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(54) SYSTEM AND METHOD FOR PROVIDING SECURE AND REDUNDANT COMMUNICATIONS AND PROCESSING FOR A COLLECTION OF MULTI-STATE INTERNET OF THINGS (IOT) DEVICES

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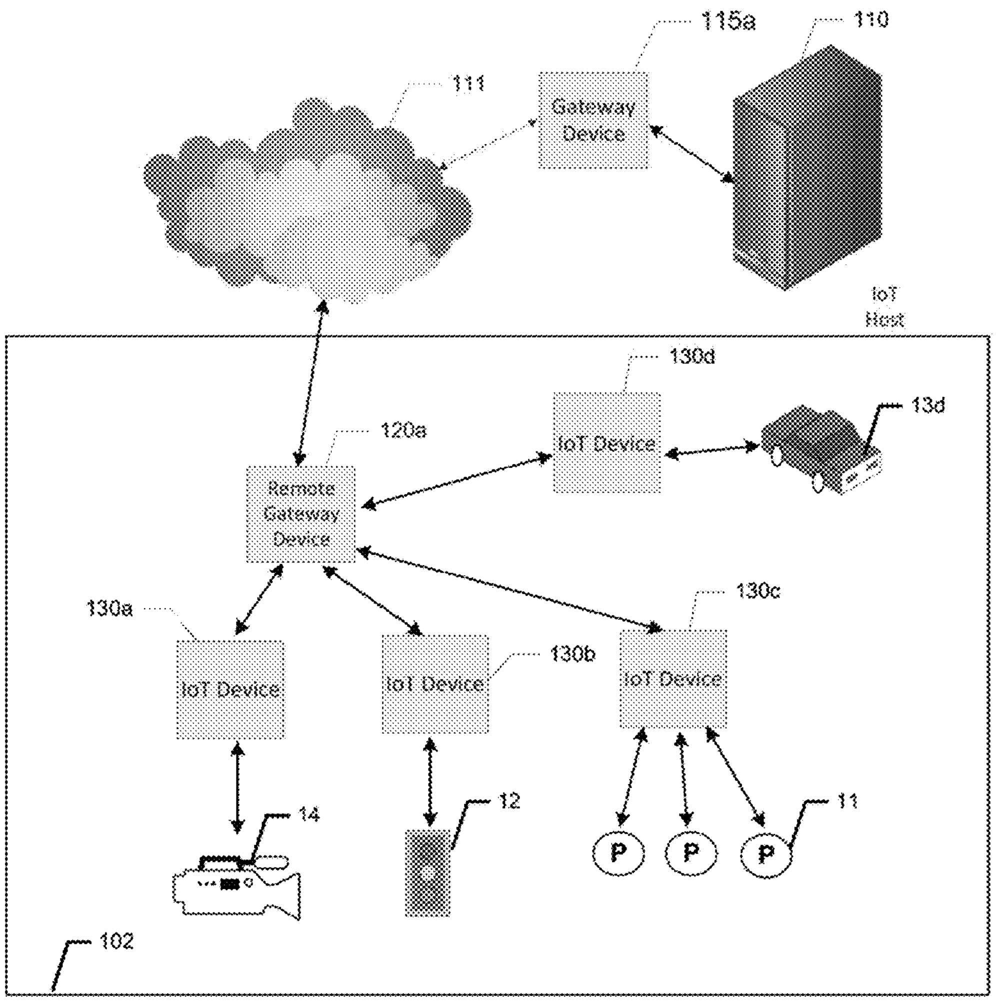
(57) **ABSTRACT**

This application relates in general to a method, apparatus, and article of manufacture for providing secure and redundant communications and processing for a collection of Internet of Things having multi-state and programmable IoT devices. These multi-state edge devices typically operate in a default state with a default network configuration. When a scheduled or external event is detected by a IoT host server, this server reconfigures the operating state of the multi-state edge devices and supporting network components to support the needs corresponding to the detected event.



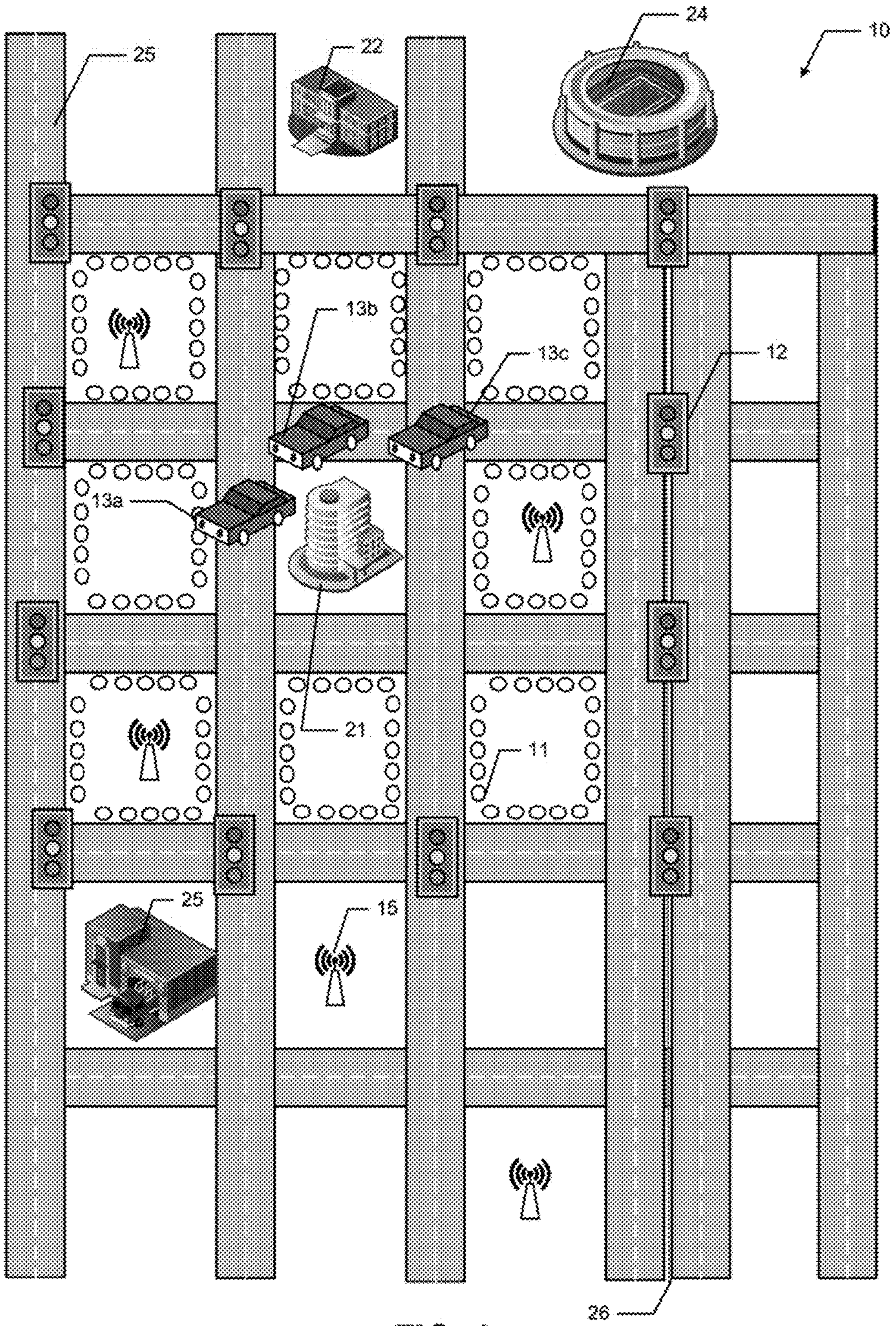


FIG. 1a

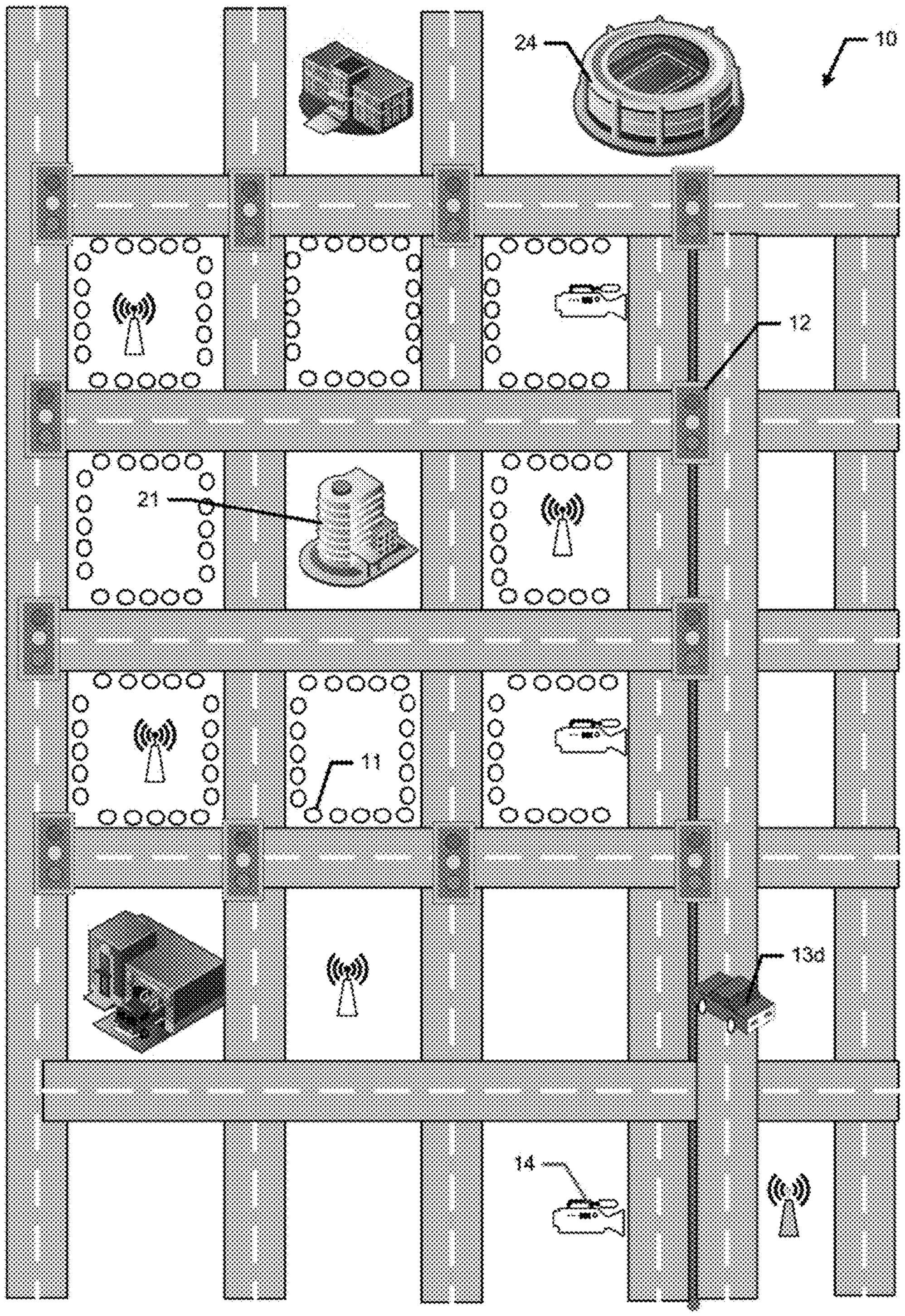


FIG. 1b

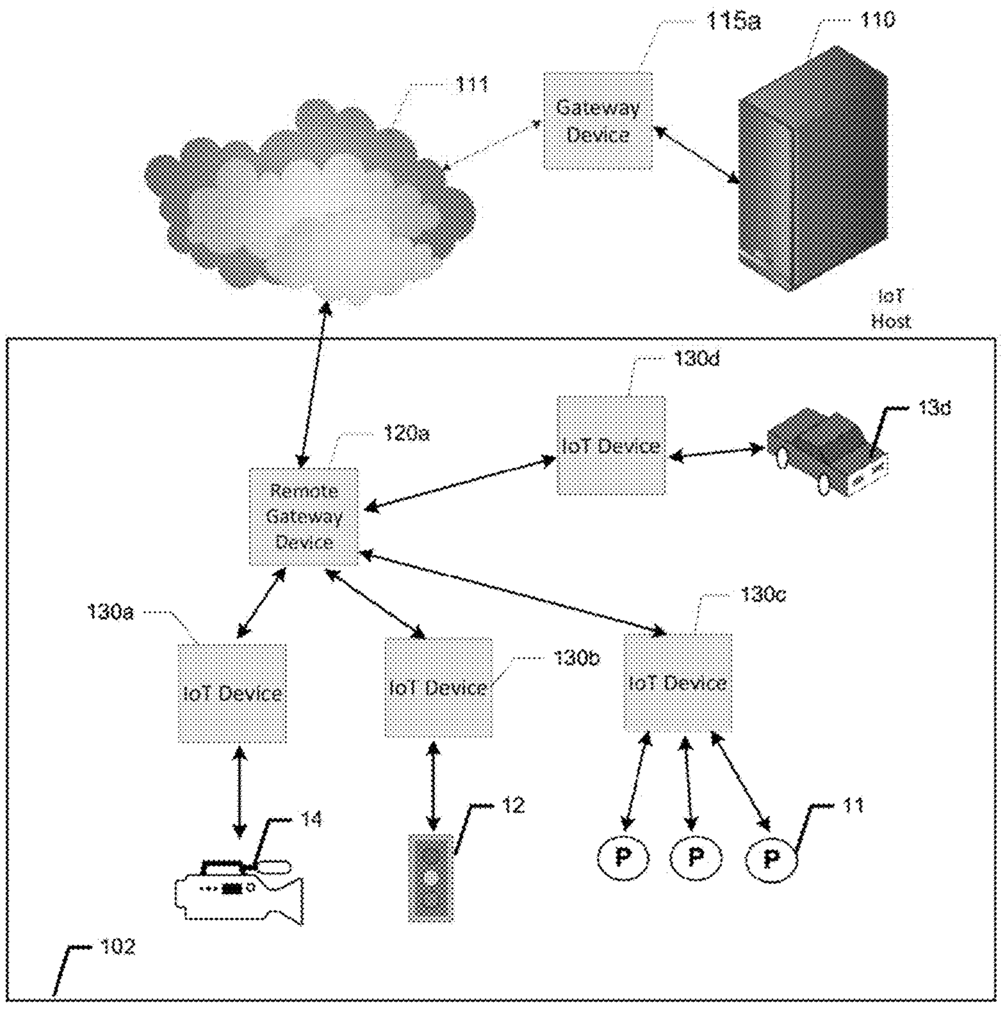

115a
110
111
Gateway Device
IoT Host
130d
13d
120a
IoT Device
Remote Gateway Device
130a
130b
130c
IoT Device
IoT Device
IoT Device
14
12
11
P
P
P
102

FIG. 1c

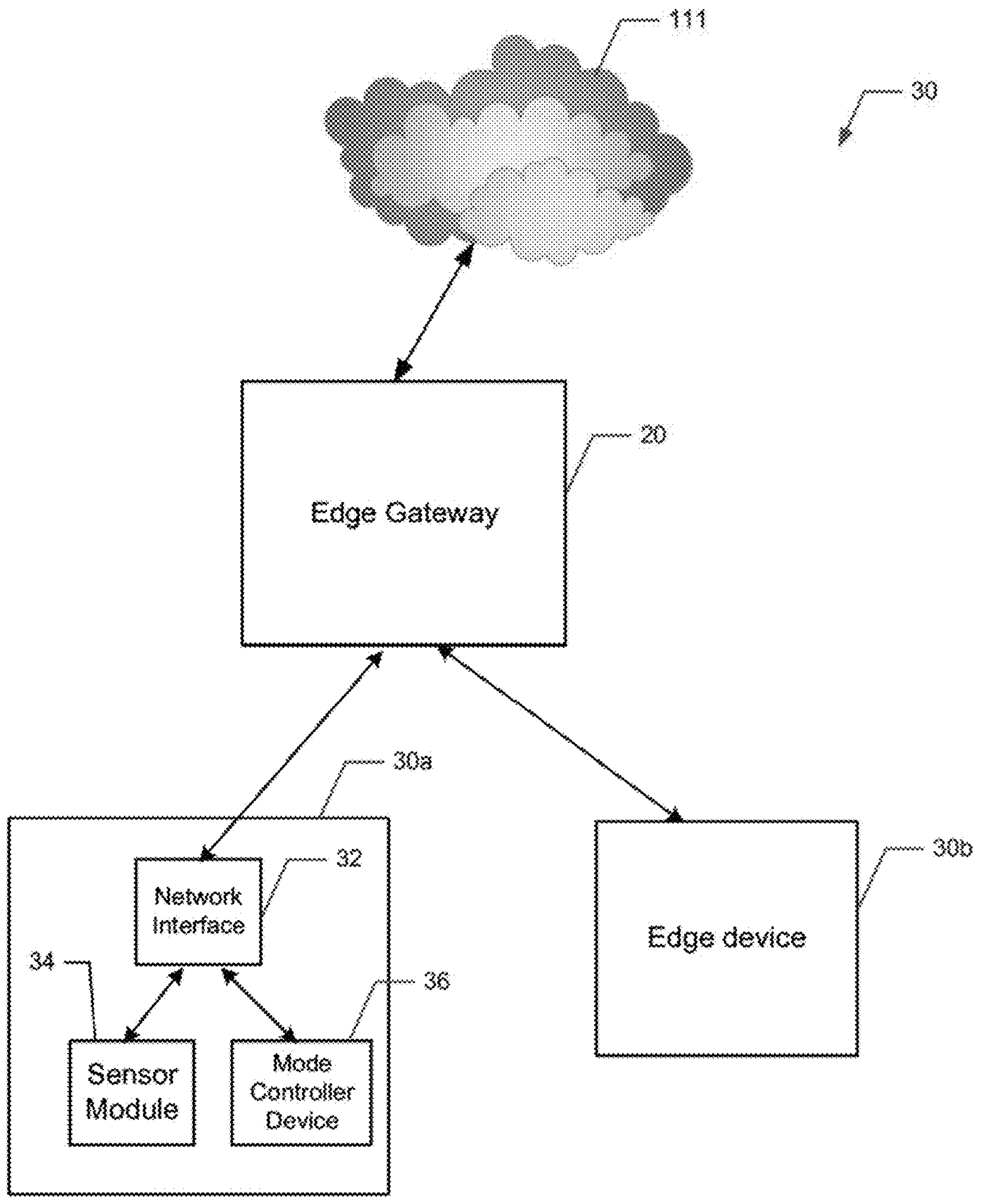

111
30
Edge Gateway
20
30a
Network Interface
32
34
36
Sensor Module
Mode Controller Device
Edge device
30b

FIG. 1d

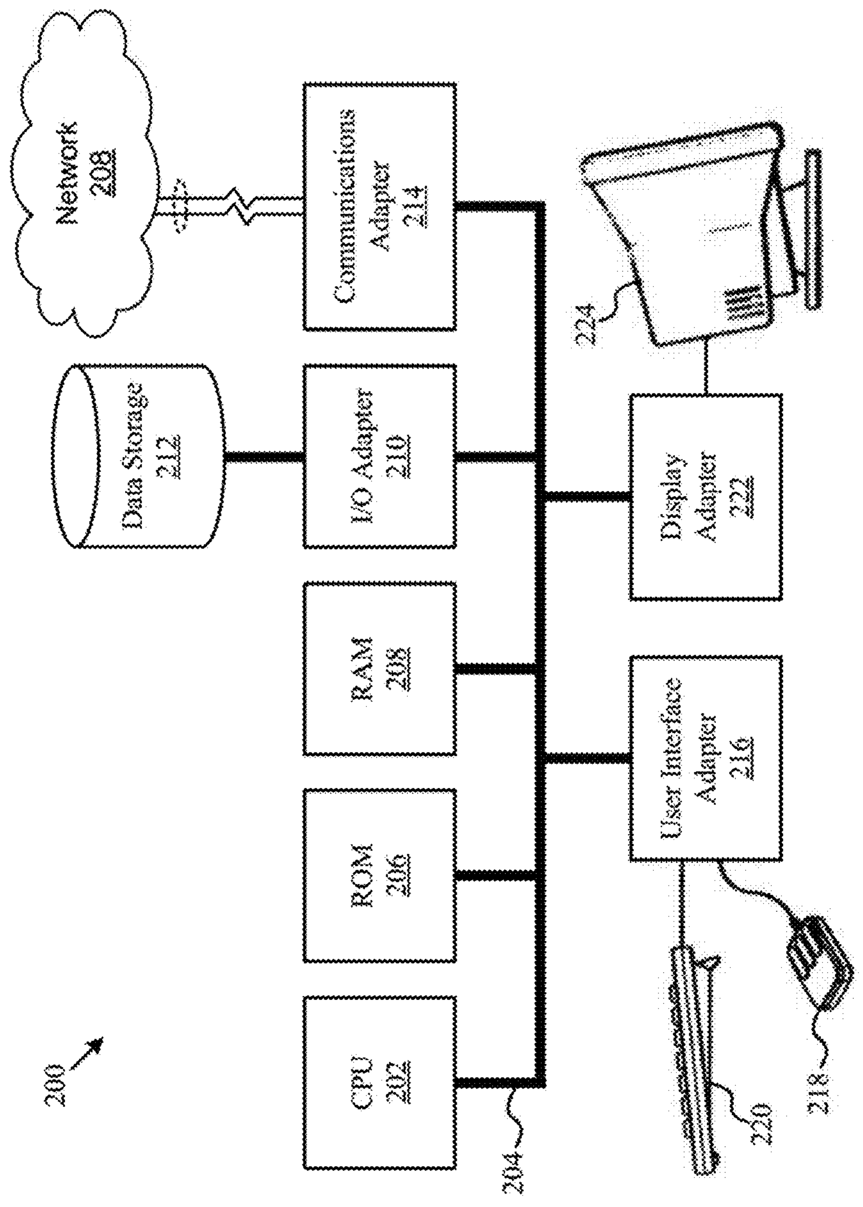

200
CPU 202
ROM 206
RAM 208
I/O Adapter 210
Data Storage 212
Communications Adapter 214
Network 208
User Interface Adapter 216
Display Adapter 222
204
218
220
224

FIG. 2

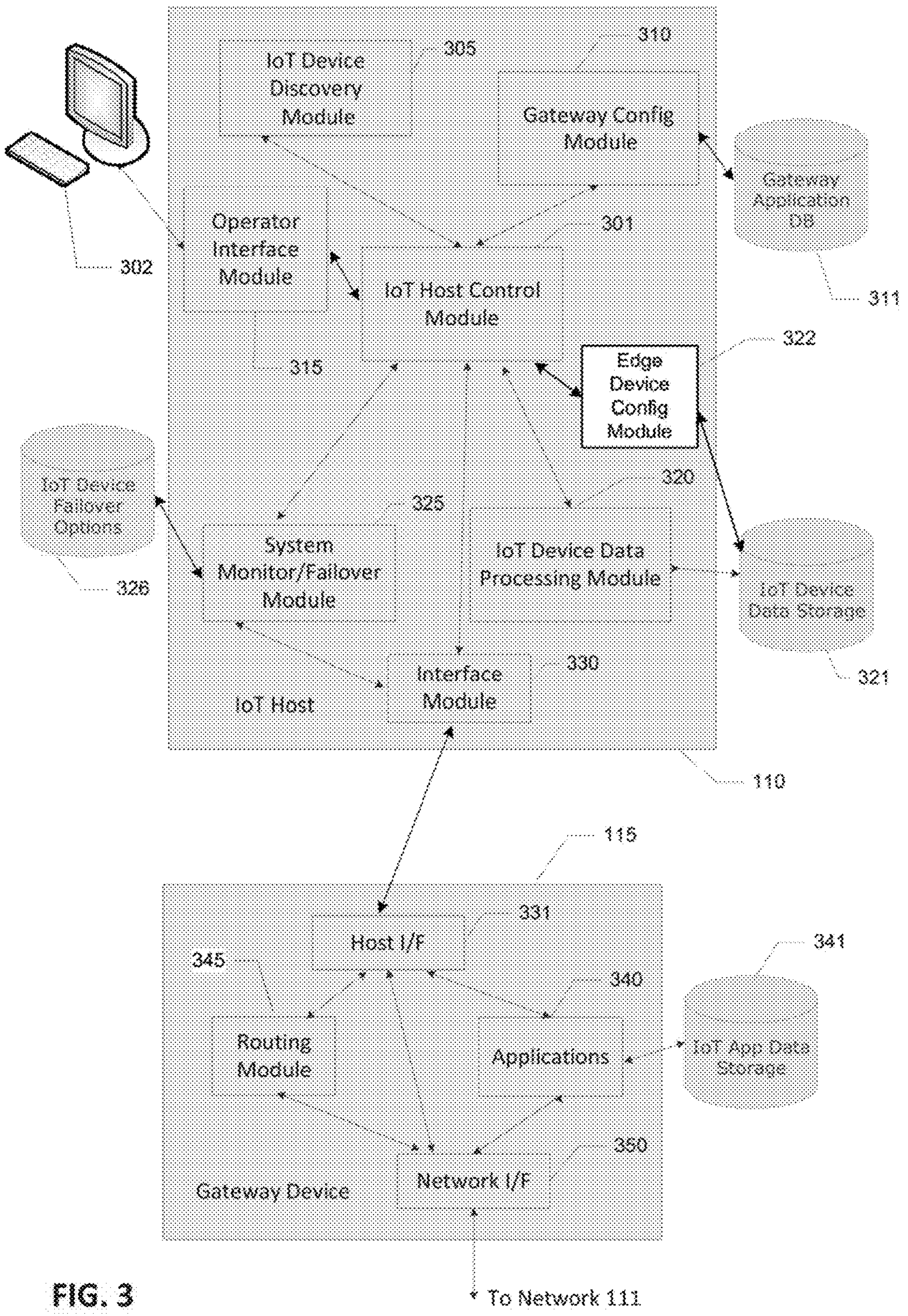

IoT Device Discovery Module
305
310
Gateway Config Module
Gateway Application DB
301
302
Operator Interface Module
IoT Host Control Module
311
322
315
Edge Device Config Module
320
IoT Device Failover Options
325
System Monitor/Failover Module
IoT Device Data Processing Module
IoT Device Data Storage
326
330
Interface Module
IoT Host
321
110
115
331
Host I/F
341
345
340
Routing Module
Applications
IoT App Data Storage
350
Gateway Device
Network I/F
To Network 111

FIG. 3

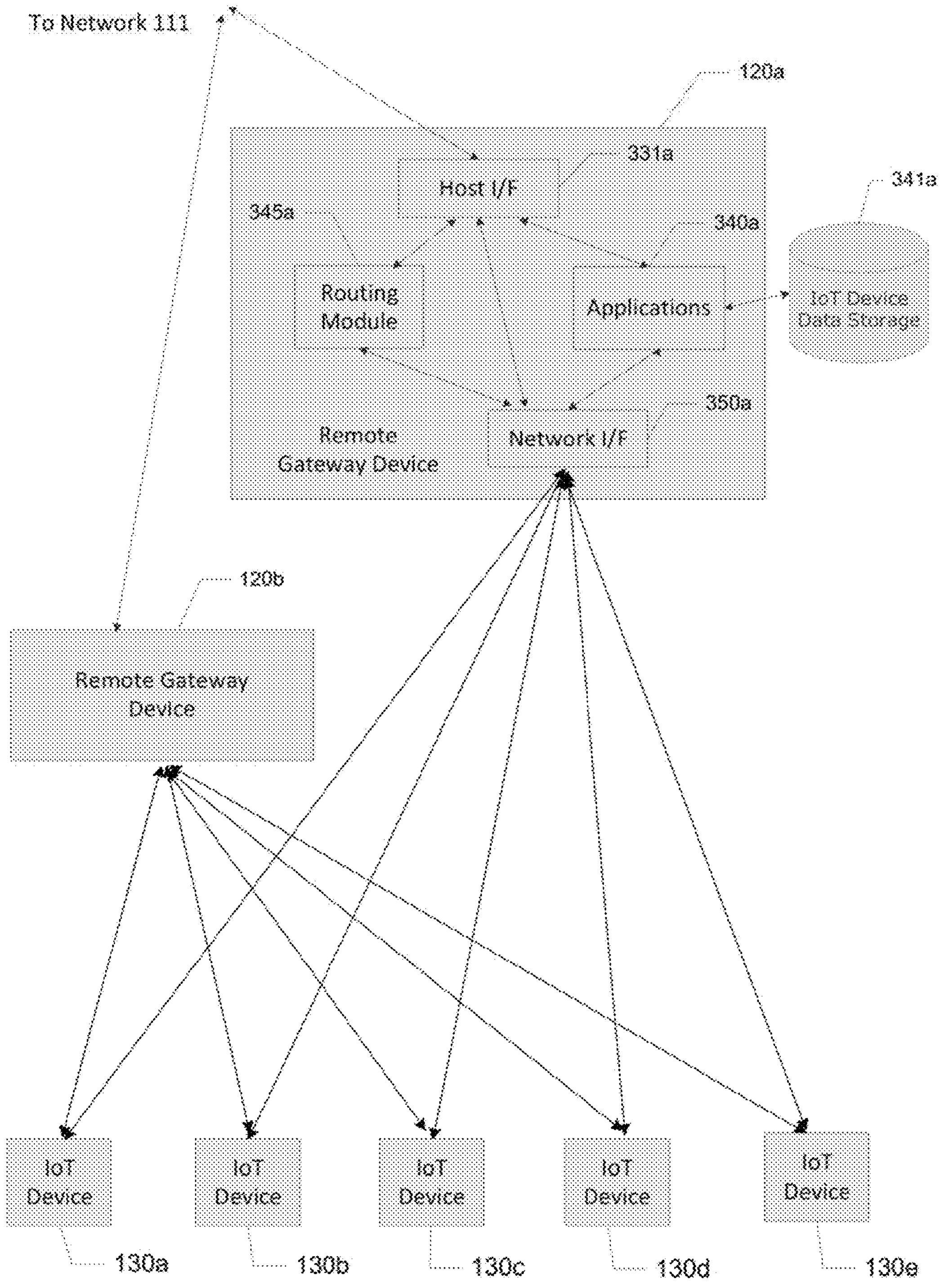

To Network 111
120a
Host I/F
331a
341a
345a
340a
Routing Module
Applications
IoT Device Data Storage
350a
Remote Gateway Device
Network I/F
120b
Remote Gateway Device
IoT Device
IoT Device
IoT Device
IoT Device
IoT Device
130a
130b
130c
130d
130e

FIG. 4

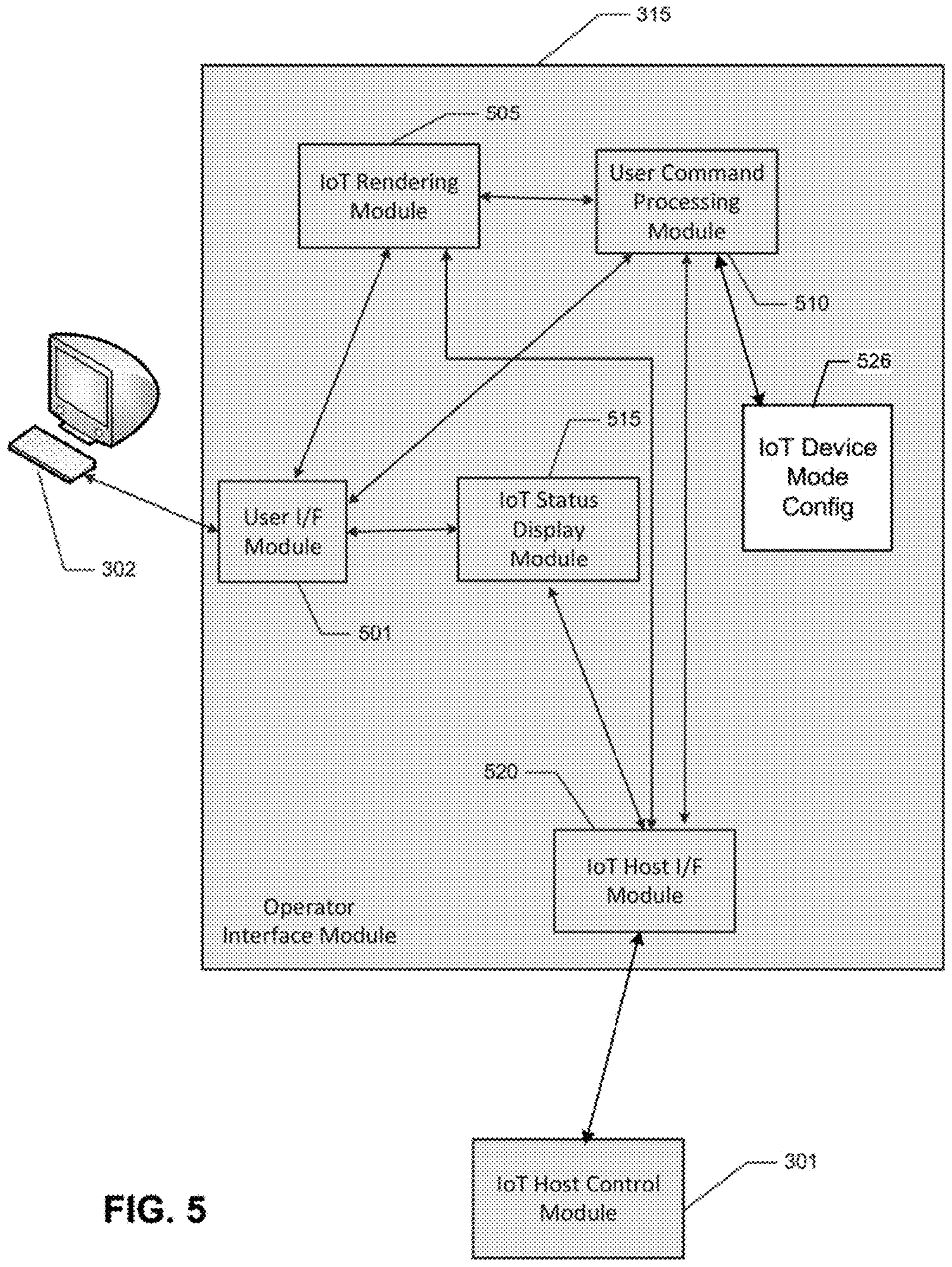

315
505
IoT Rendering Module
User Command Processing Module
510
526
IoT Device Mode Config
515
User I/F Module
IoT Status Display Module
302
501
520
IoT Host I/F Module
Operator Interface Module
IoT Host Control Module
301

FIG. 5

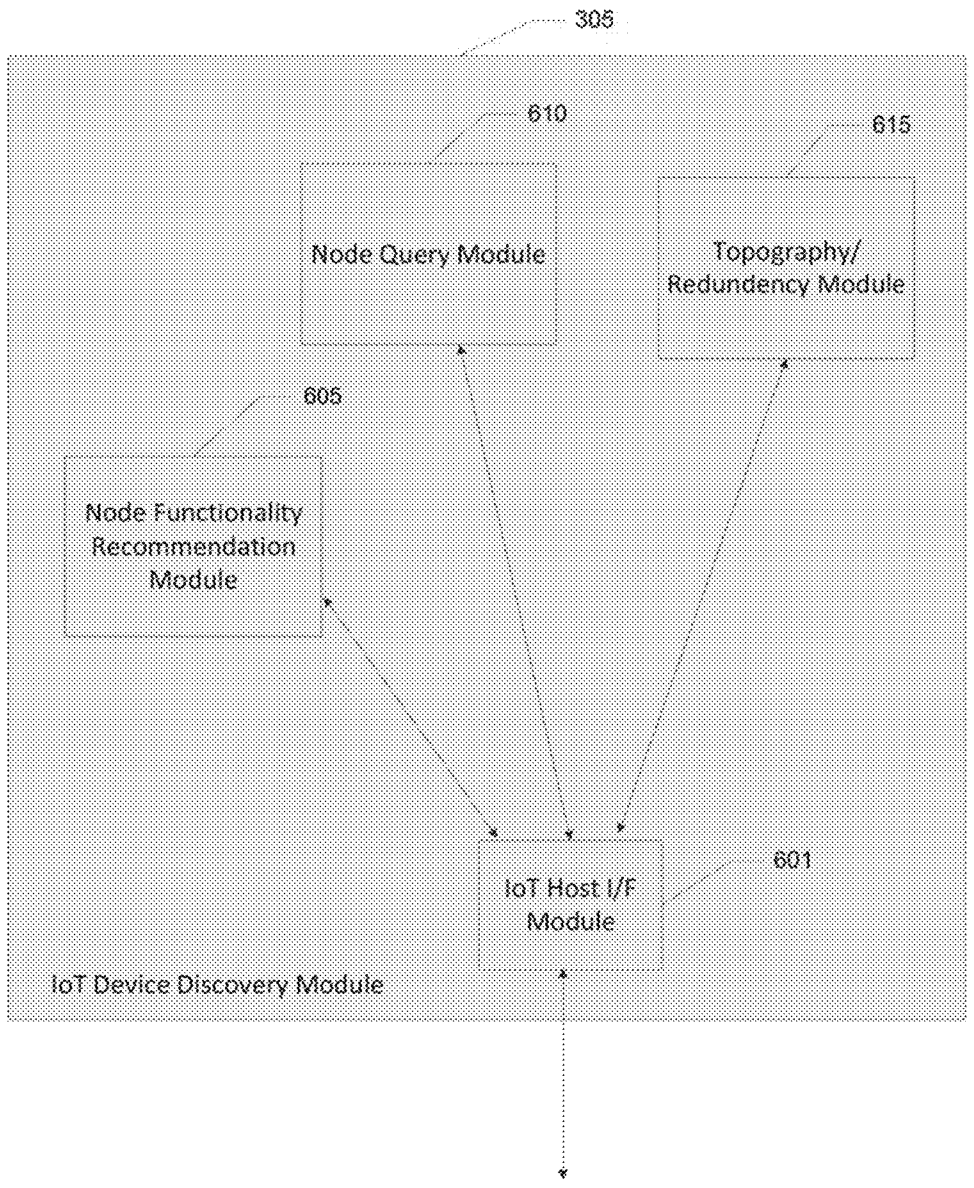

305
610
615
Node Query Module
Topography/
Redundency Module
605
Node Functionality
Recommendation
Module
IoT Host I/F
Module
601
IoT Device Discovery Module

FIG. 6

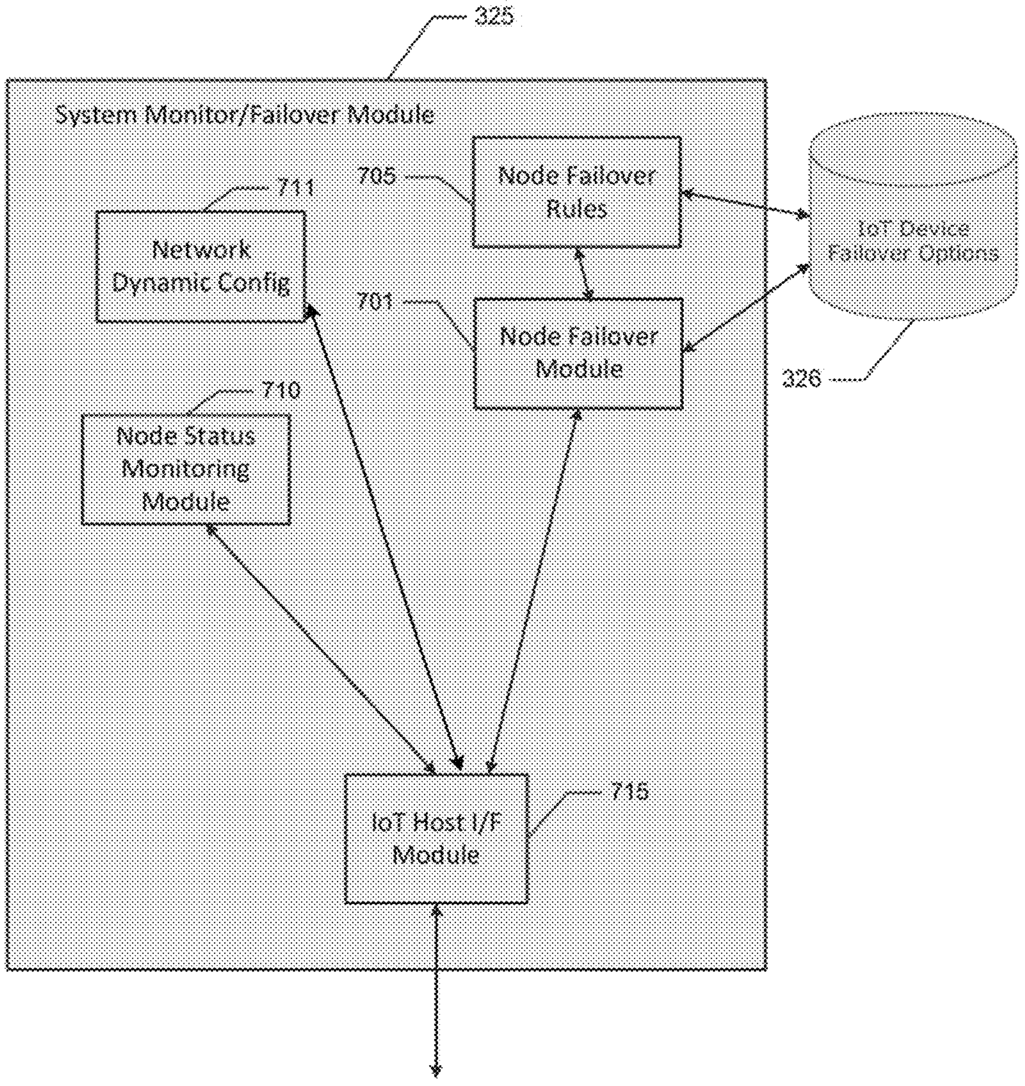

325
System Monitor/Failover Module
711
Network Dynamic Config
705
Node Failover Rules
701
Node Failover Module
IoT Device Failover Options
326
710
Node Status Monitoring Module
IoT Host I/F Module
715

FIG. 7

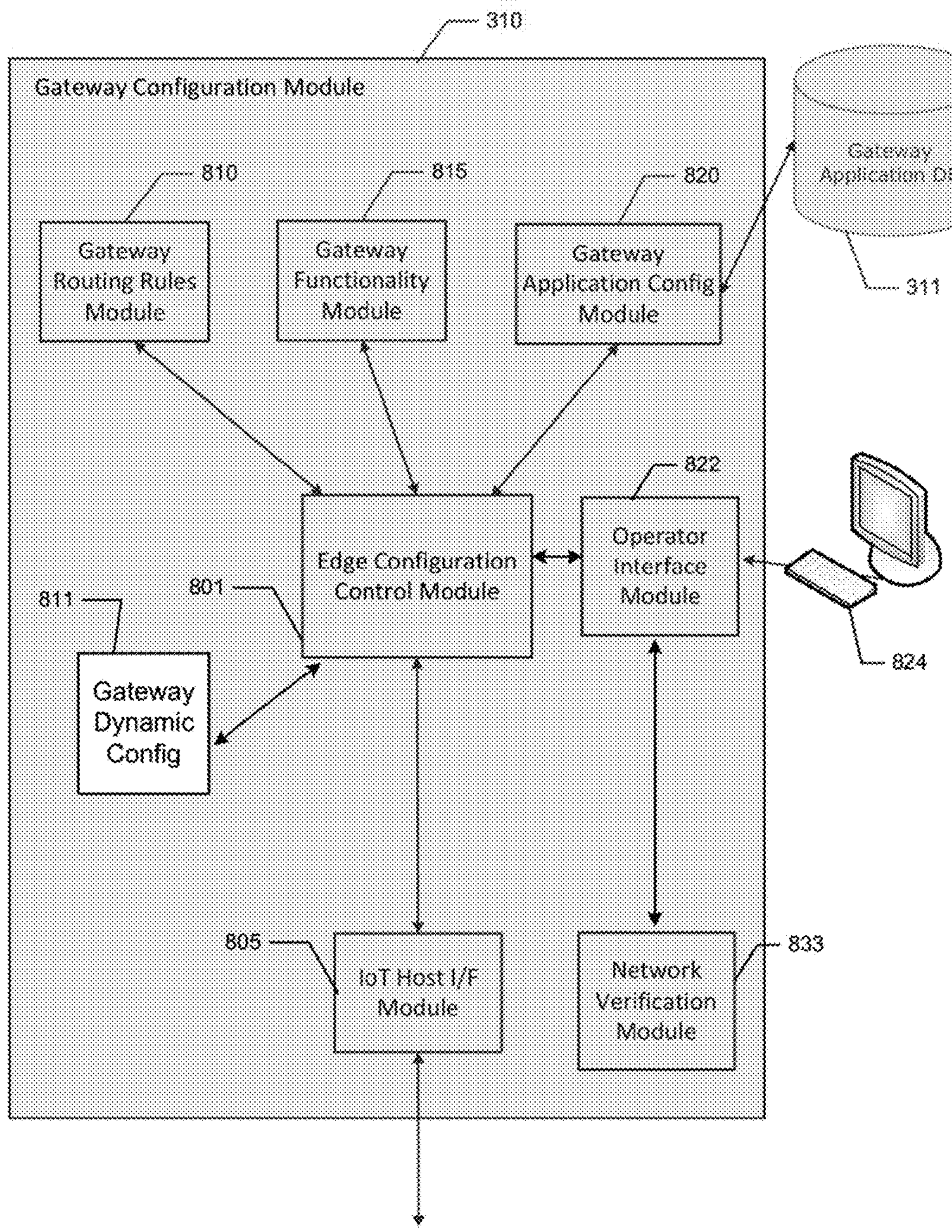

310
Gateway Configuration Module
810
Gateway Routing Rules Module
815
Gateway Functionality Module
820
Gateway Application Config Module
Gateway Application DB
311
822
Operator Interface Module
824
811
Gateway Dynamic Config
801
Edge Configuration Control Module
805
IoT Host I/F Module
Network Verification Module
833

FIG. 8a

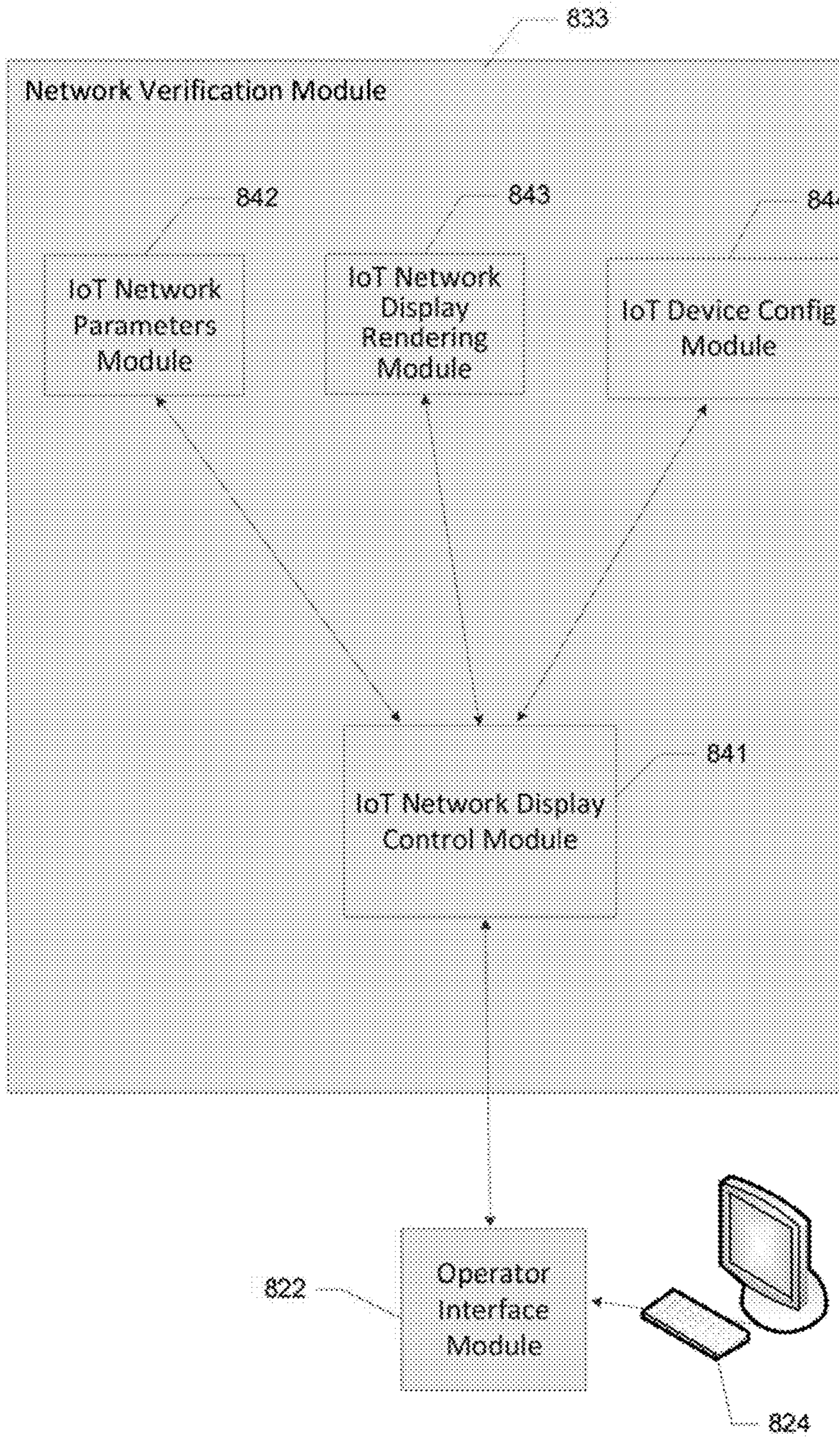

833
Network Verification Module
842
IoT Network Parameters Module
843
IoT Network Display Rendering Module
844
IoT Device Config Module
841
IoT Network Display Control Module
822
Operator Interface Module
824

FIG. 8b

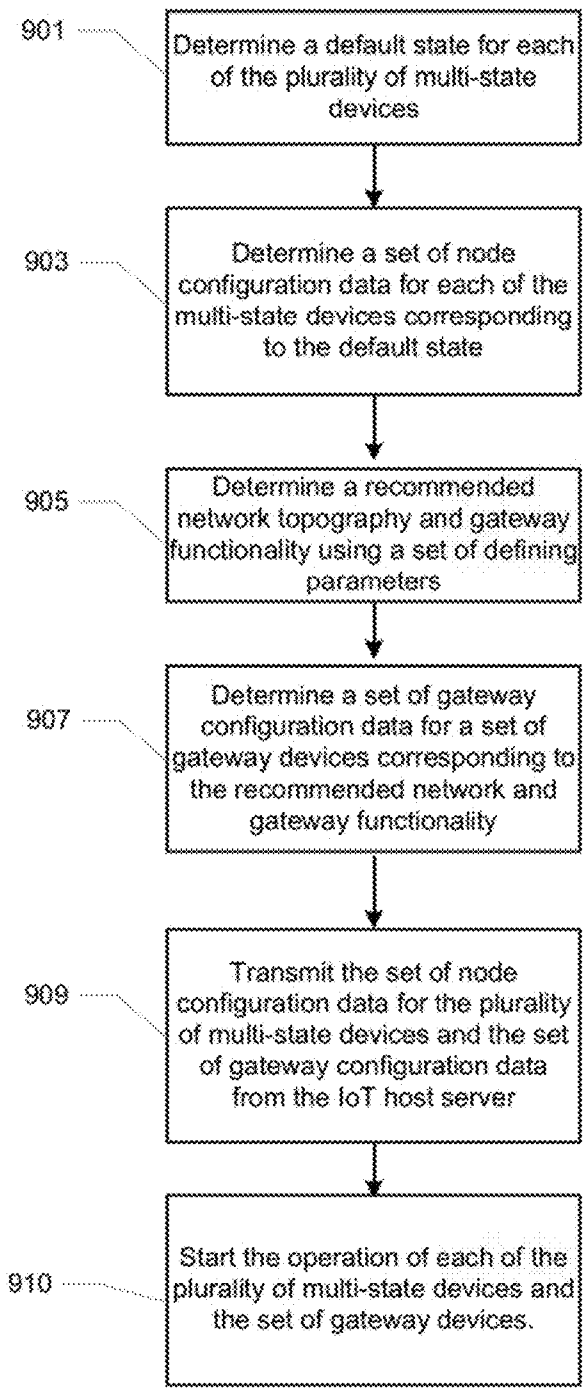

901
Determine a default state for each of the plurality of multi-state devices
903
Determine a set of node configuration data for each of the multi-state devices corresponding to the default state
905
Determine a recommended network topography and gateway functionality using a set of defining parameters
907
Determine a set of gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality
909
Transmit the set of node configuration data for the plurality of multi-state devices and the set of gateway configuration data from the IoT host server
910
Start the operation of each of the plurality of multi-state devices and the set of gateway devices.

FIG. 9

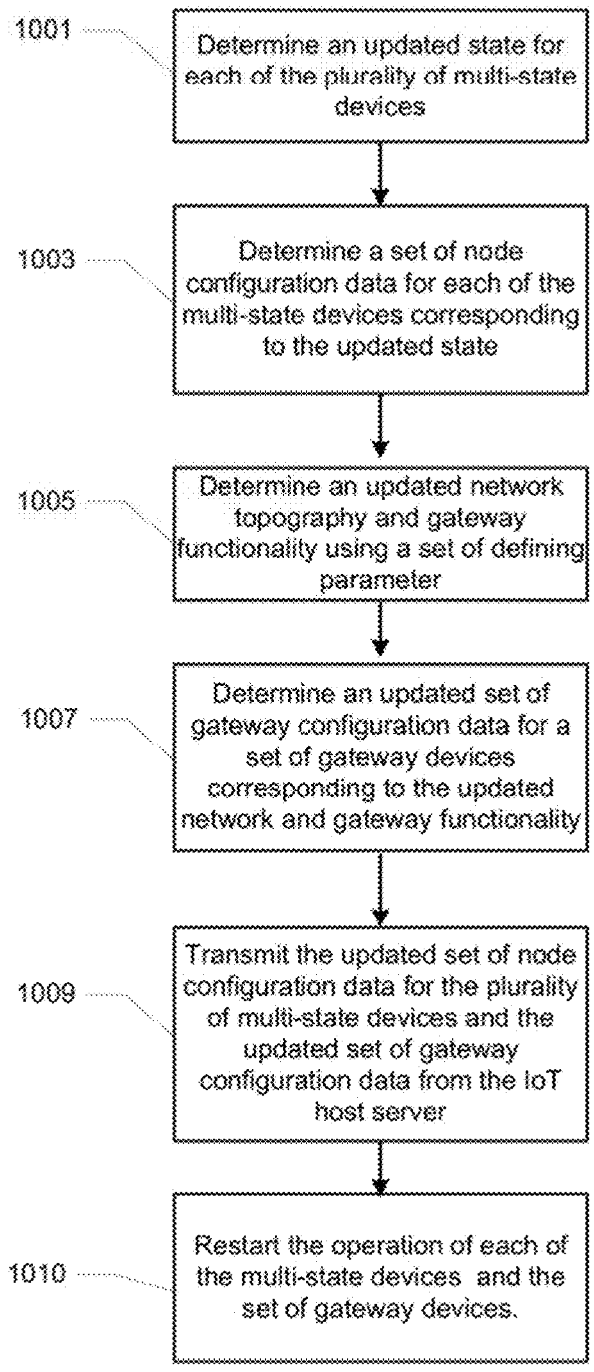

1001
Determine an updated state for each of the plurality of multi-state devices
1003
Determine a set of node configuration data for each of the multi-state devices corresponding to the updated state
1005
Determine an updated network topography and gateway functionality using a set of defining parameter
1007
Determine an updated set of gateway configuration data for a set of gateway devices corresponding to the updated network and gateway functionality
1009
Transmit the updated set of node configuration data for the plurality of multi-state devices and the updated set of gateway configuration data from the IoT host server
1010
Restart the operation of each of the multi-state devices and the set of gateway devices.

FIG. 10

SYSTEM AND METHOD FOR PROVIDING SECURE AND REDUNDANT COMMUNICATIONS AND PROCESSING FOR A COLLECTION OF MULTI-STATE INTERNET OF THINGS (IOT) DEVICES

RELATED APPLICATIONS

[0001] This application related to the following commonly assigned U.S. Patents and U.S. Patent Applications:

[0002] a. Hunter, et al., entitled SYSTEM AND METHOD FOR PROVIDING SECURE AND REDUNDANT COMMUNICATIONS AND PROCESSING FOR A COLLECTION OF MULTI-STATE INTERNET OF THINGS (IOT) DEVICES, attorney docket no. TN649A, Ser. No. 15/613,612, filed Jun. 5, 2017, currently pending; and

[0003] b. Hunter, et al., entitled SYSTEM AND METHOD FOR PROVIDING SECURE AND REDUNDANT COMMUNICATIONS AND PROCESSING FOR A COLLECTION OF MULTI-STATE INTERNET OF THINGS (IOT) DEVICES, attorney docket no. TN649B, Ser. No. 15/613,624, tiled Jun. 5, 2017, currently pending.

[0004] The above applications are incorporated by reference in their entirety as if they were recited herein.

TECHNICAL FIELD

[0005] This application relates in general to a method, apparatus, and article of manufacture for providing secure and redundant communications and processing for a collection of multi-state and programmable Internet of Things (IoT) devices connected to a computer network and under control of an IoT Host Server.

BACKGROUND

[0006] For anyone who relies on an IoT network for their 24/7 business needs, “100% uptime” of enough of its components to prevent a usage outage is critical. Given that “100% uptime” has been a longtime goal/characteristic of Unisys and the products it delivers (e.g. Clearpath Forward HA), this segment of the IoT market might align well with our core strengths and with our enterprise customer needs in various verticals we are already in.

[0007] There are many “large client” market segments which quickly come to mind, where this could be needed, e.g. “large client,” e.g. transportation, financial, manufacturing companies, which will very likely depend on IoT networks around the clock every day of the year. But even smaller companies using IoT for various purposes might have a need for “100% uptime” for certain aspects of their business, e.g. an IoT network to provide building perimeter/access security via surveillance devices, access devices, etc. In an earlier application, systems and methods are disclosed to provide secure and redundant communications. In these systems, a network is configured and operated to automatically reconfigure its communications links to provide automatic failover ensuring uptime of the IoT device functionality. A need exists to allow for dynamic reconfiguration of network links in response to scheduled events and in response to other external events. Additionally, a need exists to also include programmable, multi-state IoT devices that utilize this communications network to provide additional functionality to the network of IoT devices. A multi-state and programmable IoT device operates in a default mode and can also be programmed to operate is one or more alternate operating modes.

[0008] The benefit of the present invention is that it may permit an IoT network of programmable, multi-state IoT devices while operating with improved uptime with automated failover for some of the critical components of the network without requiring the cost of acquisition and installation of a fully redundant set of components. By allowing for dynamic reconfiguration of network links in response to scheduled events and in response to other external events along with specification of how device failures will be reconfigured in a controlled manner, the entire IoT network may remain operational within the possible performance of the remaining devices while providing additional functionality to the network of IoT devices.

[0009] The present invention attempts to address the existing limitations in current IoT network and device monitoring according to the principles and example embodiments disclosed herein.

SUMMARY

[0010] In accordance with the present invention, the above and other problems are solved by providing a network of IoT edge devices that operate in a plurality of states and the devices and the supporting network elements are dynamically configured to provide needed functionality in response to detected events.

[0011] The great utility of the invention is that a Client can rely on programmable, multi-state IoT device functionality provided by the IoT network around the clock and around the year without concern of an outage that could cause a portion of the business to come to a standstill or could result in a breach of security, safety, or any other absolutely essential usage.

[0012] In one embodiment, the present invention corresponds to a method for configuring a plurality of multi-state network devices within a dynamically configurable multi-path communications network within a IoT host server. The method determines a default state for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network, determines a set of node configuration data for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network corresponding to the default state, determines a recommended network topography and gateway functionality using a set of defining parameters; determines a set of gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality, transmits the set of node configuration data for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network and the set of gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality from the IoT host server and starts the operation of each of the plurality of multi-state devices within the dynamically configurable multi-path communications network and the set of gateway devices.

[0013] In another embodiment, the present invention corresponds to a computer program product for causing a programmable computing system to implement a method for configuring a plurality of multi-state network devices within a dynamically configurable multi-path communications net-

work within a IoT host server. The method determines a default state for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network, determines a set of node configuration data for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network corresponding to the default state, determines a recommended network topography and gateway functionality using a set of defining parameters; determines a set of gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality, transmits the set of node configuration data for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network and the set of gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality from the IoT host server and starts the operation of each of the plurality of multi-state devices within the dynamically configurable multi-path communications network and the set of gateway devices.

[0014] In yet another embodiment, the present invention corresponds to a distributed computing system having an IoT Host server, one or more Gateway devices, and a plurality of IoT Edge devices, for configuring a set of network devices. The IoT Host computer includes an IoT Device Discovery module for discovering all devices within an IoT network, the IoT network comprising an IoT Host computer, one or more gateway devices, and a plurality of IoT Edge devices; a Gateway Config module for recommending a network topography and node functionality using a set of defining parameters; an operator interface module for accepting modifications to one or more of the defining parameters within the set of defining parameters; a Network Present module for updating the network topography and node functionality using the modifications to the defining parameters; and an edge device config module for determining an operating state for each of the plurality of multi-state edge devices within the dynamically configurable multi-path communications network. The operating state for each of the plurality of multi-state edge devices includes a default state and an updated state for each detected event; and each detected event includes a scheduled event and an external event

[0015] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter that form the subject of the claims of the invention. 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 strictures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. The novel features that are believed to be characteristic of the invention, 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 description only and is not intended as a definition of the limits of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

[0017] FIG. **1***a* represents one potential embodiment of a IoT network connecting a plurality of multi-state IoT devices providing smart cities functionality;

[0018] FIG. **1***b* represents another potential embodiment of a IoT network connecting a plurality of multi-state IoT devices providing smart cities functionality;

[0019] FIG. **1***c* represents one potential embodiment of a IoT network connecting a plurality of IoT devices to an IoT Host Server via a communications network passing data thru multiple gateway devices according to one embodiment of the present invention;

[0020] FIG. **1***d* illustrates an example embodiment of multi-state IoT devices providing smart cities functionality;

[0021] FIG. **2** illustrates a general-purpose computing system for use in implementing as one or more computing embodiments of the present invention;

[0022] FIG. **3** illustrates an example IoT Host Server and one Gateway device according to another embodiment of the present invention;

[0023] FIG. **4** illustrates an example Remote Gateway device and plurality of IoT devices in the IoT network according to yet another embodiment of the present invention;

[0024] FIG. **5** illustrates an example operator interface module within the IoT Host server according to an embodiment of the present invention;

[0025] FIG. **6** illustrates an IoT Edge Device Discovery module within the IoT Host server according to another embodiment of the present invention;

[0026] FIG. **7** illustrates a System Monitor/Failover module within the IoT Host server according to an embodiment of the present invention;

[0027] FIG. **8***a* illustrates a Gateway Config module within the IoT Host server according to an example embodiment of the present invention;

[0028] FIG. **8***b* illustrates a Gateway Config module within the IoT Host server an example embodiment of the present invention;

[0029] FIG. **9** illustrates a flowchart of possible operations that may be performed according to an embodiment of the present invention; and

[0030] FIG. **10** illustrates another flowchart of possible operations that may be performed according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0031] This application relates in general to a method, apparatus, and article of manufacture for providing secure and redundant communications and processing for a collection of multi-state and programmable Internet of Things (IoT) devices.

[0032] Various embodiments of the present invention will he described in detail with reference to the drawings, wherein like reference numerals represent like parts and assemblies throughout the several views. Reference to various embodiments does not limit the scope of the invention, which is limited only by the scope of the claims attached hereto. Additionally, any examples set forth in this specification are not intended to be limiting and merely set forth some of the many possible embodiments for the claimed invention.

[0033] FIG. **1***a* represents one potential embodiment of a IoT network connecting a plurality of multi-state IoT devices providing smart cities functionality. The creation of IoT devices suggests the possibility to create smart cities in which various devices provided by the city to control areas at various times automatically as well as quickly in response to events. The example embodiment of FIG. **1***a-b* represent a portion of a city **10** having various multi-state and programmable IoT devices including parking meters **11**, traffic lights **12**, municipal vehicles **13** *a-d*, cameras **14**, and multiple network wireless access points **15**. Each of these devices are coupled to a network **111** via the network wireless access points **15** or directed wired connections. These devices communicate with an IoT host server **110** within a remote data center.

[0034] The city **10** may have various locations and structures including an office building **21**, fire station **22**, school **23**, stadium **24**, multiple 2-lane roads **25**, and divided 4-lane boulevard **26**. These locations and structures are meant to be examples of locations that may interact with the IoT devices as described herein. Many other locations and structures are possible for interaction with the disclosed system as recited within the attached claims.

[0035] Base Device Operations

[0036] Each of the IoT devices shown in FIG. **1***a* operate in a base or default operating mode as described below. The IoT devices include a network interface **32**, a sensor module **34**, and a programmable multi-state mode controller **36**. Each of these modules are described below in further detail and the operation of the IoT devices are discussed herein. In FIG. **1***a*, the illustrated IoT devices include parking meter devices **11**, traffic control lights **12**, municipal vehicles **13***a-d*, and cameras **14**.

[0037] In a default operating mode, each of the devices operates according to a predetermined mode. For example, the parking meter devices **11** operate as countdown timers providing a vehicle parked in a space associated with each meter device **11** time to be permissibly parked. A driver may purchase an amount of time using the parking meter IoT device **11** and a time period for parking will begin. When the amount of time purchased has expired, the vehicle, if still in the corresponding parking spot, may be subjected to a parking violation. The parking meter IoT device **11** may communicate with the IoT host server **110** (shown in FIG. **1***c*), to obtain payment from a credit/debit card processing system in some embodiments. The parking meter IoT device **11** may also communicate with one or more municipal vehicles **13***a-d* to indicate when the purchase time period has ended and a parking violation may be issued via the IoT host server **110**. The parking meter IoT device **11** may also be configured to send a message, such as an e-mail or a text message to the driver as the time remaining on the meter is ending via an application on the IoT host server **110**.

[0038] The traffic control lights **12** are typically located at the intersection_ of two or more 2-lane roads **25** and divided 4-lane boulevards **26** to provide vehicle flow control for drivers operating vehicles within the city. These traffic control lights **12** are typically the red-yellow-green traffic lights that are used throughout the United States that may also possess additional lights to control turning lanes. In a default operating mode, these traffic control lights **12** alternate between red and green light states for each of the roads that they control, passing thru a yellow light state when transitioning from a green light state and a red light state. The traffic control lights **12** may change states, and thus the roads that are permitted to pass thru an intersection, using a timed state approach in which each controlled roadway is in a green state and a red state for predetermined amount of time. The length of time for the red state and the green state may not necessarily be of equal length as expected traffic flow in one direction may be greater than a competing direction. Additionally, the changing of states from a red state to a green state may be triggered by sensors that detect the presence of a vehicle waiting to pass thru an intersection controlled by the traffic control lights **12**. The traffic control lights **12** operate in this mode until reprogrammed by commands from the IoT host server **110**.

[0039] The one or more municipal vehicles **13***a-d* may communicate with the IoT host server **110** to update the host server with the location of the vehicles at any given moment in time. The IoT host server **110** may transmit messages to the municipal vehicles **13***a-d* as needed to direct them to a location with instructions regarding action to be taken. One such example is stated above in which a vehicle is instructed to go to a vehicle in which its parking time has expired and has not as of yet left the parking spot. Other municipal employees such as first responders may also be directed to locations in which they are needed. The IoT host server **110** may use the location of the vehicles to determine which responder will arrive the fastest. The municipal vehicles **13***a-d* may also provide voice communications over the network **111** using a Voice-Over-IP communications protocol between drivers of the municipal vehicles **13***a-d* and others in the city.

[0040] One or more cameras **14** may be located throughout the city to provide periodic images of the areas around each camera to municipal employees monitoring the city via the IoT host server **110**. In a default operating mode, these cameras may transmit at a low frame rate, such as a few frames per minute, to minimize the network bandwidth needed to support these images. The cameras **14** may operate at a higher frame rate including a standard video frame rate of 24 or 30 frames per second when an operator has determined that a particular location is of interest.

[0041] Planned Events

[0042] All of the above devices may also operate in other operating modes to control events occurring within areas of the city. In one embodiment, the IoT devices may be programmed to operate in an alternate operating mode upon command from the IoT host server **110** according to a predetermined schedule. In one possible situation, a planned event may be scheduled to occur in an office building **21** at a known date and time that requires heightened security such as when a head of state or other official is expected to be present in which access to the area near the office building **21** is to be limited. In such a situation, the IoT host server **110** may instruct the IoT devices to operate in an alternate operating mode for some time before the scheduled event and continue until after the event has ended. All of the operating modes may be programmed into configuration data files within the IoT host server **110** and transmitted to the IoT devices at predetermined times.

[0043] For example, security for this event may desire to limit all traffic within a nine (9) square block area surrounding the office building **21**, may desire to eliminate all parked vehicles from this nine (9) square block area, and may wish to instruct municipal vehicles **13***a-d* to various locations as the event preparation occurs until the event has ended. The above IoT devices may be set into an alternate operating mode to assist in these plans.

[0044] For example, the parking meter devices **11** may be instructed to not sell parking time that would extend into the time period of the event, including any preparation time before the event and any time after the event. The parking meter devices **11** may also begin transmitting messages to drivers informing them of the upcoming event in which their vehicles are not permitted within the nine (9) square block area. The parking meter devices **11** may communicate with municipal vehicles **13***a-d*, such as tow trucks as the time of the event nears to remove any remaining vehicles.

[0045] The traffic light devices **12** may be programmed into a mode that indicates to drivers not to enter into a nine (9) square block area from a starting time 2 hours before the scheduled event. The IoT host server **110** may communicate with each of the IoT traffic signals **12** instructing them to display a defined light pattern that does not change.

[0046] The camera devices **14** may be controlled as needed by operators connected to the IoT host server **110** to monitor the area before the event to ensure that all of the preparations occur, to monitor the area to ensure that no unauthorized person or vehicle enters the nine (9) square block area, and to assist in responding to situations that may arise during the event. The frame rate, and thus network bandwidth needed for these activities may change throughout the time when the event is occurring.

[0047] As noted in the parent application, the network **111** may be dynamically reconfigured to ensure 100% uptime for the IoT devices communicating with the IoT host server **110**. During the above events, the bandwidth needs of various devices may change. For example, during the time leading up to the scheduled event at the office building **21**, the traffic light devices **12** may need some amount of bandwidth to reconfigure the IoT traffic signal device **12** for a short period of time. Once the devices are reconfigured, the traffic signals **12** may not need any bandwidth at all until the event ends and they are reset to a default operating mode. Similarly, parking meter devices **11** may require bandwidth during the beginning of the time allotted for preparation for the event to send messages to the vehicle owners to move their vehicles and to municipal vehicles **13***a-d* as the remaining vehicles are moved. Once the parking spots have been cleared, no network bandwidth may be needed for the parking meter devices **11**.

[0048] Finally, during the event itself, all of the network bandwidth may be allocated to the camera devices **14** and municipal vehicle **13** communications as security is provided for the event. Host server **110** may reconfigure the operation of the network dynamically as needed to support these remaining IoT devices during the event. Once the event has ended and security is terminated, the network **111** may be reconfigured to a default operating mode in which the traffic signals **12** are configured to change state to control traffic, parking meter devices operate in a default mode to collect parking fees, and camera devices returning to a low frame rate as needed.

[0049] Externally Triggered Event

[0050] In an alternate situation, consider an unplanned emergency, such as a major fire occurs in the office building **21**, instead of a scheduled event. Much of the same changes to the IoT devices to prevent traffic from entering the nine (9) square block area, to encourage vehicles parked in the area to leave the area allowing emergency vehicles to access the area, and to permit communications between municipal vehicles **13** coming to the area as well as operating within the area while fighting the fire. The IoT host server **110** may send the commands to each of the above IoT devices as well as reconfigure the operation of the network as needed under the instruction of operators and dispatchers via the IoT host server **110**. Once the existence f the fire is detected and passed on to the fire department, operators and dispatchers may interact with a control program on IoT host server **110** to implement any changes to the operation of the IoT devices and the network.

[0051] FIG. **1***b* represents another potential embodiment of a IoT network connecting a plurality of multi-state IoT devices providing smart cities functionality. Consider an unplanned event such as a major snowstorm is making the 2-lane roads **25**, and divided 4-lane boulevard **26** impassible. The city may wish to ensure that drivers from locations such as office building **21** and stadium **24** can travel through the area safely on their way home. In such an arrangement, the camera devices **14** may be providing images of the various intersections and roadways to inform dispatchers of the existing conditions. The dispatchers may also communicate with municipal vehicles **13***d*, such as a truck with a snow plow, to best attempt to remove the snow from high priority roadways such as divided 4-lane boulevard **26** to allow traffic from the stadium **24** to exit the area. The dispatcher may also communicate with traffic signal devices **12** in an attempt to keep traffic flowing only on the cleared areas. By tracking the location of the snow plow vehicle **13***d*, the host server **110** may change the operation of various traffic signal devices **12** shortly after the snow plow has passed through an intersection.

[0052] All of these changes are controlled by the dispatcher communicating with the IoT host server **110** as the snow event is occurring. Once the snow stops falling, the dispatcher may direct the snow plow vehicle **13***d* to each of the roadways with the high priority roadways plowed first, and once these roadways are observed to be clear, directing the snow plow vehicles to other roadways until all of the roadways have been cleared. Throughout the entire event, host server **110** may be dynamically reconfiguring the network **111** to provide needed bandwidth to individual cameras **14**, traffic signal devices **12**, and snow plow vehicles **13***d* to ensure the snow removal process occurs efficiently. The host server **110** may also be monitoring the network **111** and its components as discussed in the parent application to address any network communication issues that may arise if, for example, snow fall has covered wireless access points **16** that are part of the network **111** making some communications difficult or intermittent.

[0053] The example of a city disclosed herein is provided as a method of example of possible embodiments of the present invention. A city in the above embodiments may represent any type of contiguous area such as university and business campuses, building complexes, large parks, stadiums, and other similar areas in which control of the area is defined. The example of multi-state devices such as traffic lights, parking meters, municipal vehicles as discussed above are also presented as example multi-state devices usable within the IoT network disclosed herein. Other similar devices may include remotely programmable lock devices, access gates, fire suppression devices, sensors, and other devices having multiple operating states that may be desired into particular states for scheduled and external events similar to the ones discussed herein. The scope of the present invention should be limited only by the limitations contained within the claims attached herein.

[0054] FIG. **1***c* illustrates an IoT Host computer **110** connected to a network **111** that is also connected to an IoT network **102** of IoT edge devices **130***a*-**130***f*. IoT Host **110** communicates with the IoT edge devices **130***a*-**130***d* thru one or more gateway devices **115***a*-**115***b*, network **111**, and Remote Gateway devices **120***a*. Each of the IoT edge devices **103***a*-**130***d* may be connected to Remote Gateway device **120***a* to provide multiple communications paths between the IoT edge devices **130***a*-**130***c* and IoT Host **110**. If a device fails in any part of this network, the multiple communication paths provide a mechanism to reestablish communications between the IoT edge devices **130***a*-**130***d* and IoT Host **110**.

[0055] While the present invention may make use of any unused IoT hardware to failover to, and could look for this possibility first, it would also gladly use unused bandwidth on an already-being-used IoT hardware component, e.g. path, gateway or edge device, at the time of a failure. Obviously, the more hardware cross-connections and the more available bandwidth that exists in an IoT network, the better, as that provides more failover choices. But once again, the key here is that this present invention obviates the need and cost of having fully redundant standby hardware and communications paths.

[0056] Depending on the topology of a particular IoT network and the failing component, there could be different ways in which "100% uptime" could be achieved. In all cases, the solution would choose which secondary component(s) to replace the failing one(s). The strategy used to make any failover decision may be Administrator selectable: it can either be based on detailed, specific topology rules given in advance by the Administrator (Admin) for that particular network operating in an "expert mode" or it can be based on a set of "general" load balancing rules in an "automated" mode that doesn't require Admin rules be given.

[0057] Expert mode would allow an Admin who wishes to pre-designate in fine-grained detail which component(s) is to provide backup processing for a particular failing component. For example, for a particular IoT edge device, the Admin could choose to designate which of a set IoT Gateways would take over communications to the device in the event that the device's primary Gateway would fail. Or the Admin could choose which of different alternative paths would be used to an IoT edge device should its primary path fail. This mode would allow more upfront planning & decision making to be designated by the Admin, but would allow for detailed failover strategies tailored to the specific IoT network to be specified by the Admin, to be carried out by the underlying solution implementation.

[0058] Automated mode would be a simpler user interface (UI) that does not require detailed input from the Admin and would instead allow him/her to inform the underlying solution of a more general strategy for failover component selection. For instance, in this mode, the Admin might choose a strategy such as "evenly load balancing" where the least busy component is chosen or "round robin" where a failover component would be picked based on the most recent failover choice. These choices would allow the solution to make a reconfiguration choice based on a criteria such as "which of the possible failover components currently has the lightest load" or "choose a failover component different from the one we chose last time", etc.

[0059] Either way, at failure time, the underlying solution will choose component(s) to replace the failing one(s) and then dynamically do the reconfiguration work necessary to reorient the network such that there won't be a service outage. The solution will also report the failure to an IoT Administrator so that the failed component can be scheduled for replacement. In the meantime, service will continue as best as possible, depending on the amount of extra bandwidth available in the chosen replacement component(s) at the time of the failure.

[0060] For instance, the ability to failover an IoT gateway **115***a*, i.e. the main cloud gateway through which IoT traffic from IoT devices funnels into the IoT Host **110**, is an example of providing "100% uptime" for one particular component type of an IoT network **102**-**103**. Other IoT component types could fail (via either hardware breakage or software bug) and cause a failure to achieve "100% uptime". For instance, the failure of a lone data path between an IoT edge device **130***d* and the IoT Remote Gateway **120***a* may cause a usage outage. Or, in larger IoT networks that employ multiple levels of gateways "outboard from the cloud," e g. the AZURE™ model allows for outboard IoT Protocol and IoT Field gateways (not shown), in addition to the inboard cloud IoT Remote Gateway, a hardware or software failure of an outboard gateway could cause an outage.

[0061] Additionally, an IoT edge device, that typically comprises a sensor multi-state device as discussed above, may also fail and cause an outage. All of the various pieces of an overall IoT network need to be considered/reconfigured in order to achieve "100% uptime" in the face of various IoT component failures. The present invention identifies failures of any device in an IoT network **102**-**103** and then chooses appropriate reconfiguration components before dynamically reconfiguring the IoT network to use chosen replacement devices.

[0062] Because of the large number of component failure and topology types that may require reconfiguration, rather than trying to design/implement replacement solutions for all of possible failures in one large waterfall model, the present invention breaks down and prioritizes various use cases, then orders the design/implementation of the overall solution to deal first with those use cases believed to be most likely to occur in the field. The actual implementation would consist of an application operating as a service that would most likely run on one or more "highest level" gateway(s) **115***a* that have visibility to the overall IoT network. The service would direct the initial "primary" configuration of the overall IoT network **102**, such as designating which IoT devices **130***a*-**130***j* are served by which Remote Gateways **120***a*-**120***e* via which paths during "normal running."

[0063] The service(s) would then monitor the IoT network **102** for outages which would require redirecting to usage of a "secondary" component. For instance, by generating and routing periodic "status" operations through the various paths and gateways to particular devices, the service could monitor the health of the IoT components. If there already exists "known periodic" traffic between the host(s) **110** and IoT edge device(s) **130***a*-**130***d*, the service could track this traffic and when the service notices that traffic has not been generated for a particular period of time, the service may route its own status ops through the IoT network **102** to quickly ascertain which IoT edge devices **130*a*-130*d*** or Remote Gateways **120*a*** have failed, choose a replacement device based on how the Administrator specified that replacements would be chosen, do the reconfiguration, i.e. set up the routing in the appropriate gateways and/or devices for whichever gateway, path or device should he used instead of the failing one, and alert, the Client with a notification. This notification may consist of a popup message on a host service screen, an audible alarm, and/or an email/phone call or log entry, etc.

[0064] FIG. **1*d*** illustrates an example embodiment of multi-state IoT devices providing smart cities functionality. In this embodiment, an IoT device network **30** includes two edge devices **31*a*-31*b*** connected to an edge gateway device **20** for communications over network **111**. Each edge device **31*a*-31*b*** contains a network interface **32**, a sensor module **34**, and a programmable multi-state mode controller **36**. The network interface **32** connects edge device **31**a to edge gateway **20** using a communications protocol. This communication may be wired or wireless and may utilize any communications protocol. The sensor module **34** is a data generating device such as a sensor or in the above embodiments for example, a camera and parking meter user interface module. The programmable multi-state mode controller **36** is a programmable device that operates in a default mode as discussed above as well as one or more alternate operating modes. The controller **36** implements the logic or instructions necessary to implement the functionality of the IoT device.

[0065] Because multiple types of IoT devices as discussed above may share a single communications network **111**, it may be desirable to segregate the network communications into separate communities of interest such that entities and operators may only receive data and control operation of the IoT devices when the particular operators are authorized. The various IoT devices may be segregated into separate communities of interest utilizing micro-segmentation of devices into separate conclaves using the STEALTH™ technology created and owned by the Unisys Corporation. Additional details of the operation of micro-segmentation of IoT devices over a shared network is described in more detail in commonly assigned and concurrently pending U.S. patent application: Entezari, entitled MICRO-SEGMENTATION OF AN APPLICATION RUNNING IN AN IoT GATEWAY, Attorney Docket no. TN650, Ser. No. 15/695,359, filed Sep. 5, 2017, currently pending. This application is incorporated by reference herein as if it was recited in its entirety.

[0066] FIG. **2** illustrates a computer system **200** adapted according to certain embodiments of the server **102** and/or the client computer **101**. The central processing unit ("CPU") **202** is coupled to the system bus **204**. The CPU **202** may be a general-purpose CPU or microprocessor, graphics processing unit ("GPU"), and/or microcontroller. The present embodiments are not restricted by the architecture of the CPU **202** so long as the CPU **202**, whether directly or indirectly, supports the operations as described herein. The CPU **202** may execute the various logical instructions according to the present embodiments.

[0067] The computer system **200** also may include random access memory (RAM) **208**, which may be synchronous RAM (SRAM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), or the like. The computer system **800** may utilize RAM **208** to store the various data structures used by a software application. The computer system **800** may also include read only memory (ROM) **206** which may be PROM, EPROM, EEPROM, optical storage, or the like. The ROM may store configuration information for booting the computer system **200**. The RAM **208** and the ROM **206** hold user and system data, and both the RAM **208** and the ROM **206** may be randomly accessed.

[0068] The computer system **200** may also include an input/output (I/O) adapter **210**, a communications adapter **214**, a user interface adapter **216**, and a display adapter **222**. The I/O adapter **210** and/or the user interface adapter **216** may, in certain embodiments, enable a user to interact with the computer system **200**. In a further embodiment, the display adapter **222** may display a graphical user interface (GUI) associated with a software or web-based application on a display device **224**, such as a monitor or touch screen.

[0069] The I/O adapter **210** may couple one or more storage devices **212**, such as one or more of a hard drive, a solid-state storage device, a flash drive, a compact disc (CD) drive, a floppy disk drive, and a tape drive, to the computer system **200**. According to one embodiment, the data storage **212** may be a separate server coupled to the computer system **200** through a network connection to the I/O adapter **210**. The communications adapter **214** may be adapted to couple the computer system **200** to the network **708**, which may be one or more of a LAN, WAN, and/or the Internet. The communications adapter **214** may also be adapted to couple the computer system **200** to other networks such as a global positioning system (GPS) or a Bluetooth network. The user interface adapter **216** couples user input devices, such as a keyboard **220**, a pointing device **218**, and/or a touch screen (not shown) to the computer system **200**. The keyboard **220** may be an on-screen keyboard displayed on a touch panel. Additional devices (not shown) such as a camera, microphone, video camera, accelerometer, compass, and or gyroscope may he coupled to the user interface adapter **216**. The display adapter **222** may be driven by the CPU **202** to control the display on the display device **224**. Any of the devices **202-222** may be physical and/or logical.

[0070] The applications of the present disclosure are not limited to the architecture of computer system **200**. Rather the computer system **800** is provided as an example of one type of computing device that may be adapted to perform the functions of a server **102** and/or the client computer **101**. For example, any suitable processor-based device may be utilized including, without limitation, personal data assistants (PDAs), tablet computers, smartphones, computer game consoles, and multi-processor servers. Moreover, the systems and methods of the present disclosure may be implemented on application specific integrated circuits (ASIC), very large scale integrated (VLSI) circuits, or other circuitry. In fact, persons of ordinary skill in the art may utilize any number of suitable structures capable of executing logical operations according to the described embodiments. For example, the computer system **200** may be virtualized for access by multiple users and/or applications.

[0071] Additionally, the embodiments described herein are implemented as logical operations performed by a computer. The logical operations of these various embodiments of the present invention are implemented (1) as a sequence of computer implemented steps or program modules running on a computing system and/or (2) as interconnected machine modules or hardware logic within the computing system. The implementation is a matter of choice dependent on the performance requirements of the computing system implementing the invention. Accordingly, the logical operations making up the embodiments of the invention described herein can be variously referred to as operations, steps, or modules.

[0072] FIG. **3** illustrates an example IoT Host Server and one Gateway device according to another embodiment of the present invention. IoT Host **110** interacts with gateway device **115** to communicate with IoT edge devices via a network **111**. IoT Host **110** comprises an IoT Host Control module **301**, an operator interface module **315** connected to a user console **302**, an IoT device discovery module **305**, a gateway config module **310** coupled to a gateway application database **311**, an IoT device data processing module **320** coupled to an IoT device data database **321**, an edge device multi-mode configuration module **322**, a system monitor/failover module **325** coupled to an IoT device failover options database **326**, and an interface module **330** coupled to the gateway device **115**.

[0073] The IoT Host Control module **301** is responsible for configuring, enabling, monitoring and controlling the operations of all of the modules within the IoT Host **110**. At start up, the IoT Host Control module **301** configures the operation of the other modules and initiates any necessary interaction between any of these modules and each other as well as Remote Gateway devices and/or IoT edge devices. During operation, the IoT Host Control module **301** monitors the operation of all other functions within the IoT Host **110** and will initiate any needed actions when an anomaly arises. The IoT Host Control module **301** may utilize other modules within the IoT Host **110** to deal with these issues when they arise. Through all of these interactions, the IoT Host Control module **301** will control the operation of the entire system.

[0074] The operator interface module **315** connected to the user console **302** provides a mechanism for an operator to observe and control the functions within the IoT Host **110**. The operator interface module **315** provides a user interface to control functions and monitoring data within the IoT Host control module **301**. The operator interface module **315** provides the data to the operator and accepts commands that start, stop, and alter the operation of the system. The operator interface module **315** provides a communications function to communicate with the user console **302** either as a console directly connected to the IoT Host **110** as well as a remote client executing on a remote computing system that is connected to communications network. One of ordinary skill will recognize that the remote client may either be a client application or a terminal emulation program without deviating from the present invention. Additionally, the operator interface module **315** may communicate with the remote client via network **111**, thru interface module **330**, or using a separate communications connection between the operator interface module **315** and the remote console.

[0075] The IoT device discovery module **305** is responsible for determining the topography of the IoT network **103** as shown in FIG. **1**. At network startup, the IoT device discovery module **305** will identify all of the IoT edge devices **130***a-f* and all of the Remote Gateway devices **120***a-c* in the IoT network **103**. The IoT device discovery module **305** also discovers all of the communications connections and paths between all of the devices in the IoT network **103**. From this data, the IoT device discovery module **305** may construct a complete topography of the IoT network **103**.

[0076] The IoT device discovery module **305** may obtain all the necessary data by sending a discovery request to all of the devices within the IoT network **103**. Each of these devices forward the discovery request to all of the devices connected to the device. The devices in IoT network **103** will respond to the first request by returning to the IoT device discovery module **305** its identity, its location, an identity of all of the devices directly attached to the device, and an identifier for every communications link between each of the devices. The IoT device discovery module **305** is discussed in additional detail in reference to FIG. **6** below.

[0077] The gateway config module **310** is responsible for configuring the operation of the attached gateway device **115** and the Remote Gateway devices **120***a-c*. The gateway config module **310** obtains all configuration data and applications that are to be loaded into the various gateway devices and provides the data and applications when a gateway device is either started or reconfigured. The gateway config module **310** is coupled to gateway application database **311** to store all of the configuration data and applications needed in the above processing.

[0078] The IoT device data processing module **320** is responsible for obtaining data from the IoT edge devices **130***a-f* while the IoT network **103** is operating. Depending upon the function of the IoT edge devices **130***a-f*, the gateway config module **310** may perform processing operations necessary for the IoT network **103** to perform a desired operation. For example, IoT edge devices **130***a-f* may consist of various sensor devices. The gateway config module **310** may perform data filtering, averaging, and alarm triggering functions based upon the sensor data obtained from the IoT edge devices. The present invention envisions that the gateway config module **310** perform any necessary operations as defined when a system **100** is designed. The gateway config module **310** is coupled to the IoT device data database **321** as attached storage to store and manage any of the data needed to perform the sensor data processing functions. Additionally, log files and other diagnostic data from the operation of the IoT network **103** may be stored in the attached database **321** for retrieval and analysis at a later time. Additional functions and operation of the gateway config module **310** are described below in reference to FIG. **8***a*.

[0079] The edge device multi-mode configuration module **322** is responsible for configuring the operating modes for all of the IoT edge devices **130***a-c*. As discussed above, edge devices **130***a-c* may operate a default operating mode and one or more programmable operating modes. The edge device multi-mode configuration module **322** obtains configuration data from the edge devices **130***a* from the IoT device data database **321** based upon a scheduled event or based upon a dispatcher's input from a user terminal **302** via the operator interface module **315**.

[0080] The system monitor/failover module **325** is responsible for detecting an occurrence of an anomaly within the operation of IoT network **103** and for attempting to reconfigure the functions of IoT network **103** and its devices to maintain operation of the IoT network **103**. In some embodiments, IoT network **103** may possess redundant IoT edge devices **103** *a-f* and redundant Remote Gateway devices

120*a-c*. When one of these types of devices fails or otherwise is not operating as desired, the system monitor/failover module **325** determines the nature of the anomaly, identifies possible replacement device and/or communications paths, and initiates a reconfiguration of devices within IoT network **103**. The system monitor/failover module **325** obtains failover options data from the IoT device failover options database **326**. The system monitor/failover module **325** may reconfigure the needed devices directly, or may instruct the gateway config module **310** to perform the reconfiguration. In the latter embodiment, the system monitor/failover module **325** may pass to the gateway config module **310** the identity of the devices to be reconfigured and the identity of a configuration role for that device. Additional details regarding the system monitor/failover module **3** may be found below in reference to FIG. **7**.

[0081] The interface module **330** provides communications for the IoT Host **110** to its local gateway device **115**. The interface module **330** permits the communications to flow as required while utilizing a particular protocol and transport mechanism. The interface module **330** prioritizes the communications from all of the modules within the IoT Host **110** to ensure that a priority between possible communications is provided. For example, the interface module **330** may perform communications related to a failover and/or an alarm process that may be considered critical over the routine transmission of IoT edge device data and/or routine status updates. The interface module **330** may implement a priority scheme to ensure that critical issues are resolved before routine operations or any other arrangement desired.

[0082] The gateway device **115** comprises a host interface module **331**, a routing module **345**, an applications module **340** coupled to an IoT application data storage **341**, and a network interface module **350**. The host interface module **331** performs the converse of the operations of the interface module **330** within the IoT Host **110**. Data is transmitted to and from the interface module **330** in the desired protocol over the implemented transport mechanism. The host interface module **331** communicates and coordinates the transfer of data and commands as requested by the interface module **330** to realize any priority scheme discussed above.

[0083] The routing module **345** utilizes the network topography for IoT network **103** that is created within the IoT device discovery module **305** and utilizes routing rules from the gateway config module **310** to route communications to and from the IoT edge devices in IoT network **103**. The routing module **345** may maintain a routing table that contains a hierarchical routing table that specifies all of the possible communications paths from the IoT Host **110** and any one of the IoT edge devices **130***a-f*. The table may also provide an order for the path to be chosen to route the communications within IoT network **103**. In many embodiments, the routing table data is updated at system configuration and at any or all failover reconfiguration events. In such an embodiment, the routing data is static.

[0084] In an alternate embodiment, the routing module may monitor the performance of the IoT network **103** communications as measured in any number of ways to identify parts of the network that may be experiencing higher levels of message traffic and in such cases, choose alternate communications paths to attempt to balance the communication load on all of the affected communications paths. The routing module **345** may attempt to measure these message traffic levels by examining any observed latency in the gateway device **115** receiving acknowledgement of messages and commands. The routing module **345** may use an indication of the number of pending messages and commands within any communications buffers within the network **103** to approximate message traffic loads.

[0085] The applications module **340** supports any application functions requested during configuration to process data from IoT edge devices before the data is forwarded to the IoT Host **110**. As noted above, data from the IoT edge devices may represent time sampled data from sensor devices that may require filtering, averaging, and other similar processing before the sensor data may be useful. The gateway devices **115** and Remote Gateway devices **120***a-c* are envisioned to be programmable computing devices possibly within the network infrastructure. These devices typically possess unused computational capacity and may be sized to provide a desired level of computational capacity, to permit the large amount of data that is expected to be generated by a network of IoT edge devices to be efficiently processed at the various gateway devices within the IoT network **103** while reducing the amount of data that needs to be communicated through the network to the IoT Host **110**. The applications module **340** may use the IoT application data storage **341** to store, organize and maintain data from its processing of the IoT edge device data for use at a later date when necessary.

[0086] Additionally, applications module **340** may utilize a Docker containerized application that permits an application to execute as a self-contained virtual computing system that implements the desired application function. The container may include an application and a small OS kernel including any needed function libraries to permit the application to function. The Remote Gateway device **120***a-b* may permit these containers execute as a virtual computing device within itself to implement any desired functionality. Because a container may be launched within any device supporting these virtual computing applications and also contain any application written and configured to execute within the container, any functionality needed may be supported within a gateway device **115**, **120**. Additionally, the functionality of the gateway device may be altered by starting a new containerized application within a gateway device. The new application may either replace an existing application or add an additional application to the gateway device. The number of virtual applications that may exist within a given gateway device is limited by the computing resources of the gateway devices. Large numbers of virtualized applications within these containers may be supported by a single computing system if there is sufficient memory, network bandwidth, and CPU support to provide the processing needed by these applications. Gateway devices may be implemented with computing components to support these requirements.

[0087] The network interface module **350** provides an interface between the gateway device **115** and the main communications network **111**. Because this network **111** may include both private and public networks, thee network interface module **350** may also provide security between itself and a corresponding Remote Gateway module **120***a-c* over these more generally accessible data networks. One of ordinary skill will also recognize that the security functionality may also he located elsewhere in the IoT Host **110**

should the communications between the IoT Host **110** and the gateway device **115** also utilize accessible communications networks.

[0088] FIG. **4** illustrates an example of Remote Gateway devices and plurality of IoT devices in the IoT network according to yet another embodiment of the present invention. Within IoT network **103**, multiple Remote Gateway devices **120**_a-b_ may be included to support a large number of IoT edge devices **130**_a-e_. In the embodiment of FIG. **4**, two Remote Gateway devices **120**_a-b_ are shown supporting five IoT edge devise **130**_a-e_. Both of the Remote Gateway devices **120**_a-b_ are connected to the network **111** for communications to the IoT Host **110** via the Remote Gateway device **115** attached to the host **110**. Additionally, both Remote Gateway devices **120**_a-b_ are also connected to all five MT edge devices **130**_a-e_. When the IoT Host **110** communicates with one of the IoT edge devices **130**_a-e_, the message traffic may be transmitted via either Remote Gateway device **120**_a-b_ with the utilized Remote Gateway device using its connection to the particular IoT edge device **130**_a-e_. Should one of the remote gateway devices **120**_a-b_ or one of their connections to the particular IoT edge device fail, an alternate path may be used via the other Remote Gateway device. The number of multiple communications paths and thus alternate ways of communicating between the IoT Host **110** and the IoT edge devices depend upon the network topography of IoT network **103** and the number of devices existing in parallel.

[0089] In a typical embodiment in which the IoT edge devices comprise sensors, the number of Remote Gateway devices **120**_a-b_ and whether the particular gate device connects to an individual IoT sensor may also depend upon the type of sensor within the IoT edge device, the physical location of the IoT sensors, the amount of data to be transmitted by the IoT sensor, and any number of other factors. If the sensors are measuring conditions across a large physical space, the number and location of the sensors may determine the connections and number of Remote Gateway devices used as well as the cost in installing the sensors and connections to the Remote Gateway devices.

[0090] The connections between the Remote Gateway devices **120**_a-b_ and the IoT edge devices **130**_a-e_ may be implemented using any type of communications protocol and communications transport, that is supported by both the Remote Gateway devices and the IoT edge devices. These connections may be wired connections or wireless connections that may implement secure or unsecure communications as needed by the implementation. Examples of protocols that may be supported: Wifi, LoRaWAN, wired Ethernet, serial, Bluetooth, Zigbee, 4G Cellular, and fiber channel connections.

[0091] Within each Remote Gateway device **120**_a-b_, the devices include a host interface module **331**, a routing module **345**, an applications module **340**, and a network interface module **350**. The Applications module **340** may be coupled to an IoT application data storage database **341**. All of these modules perform the functions described above with respect to the gateway device **115** of FIG. **3**. Each of these Remote Gateway devices **120**_a-b_ control the portion of the IoT network **103** within its connections. In addition, alternative embodiments, may utilize multiple levels of Remote Gateway devices when appropriate because of the number of connections, the geographic locations to be covered, and similar factors that relate to design of a network. The Applications module **340** also supports the Docker containerized application functionality described above in reference to FIG. **3**.

[0092] FIG. **5** illustrates an example operator interface module within the IoT Host server according to an embodiment of the present invention. The Operator Interface module **315** includes an IoT Host Interface module **520**, an IoT Status Display module **515**, an IoT edge device mode configuration module **526**, a User Interface module **501**, an IoT Rendering module **505**, and a User Command Processing module **510**. The User Interface module is connected to a user console **302** to display data to an operator and to accept inputs to initiate commands.

[0093] The IoT Host-Command interface module **520** is connected to the IoT Host Control module **301** to provide a connection from the user console **302** to the operation of IoT Host **110**. The IoT Host-Command Interface module **520** also connects to the IoT Status Display module **515**, the User Interface module **501**, the IoT Rendering module **505**, and the User Command Processing module **510** within the Operator Interface module **315** for facilitating the interaction of the IoT Host **110** and all of the functions supported by the Operator Interface module **315**.

[0094] The IoT Status Display module **515** prepares a display of the current status of the IoT network **103** and its devices to the user console **302**. The IoT Status Display module **515** obtains the status information from the IoT Host Control module **301** and formats the data to match a user interface (UI) that is to be presented on the user console **302**. The IoT Status Display module **515** communicates with the user console **302** via the User Interface module **501**.

[0095] The User Interface module **501** provides a communications interface between the Operator Interface module **315** and the user console **302**. The module **501** provides the data formatting for the protocol and transport mechanism needed to communicate with the user console **302**. As such, all of the modules in the Operator Interface module **315** may communicate with the user console **302** regardless of the type of connection used to communicate with the user console **302**. As noted above, the connection may be a wireless connection, a network connection, and a direct wired connection.

[0096] The IoT Rendering module **505** prepares a display of the current topography of the network **103** and its devices. The IoT Rendering module **505** also prepares for display to an operator an indication of the operating mode for each IoT edge device. The IoT Rendering module **505** obtains the status information from the IoT Host Control module **301** and formats the data to match a user interface (UI) that is to be presented on the user console **302**. The IoT Rendering module **505** communicates with the user console **302** via the User interface module **501**.

[0097] The User Command Processing module **510** receives commands initiated by an operator via the user console **302** and generates all necessary requests to other modules within the IoT Host **110** to implement the command. The user command processing module **510** communicates with the user console **302** via the user interface module **501**. The user command processing module **510** communicates with other modules within the IoT Host **110** via the IoT Host-Command Interface module **520**. In most commands, the User Command Processing module **510** will communicate with the IoT Host Control module **301** when initiating the user commands; however, one of ordinary skill in the art will recognize that the User Command Processing module **510** may directly communicate with any module within the IoT Host **110** to initiate a command. When a command is associated with a change in an operating mode for an IoT edge device **130***a*, the User Command Processing module **510** communicates with the IoT edge device mode configuration module **326** to generate the necessary configuration data to be sent to the IoT edge devices to change their operating modes.

[0098] The IoT edge device mode configuration module **526** generates the necessary configuration data to be sent to the IoT edge devices to change their operating modes. The IoT edge device mode configuration module **526** may obtain configuration data that has been stored within the IoT application data storage database **341** or generate the configuration data as needed.

[0099] FIG. **6** illustrates an IoT Edge Device Discovery within the IoT Host server according to another embodiment of the present invention. The IoT Edge Device Discovery module **305** communicates with all of the devices in IoT network **103** to determine the status and topography of the network. The IoT Edge Device Discovery module **305** contains a Node Query module **610**, a Topography/Redundancy/Mode Module **615**, a Node Functionality Recommendation module **605**, and an IoT Host interface module **601**.

[0100] The Node Query module **610** at start up sends out a broadcast command to all of the devices within the IoT network **103** requesting its identity, its connected devices, and its status. Each of these devices forward the discovery request to all of the devices connected to the device. The discovery request will possess an ID or timestamp so that these devices may recognize when they are receiving multiple copies of the same request. The devices may only forward the first occurrence of the discovery request while ignoring the later requests. As such, the discovery request will eventually be received by all of the devices within IoT network **103**.

[0101] The devices in IoT network **103** will respond to the first request by returning to the IoT device discovery module **305** its identity, its location, an identity of all of the devices directly attached to the device, and an identifier for every communications link between each of the devices. The IoT device discovery module **305** may also receive other status information regarding the devices health and operating status. All of the received data is then made available to the Topography/Redundancy Module **615**.

[0102] Using all of the received data, the Topography/Redundancy Module **615** may construct a topography graph for the IoT network **103**. The topography graph may be maintained within the topography graph to permit the IoT Host control module **301** or the operator interface module **315** to obtain a current status for all of the devices and connection paths within IoT network **103**. The Topography graph contains all of the devices in the IoT network **103**, all of the connections between these devices, and is organized into a traversable graph that illustrates every communications path from the IoT Host **110** and every IoT Edge Device **130**. The Topography/Redundancy Module **615** identifies a primary communications path and all possible alternate communications paths to each IoT Edge Device **130**.

[0103] The Node Functionality Recommendation module **605** utilizes the topography graph created in the Topography/Redundancy/Mode Module **615** to determine what, if any, applications may be needed in each of the Remote Gateway devices **120** to support the IoT edge devices as well as the operating modes, both default and alternate operations. The Node Functionality Recommendation module **605** may use the number of IoT edge devices **130** that are connected to a particular Remote Gateway Device **120** to determine whether an application is best located at that Remote Gateway Device, or is best located at a higher or lower Gateway Device between the IoT Edge Device **130** and the IoT Host **110**. Other factors in determining the applications needed by each of the Remote Gateway Devices **120** may include, the number of device types contained within primary communications paths thru the particular Gateway Device, an estimated amount of message traffic and corresponding data to be passing thru the particular Gateway Device, an estimate of the processing requirements for the estimated amount of traffic and data, and the resources available in other Remote Gateway devices. These recommendations may be made available to the Gateway Config Module **310** for use in configuring all of these devices.

[0104] The Host-Topography interface module **601** is connected to the IoT Host control module **301** to provide a connection from the Topography/Redundancy Module **615** to the IoT Host **110**. The Host-Topography interface module **601** provides the data formatting for the protocol and transport mechanism needed to communicate with the IoT Host Interface Module **330**. As such, all of the modules in the IoT Edge Device Discovery may communicate with the IoT Host **110** regardless of the type of connection used to communicate with IoT Host **110**.

[0105] FIG. **7** illustrates a System Monitor/Failover module within the IoT Host server according to an embodiment of the present invention. The System Monitor/Failover module **325** actively monitors the status of all of the Remote Gateway Devices **120** and all of the IoT edge Devices **130** that are part of the IoT network **103**. The System Monitor/Failover module **325** obtains the topography of IoT network **103** from IoT Host Discovery module **305** as well as the primary and alternate communications paths from IoT Host **110** and each of the IoT Edge devices **130**. The dynamic reconfiguration module **711** determines a default operating mode for each IoT edge device as well as alternate operating modes used by operators for scheduled and non-scheduled events as discussed above.

[0106] The System Monitor/Failover module **325** may monitor the status of the devices by monitoring the message traffic that returns to the IoT Host **110** to identify a period of time in which one or more of the devices have not responded that may be greater than a predetermined value. The System Monitor/Failover module **325** may then, or as an alternative to monitoring traffic, may ping each device with a status query message. Failure to receive a response to the query may be used to indicate a failure. The System Monitor/Failover module **325** may attempt to communicate with all of the other devices in a particular communications path to isolate the one or more devices that are failing as well as determine if the failure is related to on communications link between two devices where the devices are otherwise operating.

[0107] In other embodiments, Remote Gateway devices **120** may be tasked with the responsibility to monitor the attached IoT Edge devices **130** using a containerized application. This application may transmit the failure information to The System Monitor/Failover module **325** to initiate further failover processing. The System Monitor/Failover module **325** includes a Host-Failover Interface module **715**, a Node Status Monitoring module **710**, a Node Failover module **701**, a Node Failover Rules module **705**, and an IoT Device Failover Options database **326** coupled to the Node Failover module **701** and the Node Failover rules module **705**. This application may also perform processing needed to support any default and alternate operating modes for IoT edge devices.

[0108] The Host-Failover Interface module **715** is connected to the IoT Host control module **301** to provide a connection from the System Monitor/Failover module **325** to the IoT Host **110**. The Host-Failover Interface module **715** provides the data formatting for the protocol and transport mechanism needed to communicate with the IoT Host Interface Module **330**. As such, all of the modules in the Host-Failover Interface module **715** may communicate with the IoT Host **110** regardless of the type of connection used to communicate with the IoT Host.

[0109] As discussed above, the Node Status Monitoring module **710** may monitor the operating status of each of the devices in IoT network **103** in multiple ways. The Node Status Monitoring module **710** implements the chosen monitoring mechanism, determines the failure in as much detail as is possible, and initiates a failover operation.

[0110] The Node Failover module **701** performs a failover operation once identified by the Node Status Monitoring module **710**. The Node Failover module **701** determines all of the functions to be provided by the failed device, determines one or more possible reconfiguration of the devices within IoT network **103**, and initiates a reconfiguration of the effected devices to implement the reconfiguration. The Node Failover module **701** interacts with the Node Failover Rules module **705** when identifying the type of reconfiguration to be implemented. For example, if IoT network **103** possesses an available inactive backup device for the failed device, the Node Failover Rules module **705** may instruct the Node Failover module **701** to utilize the available device. Similarly, if IoT network **103** possesses multiple communications paths to all of the IoT Edge devices **130** that correspond to a no longer working communications path that went thru a failed Remote Gateway device **120**, the Node Failover Rules module **705** may instruct the Node Failover module **701** to reconfigure the primary communications paths to be used to support the IoT Edge devices **130**. When the reconfiguration of a Remote Gateway device or the communications paths passing thru the Remote Gateway occurs, any containerized applications within the failed Remote Gateway device may need to be added to other devices taking over its function. The Node Failover module **701** ensures that all of these operations are successfully implemented.

[0111] In one embodiment, the Node Failover module **701** may communicate with the Gateway Config module **310** to request the reconfiguration operation to occur. The reconfiguration of devices and primary communications paths are similar to the initial configuration of these devices at startup that is performed by the Gateway Config module **310**. In an alternate embodiment, the Node Failover module **701** may directly communicate with the devices to be reconfigured in a manner that is similar to the original configuration to ensure that the reconfiguration takes into account the current operations being performed with the devices to be reconfigured. In the latter case, the Node Failover module **701** may obtain any data and containerized applications needed for the reconfiguration operations from the Gateway Config module **310**.

[0112] The Node Failover Rules module **705** processes a set of reconfiguration rules from a set of rules in the IoT Device Failover Options database **326** that it determines are applicable to the type of failover situation that has been detected. By processing the applicable set of rules, a failover configuration is returned to the Node Failover module **701** for implementation.

[0113] Both the Node Failover module **701** and the Node Failover rules module **705** access the database **326** to identify alternatives for the device that has failed. The database **326** may contain information regarding the devices in IoT network **103**, the functions performed by each of these devices, the containerized applications that may be used in Remote Gateway devices **120** to support particular IoT edge devices **130** attached to each of the Remote Gateway devices **120**, as well as failover options corresponding to one or more of the expected configuration options for all of the devices within IoT network **103**.

[0114] FIG. **8***a* illustrates a Gateway Config module within the IoT Host server as an example embodiment of the present invention. The Gateway Config module **310** generates all of the configuration data, containerized applications, primary and alternate communications paths, and gateway device functionality required to configure all of the devices within IoT network **103**. The Gateway Config module **310** includes a Gateway Config Control module **801**, an IoT Host-Config Interface module **805**, an Operator Config Interface module **822**, an IoT Network User Config/Present module **833**, a Gateway Routing Rules module **810**, a Gateway Functionality module **815**, a dynamic gateway reconfig module **811**, and a Gateway Application Config module **820** coupled to a Gateway Application database **311**.

[0115] The Gateway Config Control module **801** defines the functionality of the Remote Gateway devices **120** within the IoT network **103** in cooperation with the Gateway Routing Rules module **810**, the Gateway Functionality module **815**, and the Gateway Application Config module **820**. The Gateway Config Control module **801** also interacts with the Operator Config Interface module **822**, and the IoT Network User Config/Present module **833** to permit a user from providing input o assist in defining the desired functionality of the devices in the IoT network **103**. The Gateway Config Control module **801** receives the network topography obtained from the Topography/Redundancy Module **615**, the primary and alternate communications paths within the IoT network **103** from Gateway Routing Rules module **810**, the functionality to be located within each of the Remote Gateway devices **120** from the Gateway Functionality module **815**, and the containerized applications to be used within the Gateway devices **120** from the Gateway Application Config module **820**,

[0116] Using all of this data, the Gateway Config Control module **801** creates a set of configuration data for the devices in the IoT network **103**. The module **801** uploads all the configuration data and containerized applications to the devices in the IoT network **103** and when all are configured, initiates the enabling of the devices to begin operation.

[0117] The IoT Host-Config interface module **805** is connected to the IoT Host control module **301** to provide a connection from the Gateway Config module **310** to the IoT Host **110**. The IoT Host-Config interface module **805** provides the data formatting for the protocol and transport mechanism needed to communicate with the IoT Host Interface Module **330**. As such, all of the modules in the IoT Host-Config Interface module **805** may communicate with the IoT Host **110** regardless of the type of connection used to communicate with the IoT Host.

[0118] The Operator Config Interface module **822** provides a communications interface between the Operator Config Interface module **822** and the user config terminal **824**. The module **822** provides the data formatting for the protocol and transport mechanism needed to communicate with the user config terminal **824**. As such, all of the modules in the Gateway Config module **310** may communicate with the user config terminal **824** regardless of the type of connection used to communicate with the user console **302**. As noted above, the connection may be a direct connection, a networked connection, a wired connection or a wireless connection. Additionally, the Operator Config Interface module **822**, in alternate embodiments, may communicate with the user console **302** used to control the operation of the IoT Host **110**.

[0119] The IoT Network User Config/Present module **833** assists a user to configure the IoT network **103** by presenting the user with a representation of a configured IoT network with an ability to vary one or more defining parameters. A user may view a proposed topography for the IoT network **103** and the functionality of the Edge devices **130** as well as the functionality of the Remote Gateway devices **120** to determine if system requirements may be met. The user may vary one or more of the defining parameters and the IoT Network User Config/Present module **833** modifies the display of the proposed IoT network **103** as affected by the parameter modification.

[0120] The Gateway Routing Rules module **810** defines the primary and secondary communications paths to be used within the IoT network **103**. The Gateway Routing Rules module **810** utilizes the network topography obtained from the Topography/Redundancy Module **615** and its internal rules to determine the primary communications paths for each of the IoT Edge devices **130** to the IoT Host **110**. The Gateway Routing Rules module **810** may select the primary communications path by determining the communications path from the IoT Edge device to the IoT Host **110** using a selection criteria. The selection criteria fray include the most direct path, the path having the fewest connections, the path having the lowest latency as measured by a determination using the communications bandwidth and estimated message traffic, or a multi-level priority scheme that ensures priority to message traffic depending upon the function of the IoT Edge device **130** and/or the functionality present in a Remote Gateway device **120** in the communications path. Additionally, the Gateway Routing nodule **810** may also include a process to check the status of all primary and alternate communications paths by forcing message traffic thru each path in order to determine its status. This process may use a round robin, least recently used, and similar methodologies to determine which of the communications paths may be tested at any given time.

[0121] AU of the identified non-primary communications paths will then be considered alternate paths for use in reconfiguration. Also, a primary communications path may consist of two different identified communications paths that both transport message traffic based upon a real-time estimate of the latency and message congestion present in the multiple paths. The primary communications paths may be determined to support the fastest communications or the use of a minimum number of devices or some combination of both approaches as needed to support the performance of the IoT network **103**.

[0122] The Gateway Functionality module **815** defines the functionality to be located within each of the Remote Gateway devices **120** to support the needs of the IoT network **103**. The Gateway Functionality module **815** utilizes the network topography obtained from the Topography/Redundancy Module **615**, the primary communications paths for each of the IoT Edge devices **130** to the IoT Host **110** from the Gateway Routing Rules module **810**, and its own internal rules to define the functionality for each Remote Gateway device **120**. The Gateway Functionality module **815** may select functions needed by determining the data processing needs for data received from the IoT Edge devices **130** before passage to the IoT Host **110** using a selection criteria. The selection criteria may include the number, type, and functions of the IoT Edge devices **130**, the available containerized applications from the Gateway Application Config module **820**, the processing capacity of each Remote Gateway device **120** present within each primary communications path between the IoT Edge devices **130** to be supported by the Gateway device, and the availability of other Remote Gateway devices **120** that are available for load sharing. Once the functionality is defined, the processing communicates with the Gateway Application Config module **820** for identification of the containerized applications to be used in configuring the Remote Gateway devices **120**.

[0123] The dynamic gateway reconfig module **811** processes any requests to reconfigure the network to assign more bandwidth to one set of IoT devices and less bandwidth to a second set of IoT devices based upon the current operating mode for each of the IoT devices.

[0124] The Gateway Application Config module **820** determines the containerized application to be used in the Remote Gateway devices **120** to provide the needed functionality of the gateway devices. The Gateway Application Config module **820** is coupled to the Gateway Application database **311** to obtain the possible applications needed to implement the gateway functionality as defined within the Gateway Functionality module **815**. The Gateway Application Config module **820** and the Gateway Application database **311** may possess all of the containerized applications available for use in the IoT network **103**. If the requirements for the Remote Gateway device's applications depend upon characteristics of the individual Remote Gateway device such as support for a particular operating system or version of a Gateway device, the Gateway Application database **311** may contain the needed versions for an application for each of these possible variations.

[0125] FIG. **8*b*** illustrates an IoT Network User Config/Present module within the IoT Host server as an example embodiment of the present invention. The IoT Network User Config/Present module **833** assists a user to configure the IoT network **103** by presenting the user with a representation of a configured IoT network with an ability to vary one or more defining parameters. These parameters may include, the number of device types contained within primary communications paths thru the particular Gateway Device, an estimated amount of message traffic and corresponding data to be passing thru the particular Gateway Device, an estimate of the processing requirements for the estimated amount of traffic and data, and the resources available in other Remote Gateway devices. These parameters may also include the most direct communications path, the communications path having the fewest connections, the communications path having the lowest latency as measured by a determination using the communications bandwidth and estimated message traffic, or a multi-level priority scheme that ensures priority to message traffic depending upon the function of the IoT Edge device **130** and/or the functionality present in a Remote Gateway device **120** in the communications path, and any other factor used in the routing and application configuration.

[0126] The IoT Network User Config/Present module **833** includes an IoT Network Display Control module **841**, an IoT Network Parameters module **842**, IoT Network Display Rendering module **843**, and an IoT Device Config module **844**. The IoT Network Display Control module **841** is coupled to the Operator Interface module **822** to provide display data to the user terminal **824** and to receive user commands from the user terminal **824** to modify the defining parameters of the IoT network **103**. The IoT Network Display Control module **841** also coordinates the processing of the other modules within the IoT Network User Config/Present module **833** to generate the proposed topography for the IoT network **103** and the functionality of the IoT Edge devices **130** as well as the functionality of the Remote Gateway devices **120**. The IoT Network Display Control module **841** receives user commands and processes them to change the defining parameters for IoT network **103** and it proposed configuration.

[0127] The IoT Network Parameters module **842** presents the defining parameters for IoT network **103** to the user via the user terminal **824** in a graphical form. The user may interact with the defining parameter settings to change the configuration of the IoT network **103**. The IoT Network Display Control module **841** may display any or all of the defining parameters grouped into logical collections of similar parameters. Each defining parameter may be represented by a graphical user interface object such as a user controlled slider, a user modifiable numeric value, a user controlled dial or similar user interface object that permits the modification of each defining parameter within a predefined range of values. Once the user modifies one or more defining parameters, the IoT Network Display Control module **841** receives the updated parameters and causes the proposed topography and device functionality to be updated.

[0128] The IoT Network Display Rendering module **843** generates a visual representation of the topography and device functionality for the proposed IoT network **103** using the current values for the defining parameters and presents the visual representation to the user on the user terminal **824**. Each time the defining parameters are updated, the IoT Network Display Rendering module **843** generates a new visual representation of the topography and device functionality for the proposed IoT network **103**.

[0129] The IoT Device Config module **844** generates all of the configuration data for the devices within the network **103** once the user is satisfied with the topography and device functionality for the proposed IoT network **103**. The module **844** may perform the configuration directly or using the Gateway Config module **310** discussed in reference to FIG. **8***a*. The configuration data and corresponding containerized applications may be uploaded to the devices within IoT network **103** to initiate operation of the network.

[0130] FIG. **9** illustrates a flowchart of possible operations that may be performed according to an embodiment of the present invention. The sequence of operations of FIG. **9** correspond to the operation of network of multi-state edge devices of FIG. **1-8** above when the edge devices are operating in a default state. The process begins in block **901** in which a default operating state is determined for each of the multi-state edge devices. In block **903**, a set of configuration data is generated for each of the multi-state edge devices that will place the devices into the default operating state.

[0131] Block **905** determines a recommended network topography and edge gateway operating parameters to support network communications when he edge devices are operating in the default state. Block **907** then generates a set of configuration data for the edge device network modules and the edge gateways to generate the recommended network topography and edge gateway operating parameters.

[0132] All of the above generated configuration data is transmitted by the IoT host server to the edge devices and edge gateways in block **909**. Once all of the data is in place in the devices, block **910** starts the operation of the devices that causes the network of IoT devices and its network to operate in its default state. The network and devices remain in this default operating state until the detection of a detected event in which a new operating state corresponding to the requirements of the detected event are generated.

[0133] FIG. **10** illustrates a flowchart of possible operations that may he performed by an IoT network according to an embodiment of the present invention. The sequence of operations of FIG. **10** correspond to the operation of network of multi-state edge devices of FIG. **1-8** above when the edge devices are operating in an updated state upon the receipt of a detected event by the IoT host server. The process begins in block **1001** in which the updated operating state is determined for each of the multi-state edge devices needed to support the detected event. As discussed above, the detected event may correspond to a scheduled event or an external event received by the IoT host server. In block **1003**, a set of configuration data is generated for each of the multi-state edge devices that will place the devices into the updated operating state for the detected event.

[0134] Block **1005** determines an updated network topography and edge gateway operating parameters to support network communications when the edge devices are operating in the updated state. Depending upon the needs of the network in the updated state, the network configuration, topography, and allocated bandwidth may change as needed. Block **1007** then generates a set of configuration data for the edge device network modules and the edge gateways to generate the updated network topography and edge gateway operating parameters.

[0135] All of the above updated configuration data is transmitted by the IoT host server to the edge devices and edge gateways in block **1009**. Once all of the data is in place in the devices, block **1010** restarts the operation of the devices that causes the network of IoT devices and its network to operate in its new operating state. The network and edge devices will remain in the updated state until the next detected event in which the IoT host server will again reconfigure all of the devices; either to a second updated state or back to the default operating state depending upon the next detected event.

[0136] While the above embodiments of the present invention describe the interaction of System and Method for Providing Secure and Redundant Communications and Processing for a Collection of Internet of Things (IoT) Devices, one skilled in the art will recognize that the use of software within programmable servers may be replaced with firmware or programmable logic within the network devices. It is to be understood that other embodiments may be utilized and operational changes may be made without departing from the scope of the present invention.

[0137] One of ordinary skill in the art will appreciate that any process or method descriptions herein may represent modules, segments, logic or portions of code which include one or more executable instructions for implementing logical functions or steps in the process. It should be further appreciated that any logical functions may be executed out of order from that described, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art. Furthermore, the modules may be embodied in any non-transitory computer readable medium for use by or in connection with an instruction execution system, apparatus, or device, such as a computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions. It will be apparent to those skilled in the art that many changes and substitutions can be made to the embodiments described herein without departing from the spirit and scope of the disclosure as defined by the appended claims and their hill scope of equivalents.

What is claimed is:

1. A method for configuring a plurality of multi-state network devices within a dynamically configurable multi-path communications network within a IoT host server, the method comprising:

determining a default state for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network;

determining a set of node configuration data for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network corresponding to the default state;

determining a recommended network topography and gateway functionality using a set of defining parameters;

determining a set of gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality;

transmitting the set of node configuration data for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network and the set of gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality from the IoT host server;

starting the operation of each of the plurality of multi-state devices within the dynamically configurable multi-path communications network and the set of gateway devices.

2. The method according to claim **1**, wherein the method further comprises:

responding to a detected event by the IoT host server by:

determining a default state for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network;

determining an updated set of node configuration data for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network corresponding to a new device state needed by the detected event;

determining recommending an updated network topography and updated gateway functionality using a set of defining parameters as needed by the detected event;

determining a set of updated gateway configuration data for the set of gateway devices corresponding to the updated recommended network and gateway functionality;

transmitting the set of updated node configuration data for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network and the set of updated gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality from the IoT host server;

restarting the operation of each of the plurality of multi-state devices within the dynamically configurable multi-path communications network and the set of gateway devices.

3. The method according to claim **2**, wherein the detected event corresponds to a scheduled event.

4. The method according to claim **2**, wherein the detected event corresponds to an external event.

5. A computer program product for configuring a set of network devices, comprising:

a non-transitory computer-readable medium comprising a set of instructions that when executed by a programmable computing device causes the computing device to implement a method for configuring a set of network devices, the method comprising:

determining a default state for each of the plurality of multi-state edge devices within the dynamically configurable multi-path communications network;

determining a set of node configuration data for each of the plurality of multi-state edge devices within the dynamically configurable multi-path communications network corresponding to the default state;

determining a recommended network topography and gateway functionality using a set of defining parameters;

determining a set of gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality;

transmitting the set of node configuration data for each of the plurality of multi-state edge devices within the dynamically configurable multi-path communications network and the set of gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality from the IoT host server;

starting the operation of each of the plurality of multi-state edge devices within the dynamically configurable multi-path communications network and the set of gateway devices.

6. The computer program product according to claim **5**, wherein the method further comprises:

responding to a detected event by the IoT host server by:

determining a default state for each of the plurality of multi-state devices within the dynamically configurable multi-path communications network;

determining an updated set of node configuration data for each of the plurality of multi-state edge devices within the dynamically configurable multi-path communications network corresponding to a new device state needed by the detected event;

determining recommending an updated network topography and updated gateway functionality using a set of defining parameters as needed by the detected event;

determining a set of updated gateway configuration data for the set of gateway devices corresponding to the updated recommended network and gateway functionality;

transmitting the set of updated node configuration data for each of the plurality of multi-state edge devices within the dynamically configurable multi-path communications network and the set of updated gateway configuration data for a set of gateway devices corresponding to the recommended network and gateway functionality from the IoT host server;

restarting the operation of each of the plurality of multi-state devices within the dynamically configurable multi-path communications network and the set of gateway devices.

7. The method according to claim **6**, wherein the detected event corresponds to a scheduled event.

8. The method according to claim **6**, wherein the detected event corresponds to an external event.

9. A distributed computing system, having an IoT Host server, one or more Gateway devices, and a plurality of IoT Edge devices, for configuring a set of network devices, the IoT Host computer comprising:

an IoT Device Discovery module for discovering all devices within an IoT network, the IoT network comprising an IoT Host computer, one or more gateway devices, and a plurality of IoT Edge devices;

a Gateway Config module for recommending a network topography and node functionality using a set of defining parameters;

an operator interface module for accepting modifications to one or more of the defining parameters within the set of defining parameters;

a Network Present module for updating the network topography and node functionality using the modifications to the defining parameters; and

an edge device config module for determining an operating state for each of the plurality of multi-state edge devices within the dynamically configurable multi-path communications network;

wherein the operating state for each of the plurality of multi-state edge devices includes a default state and an updated state for each detected event; and

each detected event includes a scheduled event and an external event.

10. The distributed computing system according to claim **9**, wherein the plurality of IoT edge devices comprises:

a network interface module;

a sensor module; and

a multi-state control module.

* * * * *