retrofitted with an electrical actuator (14). The actuator is mounted on top of the valve with supporting structures. The actuator is elevated above the valve chamber to prevent the actuator from being submerged into the water due to leakage in valve gland and rainwater. For example, the actuator has a potentiometer (15) for measuring valve position, it is calibrated such that when the valve is fully open the resistance will be 230 ohms and if the valve is fully closed the resistance will be 100 ohms. The resistance varied between 100 to 230 ohms based on the actuator movement. The variable resistance value is converted into a proportional voltage (0 - 3.3V) using a voltage divider (16) circuit.

Microcontroller (17) reads the voltage and then converts that into a percentage of opening and then transmits to the gateway using LoRa (18). Though the actuator is ON/OFF type, voltage feedback enables the system/user to control the actuator to any position between two extremes (fully open or fully close). The power for the actuator node is taken from actuator terminals which are powered from a three-phase power supply. Switch mode power supply (SMPS) (19) is used to power the circuit. Two electromagnetic relays (20) are used to keep the actuator in desired position.

The block diagram of an embodiment of the plurality of actuators is shown in **figure 5**. All the electronic components are enclosed in a IP65 box to protect from rain and

dust. The actuator module also has a sensor (21) to measure the temperature and humidity inside the IP65 box (22).

In an embodiment, a plurality of gateways is required to provide compatibility between different communication technologies used in the system to enable better communication. For example, the communication between the plurality of sensors, plurality of actuators and one or more gateways is governed by LoRa, whereas the communication between one or more gateways and the server/system is governed by 3G/4G, Wi-Fi or similar technology (as shown in Figure 1). In an embodiment, the gateway aggregates the data received from the plurality of sensors and the plurality of actuators using LoRa, processes the data and sends to the system. Commercial LoRaWAN gateways can listen to many LoRa channels simultaneously.

Semtech SX1301 concentrator is commonly used in all gateways and it can process 8 channels simultaneously and are expensive. Water distribution networks generally do not have the need to acquire data from all the plurality of sensors/plurality of actuators and transmit them very frequently. Hence, a single channel LoRa gateway which itself can handle multiple sensors and actuator nodes.

An exemplified embodiment of the single channel LoRa gateway is depicted in **Figure 6**. Raspberry PI 3 (23) is used in the example for building the gateway. Shield is custom built to provide LoRa interface and power supply to the raspberry PI 3 using SPI (serial peripheral interface). RFM95 LoRa (24) transceiver is used for wireless connectivity. The shield also has Real-time clock (RTC) (25) to set the time for Raspberry Pi using I2C (inter-integrated circuit) protocol. The block diagram of the gateway is shown in figure 4. Temperature and humidity sensor (26) is used to monitor the ambient conditions inside the IP 65 Box (27). Raspberry Pi is connected to a centralized server (28) using a local area network (LAN) or 3G/4G.

Pipeline surge protection

Further, in an embodiment of the disclosure, the system may comprise pipeline surge protection. Hydraulic surges are generated in the pipelines due to changes in velocity/pressure caused by valve open/close, pump start/stop, or variation in pipeline size. Transients can be created anywhere in the pipeline and can travel at very high speed through the pipelines. The transients severely affect the pipelines and cause pipe ruptures and damage the equipment due to large pressure surges. Whenever a heavy pump is started or stopped, the downstream valve is throttled to 10 percent open and then the pump is started. Once the pump reaches its maximum speed then the valve is throttled to fully open. This prevents sudden surges generated

into the pipelines. Similarly, whenever a heavy pump is to be stopped, the downstream valve is throttled to 10 percent open and then the pump is stopped.

In an embodiment of the present disclosure, operation is automated and pump operation is remotely controlled by LoRa enabled wireless interface. In the exemplified system with existing manual valve is retrofitted with an electrical actuator for remote monitoring and control of valve position, Variable frequency drive (VFD) is installed in pump control panel and interfaced with at least one sensor of plurality of sensors to start and stop the pump. The at least one sensor of plurality of sensors also measures current, voltage and power consumption of the pump and transmit the data to the receiving unit through gateway. Whenever pump start command is given by the user locally (in pump control panel) or through remote interface (mobile/web interface), the control logic created in the gateway first checks the downstream valve position, if it is fully open, then it issue command to at least one actuator of the plurality of actuators to close the valve to 90 percentage. Once the valve is set to 90 percent close, the gateway issues command to the at least one sensor to start the pump. Then at least one sensor then issues command to VFD to gradually increase the voltage to the pump for smooth start and the status is also communicated to the gateway. If the pump reaches its maximum speed, then the gateway issues command to the actuator node to fully open the valve. Similarly, when stop command is given locally or remotely by the system/user, first the downstream valve is throttled to 10 percent open and then the command is given to VFD to stop. VFD gradually reduces the voltage for smooth stop. VFD is not mandatory for using this method, the same technique can be used for pumps without VFD to avoid surge protection. This method can also be leveraged for unscheduled break down of power. Batteries with suitable capacity will be used for gradually reducing the pump speed as well as open/close the valve.

Pump dry run protection

In an embodiment, ultrasonic level transmitter or hydrostatic pressure sensor or any other sensor capable of measuring water level may be installed in the sump/collection well/reservoir/bore well. The level sensor is interfaced with the sensor node for communicating the level information to the central server. Gateway periodically monitors the water level in collection well/sump/reservoir/bore well. If the level goes below threshold value, system/gateway will initiate the sequence of stopping operations mentioned above to stop the pump. Similarly, if the water reaches certain level (can be set by the user) due to infiltration or by any other means, then the gateway will initiate the sequence of start operation mentioned above to start the pump. This technique may prevent pump dry run and motor failure due to prolong dry run operation. The main advantage of this technique is that the system automatically decides or informs the user when to start the pump. The speed of the

pump can also be controlled based on the water availability (from level sensor) using VFD. This will minimize energy consumption.

Network topology

- 5 Cyber physical systems such as water distribution networks are geographically distributed. Plurality of sensor and plurality of actuators are spread across the network. Gateways are installed in different parts of the network to aggregate the data from the plurality of sensors and plurality of actuators. The location and number of gateways required to monitor and control the network depends on density of
- 10 plurality of sensor/actuators and the actual line of sight conditions that exists between the sensor nodes and gateway. Commercial multi-channel LoRaWAN gateways available is meant for handling star topology-based network. Hence all the sensor nodes are expected to only send the data directly to the gateway. But this topology may not be feasible to implement in field locations where direct line of
- 15 sight conditions does not exist. The single channel gateway as disclosed in **figure 6** may receive data from any of the plurality of sensors/ plurality of actuators either directly or indirectly through other intermediate plurality or sensors or plurality of actuators, to circumvent the above line of sight issues. Hence, using this approach, the plurality of sensors/actuators and gateways may be interconnected using any of
- 20 the network topologies like star/mesh/tree based on the geographical location and density of sensor nodes. This may optimize the number of gateway required to monitor and control the given water distribution network.

According to an embodiment of the disclosure, an end to end procedure for devising a network for a selected set from the plurality of sensors and plurality of actuators

25 when the geographical co-ordinates of the selected set is given. Once the location data is obtained, it is processed into a data type, which can store the corresponding longitude, latitude and the elevation data, e.g., comma separated variable (csv) file with columns corresponding to longitude, latitude and elevation. Further, the elevation data is processed and stored in the memory. In a Digital Elevation Model

30 (DEM), a 3D computer generated surface using the elevation data of the terrain is used to obtain location data. **Figure 7** depicts an example of location data of a few point in a geographical region

For establishing a wireless network of plurality of sensors and actuators that operates on line of sight communication in an exemplified embodiment of the disclosure, the

35 requirement to place a repeater between two of the plurality of sensors and plurality of actuators arises when there is an obstruction in the line of sight path between any of the plurality of sensors and plurality of actuators. A wireless network may also have gateways that may communicate using for example GPRS and push the data

with the receiving unit. An example of a typical wireless network is shown in **Figure 8**, in accordance with an embodiment of the present disclosure.

5 Provided at least two of the plurality of sensors and the plurality of actuators that are not in line of sight (LoS) of each other, and a plurality of location data of the geographical region stored in the system, the method of identifying number and placement of repeater in between any two of the plurality of sensors and actuators comprise determining an elevation data along the path between the at least two of the plurality of sensors and the plurality of actuators based on the plurality of location data. The method further comprises determining a plurality of peak elevation points from the elevation data. Further, the method comprises identifying at least one peak elevation point from the plurality of peak elevation points to setup repeaters to establish communication network between the two or more of plurality.

15 For finding the repeater locations between a selected two of the plurality of sensors and plurality of actuators not in line of sight of each other, the elevation profile between the identified is generated. The elevation of the points lying in the straight line connecting the selected two of the plurality of sensors and actuators are required, which are stored in the memory as the location data. Distance between the selected two and the intermediate points can be calculated by the haversine distance formula. 20 Elevation profile is obtained by plotting elevation versus distance. An elevation profile generated between two of the plurality of sensors is shown in **Figure 9**

For finding the repeater location, an iterative procedure may be followed:-

The selected two of the plurality of sensors and plurality of actuators that are out of line of sight of each other for example comprise sensor Node 1 and sensor Node 2.

25 **Step 1** - Sensor Node 1 is set as source and Sensor Node 2 is set as target. The possibility for line of sight communication is checked between source and target. If the communication is possible, then no repeaters are required and the procedure ends. Else proceed to step 2

30 **Step 2** - Traverse from target to source along the line connecting the target and source. Check for the line of sight connectivity as you traverse. When line of sight communication is established between the source and the traversed point, place the repeater at the point and set that point as the new source.

Step 3 - Now with the new source and the target, repeat step 2. Continue until source is equal to the target.

35 According to an embodiment of the present disclosure, an example of a repeater locator is shown in **Figure 10**.

Clustering the plurality of sensor/plurality of actuators (nodes) and constructing the optimal network-

- Certain wireless technologies (e.g., LoRA) required line of sight for communication (los). A clustering algorithm is used to cluster the sensor nodes with their maximum inter-cluster distance less than the specified threshold. Now, within each cluster, all possible combinations of two sensor nodes are generated. The number of repeaters required between the selected two sensor nodes for line of sight communication and location of the repeaters are identified.

Placing gateways-

- Gateway for the network is located in such a way that the communication overhead is minimized. First, a threshold is set by the system for the maximum number of hops required to reach from a sensor node to a gateway. Then the plurality of sensors and plurality of actuators (nodes) are sorted in decreasing order of its degree. Now the gateways are found through an iterative method as follows-

- Step 1-**Set the first sensor node in the sorted list as a gateway. Determine the minimum number of hops required to reach the gateway for each sensor node.

Step 2-If the minimum number of hops for all the sensor nodes are less than the threshold, then stop the process. Else, the next sensor node in the sorted list is also set as a gateway.

- Step 3 -** determine the minimum number of hops required to reach any gateway for each sensor node. If the minimum number of hops for all the sensor nodes are less than the threshold, then stop the algorithm. Else, continue Step 2 until the minimum number of hops required to reach any gateway for each sensor node is less than the threshold.

- Now a complete graph with the given sensor nodes is generated, with edges between the sensor nodes having a weight proportional to the number of repeaters. The edge weight is set as follows

- A graph with given sensor nodes with corresponding edge weight value in accordance with an embodiment of the present disclosure is depicted in **Figure 11(a)**. A minimum weighted spanning tree is constructed for the optimal network. The tree corresponding to **Figure 11(a)** is shown in **Figure 11(b)**.

- While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting.

The claims:

1. A system for providing monitoring and control of a supply in a cyber-physical environment, wherein the system comprises:
 - 5 a plurality of sensors for sensing at corresponding plurality of physical components present in the cyber physical environment, and a plurality of actuators for controlling a plurality of control elements connected with the plurality of physical components, wherein the control elements comprises at least one of valves and pumps, and wherein the system, coupled
10 with a memory, further comprises:
 - a receiving unit to receive a plurality of sensor data, from the plurality of sensors, indicating functioning of the plurality of physical components responsible for providing the supply at a plurality of supply locations distributed over a geographical region, wherein a plurality of location data,
15 corresponding to plurality of supply locations depending upon the geographical region is stored in the memory;
 - a determining unit to determine a plurality of supply parameters based on hydraulic model required for adequately supplying the supply to each of the plurality of supply locations, wherein the supply parameters comprises at
20 least one of pressure, flowrate, and quantity of supply; and
 a control unit to enable the plurality of actuators to control operations of the plurality of control elements, based on the plurality of supply parameters, to provide the supply to the plurality of supply locations.
2. The system as claimed in claim 1, wherein the system is further configured to
25 determine demand and supply information for at least one of the plurality of supply locations based on the plurality of sensor data, wherein the demand and supply information indicates an amount of supply required at the at least one supply location and an amount of supply available from the at least one of the plurality of physical component.

3. The system as claimed in claim 1, wherein the plurality of physical components comprises at least one of reservoir, pipeline, over-head tank, sump, and power panel.
4. The system as claimed in claim 1, wherein the location data comprise at least one of latitudinal data, longitudinal data and elevation data.
5. The system as claimed in claim 1, wherein the control unit is configured to determine a sequence and a time duration for operating one or more valves, of the plurality of valves, to provide the supply to the plurality of supply locations.
- 10 6. A method of monitoring and controlling supply in a cyber-physical environment, the method comprising,
 providing a plurality of sensors for sensing at corresponding plurality of physical components present in the cyber physical environment, and
 a plurality of actuators for controlling a plurality of control elements
15 connected with the plurality of physical components, wherein the control elements comprises at least one of valves and pumps, and wherein the method further comprising:
 receiving, by a receiving unit associated with a system, a plurality of sensor data, from the plurality of sensors, indicating functioning of the
20 plurality of physical components responsible for providing the supply at a plurality of supply locations distributed over a geographical region, wherein a plurality of location data, corresponding to plurality of supply locations depending upon the geographical region is stored in the memory;
 determining, by a determining unit associated with the system, a
25 plurality of supply parameters based on hydraulic model required for adequately supplying the supply to each of the plurality of supply locations, wherein the supply parameters comprises at least one of pressure, flowrate, and quantity of supply ; and
 controlling, by a control unit associated with the system, through the
30 plurality of actuators operation of the plurality of control elements, based on the plurality of supply parameters, to provide the supply to the plurality of supply locations.

- 5 7. The method as claimed in claim 6, wherein the method further comprises determining demand and supply information for at least one of the plurality of supply locations based on the plurality of sensor data, wherein the demand and supply information indicates an amount of supply required at the at least one supply location and an amount of supply available from the at least one of the plurality of physical component.
8. The method as claimed in claim 6, wherein the plurality of physical components comprises at least one of reservoir, pipeline, over-head tank, sump, and power panel.
- 10 9. The method as claimed in claim 6, wherein the location data comprise one or more of latitudinal data, longitudinal data and elevation data.
10. The method as claimed in claim 6, wherein the controlling further comprises determining a sequence and a time duration for operating one or more of valves of the plurality of valves to provide the supply to the plurality of supply locations.
- 15 11. The method as claimed in claim 6, wherein the method further comprising,
provided at least two of the plurality of sensors and the plurality of actuators that are not in line of sight (LoS) of each other; and
a plurality of location data of the geographical region stored in the
20 system;
determining, by the system, an elevation data along the path between the at least two of the plurality of sensors and the plurality of actuators based on the plurality of location data;
determining, by the system, a plurality of peak elevation points from
25 the elevation data; and
identifying, by the system, at least one peak elevation point from the plurality of peak elevation points to setup repeaters to establish communication network between the two or more of plurality.

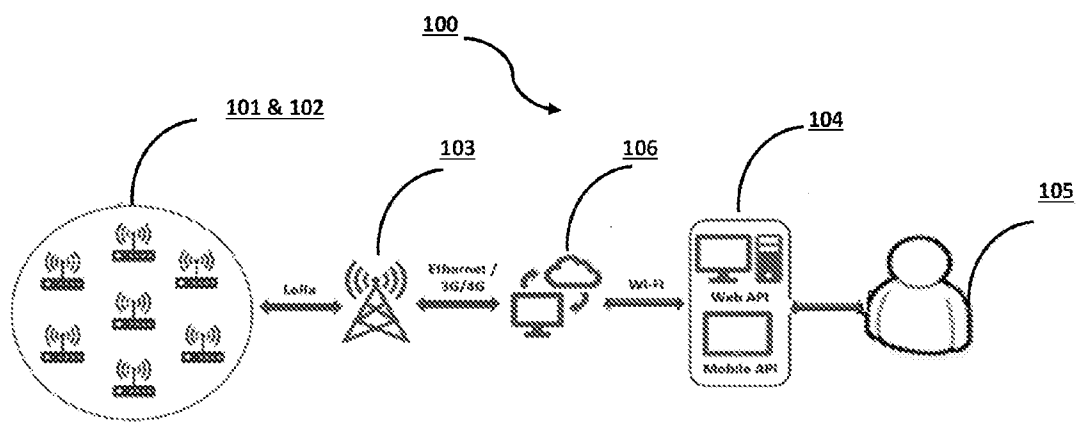


Figure 1

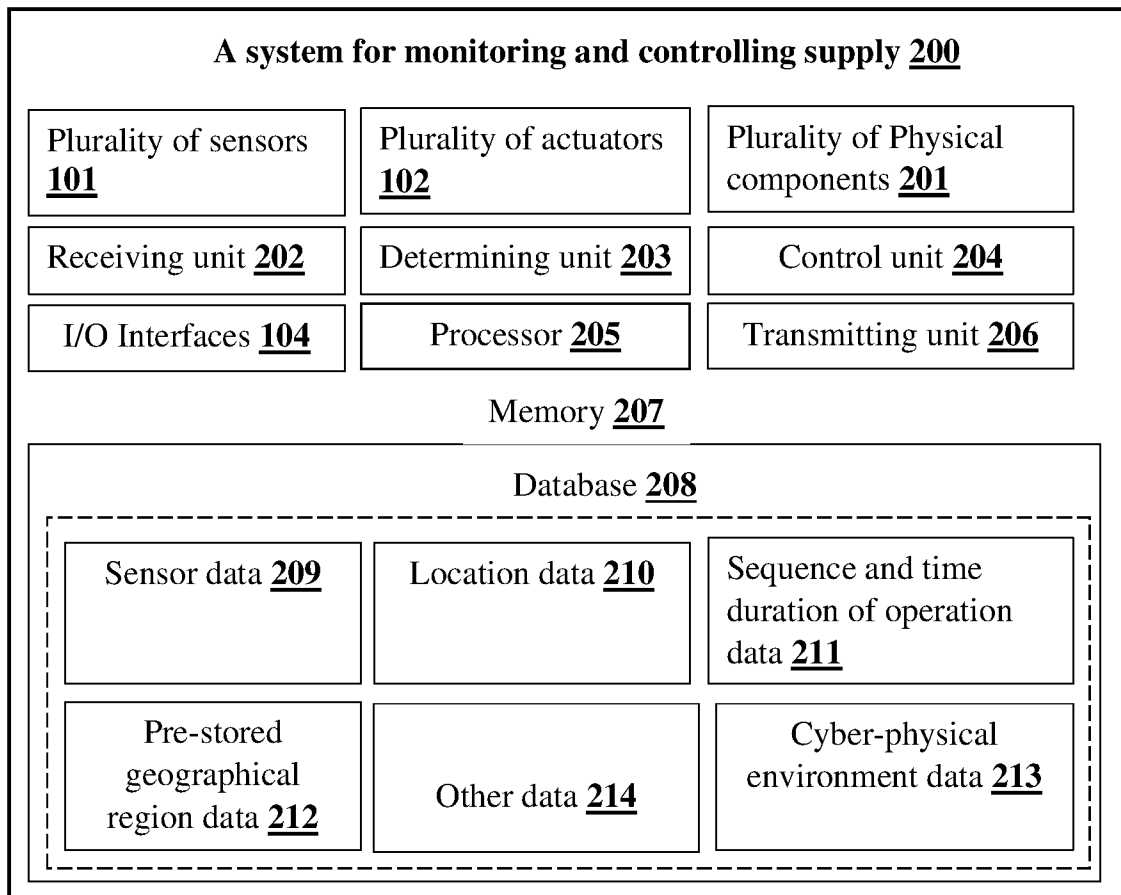
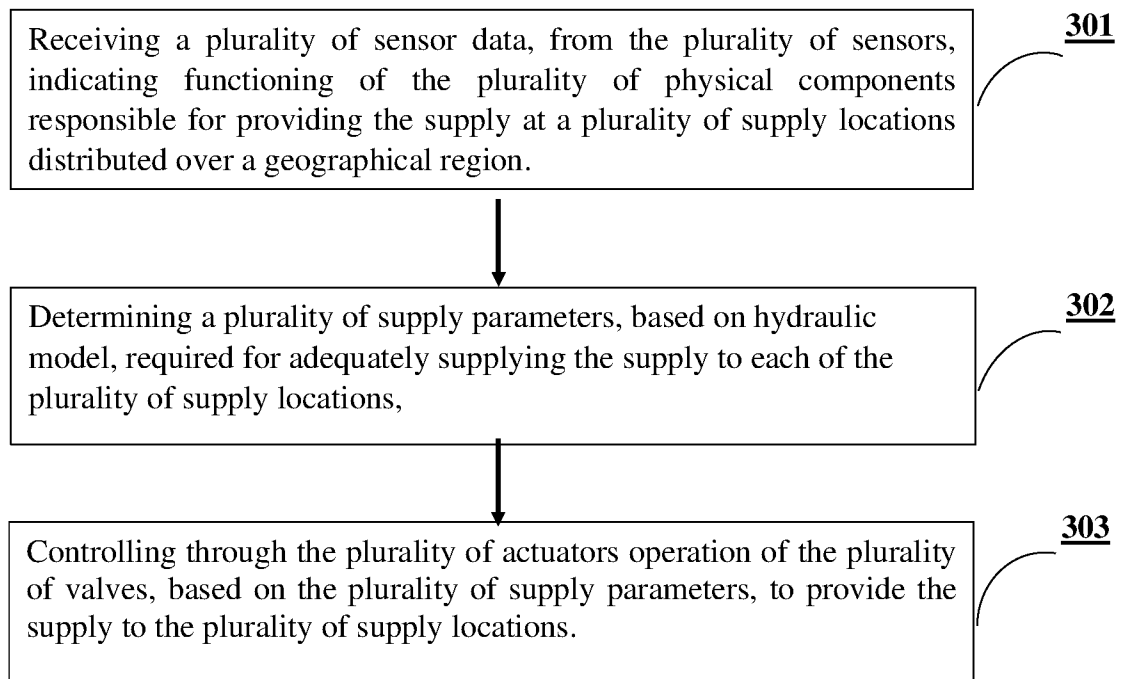


Figure 2

**Figure 3**

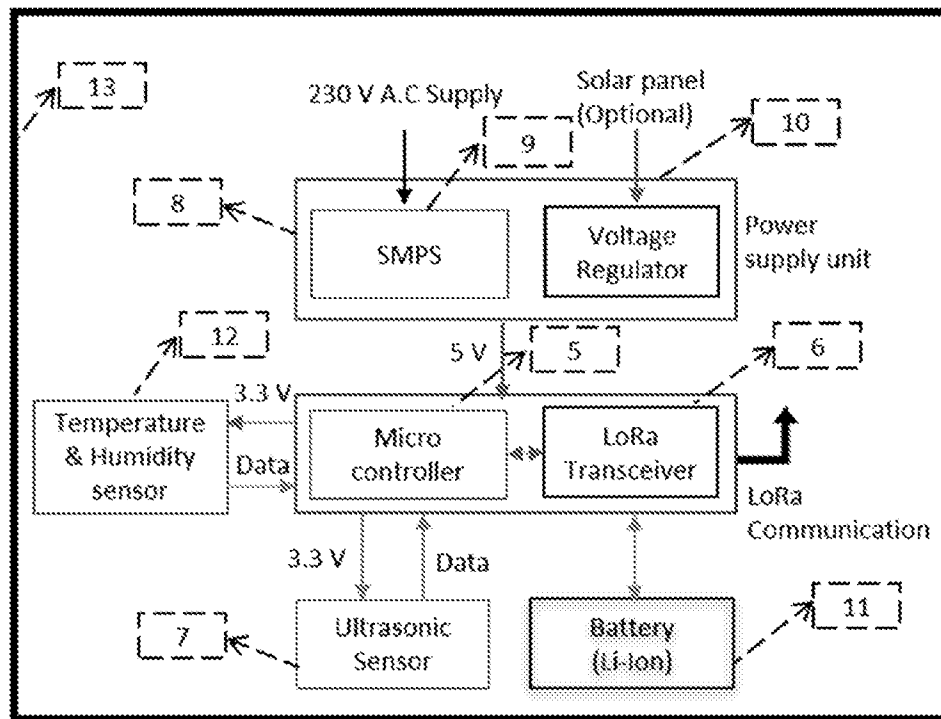


Figure 4

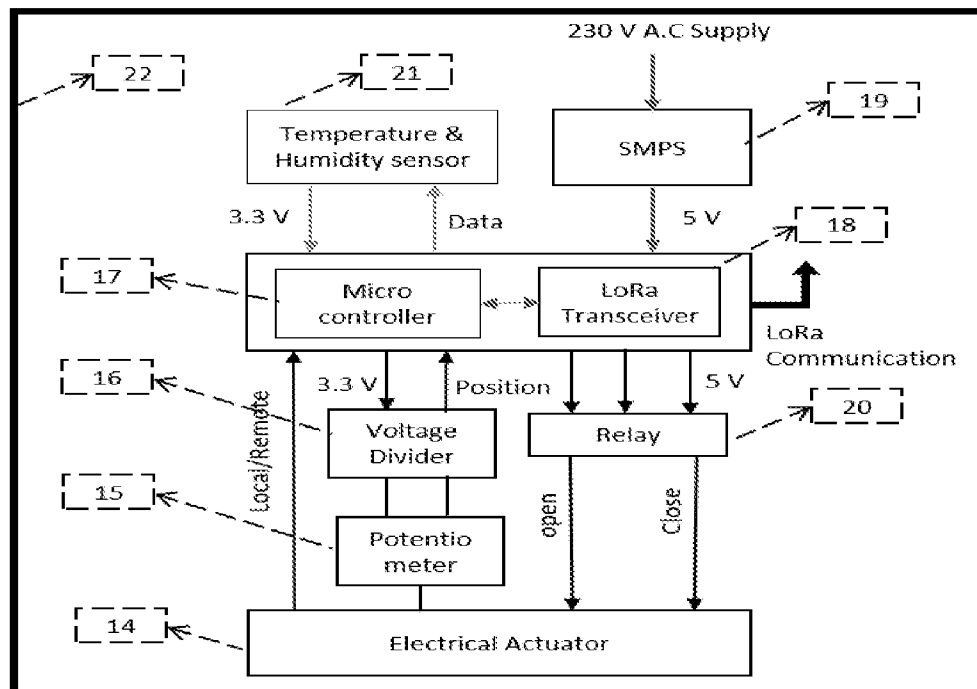


Figure 5

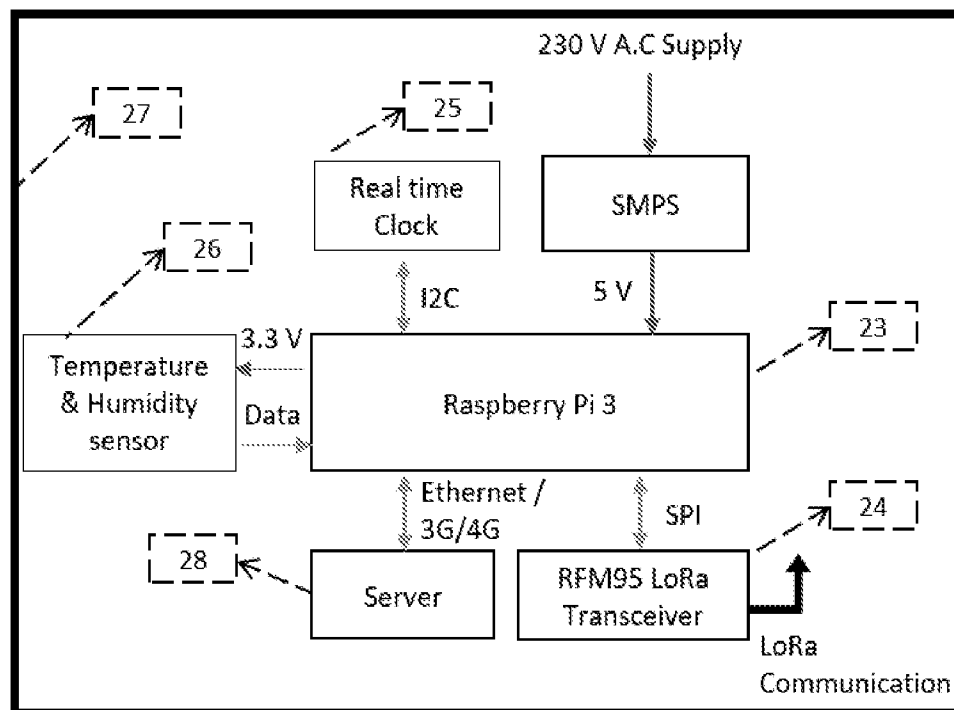


Figure 6

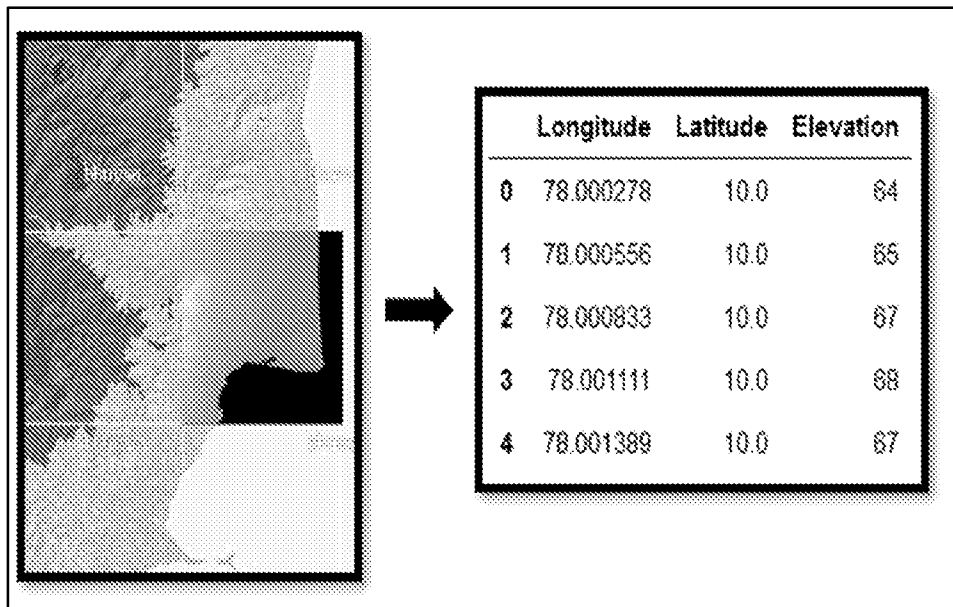


Figure 7

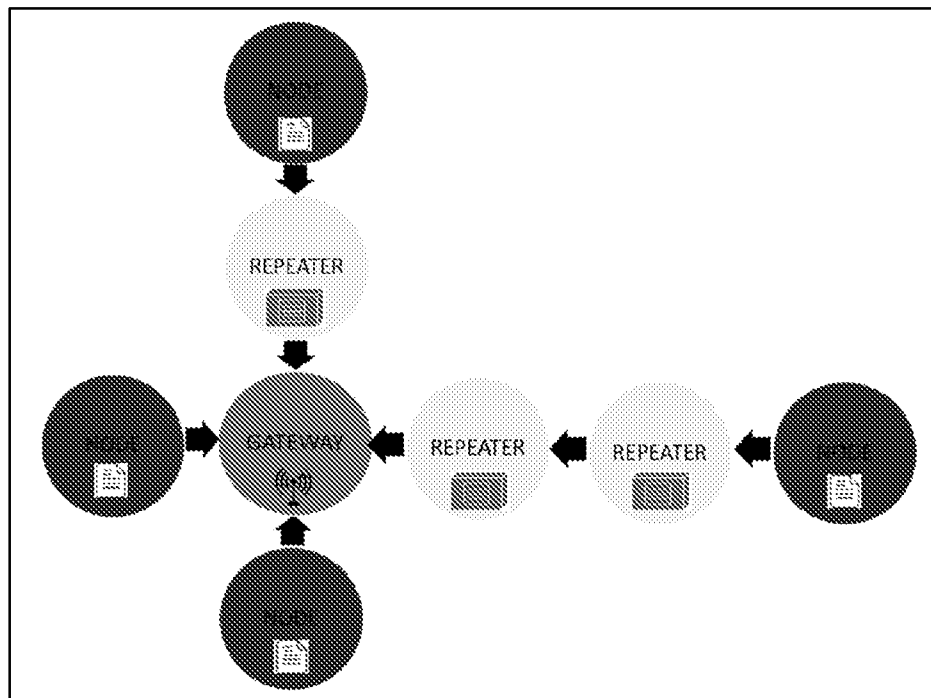


Figure 8

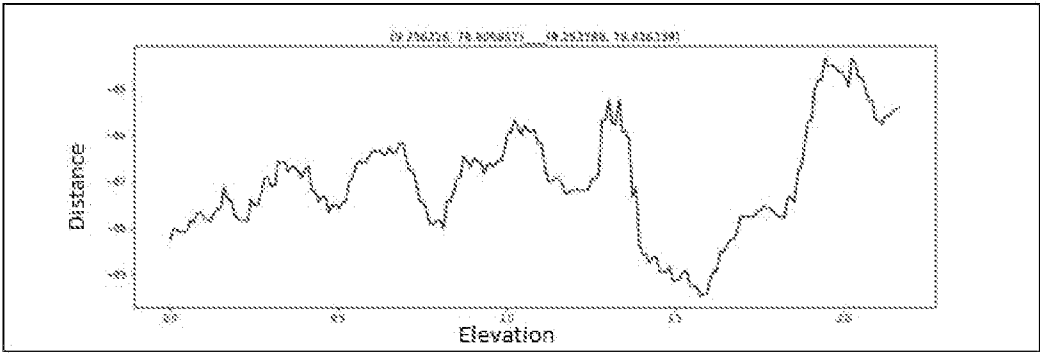


Figure 9

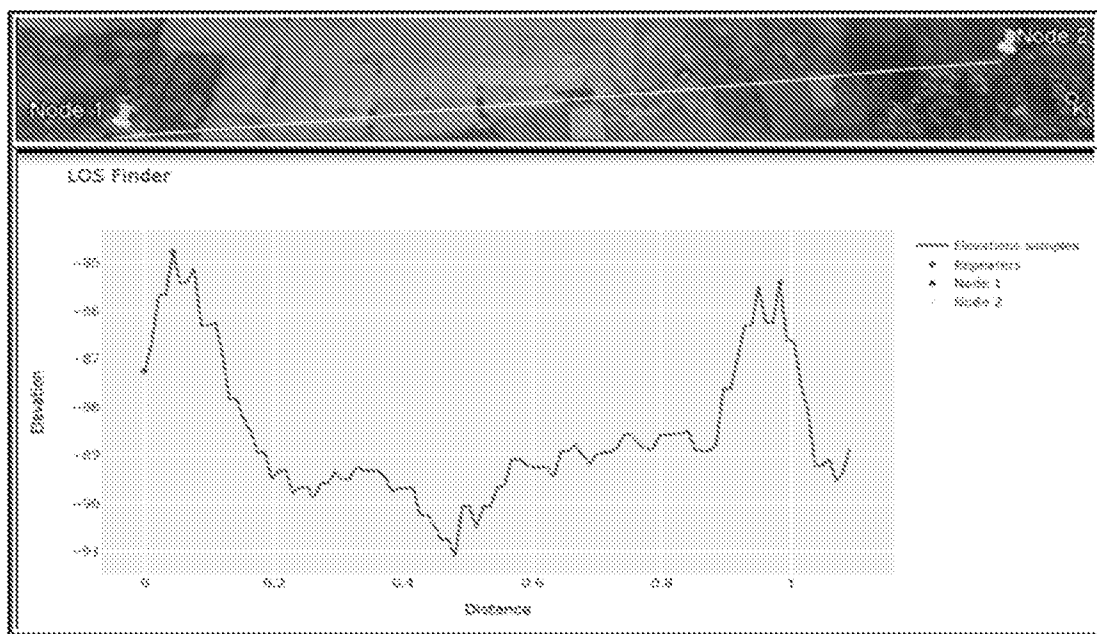
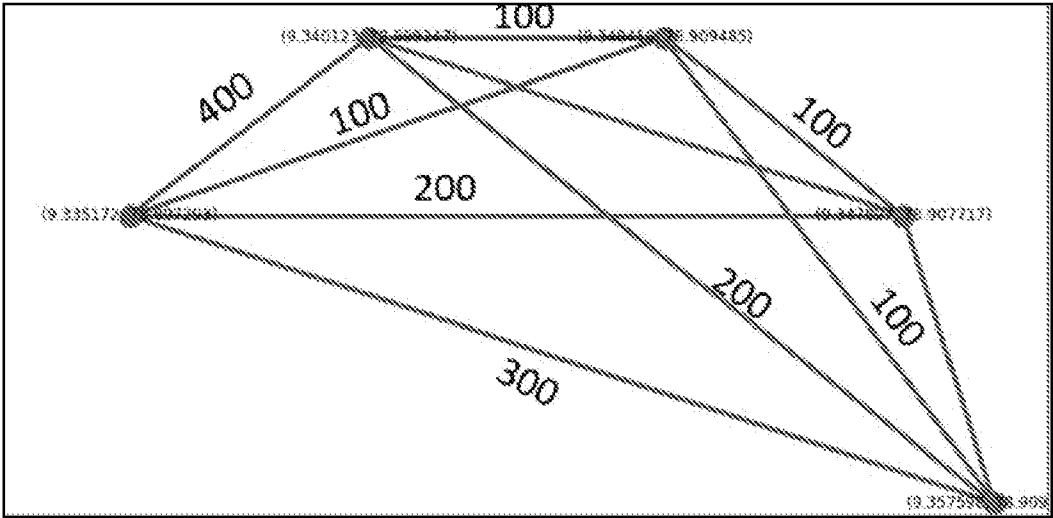
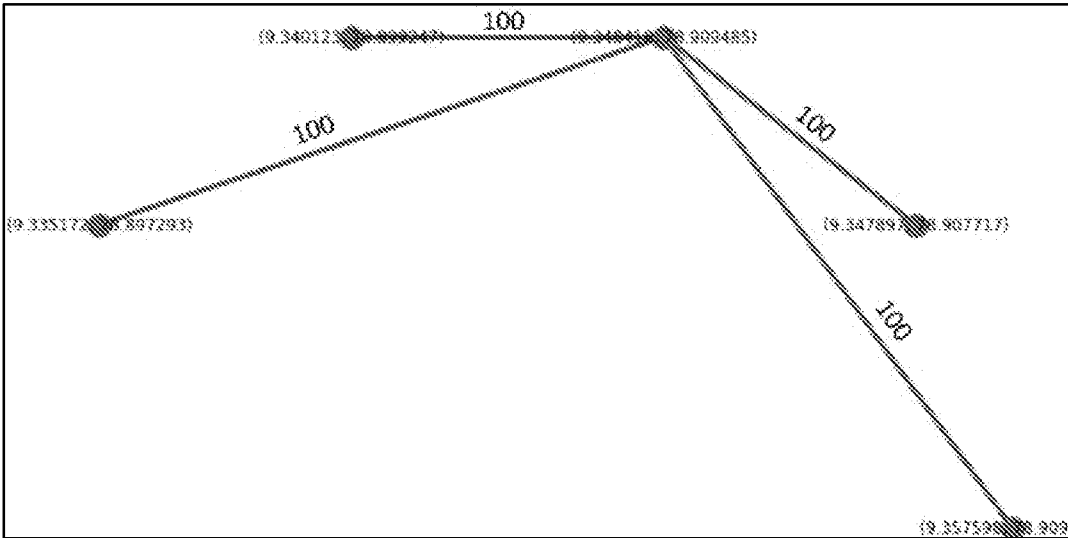


Figure 10



(a)



(b)

Figure 11

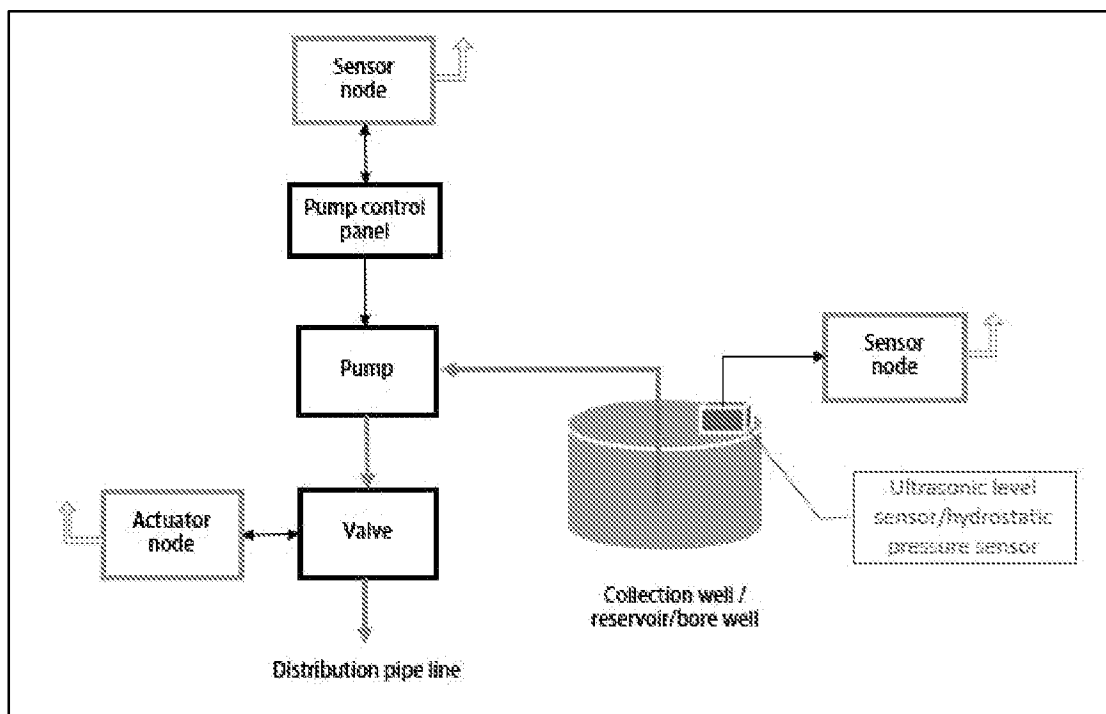


Figure 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2020/050345

A. CLASSIFICATION OF SUBJECT MATTER
G05B19/042, G05B19/418 Version=2020.01

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases- TotalPatent One, IPO Internal Database

Keywords- Control, Cyber-physical, Data, Elevation, Supply

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20180039290 A1 (SENSUS USA, INC.) 8 FEBRUARY 2018 (08.02.2018) Abstract, Description(Paragraphs 6-51), Claims 1-22, Fig. 1-4	1-11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24-07-2020

Date of mailing of the international search report

24-07-2020

Name and mailing address of the ISA/

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Authorized officer

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IN2020/050345

Citation	Pub.Date	Family	Pub.Date
US 20180039290 A1	08-02-2018	WO 2018026651 A1	08-02-2018
		CA 3031517 A1	08-02-2018
		EP 3475893 A1	01-05-2019
		CN 109791637 A	21-05-2019
		MX 2019001488 A	01-07-2019