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Swengler

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(54) **SYSTEM AND METHODS FOR INTERNET OF THINGS (IOT) DEVICE AUTHENTICATION AND SECURITY**

(71) Applicant: **Paul Stuart Swengler**, Honolulu, HI (US)

(72) Inventor: **Paul Stuart Swengler**, Honolulu, HI (US)

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H04W 88/16	(2009.01)
H04L 29/06	(2006.01)

(52) **U.S. Cl.**
CPC ***H04L 67/146*** (2013.01); ***H04L 63/0236*** (2013.01); ***H04L 63/0876*** (2013.01); ***H04L 67/125*** (2013.01); ***H04W 88/16*** (2013.01)

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CPC H04L 63/08; H04L 67/125; H04L 67/146; H04L 67/42; H04L 45/12; H04L 45/128; H04W 40/00; H04W 28/18
See application file for complete search history.

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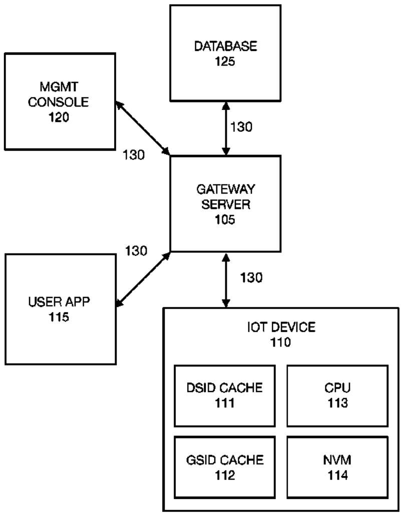
Primary Examiner — Raj Jain
(74) *Attorney, Agent, or Firm* — Law Office of Steven R. Olsen, PLLC; Steven R. Olsen

(57) **ABSTRACT**

One or more IoT devices are coupled to a gateway server. The gateway server preferably includes enhanced administrative features for restricting access to IoT devices, and for monitoring IoT device communications. In embodiments of the invention, communications between the gateway server and IoT devices are secured, in part, via IP address restriction, the use of transitory identifiers, and/or encryption.

10 Claims, 12 Drawing Sheets



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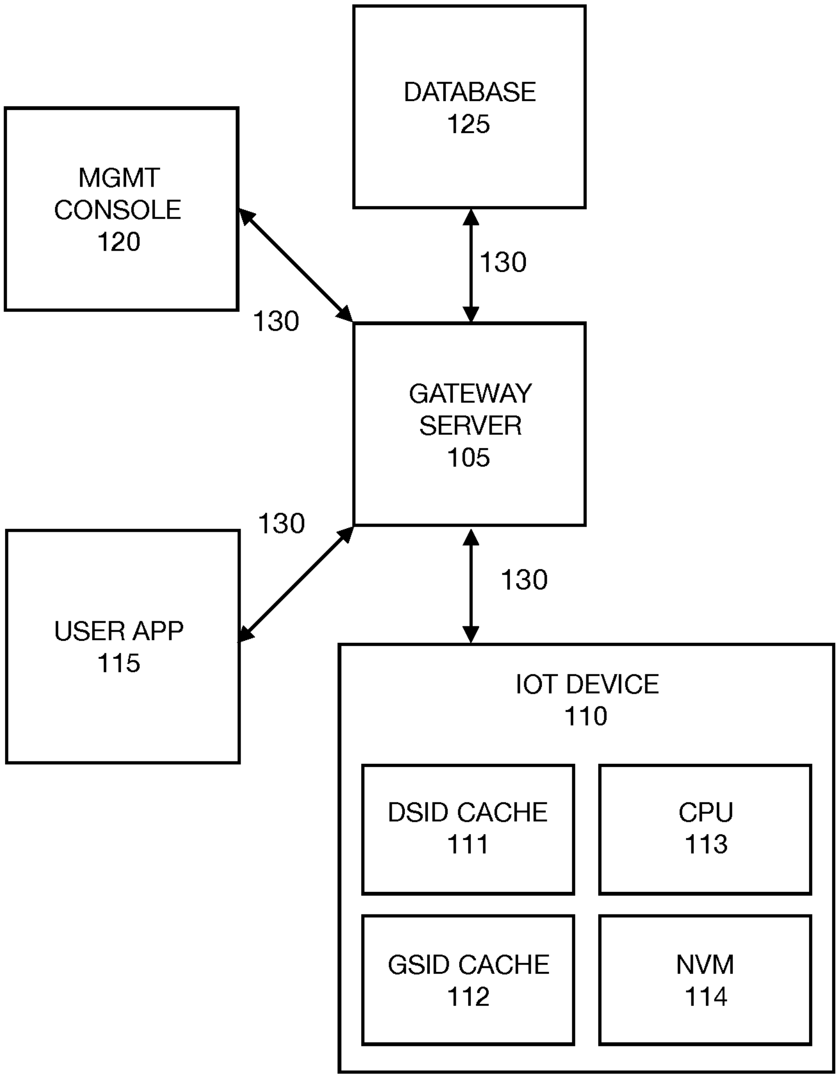

DATABASE
125
MGMT
CONSOLE
120
130
130
GATEWAY
SERVER
105
130
USER APP
115
130
IOT DEVICE
110
DSID CACHE
111
CPU
113
GSID CACHE
112
NVM
114

FIG. 1

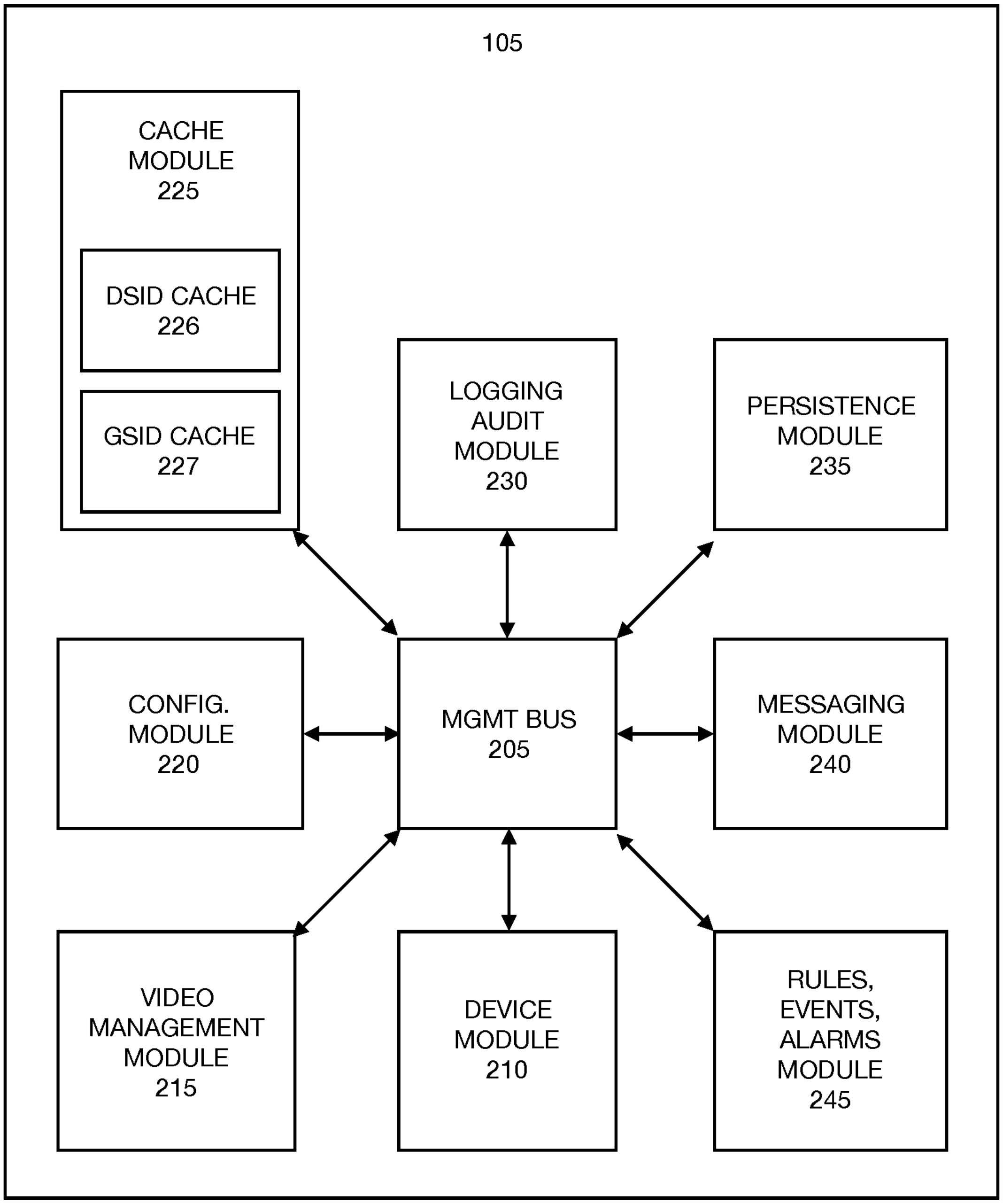

105
CACHE MODULE 225
DSID CACHE 226
GSID CACHE 227
LOGGING AUDIT MODULE 230
PERSISTENCE MODULE 235
CONFIG. MODULE 220
MGMT BUS 205
MESSAGING MODULE 240
VIDEO MANAGEMENT MODULE 215
DEVICE MODULE 210
RULES, EVENTS, ALARMS MODULE 245

FIG. 2

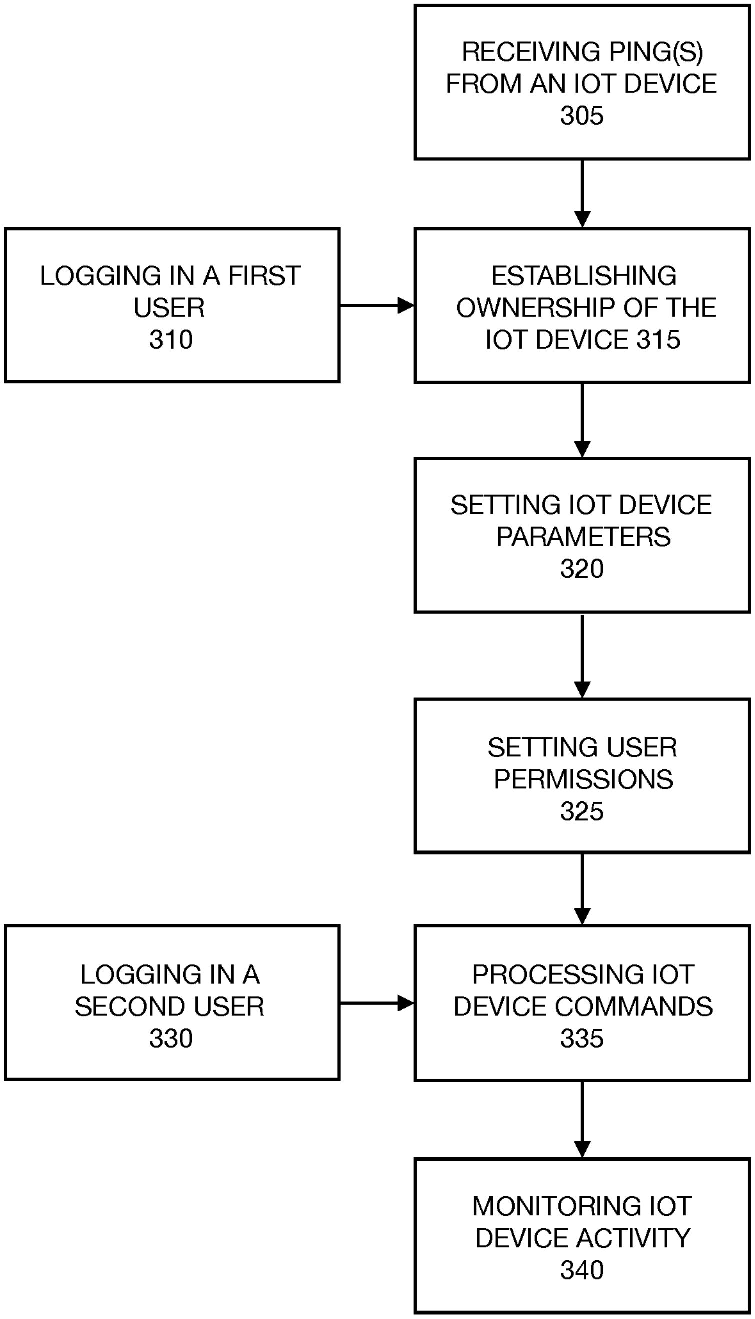

RECEIVING PING(S) FROM AN IOT DEVICE 305
LOGGING IN A FIRST USER 310
ESTABLISHING OWNERSHIP OF THE IOT DEVICE 315
SETTING IOT DEVICE PARAMETERS 320
SETTING USER PERMISSIONS 325
LOGGING IN A SECOND USER 330
PROCESSING IOT DEVICE COMMANDS 335
MONITORING IOT DEVICE ACTIVITY 340

FIG. 3

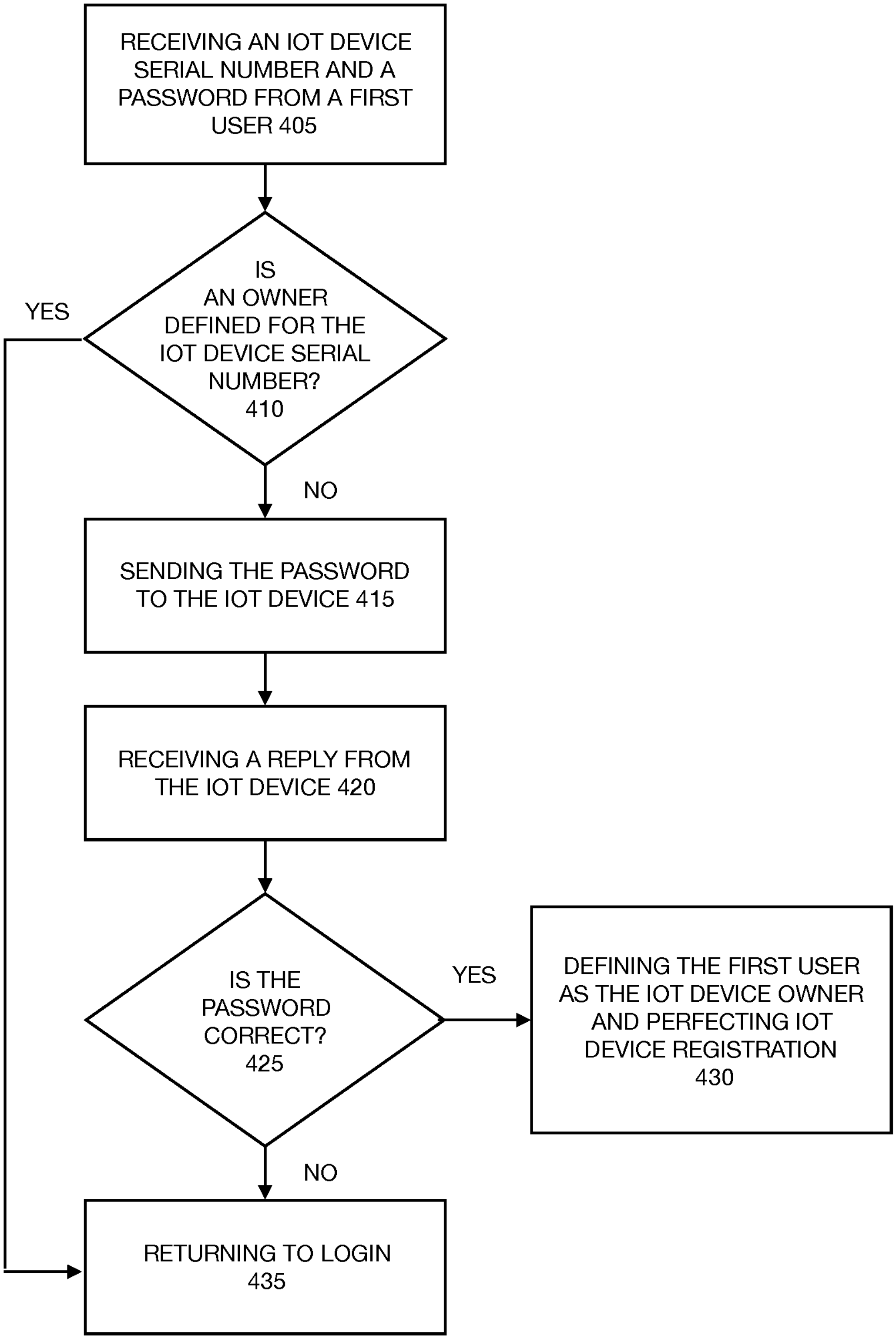

RECEIVING AN IOT DEVICE SERIAL NUMBER AND A PASSWORD FROM A FIRST USER 405
IS AN OWNER DEFINED FOR THE IOT DEVICE SERIAL NUMBER? 410
YES
NO
SENDING THE PASSWORD TO THE IOT DEVICE 415
RECEIVING A REPLY FROM THE IOT DEVICE 420
IS THE PASSWORD CORRECT? 425
YES
DEFINING THE FIRST USER AS THE IOT DEVICE OWNER AND PERFECTING IOT DEVICE REGISTRATION 430
NO
RETURNING TO LOGIN 435

FIG. 4

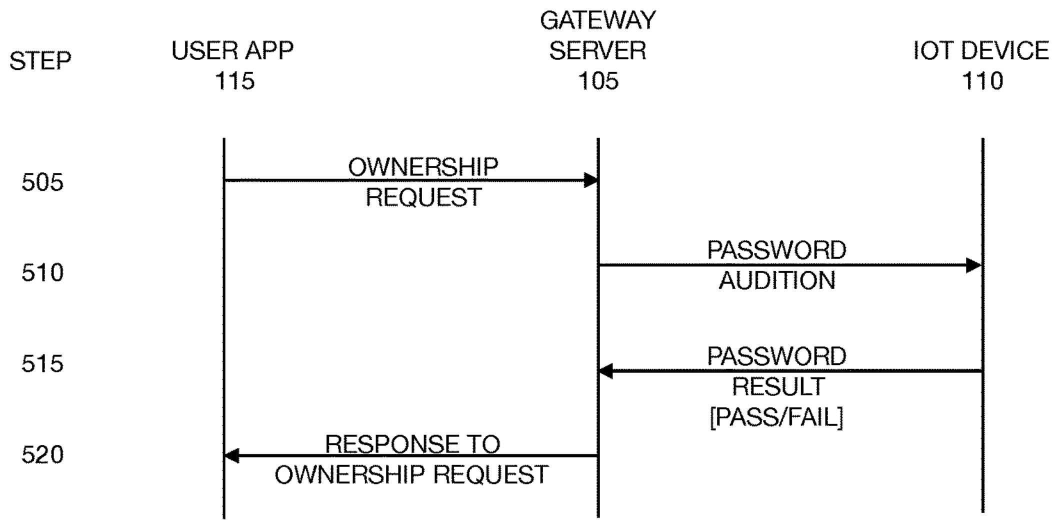

STEP
USER APP
115
GATEWAY
SERVER
105
IOT DEVICE
110
505
OWNERSHIP
REQUEST
510
PASSWORD
AUDITION
515
PASSWORD
RESULT
[PASS/FAIL]
520
RESPONSE TO
OWNERSHIP REQUEST

FIG. 5

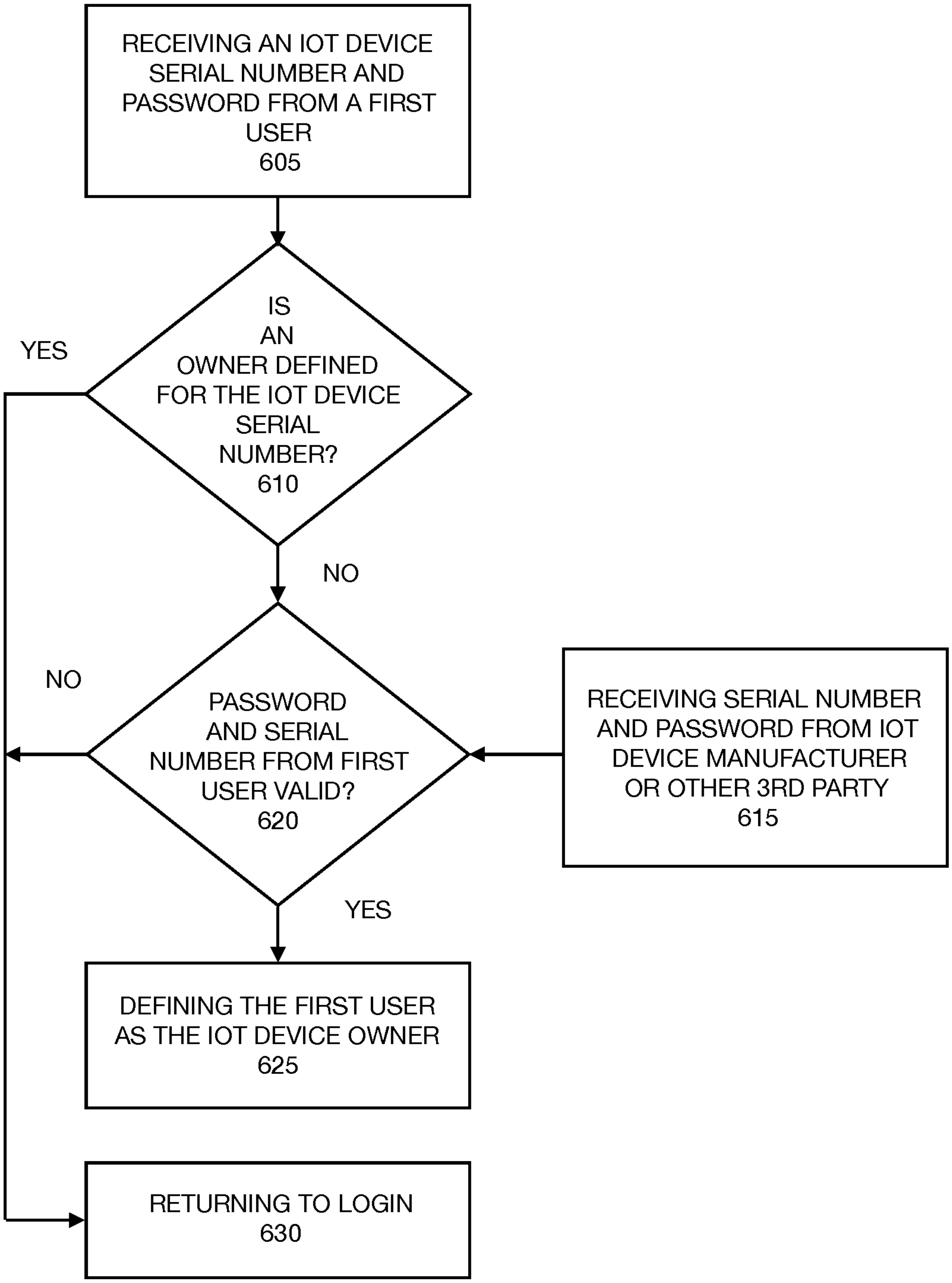

RECEIVING AN IOT DEVICE SERIAL NUMBER AND PASSWORD FROM A FIRST USER
605
IS AN OWNER DEFINED FOR THE IOT DEVICE SERIAL NUMBER?
610
YES
NO
PASSWORD AND SERIAL NUMBER FROM FIRST USER VALID?
620
NO
YES
RECEIVING SERIAL NUMBER AND PASSWORD FROM IOT DEVICE MANUFACTURER OR OTHER 3RD PARTY
615
DEFINING THE FIRST USER AS THE IOT DEVICE OWNER
625
RETURNING TO LOGIN
630

FIG. 6

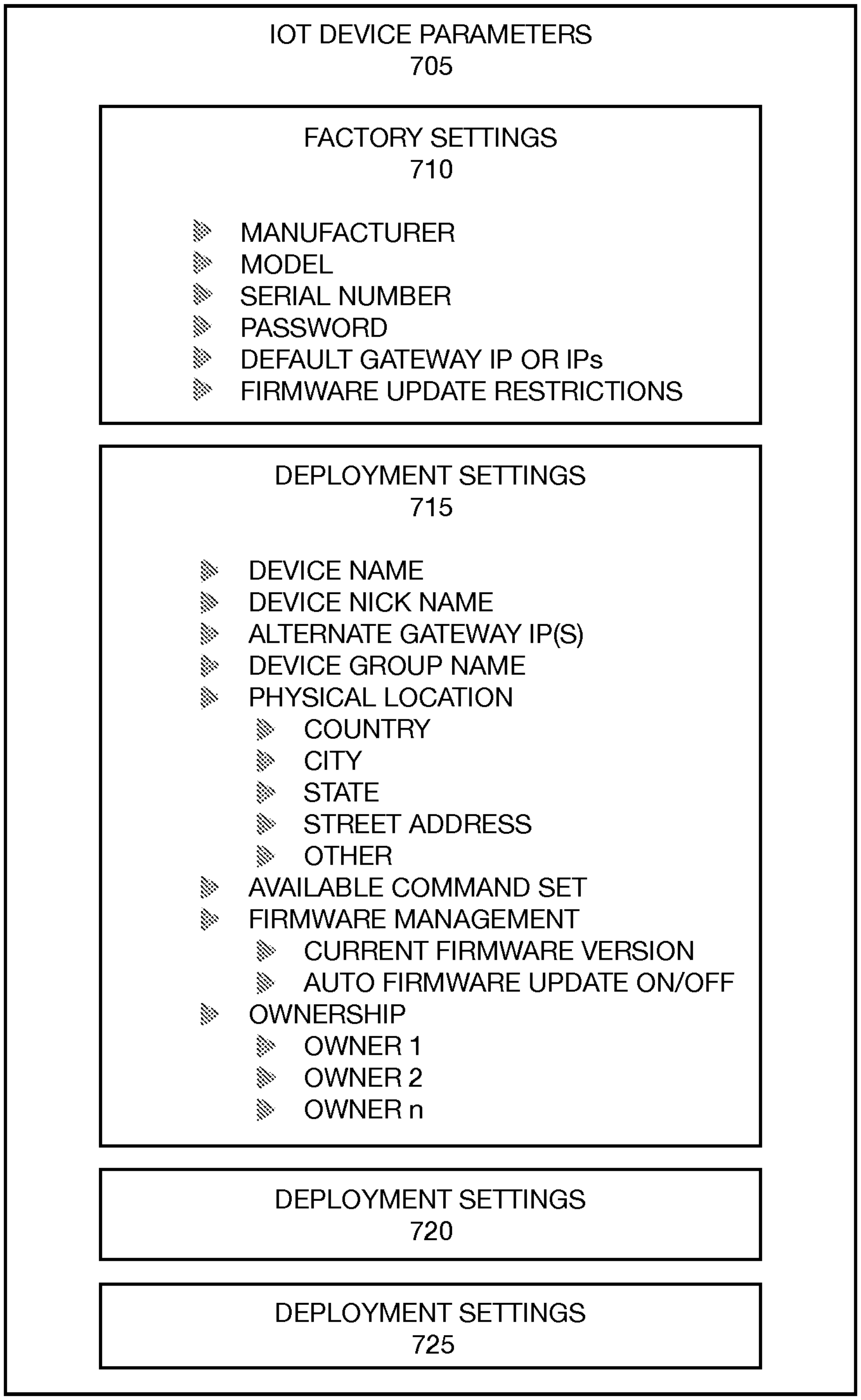
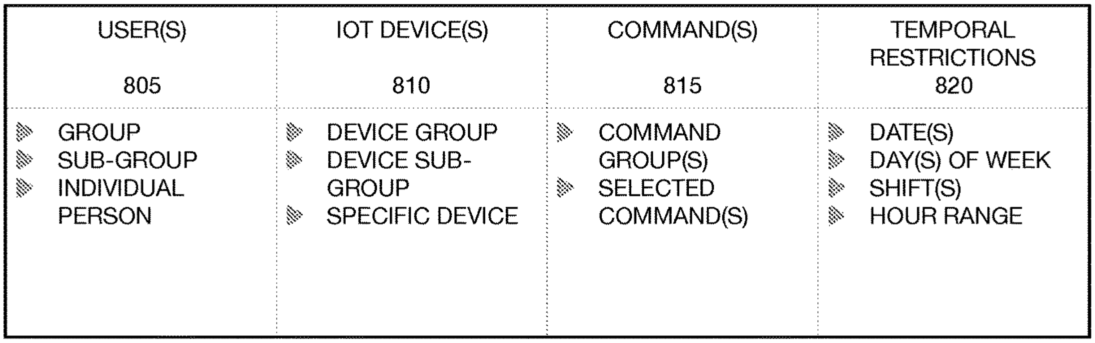
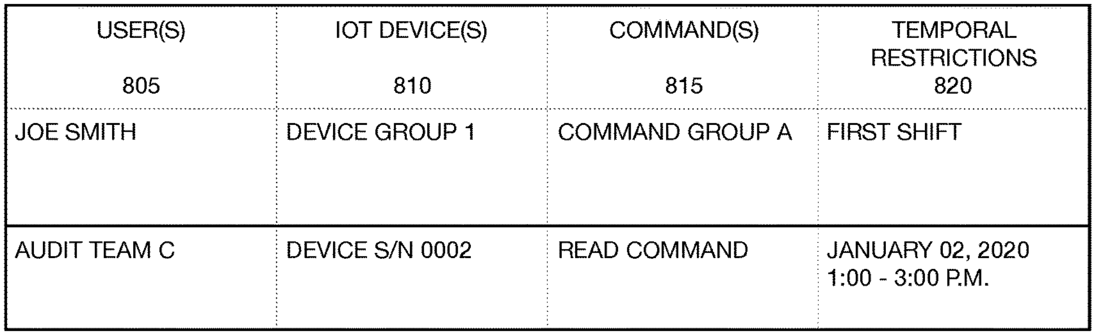

IOT DEVICE PARAMETERS
705
FACTORY SETTINGS
710
MANUFACTURER
MODEL
SERIAL NUMBER
PASSWORD
DEFAULT GATEWAY IP OR IPs
FIRMWARE UPDATE RESTRICTIONS
DEPLOYMENT SETTINGS
715
DEVICE NAME
DEVICE NICK NAME
ALTERNATE GATEWAY IP(S)
DEVICE GROUP NAME
PHYSICAL LOCATION
COUNTRY
CITY
STATE
STREET ADDRESS
OTHER
AVAILABLE COMMAND SET
FIRMWARE MANAGEMENT
CURRENT FIRMWARE VERSION
AUTO FIRMWARE UPDATE ON/OFF
OWNERSHIP
OWNER 1
OWNER 2
OWNER n
DEPLOYMENT SETTINGS
720
DEPLOYMENT SETTINGS
725

FIG. 7



USER(S) 805	IOT DEVICE(S) 810	COMMAND(S) 815	TEMPORAL RESTRICTIONS 820
▶ GROUP ▶ SUB-GROUP ▶ INDIVIDUAL PERSON	▶ DEVICE GROUP ▶ DEVICE SUB-GROUP ▶ SPECIFIC DEVICE	▶ COMMAND GROUP(S) ▶ SELECTED COMMAND(S)	▶ DATE(S) ▶ DAY(S) OF WEEK ▶ SHIFT(S) ▶ HOUR RANGE

FIG. 8



USER(S) 805	IOT DEVICE(S) 810	COMMAND(S) 815	TEMPORAL RESTRICTIONS 820
JOE SMITH	DEVICE GROUP 1	COMMAND GROUP A	FIRST SHIFT
AUDIT TEAM C	DEVICE S/N 0002	READ COMMAND	JANUARY 02, 2020 1:00 - 3:00 P.M.

FIG. 9

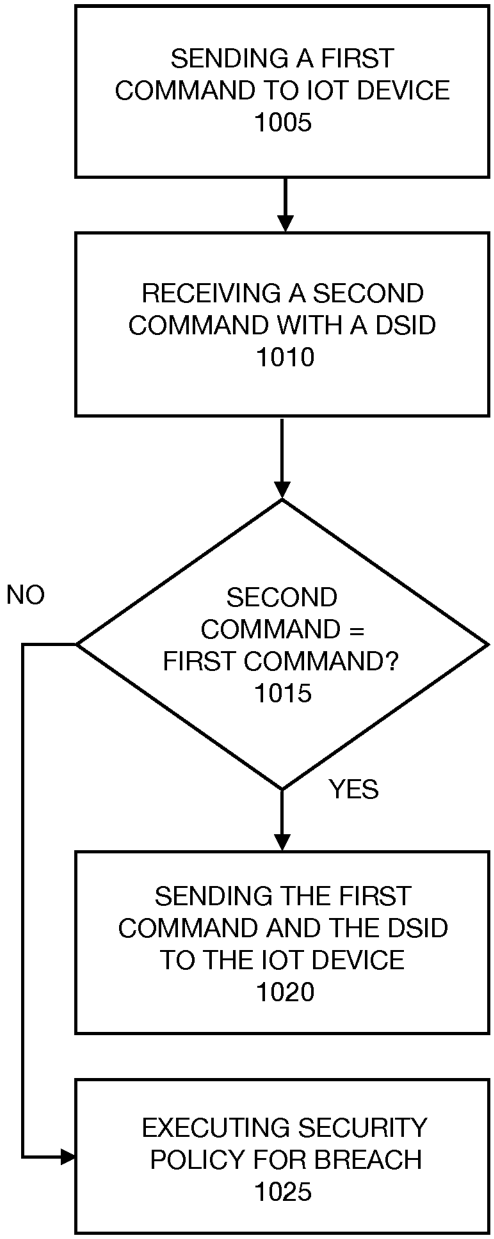

SENDING A FIRST COMMAND TO IOT DEVICE
1005
RECEIVING A SECOND COMMAND WITH A DSID
1010
SECOND COMMAND = FIRST COMMAND?
1015
NO
YES
SENDING THE FIRST COMMAND AND THE DSID TO THE IOT DEVICE
1020
EXECUTING SECURITY POLICY FOR BREACH
1025

FIG. 10

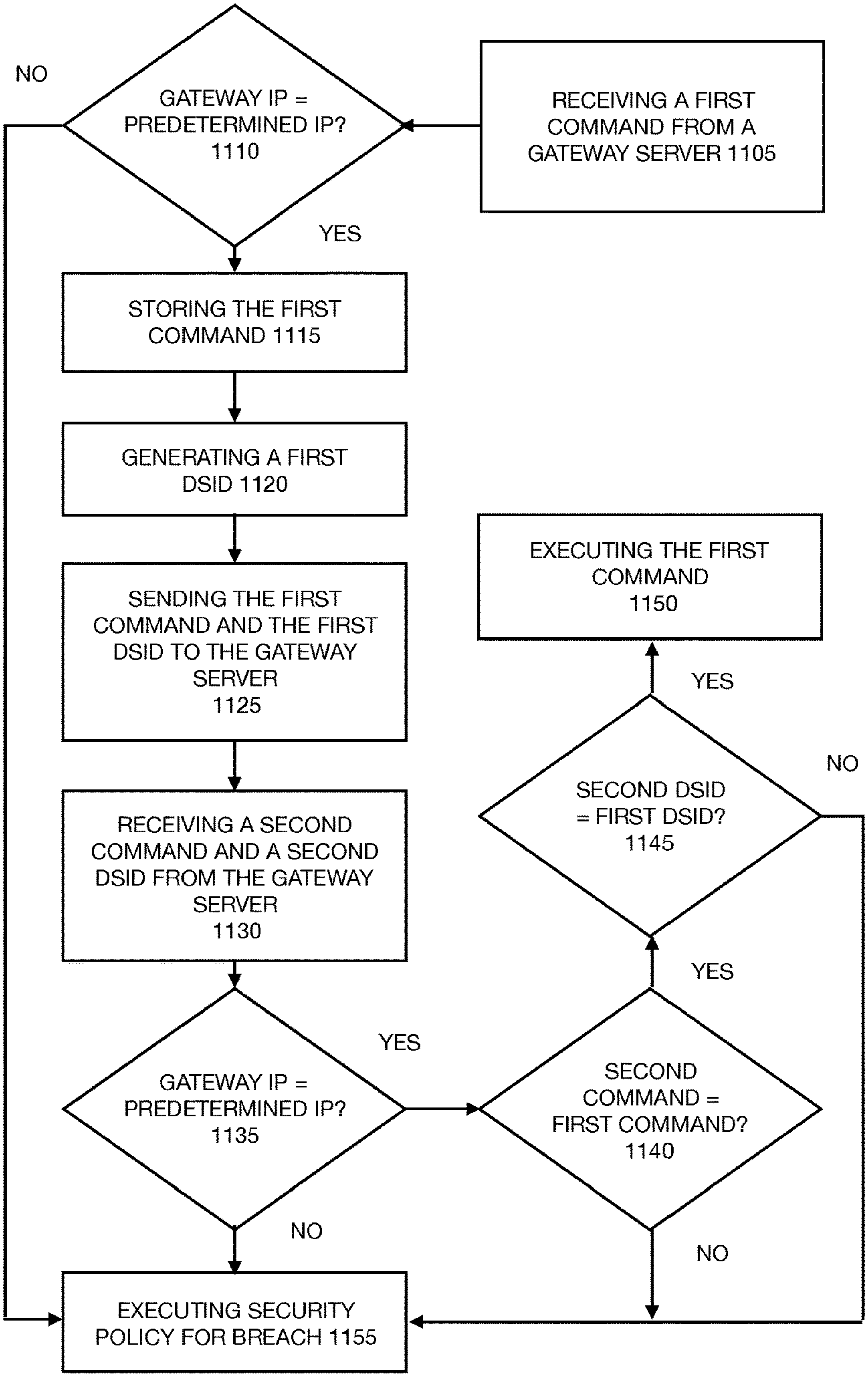

RECEIVING A FIRST COMMAND FROM A GATEWAY SERVER 1105
GATEWAY IP = PREDETERMINED IP? 1110
NO
YES
STORING THE FIRST COMMAND 1115
GENERATING A FIRST DSID 1120
SENDING THE FIRST COMMAND AND THE FIRST DSID TO THE GATEWAY SERVER 1125
RECEIVING A SECOND COMMAND AND A SECOND DSID FROM THE GATEWAY SERVER 1130
GATEWAY IP = PREDETERMINED IP? 1135
YES
NO
SECOND COMMAND = FIRST COMMAND? 1140
YES
NO
SECOND DSID = FIRST DSID? 1145
YES
NO
EXECUTING THE FIRST COMMAND 1150
EXECUTING SECURITY POLICY FOR BREACH 1155

FIG. 11

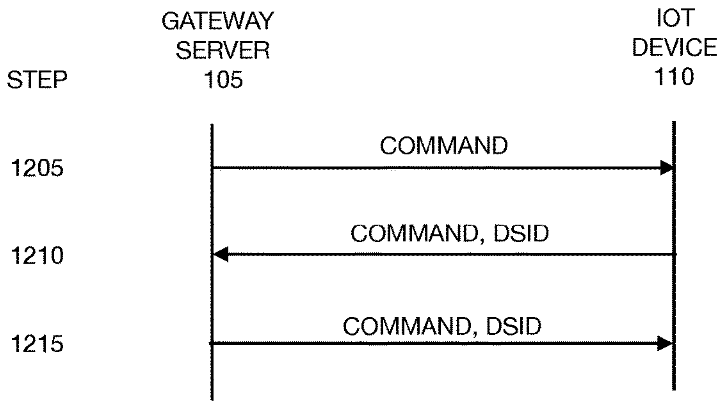

STEP
GATEWAY SERVER 105
IOT DEVICE 110
1205
COMMAND
1210
COMMAND, DSID
1215
COMMAND, DSID

FIG. 12

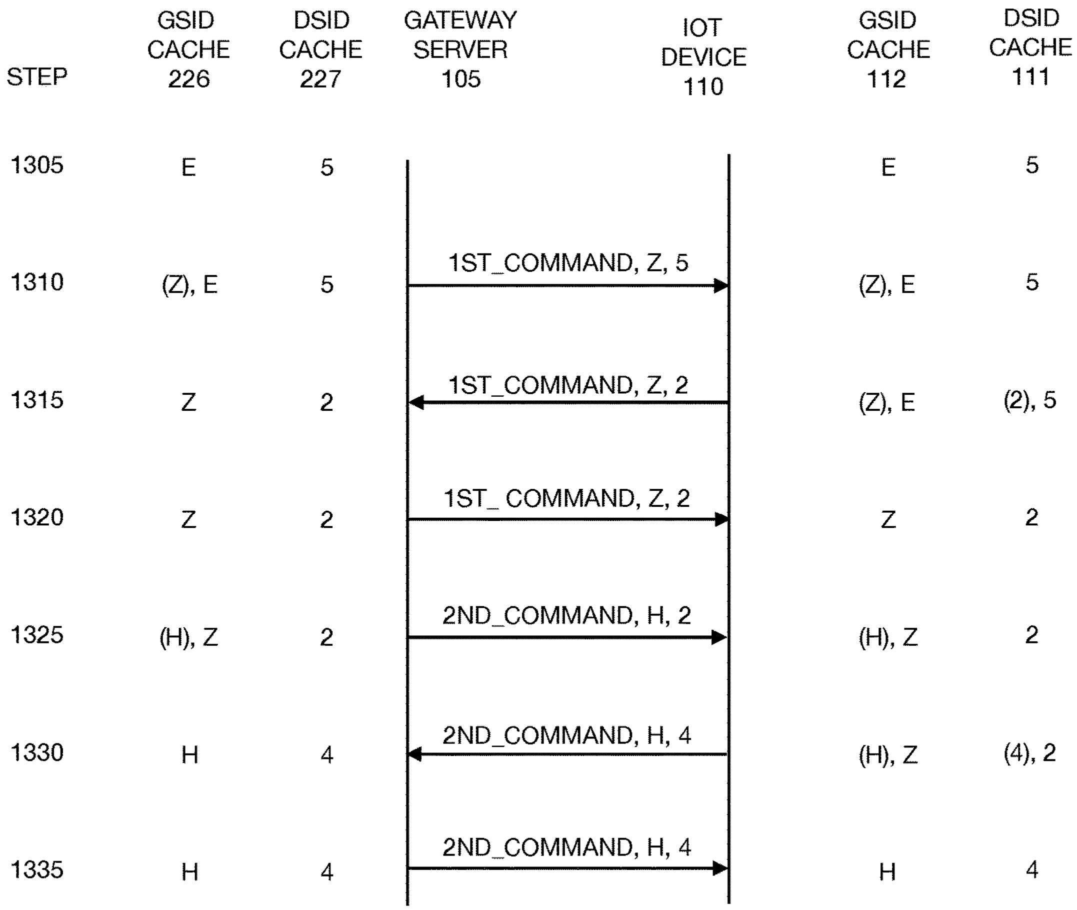

STEP
GSID CACHE 226
DSID CACHE 227
GATEWAY SERVER 105
IOT DEVICE 110
GSID CACHE 112
DSID CACHE 111
1305
E
5
E
5
1310
(Z), E
5
1ST_COMMAND, Z, 5
(Z), E
5
1315
Z
2
1ST_COMMAND, Z, 2
(Z), E
(2), 5
1320
Z
2
1ST_ COMMAND, Z, 2
Z
2
1325
(H), Z
2
2ND_COMMAND, H, 2
(H), Z
2
1330
H
4
2ND_COMMAND, H, 4
(H), Z
(4), 2
1335
H
4
2ND_COMMAND, H, 4
H
4

FIG. 13

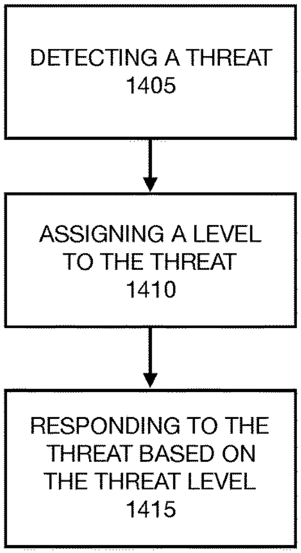

DETECTING A THREAT
1405
ASSIGNING A LEVEL TO THE THREAT
1410
RESPONDING TO THE THREAT BASED ON THE THREAT LEVEL
1415

FIG. 14

DETECTION EXAMPLE 1505	THREAT LEVEL ASSIGNMENT EXAMPLE 1510	RESPONSE EXAMPLE 1515
ROUTINE COMMUNICAITONS	VERY LOW	LOG ALL ACTIVITY
AUTHORIZED USER ATTEMPTING TO VIOLATE USER PERMISSIONS	LOW	LOG AND REPORT
ATTEMPTED ACCESS TO IOT DEVICE BY UNAUTHORIZED USER	MEDIUM	LOG, BLOCK, TRACE, AND REPORT
ATTEMPT AT SPOOFING SERVER OR IOT DEVICE	HIGH	LOG, SUSPEND COMMUNICATIONS, AND SOUND ALARM

FIG. 15

SYSTEM AND METHODS FOR INTERNET OF THINGS (IOT) DEVICE AUTHENTICATION AND SECURITY

BACKGROUND

Field of Invention

The invention relates generally to communication networks. More specifically, but not by way of limitation, embodiments of the invention provide improvements in authentication and other security features for communications with Internet of Things (IoT) devices.

Description of the Related Art

Internet of Things (IoT) devices are physical electronic devices, typically with a sensor or actuator, that are connected to a communication network. An IoT device may be stationary in use, for example in a home appliance or piece of manufacturing equipment. An IoT device can also be a mobile device, or used in a mobile device, for instance deployed in an automobile. A growing number of IoT device applications exist in consumer, industrial, energy, transportation, military, and other market segments.

Known loT device applications generally have shortcomings related to risk of unauthorized access. One reason for this is that loT devices are supplied by many different manufacturers, often targeting a narrow application space. As a result, loT devices have diverse operating systems and configurations. Security standards for loT devices are lacking. An improved system and method for secure loT device communications that can be applied to a wide range of applications is urgently needed.

SUMMARY OF THE INVENTION

The invention seeks to overcome security risks associated with the use of IoT devices. In embodiments of the invention, one or more IoT devices are coupled to a gateway server. The gateway server preferably includes enhanced administrative features for restricting access to IoT devices, and for monitoring IoT device communications. In embodiments of the invention, communications between the gateway server and IoT devices are secured, in part, via IP address restriction, the use of transitory identifiers, and/or encryption.

DESCRIPTION OF THE DRAWINGS

An embodiment of the invention is illustrated in the drawings, wherein:

FIG. **1** is a functional block diagram of a networked system, according to an embodiment of the invention;

FIG. **2** is a functional block diagram of a gateway server, according to an embodiment of the invention;

FIG. **3** is a flow diagram of a gateway server process, according to an embodiment of the invention;

FIG. **4** is a flow diagram of a process for establishing initial ownership of an IoT device, according to an embodiment of the invention;

FIG. **5** is a communication diagram for the process illustrated in FIG. **4**;

FIG. **6** is a flow diagram of a process for establishing ownership of an IoT device, according to an embodiment of the invention;

FIG. **7** is an illustration of an IoT device parameter table, according to an embodiment of the invention;

FIG. **8** is an illustration of IoT device user permission table, according to an embodiment of the invention;

FIG. **9** is an illustration of IoT device user permission table, according to an embodiment of the invention;

FIG. **10** is a flow diagram of a communication session from the perspective of a gateway server, according to an embodiment of the invention;

FIG. **11** is a flow diagram of a communication session from the perspective of an IoT device, according to an embodiment of the invention;

FIG. **12** is a communication sequence diagram for the processes illustrated in FIGS. **10** and **11**, according to an embodiment of the invention;

FIG. **13** is a communication sequence and cache status diagram for two communication sessions between a gateway server and an IoT device, according to an embodiment of the invention;

FIG. **14** is a flow diagram of a network communication monitoring process, according to an embodiment of the invention; and

FIG. **15** is an illustration of a network communication monitoring policy table, according to an embodiment of the invention.

DETAILED DESCRIPTION

This section describes embodiments of the invention with reference to FIGS. **1-15**. Such embodiments are meant to be illustrative and not restrictive. In the drawings, reference designators are reused for the same or similar features. Some features may be simplified, omitted, or not specifically referenced for descriptive clarity. Although sub-headings are used below for organizational convenience, disclosure of any particular feature is not necessarily limited to any section.

Functional Architecture

FIG. **1** is a functional block diagram of a networked system, according to an embodiment of the invention. As shown therein, a gateway server **105** is coupled to an IoT device **110**, user application **115**, management console **120**, and database **125** via communication links **130**. Each of the links **130** could be wired or wireless, and may be or include, for instance, the internet, a wide area network (WAN), and/or a local area network (LAN).

In the illustrated embodiment, the IoT device **110** includes device session identifier (DSID) cache **111**, gateway session identifier (GSID) cache **112**, central processing unit (CPU) **113**, and non-volatile memory (NVM) **114**. The purpose and function of DSID cache **111** and GSID cache **112** will be discussed further below. NVM **114** may store IoT device **110** firmware and data (such as factory settings **710**).

User application **115** and/or management console **120** could each be, for example, a mobile or other remote device with browser or other client software adapted to cooperate with the gateway server **105**. In use, user application **115** may provide user access to IoT device **110** according to pre-determined permissions. Management console **120** may facilitate administrative functions such as setting IoT device **110** parameters, setting user permissions, defining monitoring policy, and reviewing system status. Database **125** could be used to store, for example, administrative data and/or sensor data from the IoT device **110**.

Variations to the functional architecture illustrated in FIG. **1** are possible. For instance, the illustrated components could be coupled using different methods, rather than a uniform link **130**. In typical deployments, there would be multiple IoT devices **110**, user applications **115**, and management consoles **120** coupled to a gateway server **105**. In addition, a single IoT device **110** may be configured to couple to more than one gateway server **105** (e.g., in the alternative). One embodiment described below does not require GSID cache **112**.

FIG. **2** is a functional block diagram of a gateway server, according to an embodiment of the invention. As illustrated, a device module **210**, video management module **215**, configuration module **220**, cache module **225**, logging audit module **230**, persistence module **235**, messaging module **240**, rules/events/alarms module **240** are connected via a management bus **205**.

In the illustrated embodiment, device module **210** provides an interface to loT device **110**. Video management module **215** may be used, for instance, to manage the collection or playback of video received from the loT device **110**. The configuration module **220** allows an loT device **110** owner or other administrator to manage certain loT device **110** parameters (e.g., deployment settings **715**). Cache module **225** manages certain cache operations for the gateway server **105**; the purpose and function of DSID cache **226** and GSID cache **227** are discussed below. Rules/events/alarms module **245** and logging audit module **230** facilitate management of monitoring policy and execution, respectively. Persistence module **235** is a management tool to facilitate persistent data storage, for instance in the database **125**. Messaging module **240** facilitates messaging from the gateway server **105** to a user or owner (or other administrators), for example in the case of an actual or attempted security breach. Not all above-described components are required in all deployments of a gateway server **105**.

Top Level Flow

FIG. **3** is a flow diagram of a gateway server process, according to an embodiment of the invention. All process steps illustrated in FIG. **3** and discussed below may be performed by the gateway server **105**.

As shown in FIG. **3**, the process begins by receiving one or more pings from an loT device **110** in step **305**. Ping may be received in step **305**, for instance, upon power-up of a new loT device **110**. The purpose of receiving step **305** is to facilitate discovery of the loT device **110** by the gateway server **105**. As used herein, a ping includes a data transmission, for instance a packet, from the loT device **110** to the gateway server **105**; a reply transmission from the gateway **105** to the loT device **110** may not be required. Pings in step **305** may be received in the gateway server **105**, for example, at a time interval that is determined by the loT device **110**, and such pings preferably include a serial number (S/N) and internet protocol (IP) address for the loT device **110**. Additional data items could be included in the step **305** ping according to design choice.

The process logs in a first user in step **310**, and establishes the first user as an initial owner (top administrator) of the loT device **110** in step **315**. One alternative process for executing step **315** is presented below with reference to FIGS. **4** and **5**; another is described with reference to FIG. **6**. Once established, the owner can set loT device **110** parameters in step **320** and/or set user permissions in step **325**. loT device **110** parameters are described below with reference to FIG. **7**; user permissions are described with reference to FIGS. **8** and **9**.

The process logs in a second user in step **330**. The process securely relays commands from the owner or second user through the gateway **105** to the IoT device **110** in step **335** (for the second user, processing in step **335** is conditional on user permissions set in step **325**). One embodiment of step **335** is presented below with reference to FIGS. **10-12**; a second embodiment of step **335** is described with reference to FIG. **13**. All system communications are preferably

monitored in step **340**. An embodiment of step **340** is described below with reference to FIGS. **14** and **15**.

Variations to the process illustrated in FIG. **3** and described above are possible. For instance, in a controlled and static environment (i.e., one with fixed IP addresses), receiving step **305** may not be required. Steps **320** and/or **325** may not be required in embodiments where default loT device **110** parameters and/or user permissions are provided by the system. In addition, in certain applications, the owner established in step **315** may be the only user of the loT device **110**, without necessity for logging in a second user in step **330**.

Establishing Ownership of an IoT Device

A first owner is a top-level administrator. Any subsequent owners and users derive authority from the first owner (for instance in step **325**). FIG. **4** is a flow diagram of a process for establishing initial ownership of an IoT device, according to an embodiment of the invention. The process illustrated in FIG. **4** may be performed by the gateway server **105**. As shown therein, the process begins by receiving an IoT device **110** serial number (S/N) and password from a first user in step **405**.

In conditional step **410**, the process determines whether an owner (administrator) has already been defined for the IoT device **110** S/N. If an owner has not yet been assigned, the process sends the password supplied by the first user to the IoT device **110** in step **415**, and receives a reply (i.e., in the form of a validation or rejection) from the IoT device **110** in step **420**. Conditional step **425** directs further processing based on the reply. If the password is validated, then the process defines (or establishes) the first user as the IoT device **110** owner in step **430**. Step **430** also perfects registration of the IoT device **110**, making the IoT device **110** a part of the network topology.

If the process determines an owner has already been established for the IoT device **110** S/N in step **410**, or if the password supplied by the first user is not validated by the IoT device **110**, then the process returns the first user to a login process in step **435**. The process described with reference to FIG. **4** does not require the gateway server **105** to store or compare IoT device **110** passwords.

FIG. **5** is a communication diagram for the process illustrated in FIG. **4**. As shown therein, an ownership request is sent from the user app **115** to the gateway server **105** in step **505**, a password audition is sent from the gateway server **105** to the IoT device **110** in step **510**, a password result is sent from the IoT device **110** to the gateway server **105** in step **515**, and a response to the ownership request is sent from the gateway server **105** to the user app **115** in step **520**.

FIG. **6** is a flow diagram of a process for establishing initial ownership of an IoT device, according to an embodiment of the invention. The illustrated process is performed in the gateway server **105**. A distinguishing feature for the process in FIG. **6** is that at some point prior to step **620**, the process receives a serial number and associated password for an IoT device **110**, for instance from a manufacturer or other 3rd party, in step **615**.

The process receives an IoT device **110** S/N and password from a first user in step **605**. In conditional step **610**, the process determines whether an owner (administrator) has already been defined for the IoT device **110** S/N. If an owner has not yet been assigned, the process advances to conditional step **620** to determine whether the password supplied by the first user matches the password supplied for that same IoT device S/N in step **615**. If the gateway server **105** validates the password supplied by the first user, then the process establishes the first user as the owner in step **625**.

If the process determines an owner has already been established for the IoT device **110** S/N in step **610**, or if the password supplied by the first user is not validated by the gateway server **110** in step **620**, then the process returns the first user to a login process in step **630**.

Setting IoT Device Parameters and User Permissions

FIG. **7** is an illustration of an loT device parameter table **705**, according to an embodiment of the invention. Factory settings **710** may be stored in NVM **114** of the loT device **110** and, in embodiments of the invention, may not be changed by an owner. On the other hand, parameters listed in deployment settings table **715** are representative of the types of parameters an loT device **110** owner could add, delete, or change, for instance in step **320**, and according to application needs. In embodiments of the invention, deployment settings **715** may be stored in, or managed by, for example, the configuration module **220** and/or the rules/events/alarms module **245**.

In embodiments of the invention, deployment settings table **715** is representative of a graphical user interface (GUI) an owner uses to view and set IoT device parameters at management console **120**.

Deployment settings tables **720** and **725** could be configured with the same or similar parameters as listed in deployment settings table **715**. The possibility of multiple deployment settings tables **715**, **720**, **725**, illustrates that a unique set of device parameters can be set for each of multiple deployments.

FIG. **8** is an illustration of IoT device user permission table, according to an embodiment of the invention. In the illustrated embodiment, permissions can be defined according to user(s) based on options listed in column **805**, IoT device(s) based on options listed in column **810**, command(s) based on options listed in column **815**, and temporal restrictions based on options listed in column **820**.

FIG. **9** illustrates example user permissions consistent with available options presented in FIG. **8**. Joe Smith (an individual person) has been given permission to access device group 1 (a device group) using command group A (a command group) during first shift (a selected shift). Audit Team C (a group of users) has been given permission to access device S/N 0002 (a specific device) using a read command (a selected command) on Jan. 02, 2020 between 1:00 p.m. and 3:00 p.m. (date and hour range restrictions).

In embodiments of the invention, the user permission tables presented in FIGS. **8** and **9** are representative of a graphical user interface (GUI) an owner uses to view and set user permissions at management console **120**. In embodiments of the invention, IoT device **110** user permissions may be stored in the database **125**.

Network Communications

A first embodiment for command processing is presented with reference to FIGS. **10-12**, and a second embodiment for command processing is discussed with reference to FIG. **13**.

FIG. **10** is a flow diagram of a communication session from the perspective of a gateway server, according to an embodiment of the invention. The process begins by sending a first command to the IoT device **110** in step **1005**. The gateway server **105** then receives a second command and a device session identifier (DSID) in step **1010**.

As used herein, a session is an exchange of messages associated with transfer of a single command or data package between the gateway server **105** and the IoT device **110**. A DSID is a transient identifier for the IoT device **110** that changes with each session.

In conditional step **1015**, the process determines whether the second command is the same as the first command. If so, the process re-sends the first command and the DSID to the IoT device **110** in step **1020**; if not, the process terminates by executing a security policy for a breach in step **1025**. In the case of uninterrupted communications between the gateway server **105** and the IoT device **110**, the conditions of step **1015** are satisfied, and the session completes with successful transmission of the first command from the gateway server **105** to the IoT device **110**.

FIG. **11** is a flow diagram of a communication session from the perspective of an loT device, according to an embodiment of the invention. The process begins by receiving a first command from a gateway server **105** in step **1105**. In conditional step **1110**, the process determines whether a gateway IP address associated with the first command is the same as a predetermined gateway IP address. If so, the process stores the first command in step **1115**, generates a first DSID in step **1120**, and sends the first command and the first DSID to the gateway server **105** in step **1125**.

The process then receives a second command and a second DSID from the gateway server in step **1130**. In conditional steps **1135**, **1140**, and **1145**, the process tests whether a gateway IP address associated with the second command and the second DSID is the same as the predetermined gateway IP address, whether the second command is the same as the first command, and whether the second DSID is the same as the first DSID.

If the conditions in steps **1135**, **1140**, and **1145** are satisfied, then the first command has been authenticated, and the process executes the first command in step **1150**. If any of conditional steps **1110**, **1135**, **1140**, or **1145** are not satisfied, then authentication has failed, and the process terminates by executing a security policy for breach in step **1155**.

FIG. **12** is a communication sequence diagram for the processes illustrated in FIGS. **10** and **11**, according to an embodiment of the invention. FIG. **12** is a simplified view in that it only illustrates successful exchanges between the gateway server **105** and the IoT device **110**, without illustrating any of the data comparisons or possible terminations in FIGS. **10** and **11**. Accordingly, FIG. **12** shows that a command is sent from the gateway server **105** to the IoT device **110** in step **1205**; the IoT device **110** sends the command and a DSID to the gateway server **105** in step **1210**; and the gateway server **1215** sends the command and the DSID to the IoT device **110** in step **1215**.

FIG. **13** is a communication sequence and cache status diagram for two communication sessions between a gateway server **105** and an IoT device **110**, according to an embodiment of the invention. A first communication session is associated with delivery of 1st_command from the gateway server **105** to the IoT device **110**, and includes steps **1310**, **1315**, and **1320**. A second session is associated with delivery of 2nd_command from the gateway server **105** to the IoT device **110**, and includes steps **1325**, **1330**, and **1335**.

DSID was introduced above with reference to FIG. **10**. The process illustrated in FIG. **13** also uses a GSID. A GSID is a transient identifier for the gateway server **105**, and, like the DSID, changes with each session. According to the authentication scheme in FIG. **13** (and as illustrated in FIG. **2**), the gateway server **105** includes a GSID cache **226** and a DSID cache **227**. According to the authentication scheme in FIG. **13** (and as illustrated in FIG. **1**), the IoT device **110** includes GSID cache **112** and DSID cache **111**.

Step **1305** illustrates that, prior to the first communication session, the content of GSID cache **226** is “E”, the content of DSID cache **227** is “5”, the content of GSID cache **112** is “E”, and the content of DSID cache **111** is “5”.

To begin the first session, the gateway server **105** generates a new GSID “Z” in step **1310**. The GSID cache **226** is represented as “(Z), E” in FIG. **13** because the new GSID “Z” is considered provisional in the GSID cache **226**, and the prior GSID “E” is retained in the GSID cache **226**, until the new GSID “Z” is returned by the IoT device **110**. The gateway server **105** sends “1st_command” (subject of the first session), along with new GSID “Z”, and last used DSID “5”, to the IoT device **110**. The IoT device **110** updates GSID cache **112** to “(Z), E”. The IoT device **110** considers GSID “Z” to be provisional until it is received a second time.

In step **1315**, the IoT device **110** generates a new DSID “2”. DSID cache **111** is represented as “(2), 5” because the new DSID “2” is considered provisional in the DSID cache **111**, and prior DSID “5” is retained in the DSID cache **111**, until the new DSID “2” is received from the gateway server **105**. The IoT device **110** sends “1st_command”, along with GSID “Z” and DSID “2” to the gateway server **105**. Upon receipt, the gateway server **105** stores “2” in DSID cache **227**, and converts “Z” to a non-provisional status in GSID cache **226**.

In step **1320**, the gateway server **105** sends “1st_command”, GSID “Z”, and DSID “2” to the IoT device **110**. Upon receipt, the IoT device **110** converts GSID “Z” to non-provisional status in GSID cache **112**, converts DSID “2” to non-provisional status in DSID cache **111**, and execute the 1st_command.

The process described above for the first session (with reference to steps **1310**, **1315**, and **1320**) is repeated for the second session (in steps **1325**, **1330**, and **1335**). The transitory nature of the GSID and DSID enhance authentication and security. The use of provisional statuses for newly-generated GSID and DSID’s facilitates recovery of communications between the gateway server **105** and the loT device **110** if normal communications are interrupted.

In preferred embodiments of the invention, each single alpha character and single digit number used to represent GSID and DSID values in FIG. **13**, respectively, is replaced by a string of alphanumeric characters.

In embodiments of the invention, the process illustrated in FIG. **13** preferably includes command comparison steps similar to steps **1015** and **1140**. For instance, with respect to the first session, the gateway server **105** preferably verifies that the 1st_command it receives in step **1315** is identical to the 1st_command it sent in step **1310** as a condition for sending the 1st_command in step **1320**. Likewise, the IoT device **110** preferably verifies that the 1st_command it received in step **1310** is identical to the 1st_command it received in step **1320** as a condition for executing the 1st_command.

In embodiments of the invention, the process illustrated in FIG. **13** preferably includes gateway IP address comparison steps similar to steps **1110** and **1135**. For instance, with respect to the first session, the IoT device **110** preferably verifies that IP addresses associated with communications received in steps **1310** and **1320** match a predetermined (whitelisted) IP address.

Monitoring

FIG. **14** is a flow diagram of a network communication monitoring process, according to an embodiment of the invention. As shown therein, the process includes detecting a threat in step **1405**, assigning a level to the threat in step **1410**, and responding to the threat based on the threat level in step **1415**. In executing the process in FIG. **14**, the logging audit module **230** applies policy specified in the rules/events/alarms module **245**.

FIG. **15** is an illustration of a network communication monitoring policy table, according to an embodiment of the invention. In one respect, the table in FIG. **15** provides an example of how each detection example in column **1505** can be associated with a threat level in column **1510** and a response in column **12515**. In another respect, the table illustrated in FIG. **15** could be representative of a GUI for an owner setting monitoring policy at management console **120**.

Summary

Embodiments of the invention thus provide a system and method for IoT device authentication and security. Those skilled in the art can readily recognize that numerous variations and substitutions may be made in the invention, its use and its configuration to achieve substantially the same results as achieved by the embodiments described herein. Features disclosed in this specification could be combined in ways not expressly illustrated or discussed. Accordingly, there is no intention to limit the invention to the disclosed exemplary forms and applications. Many variations, modifications and alternative constructions fall within the scope and spirit of the disclosed invention.

I claim:

1. A communication system comprising: a gateway server; and

an internet of things (loT) device coupled to the gateway server, the gateway server having a first gateway session identifier (GSID) cache and a first device session identifier (DSID) cache, the loT device having a second GSID cache and a second DSID cache, the system being configured to perform a method, the method including:

generating a first GSID in the gateway server:

writing the first GSID to the first GSID cache;

reading a first DSID from the first DSID cache;

sending a first command, the first GSID, and the first DSID from the gateway server to the loT device;

receiving the first command, the first GSID, and the first DSID in the loT device;

writing the first GSID to the second GSID cache; generating a second DSID in the loT device;

writing the second DSID to the second DSID cache; and sending the first command, the first GSID, and the second

DSID from the loT device to the gateway server.

2. The communication system of claim **1**, the method further including:

receiving the first command, the first GSID, and the second DSID in the gateway server;

writing the second DSID to the first DSID cache; and

sending the first command, the first GSID, and the second DSID from the gateway server to the loT device.

3. The communication system of claim **2**, the step of sending the first command, the first GSID, and the second DSID from the gateway server to the loT device being conditioned upon the first command received by the gateway server being identical to the first command previously sent by the gateway server.

4. The communication system of claim **2**, the step of sending the first command, the first GSID, and the second DSID from the gateway server to the loT device being conditioned upon the first GSID received by the gateway server being identical to the first GSID previously sent by the gateway server.

5. The communication system of claim **2**, the method further including:

receiving the first command, the first GSID, and the second DSID in the loT device; and

executing the first command in the loT device.

6. The communication system of claim **5**, the step of executing the command being conditioned upon the first command received by the loT device with the second DSID being identical to the first command received by the loT device with the first DSID.

7. The communication system of claim **5**, the step of executing the command being conditioned upon the first GSID received by the loT device being identical to the first GSID previously received by the loT device.

8. The communication system of claim **5**, the method further including:

generating a second GSID in the gateway server;

writing the second GSID to the first GSID cache;

reading the second DSID from the first DSID cache; and

sending a second command, the second GSID, and the second DSID from the gateway server to the loT device.

9. The communication system of claim **8**, the method further including:

receiving the second command, the second GSID, and the second DSID in the loT device;

writing the second GSID to the second GSID cache;

generating a third DSID in the loT device;

writing the third DSID to the second DSID cache; and

sending the second command, the second GSID, and the third DSID from the loT device to the gateway server.

10. A communication system comprising: a gateway server; and

an internet of things (loT) device coupled to the gateway server, the gateway server having a first gateway session identifier (GSID) cache and a first device session identifier (DSID) cache, the loT device having a second GSID cache and a second DSID cache, the system being configured to perform a method, the method including:

generating a first GSID in the gateway server;

writing the first GSID to the first GSID cache;

reading a first DSID from the first DSID cache;

sending a first command, the first GSID, and the first DSID from the gateway server to the loT device;

receiving the first command, the first GSID, and the first DSID in the loT device;

determining whether the first command was received from a predetermined gateway IP address; and

if the first command was received from the predetermined gateway IP address,

writing the first GSID to the second GSID cache, generating a second DSID in the loT device,

writing the second DSID to the second DSID cache, and sending the first command, the first GSID, and the second

DSID from the loT device to the gateway server.

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