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Maksumov et al.

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(54) **INTELLIGENT GATEWAY WITH A COMMON DATA FORMAT**

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H04L 29/08	(2006.01)
H04L 12/24	(2006.01)
H04W 4/00	(2018.01)

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

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(58) **Field of Classification Search**

CPC H04L 69/08; H04L 41/0226; H04L 67/10; H04L 65/1033; H04W 4/003

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,676,123	B1 *	3/2014	Hinkle	H04M 1/274508 455/41.2
2006/0288297	A1 *	12/2006	Haitani	G06F 1/1632 715/739
2008/0119201	A1 *	5/2008	Kolber	H04W 8/18 455/456.1
2010/0178953	A1 *	7/2010	Blewett	H04L 51/38 455/550.1
2011/0131338	A1 *	6/2011	Hu	H04W 76/02 709/229
2011/0161343	A1 *	6/2011	Schimpf	G06F 17/30398 707/769

(Continued)

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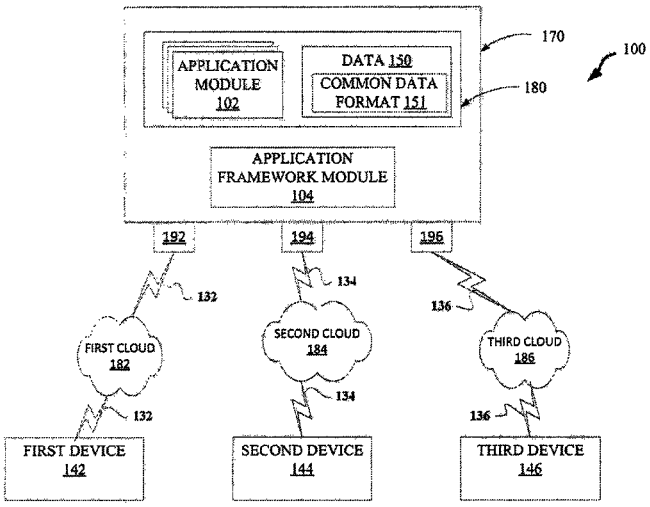
(57) **ABSTRACT**

Example embodiments of a method, apparatus, and computer readable medium for a gateway with common data format are generally described herein. The gateway may include memory to store data in a common data format to be operated on by applications, and network interfaces configured to interface an application to a remote device via a network. The gateway may further include protocol adapters configured to communicate with the remote device using a communication protocol of the remote device, and data adapters configured to convert data between a format of the remote device and the common data format. The gateway may further include a protocol selector module configured to select a protocol adapter where a selected protocol adapter communicates with a remote device, and a data adapter selector module configured to select a data adapter where a selected data adapter adapts data between the remote device and the common format.

15 Claims, 13 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0246449	A1*	9/2013	Balannik	G06F 17/30345 707/758
2014/0181277	A1*	6/2014	Burns	G06F 9/541 709/221
2014/0222793	A1*	8/2014	Sadkin	G06F 17/3053 707/723
2015/0038233	A1*	2/2015	Rom	A63F 13/42 463/42
2015/0120841	A1*	4/2015	Maria	H04L 65/1016 709/206

* cited by examiner

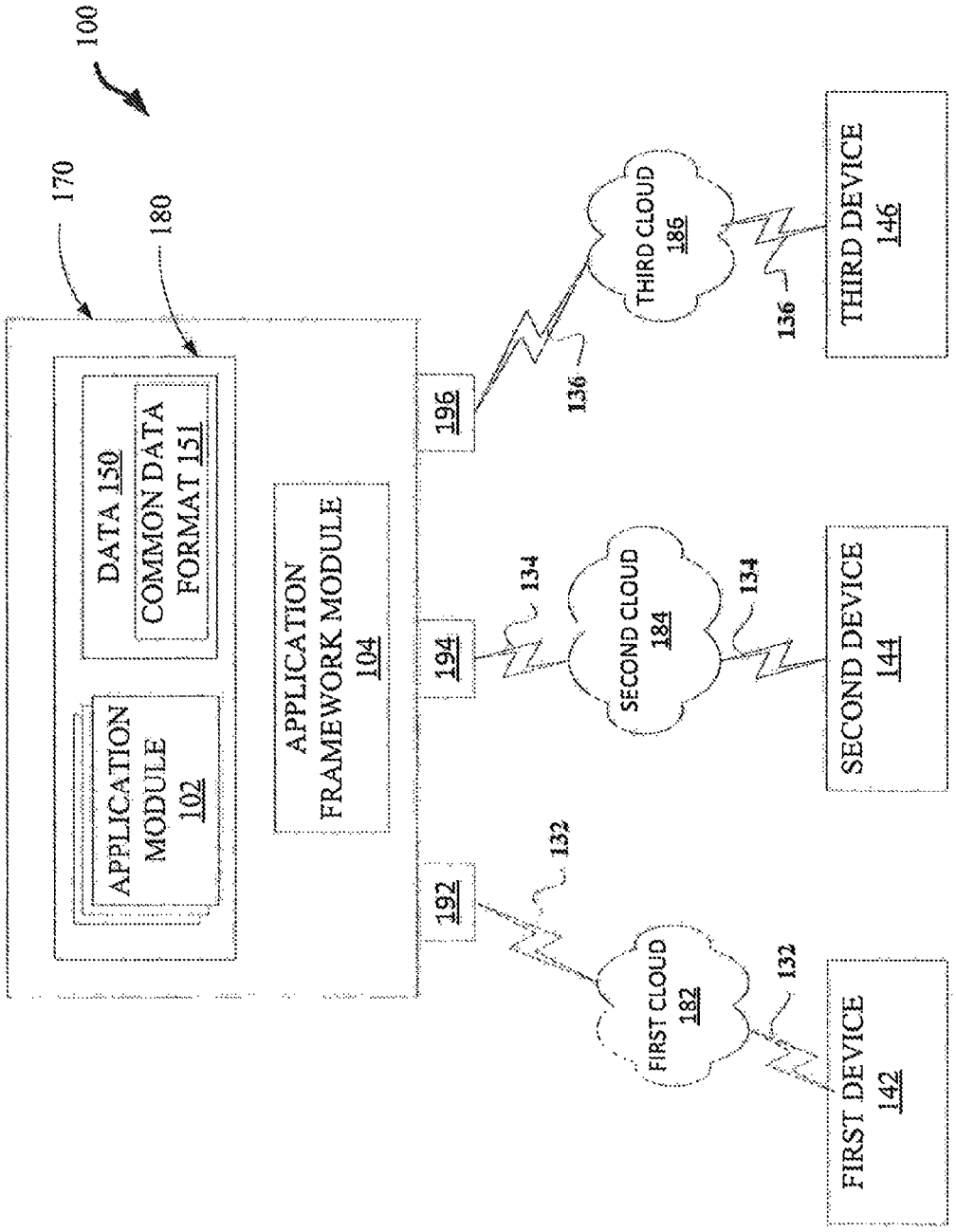

100
170
180
APPLICATION MODULE 102
DATA 150
COMMON DATA FORMAT 151
APPLICATION FRAMEWORK MODULE 104
192
194
196
132
134
136
FIRST CLOUD 182
SECOND CLOUD 184
THIRD CLOUD 186
FIRST DEVICE 142
SECOND DEVICE 144
THIRD DEVICE 146

FIG. 1

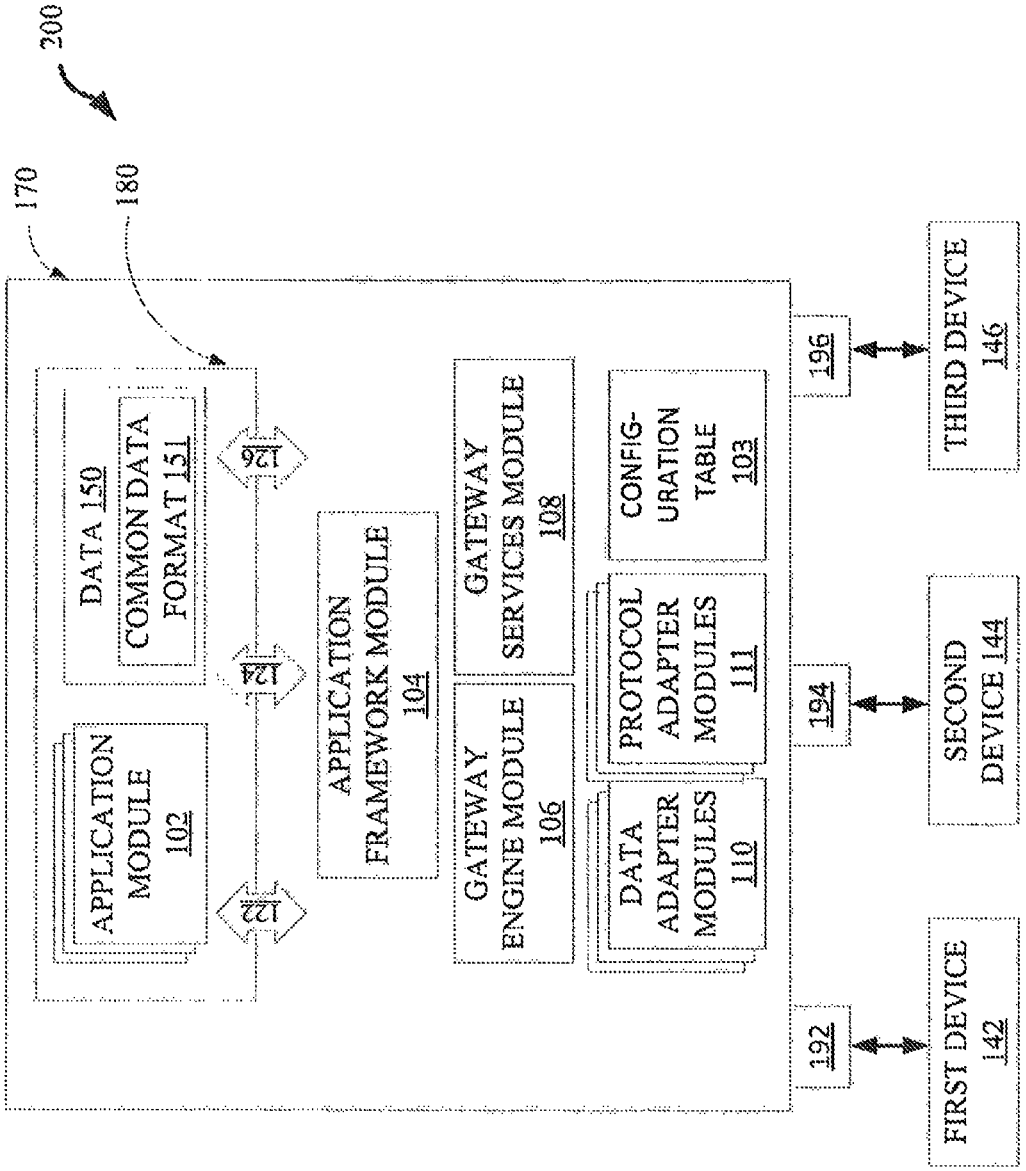

200
170
180
APPLICATION MODULE 102
DATA 150
COMMON DATA FORMAT 151
APPLICATION FRAMEWORK MODULE 104
GATEWAY ENGINE MODULE 106
GATEWAY SERVICES MODULE 108
DATA ADAPTER MODULES 110
PROTOCOL ADAPTER MODULES 111
CONFIG-URATION TABLE 103
192
194
196
FIRST DEVICE 142
SECOND DEVICE 144
THIRD DEVICE 146

FIG. 2

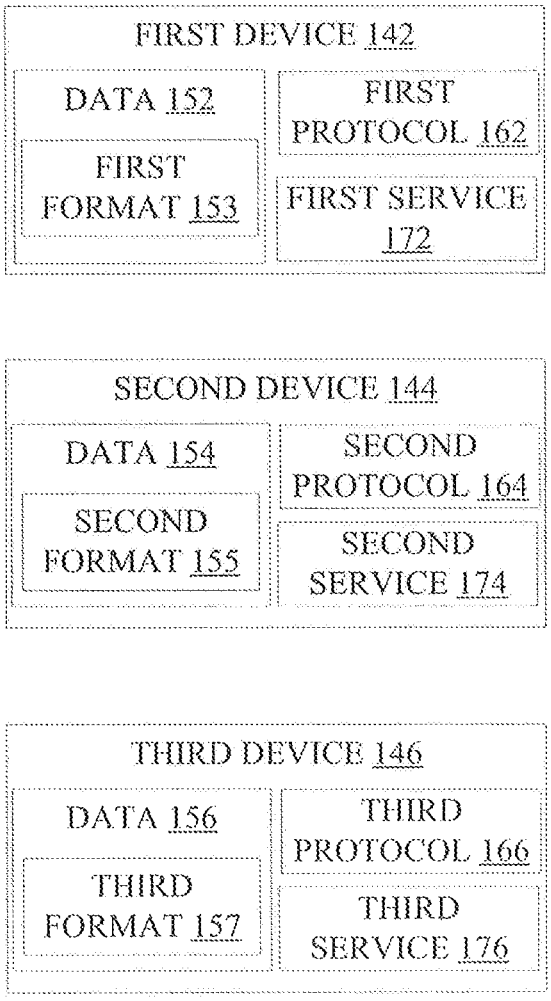

FIRST DEVICE 142
DATA 152
FIRST FORMAT 153
FIRST PROTOCOL 162
FIRST SERVICE 172
SECOND DEVICE 144
DATA 154
SECOND FORMAT 155
SECOND PROTOCOL 164
SECOND SERVICE 174
THIRD DEVICE 146
DATA 156
THIRD FORMAT 157
THIRD PROTOCOL 166
THIRD SERVICE 176

FIG. 3

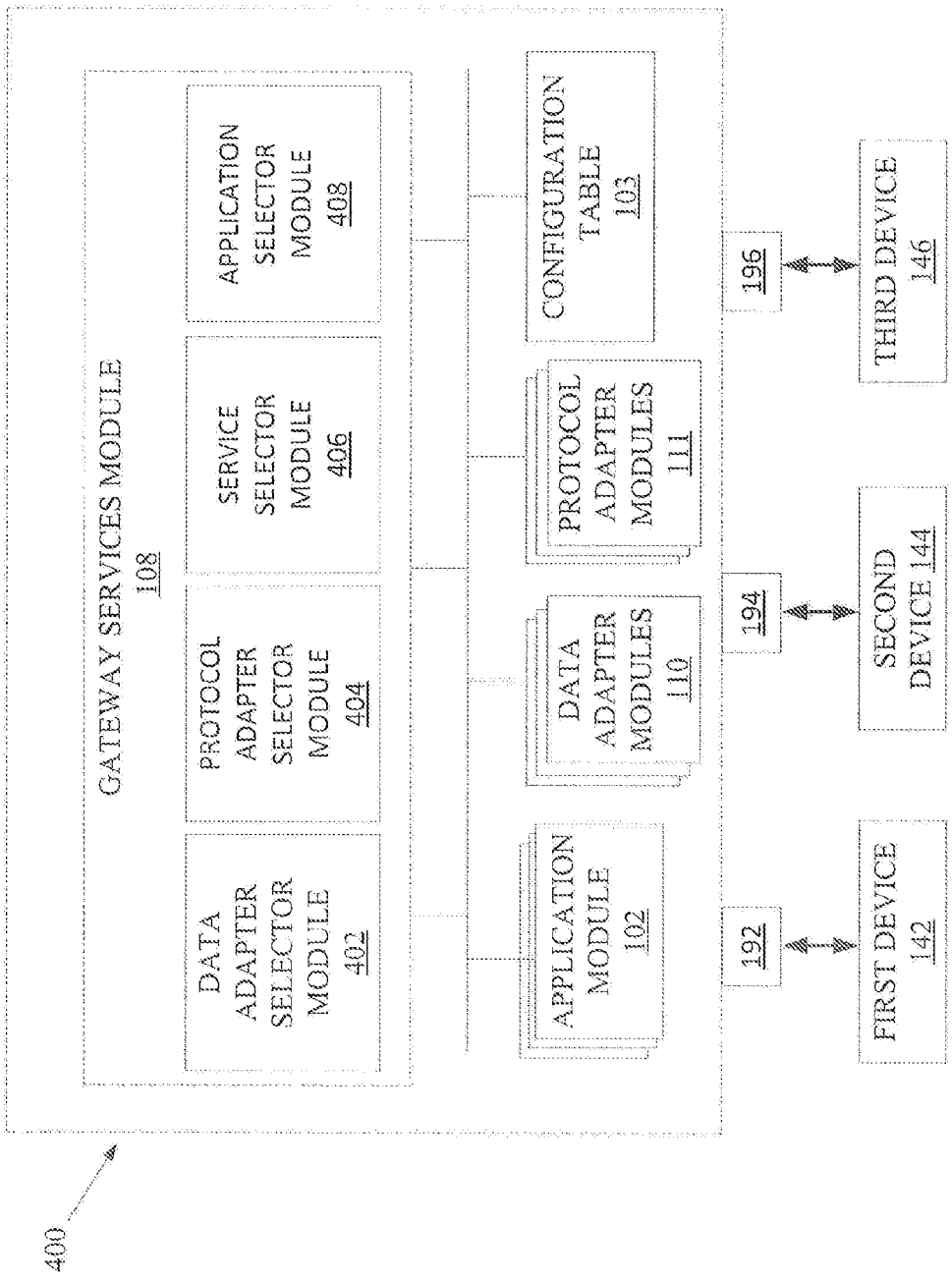

400
GATEWAY SERVICES MODULE
108
DATA ADAPTER SELECTOR MODULE
402
PROTOCOL ADAPTER SELECTOR MODULE
404
SERVICE SELECTOR MODULE
406
APPLICATION SELECTOR MODULE
408
APPLICATION MODULE
102
DATA ADAPTER MODULES
110
PROTOCOL ADAPTER MODULES
111
CONFIGURATION TABLE
103
192
194
196
FIRST DEVICE
142
SECOND DEVICE
144
THIRD DEVICE
146

FIG. 4

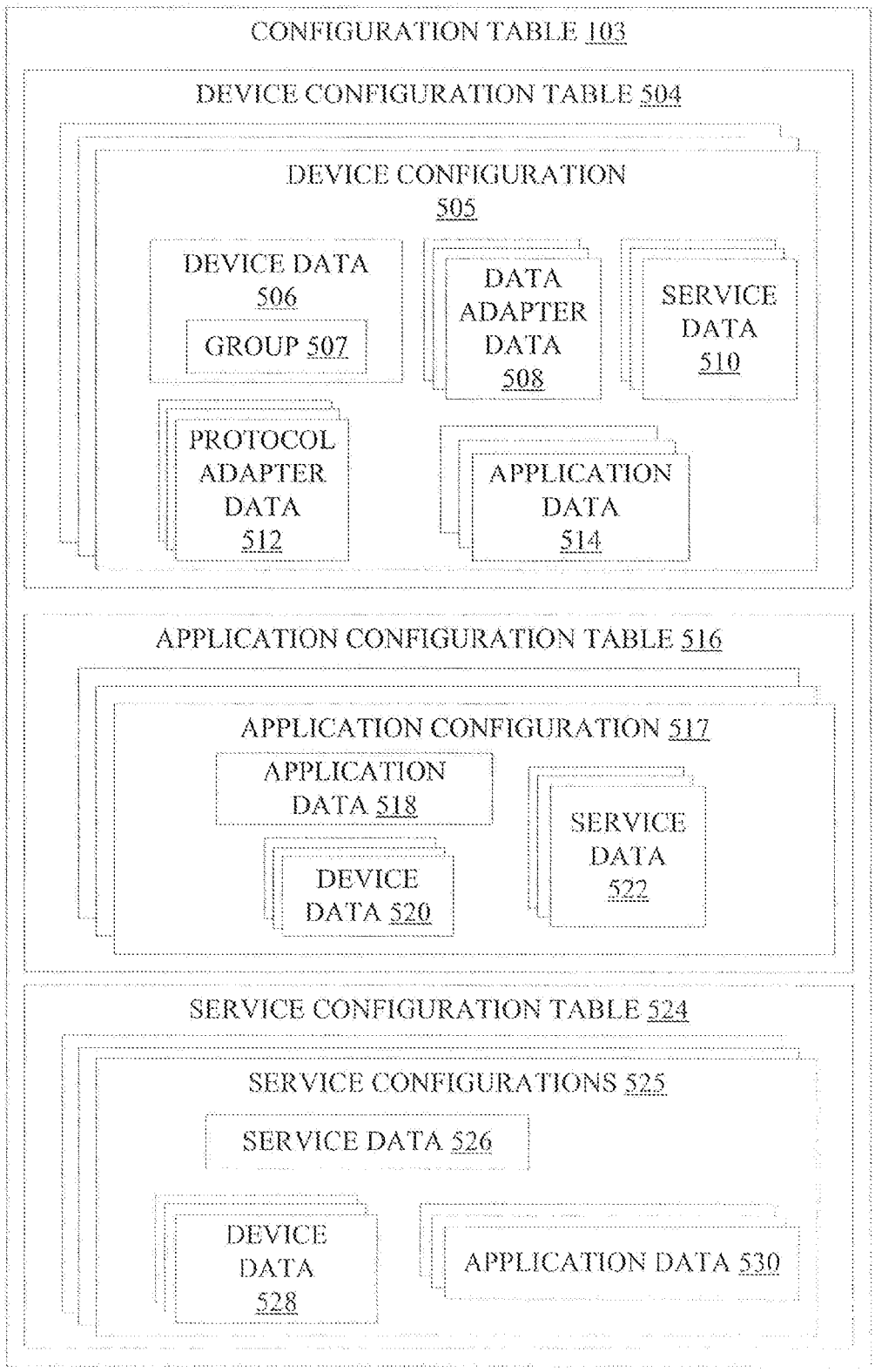

CONFIGURATION TABLE 103
DEVICE CONFIGURATION TABLE 504
DEVICE CONFIGURATION 505
DEVICE DATA 506
GROUP 507
DATA ADAPTER DATA 508
SERVICE DATA 510
PROTOCOL ADAPTER DATA 512
APPLICATION DATA 514
APPLICATION CONFIGURATION TABLE 516
APPLICATION CONFIGURATION 517
APPLICATION DATA 518
DEVICE DATA 520
SERVICE DATA 522
SERVICE CONFIGURATION TABLE 524
SERVICE CONFIGURATIONS 525
SERVICE DATA 526
DEVICE DATA 528
APPLICATION DATA 530

FIG. 5

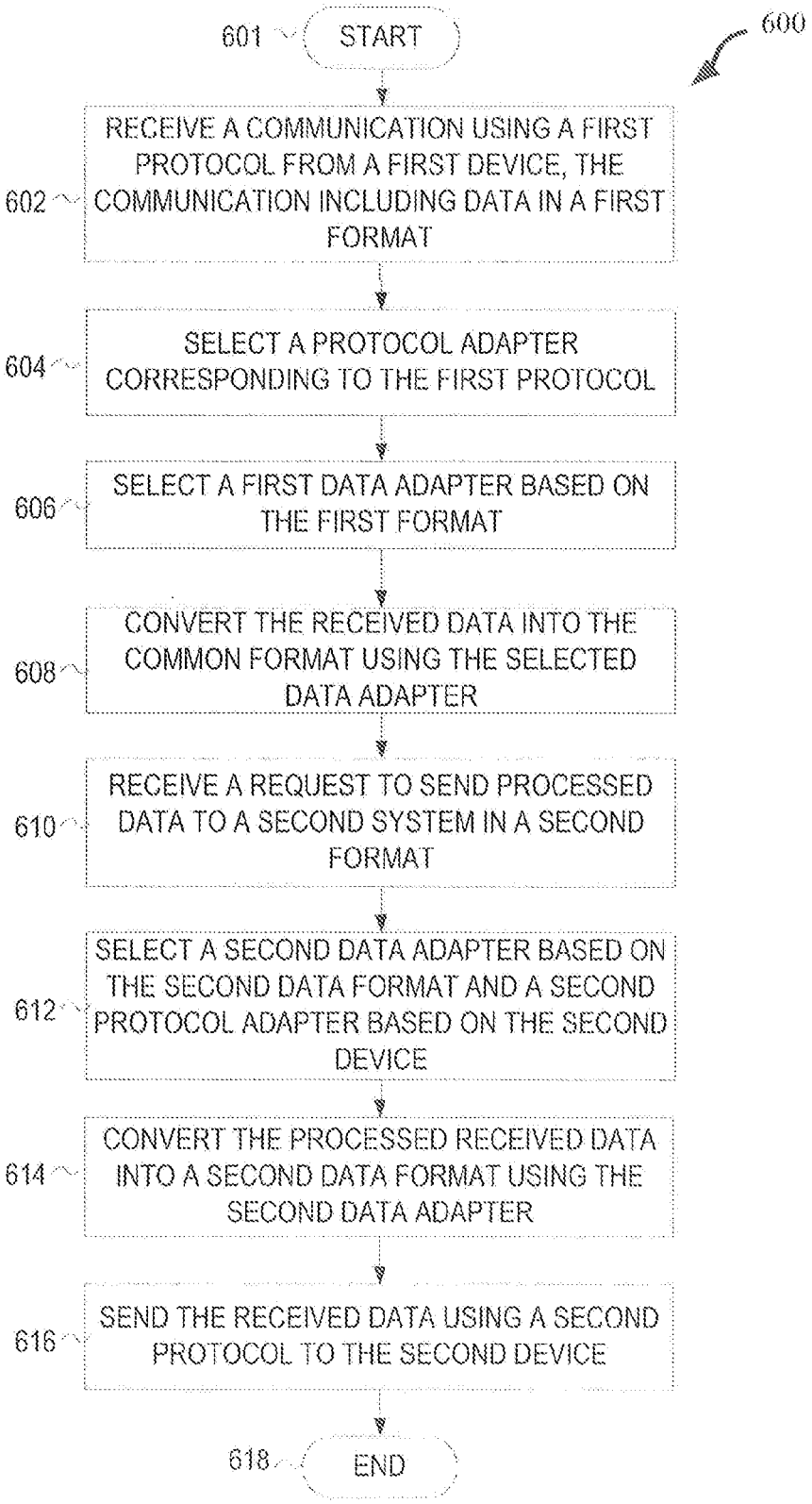

600
601
START
602
RECEIVE A COMMUNICATION USING A FIRST PROTOCOL FROM A FIRST DEVICE, THE COMMUNICATION INCLUDING DATA IN A FIRST FORMAT
604
SELECT A PROTOCOL ADAPTER CORRESPONDING TO THE FIRST PROTOCOL
606
SELECT A FIRST DATA ADAPTER BASED ON THE FIRST FORMAT
608
CONVERT THE RECEIVED DATA INTO THE COMMON FORMAT USING THE SELECTED DATA ADAPTER
610
RECEIVE A REQUEST TO SEND PROCESSED DATA TO A SECOND SYSTEM IN A SECOND FORMAT
612
SELECT A SECOND DATA ADAPTER BASED ON THE SECOND DATA FORMAT AND A SECOND PROTOCOL ADAPTER BASED ON THE SECOND DEVICE
614
CONVERT THE PROCESSED RECEIVED DATA INTO A SECOND DATA FORMAT USING THE SECOND DATA ADAPTER
616
SEND THE RECEIVED DATA USING A SECOND PROTOCOL TO THE SECOND DEVICE
618
END

FIG. 6

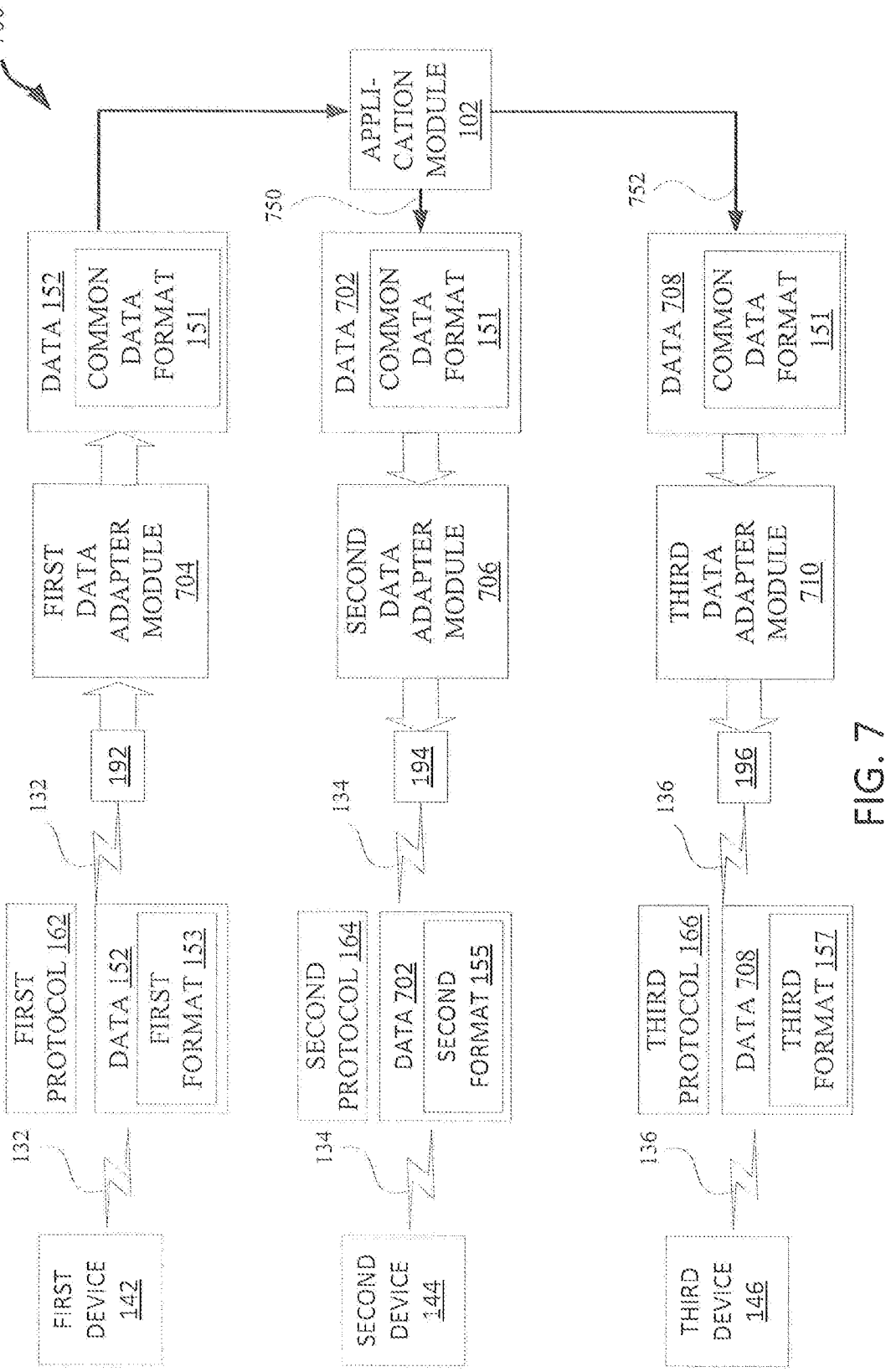

700
APPLI-CATION MODULE 102
750
752
DATA 152 COMMON DATA FORMAT 151
DATA 702 COMMON DATA FORMAT 151
DATA 708 COMMON DATA FORMAT 151
FIRST DATA ADAPTER MODULE 704
SECOND DATA ADAPTER MODULE 706
THIRD DATA ADAPTER MODULE 710
192
194
196
132
134
136
FIRST PROTOCOL 162
DATA 152 FIRST FORMAT 153
SECOND PROTOCOL 164
DATA 702 SECOND FORMAT 155
THIRD PROTOCOL 166
DATA 708 THIRD FORMAT 157
FIRST DEVICE 142
SECOND DEVICE 144
THIRD DEVICE 146

FIG. 7

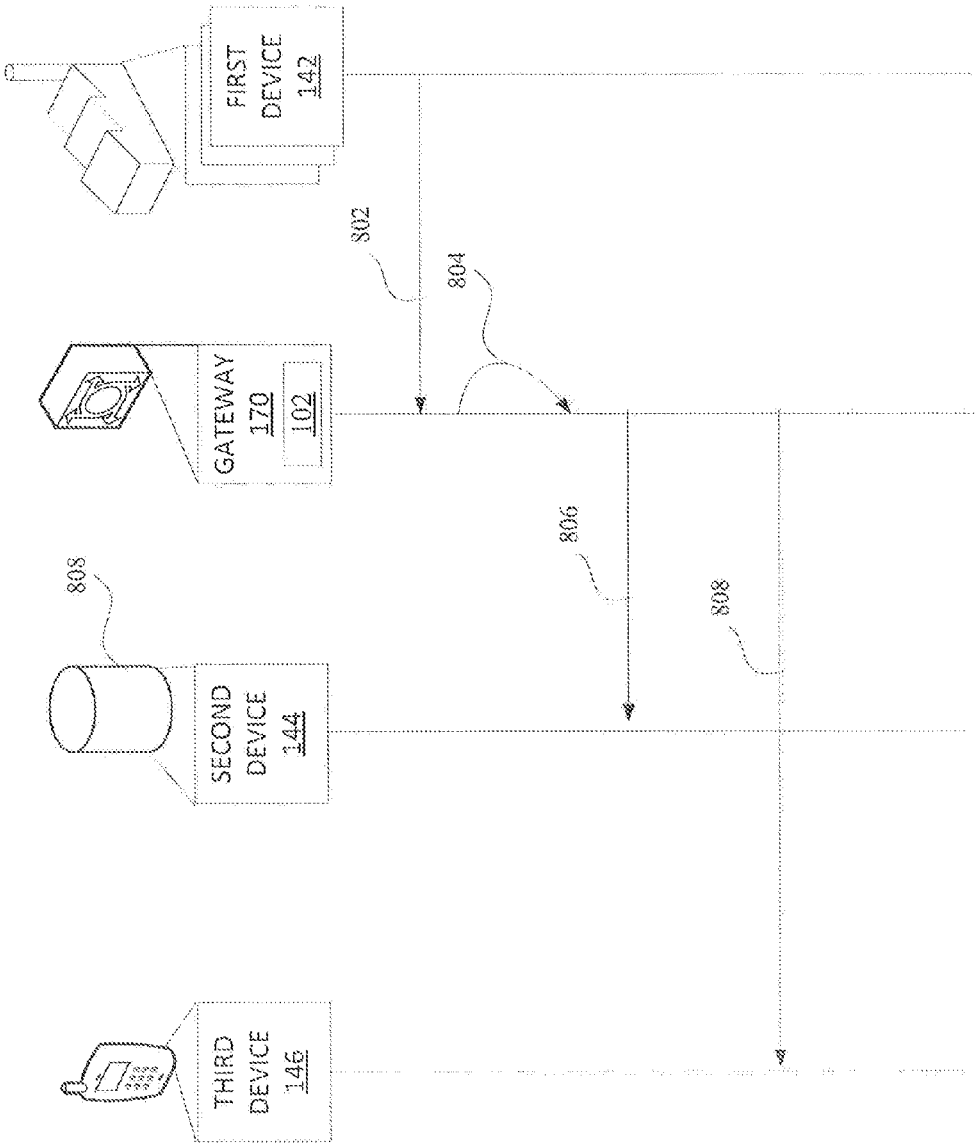

FIRST DEVICE 142
802
804
GATEWAY 170
102
806
808
808
SECOND DEVICE 144
THIRD DEVICE 146

FIG. 8

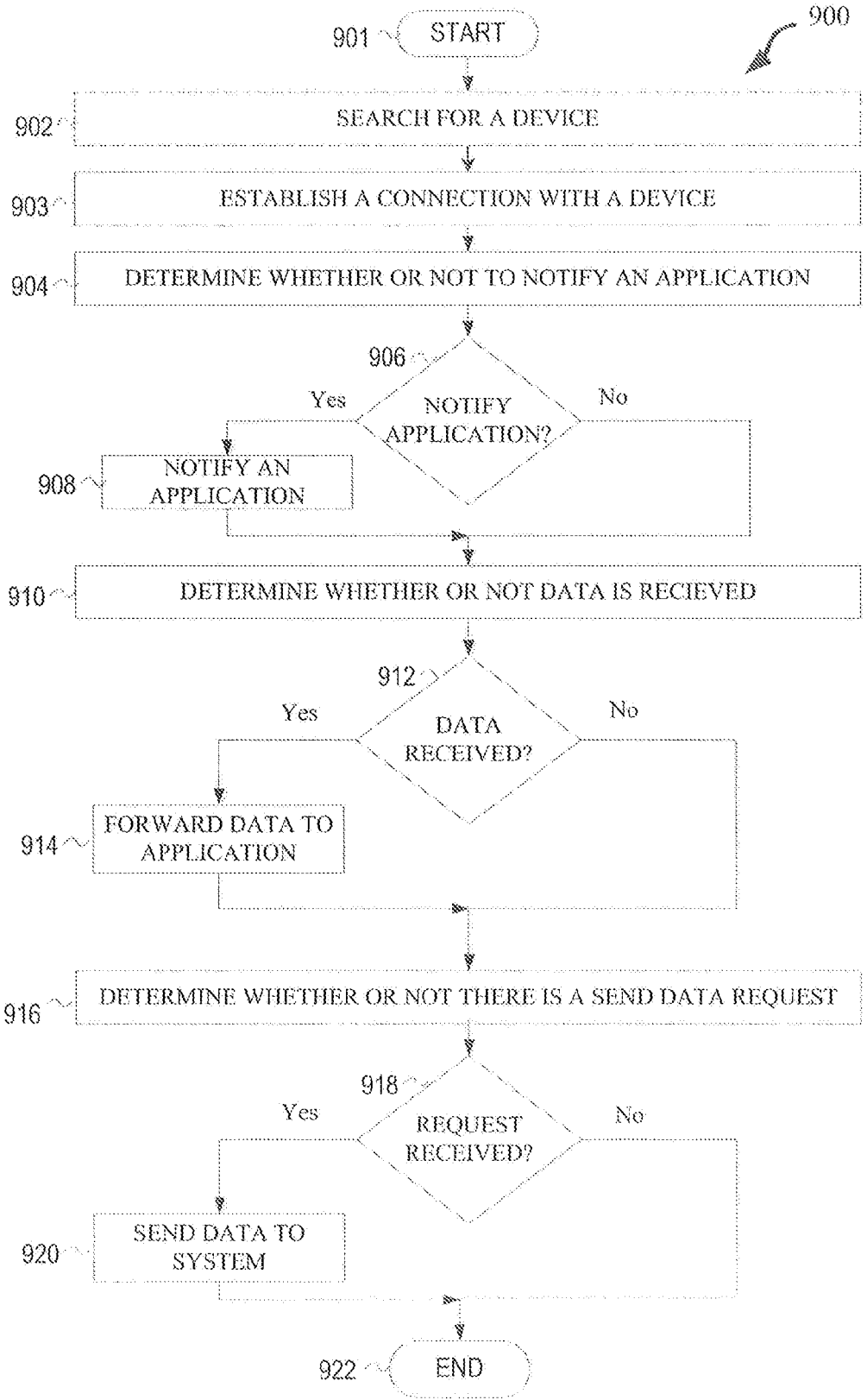

900
901
START
902
SEARCH FOR A DEVICE
903
ESTABLISH A CONNECTION WITH A DEVICE
904
DETERMINE WHETHER OR NOT TO NOTIFY AN APPLICATION
906
NOTIFY APPLICATION?
Yes
No
908
NOTIFY AN APPLICATION
910
DETERMINE WHETHER OR NOT DATA IS RECIEVED
912
DATA RECEIVED?
Yes
No
914
FORWARD DATA TO APPLICATION
916
DETERMINE WHETHER OR NOT THERE IS A SEND DATA REQUEST
918
REQUEST RECEIVED?
Yes
No
920
SEND DATA TO SYSTEM
922
END

FIG. 9

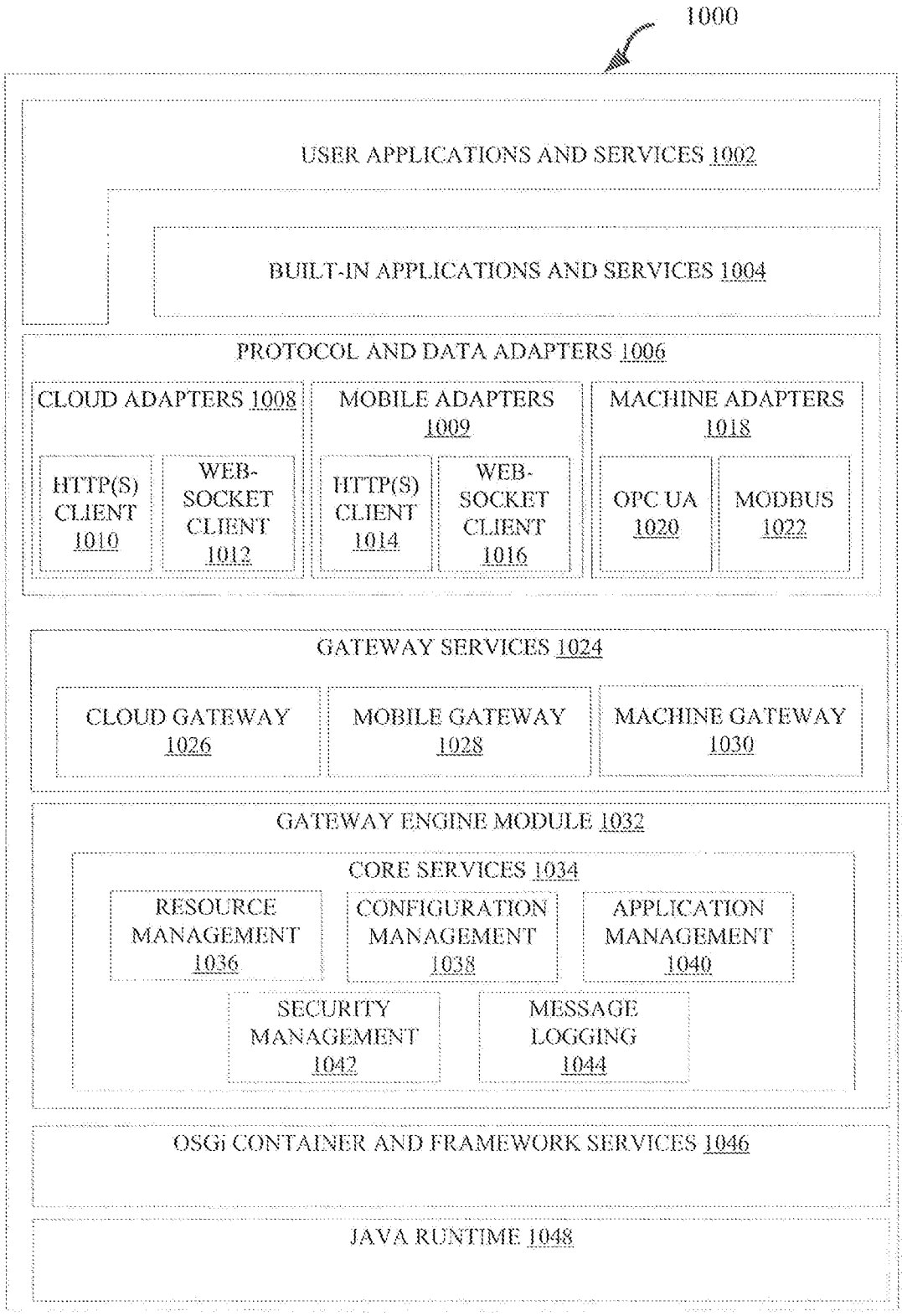

1000
USER APPLICATIONS AND SERVICES 1002
BUILT-IN APPLICATIONS AND SERVICES 1004
PROTOCOL AND DATA ADAPTERS 1006
CLOUD ADAPTERS 1008
HTTP(S) CLIENT 1010
WEB-SOCKET CLIENT 1012
MOBILE ADAPTERS 1009
HTTP(S) CLIENT 1014
WEB-SOCKET CLIENT 1016
MACHINE ADAPTERS 1018
OPC UA 1020
MODBUS 1022
GATEWAY SERVICES 1024
CLOUD GATEWAY 1026
MOBILE GATEWAY 1028
MACHINE GATEWAY 1030
GATEWAY ENGINE MODULE 1032
CORE SERVICES 1034
RESOURCE MANAGEMENT 1036
CONFIGURATION MANAGEMENT 1038
APPLICATION MANAGEMENT 1040
SECURITY MANAGEMENT 1042
MESSAGE LOGGING 1044
OSGi CONTAINER AND FRAMEWORK SERVICES 1046
JAVA RUNTIME 1048

FIG. 10

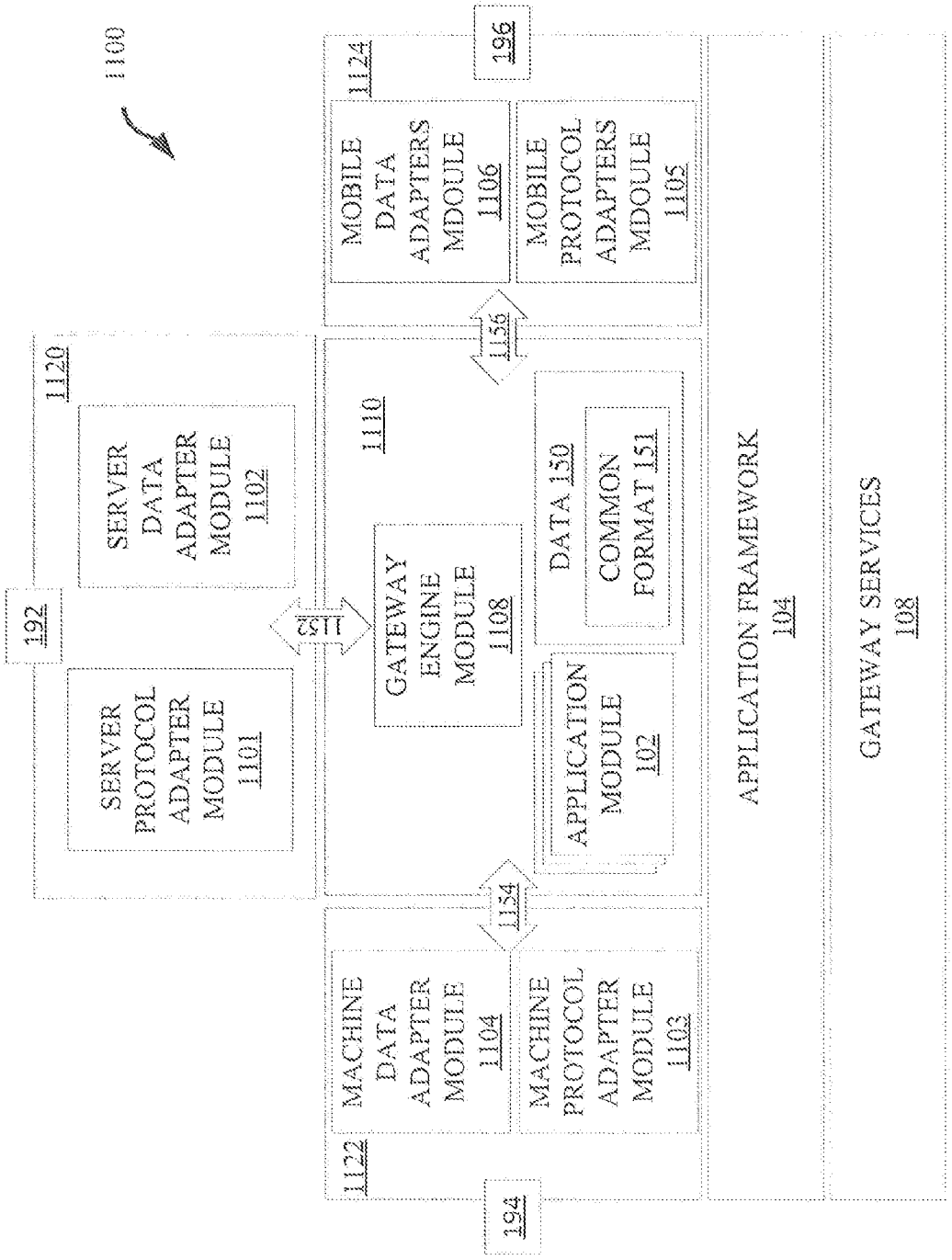

1100
1120
SERVER DATA ADAPTER MODULE 1102
192
SERVER PROTOCOL ADAPTER MODULE 1101
1110
GATEWAY ENGINE MODULE 1108
DATA 150
COMMON FORMAT 151
APPLICATION MODULE 102
APPLICATION FRAMEWORK 104
GATEWAY SERVICES 108
1124
MOBILE DATA ADAPTERS MDOULE 1106
MOBILE PROTOCOL ADAPTERS MDOULE 1105
196
1156
1154
1122
MACHINE DATA ADAPTER MODULE 1104
MACHINE PROTOCOL ADAPTER MODULE 1103
194

FIG. 11

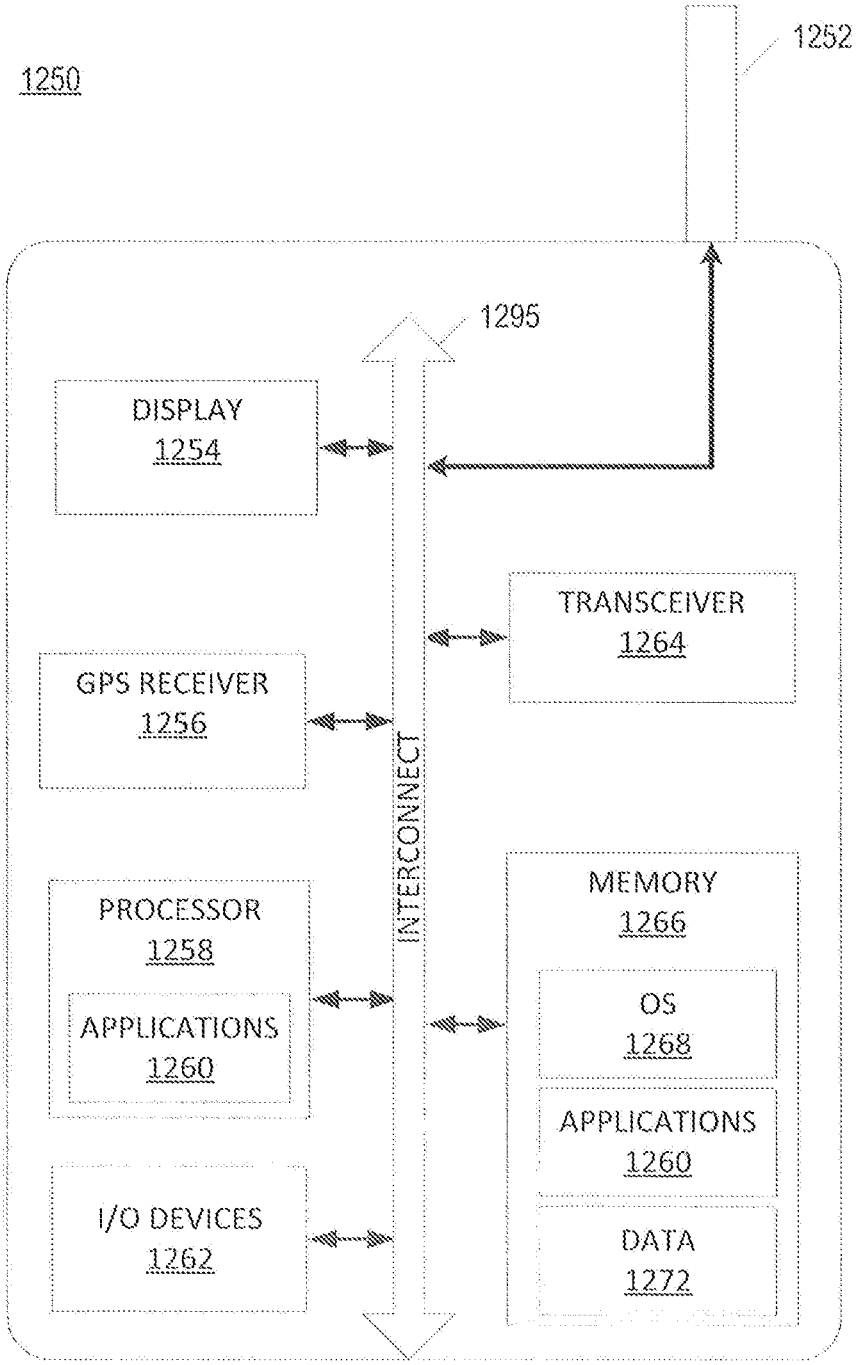

1250
1252
1295
DISPLAY
1254
TRANSCEIVER
1264
GPS RECEIVER
1256
INTERCONNECT
PROCESSOR
1258
APPLICATIONS
1260
MEMORY
1266
OS
1268
APPLICATIONS
1260
I/O DEVICES
1262
DATA
1272

FIG. 12A

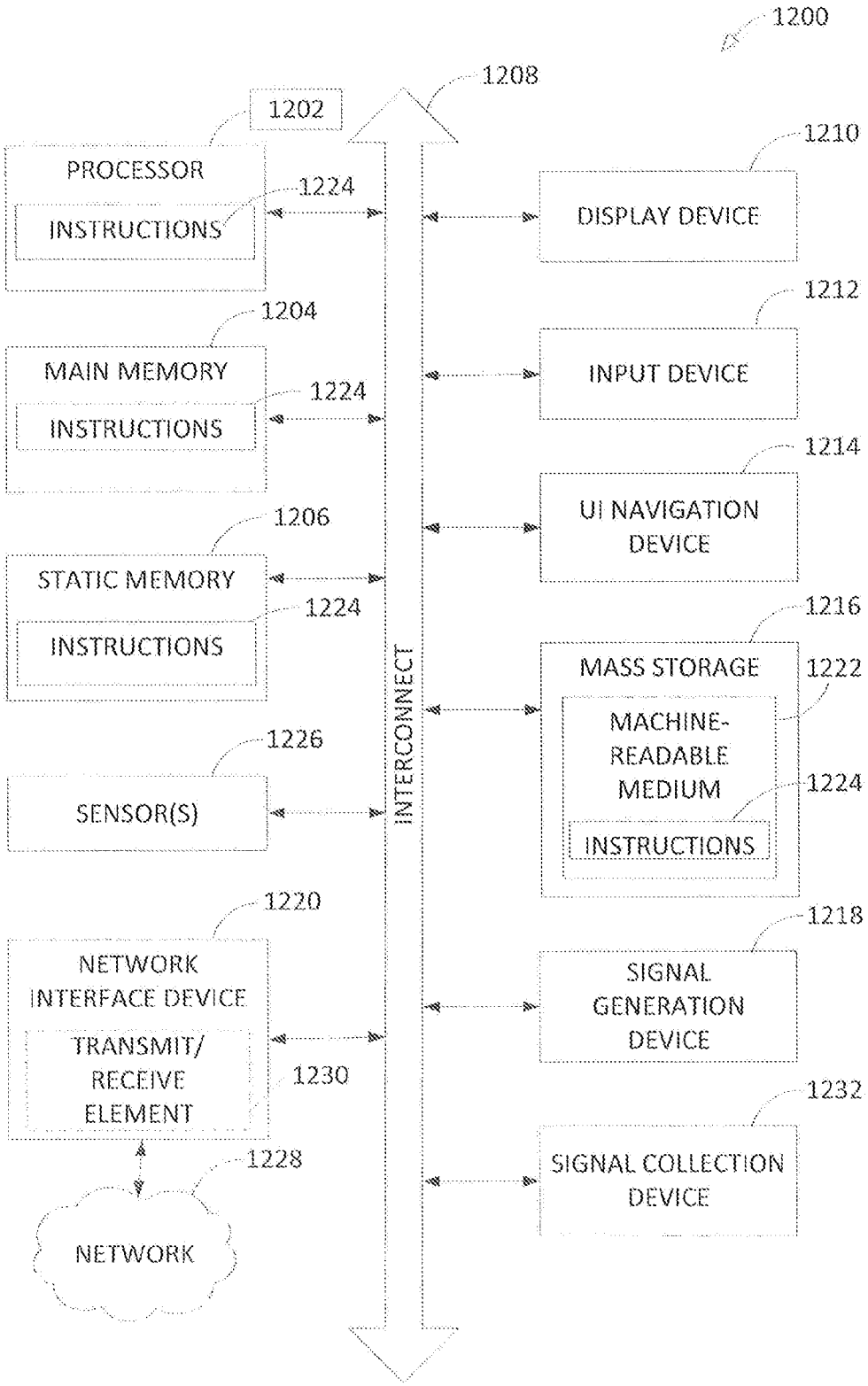

1200
1208
1202
PROCESSOR
INSTRUCTIONS
1224
1210
DISPLAY DEVICE
1204
MAIN MEMORY
INSTRUCTIONS
1224
1212
INPUT DEVICE
1206
STATIC MEMORY
INSTRUCTIONS
1224
1214
UI NAVIGATION DEVICE
1216
MASS STORAGE
1222
MACHINE-READABLE MEDIUM
INSTRUCTIONS
1224
INTERCONNECT
1226
SENSOR(S)
1220
NETWORK INTERFACE DEVICE
TRANSMIT/ RECEIVE ELEMENT
1230
1218
SIGNAL GENERATION DEVICE
1232
SIGNAL COLLECTION DEVICE
1228
NETWORK

FIG. 12B

INTELLIGENT GATEWAY WITH A COMMON DATA FORMAT

TECHNICAL FIELD

The subject matter disclosed herein relates to a gateway that supports applications and, more particularly, to a gateway with a common data format.

BACKGROUND

Many systems use different data formats and protocols. Often, applications need to process data and use services from different devices or domains. However, it may be difficult to develop applications fir the different devices because of the different protocols and data formats used by the different devices. Moreover, more and more data is being generated that is processed at central servers, but moving the data to the central servers often introduces delays and requires the use of a bandwidth to move the data to central servers.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is illustrated by way of example, and not limitation, in the figures of the accompanying drawings, in which like references indicate the same or similar elements and in which:

FIG. **1** illustrates a system, in accordance with an example embodiment, including a gateway with data in a common data format;

FIG. **2** illustrates an example system, in accordance with an example embodiment, of the system of FIG. **1**;

FIG. **3** illustrates examples of a first device, a second device, and a third device forming part of the system of FIG. **1**;

FIG. **4** illustrates another example embodiment of a gateway, in accordance with an example embodiment;

FIG. **5** illustrates a configuration table, in accordance with an example embodiment, for use in the gateway of FIG. **4**.

FIG. **6** illustrates a method, in accordance with an example embodiment, for converting data at a gateway from a first data format to a second data format using a common data format;

FIG. **7** illustrates an example application of the method of FIG. **6** in the system of FIG. **1** and the gateway of FIG. **2**;

FIG. **8** illustrates an example of an interaction diagram of communications between the gateway and the devices of FIG. **1**;

FIG. **9** illustrates a further method, in accordance with an example embodiment, for communicating data to a remote device from a gateway with a common data format for applications;

FIG. **10** illustrates a gateway, in accordance with an example embodiment, to convert data using a common data format;

FIG. **11** illustrates a gateway, in accordance with another example embodiment, to facilitate communication between a server, industrial machines, and a mobile device;

FIG. **12**A is a block diagram illustrating a mobile device, according to an example embodiment; and

FIG. **12**B is a block diagram of a machine or apparatus in the example form of a computer system within which instructions for causing the machine or apparatus to perform any one or more of the methods disclosed herein may be executed.

DETAILED DESCRIPTION

The following description and the drawings sufficiently illustrate specific example embodiments to enable those skilled in the art to practice them. Other example embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some example embodiments may be included in, or substituted for, those of other example embodiments.

FIG. **1** illustrates a system **100**, in accordance with an example embodiment, including a gateway **170** with data **150** in a common data format **151**. The system **100** is also shown to include a plurality of devices (e.g., a first device **142**, a second device **144** and a third device **146**) that may communicate using different data formats and different communication protocols with the gateway **170**. For example, the first device **142** may be a mobile device, the second device **144** may be an embedded controller in an industrial machine, and each device may use a proprietary data format and communication protocol. The gateway **170** may be an edge device on a network.

The gateway **170** is shown to further include one or more application module(s) **102** that operatively access the data **150** in the common data format **151** (e.g., XML). In the example system **100**, communications (e.g., a first communication **132**, a second communication **134**, and a third communication **136**) are shown between the gateway **170** and the devices **142**, **144**, and **146** via cloud networks (e.g., first, second and third cloud networks **182**, **184**, and **186**). It should, however, be noted that the communications **132**, **134** and **136** may be via other networks or any combination of networks (e.g., cloud-based or otherwise). To this end, a plurality of network interfaces (e.g., network interfaces **192**, **194**, and **196**) is provided to interface the gateway **170** to the cloud networks **182**, **184**, and **186**.

The gateway **170** is configured to facilitate communications (e.g., see communications **132**, **134**, and **136**) between devices **142**, **144**, and **146** and the gateway **170** using different data protocols and data formats (e.g., see FIG. **3**). To this end, the gateway **170** communicates with the first device **142**, the second device **134**, and the third device **136** and converts data **152**, **154**, and **156** (see FIG. **3**) from the first device **142**, the second device **144**, and the third device **146**, respectively into the common data format **151**. Accordingly, the application module(s) **102** can process the data **152**, **154** and **156** in the common data format **151**. The data **152** on the first device **142** is shown to be in a first format **153**, the data **154** on the second device **144** is shown to be in a second format **155**, and the data **156** on the third device **146** is shown to be in a third format **157**. Thus, although data residing on remote devices may be in a different data format, and communications may use different communications protocols, a single application module **102** can be used to process the data **152**, **154**, **156** following conversion of the data **152**, **154**, **156** to the common data format **151**.

A common data format area **180** provides an environment for the application module(s) **102** to operate on the data **150** in the common data format **151**. The data in the common data format area **180** is operatively received from the devices **142**, **144**, and **146** and converted to the common data format **151**. When the data from the common data format area **180** is sent to the devices **142**, **144**, and **146**, it is converted into a data format suitable for the respective device to which it is to be sent. For example, referring to FIGS. **1** and **3**, the gateway **170** is configured to send data to the first device **142** in the first format **153** using a first protocol **162**, send data to the second device **144** in the

second format **155** using a second protocol **164**, and so on. Likewise, the gateway **170** is configured to receive data from the first device **142** in the first format **153** using the first protocol **162**, receive data from the second device **144** in the second format **155** using the second protocol **164**, and so on. Using the common data format **151** thus allows the application module(s) **102** to be simplified in that they only need to be configured to accommodate a single data format instead of multiple data formats if they were to communicate directly with the devices **142**, **144**, and **146**.

In an example embodiment, the first device **142**, the second device **144**, and the third device **146** may be devices that generate or consume data **152**, **154**, **156** (see FIG. **3**) and provide services (e.g., a first service **172**, a second service **174**, and a third service **175**). In example embodiments, the first device **142**, the second device **144**, and the third device **146** can define data domains.

In other example embodiments, one or more of the devices **142**, **144**, and **146** include devices/components that form part of industrial machines. For example, one or more of the devices **142**, **144**, and **146** may include components to monitor and/or control industrial machines, components that include sensors to sense operating parameters of machines, or the like. As mentioned above, in other example embodiments, one or more of the devices **142**, **144**, and **146** include mobile devices, or the like. It will be appreciated that any number of different devices may be provided, and that some devices may use the same protocols and the same data format while other devices may use different protocols and different data formats. Example communications **132**, **134**, and **136** include communications using protocols such as Ethernet, 802.11, Long Term Evolution (LTE, 3rd Generation Partnership Project (3GPP) and so on.

Referring to FIG. **2**, an example system **200**, in accordance with an example embodiment, of the system of FIG. **1** is shown. The gateway **170** is shown to include one or more application module(s) **102**, and a common data area **180** including data **150** in a common data format **151**. The gateway **170** also includes an application framework module **104**, a gateway engine module **106**, and a gateway services module **108**. The application framework module **104** is configured to interface the gateway engine module **106** and the gateway services module **108** to the application module(s) **102** and the common data area **180** (e.g., via Application Programming Interface (API) calls). The gateway engine module **106** responds to requests to provide services rendered by the gateway services module **108**. Examples of services provided by the gateway services module **108** include sending and receiving data, and accessing services.

The gateway **200** is also shown to include a plurality of data adapter modules **110**, a plurality of protocol adapter modules **111**, and a configuration table **103**. The data adapter modules **110** are configured to convert or change the format of incoming and outgoing data. In an example embodiment, the data adapter modules **110** may be configured to convert data between the first data format **153** and the common data format **151**, convert data between the second data format **155** and the common data format **151**, and configured to convert data between the third data format **157** and the common data format **151**. Accordingly, in an example embodiment, three data adapter modules may be provided. However, it will be appreciated that there may be more data adapter modules. It will be appreciated that each of the data adapter modules **110** may be specifically customized for conversion of a particular data format to and from the common data format **151**.

The protocol adapter modules **111** allow the gateway **200** to communicate with devices using different protocols. For example, in the system **100**, a protocol adapter module **111** may be provided to communicate with the first device **142** in the first protocol **162**, a protocol adapter module **111** may be provided to communicate with the second device **144** in the second protocol **164**, a protocol adapter module **111** may be provided to communicate with the third device **146** in the third protocol **166**, and so on (see FIG. **3**).

Thus, data in various different formats, and communicated using various different protocols, can be stored in a common data format **151** and processed by various application module(s) **102**. Accordingly, the application module(s) **102** can be simplified to process data in the common data format **151** instead of being more complex to deal with many different data formats used by different remote devices. Moreover, the application module(s) **102** can be simplified to communicate with remote devices by using standard calls to the application framework module **104** instead of being more complex to deal with many different communication protocols used by different remote devices.

As described in more detail below, in an example embodiment, the configuration table **103** may be used to select an appropriate data adapter from the data adapter modules **110**, and select an appropriate protocol adapter from the protocol adapter modules **111** to process data conversion and communication with different remote devices.

FIG. **3** illustrates examples of a first device, a second device, and a third device forming part of the system of FIG. **1**. As mentioned above, one or more of the devices **142**, **144**, and **146** may be a wireless device. Accordingly, the first device **142** may be a wireless mobile device such as a smartphone, a tablet computer or any other portable device connected via a wireless network (e.g., a LAN, WAN, the Internet, a cellular data network or the like). When the data network is a cellular data network, the first data format may be Hyper-Text Markup Language (HTML) and the first protocol may be 802.11 or LTE. In other embodiments, the second device **144** may include components of a machine and the second data format **155** may be American Standard Code for International Interchange (ASCII) and the second protocol **164** may be Zigbee or IEEE 802.15.4. In still other embodiments, the third device **146** may be a server, and the third data format **157** may Distributed Component Object Model (DCOM), and the third protocol **166** may be Ethernet.

The data **152**, **154**, **156** may also include metadata. In example embodiments, the metadata may describe properties of the data **152**, **154**, **156**, and/or the first format **153**, the second format **155**, and the third format **157**. In example embodiments, the metadata provides information so as to facilitate conversion of the data into the common data format **151**. As an example, the metadata may indicate that the data **152**, **154**, **156** is in extensible mark-up language (XML), DCOM, Simple Object Access protocol (SOAP), ASCII, or any other known format. In an example embodiment, the gateway selects an appropriate data adapter based on the metadata.

Further examples of the protocol **162**, **164**, and **166** include 802.11x. Internet Protocol (IP), 3GPP, AppleTalk™. Long-Term Evolution (LTE), Bluetooth, token ring, WiMAX, Ethernet, virtual private network (VPN), Asynchronous Transfer Mode (ATM), passive optical subscriber loop, Integrated Services Digital Network (ISDN), physical layer protocols, media access layer protocols, network layer protocols, application layer protocols, routing protocols, address resolution protocols, or the like.

The services **172**, **174**, and **176** (or any other services provided in further devices) may be services that are used by one or more of the application module(s) **102**. For example, the first service **172** may include turning sensors on and off based on the data **152** received from the first device **142**. The second service **174** may include sending and receiving data to/from an application program on a mobile device. The third service **176** may include storing data on a remote server, querying an industrial machine to send data, and so on. Other example services include securing industrial gateways, application, services, device management, remote monitoring and diagnostics of software and devices, analytics frameworks for edge devices, supervisory control and monitoring of industrial machines, sensor data discovery and fusion, mobile access to headless devices, and so on. In example embodiments, the gateway **170** provides services that the devices may call. For example, the gateway **170** may provide a service to handle data generated by the remote devices, or store data at a backend server generated by a device.

In example embodiments, the gateway **170** allows the application module(s) **102** to get real-time access to the data **152**, **154**, **156** which is then converted and stored in the common data format area **180** where it is then accessible to the application module(s) **102**. In example embodiments, the gateway **170** is a gateway hub that provides a huh environment, or abstraction, for the application module(s) **102**.

The application framework module **104** allows the application module(s) **102** to access the gateway services module **108**, the gateway engine module **106**, the data adapter modules **110** and the protocol adapter modules **111** (e.g., via API calls). In example embodiments, the gateway **170** may discover devices (e.g., the devices **142**, **144**, and **146**) on a network.

In example embodiments, the application module(s) **102** is configured to remotely monitor and diagnose devices and/or software. Moreover, the application module(s) **102** may be configured to provide analytics regarding the monitored devices and/or software to other devices and/or users.

FIG. **4** illustrates another example embodiment of a gateway **400**, in accordance with an example embodiment. The gateway **400** substantially resembles the gateway **170** and thus includes similar modules. The gateway **400** is shown to include a gateway services module **108** including a data adapter selector module **402**, a protocol adapter selector module **404**, a service selector module **406**, and an application selector module **408**. The gateway **400** is also shown to include the application module(s) **102**, the data adapter modules **110**, the protocol adapter module **111**, and the configuration table **103**. In an example embodiment, based on data in the configuration table **103**, the selector modules **402**, **404**, **406**, **408** select an appropriate data format, protocol, services, and application to communicate with an associate device (e.g., the devices **142**, **144**, and **146**).

FIG. **5** illustrates a configuration table **103**, in accordance with an example embodiment, for use in the gateway **400**. It is to be noted that the configuration table **103** may also be used in the gateways **170** and **200**. The configuration table **103** is shown to include a device configuration table **504**, an application configuration table **516**, and a service configuration table **524**.

The device configuration table **504** is shown by way of example to include device configurations **505** that include device data **506**, a data adapter data **508**, service data **510**, protocol adapter data **512**, and application data **514**. The device data **506** may be an indication of a device (e.g., the devices **142**, **144**, **146**) and may include data to configure the device. The device data **506** may include a group **507**, which may indicate a group the device is part of. For example, there may be many sensor devices (e.g., devices **142**, **144**, **146**), and the gateway **400** may provide logical and functional grouping of the devices into groups. For example, the gateway **400** may group all data received from a group together for an application module **102** to process.

The service data **510** may indicate services (e.g., the services **172**, **174**, **176**) provided by the device. For example, a remote server device may provide a service to store data. The protocol adapter data **512** may indicate protocol adapter modules (e.g. protocol adapter modules **111**) that may be used for the device. The data adapter data **508** may indicate adapter modules (e.g. data adapter modules **110**) that may be used for the device. Moreover, the data adapter data **508** may indicate additional parameters for the data adapter module such as a directory to use on the device to access or store remote data. The application data **514** may indicate application modules (e.g. application modules **102**) that are associated with the device. For example, the application data **514** may indicate which application module **102** to notify if data is received from the device. As another example, the application data **514** may include security information regarding which application modules **102** are permitted to access the device. The applications referred to in application data **514** may have an entry in the application configuration table **516**.

TABLE 1

DEVICE CONFIGURATION TABLE

DEVICE DATA	DATA ADAPTER DATA	SERVICE DATA	PROTOCOL ADAPTER DATA	APPLICATION DATA
thermometer 192.168.8.1	machine adapter	send data	OPC adapter	
Backendserver.com 192.168.8.102	Backendserver adapter	Store, Retrieve	HTTP	process sensor data
mobile 192.168.8.193	mobile adapter	mobile app	802.11	process sensor data

Table 1 illustrates an example of the device configuration table **504** of FIG. **5** with three device configurations **505** of remote devices (e.g., devices **142**, **144**, **146**) one per row. The device data **506** of the first row indicates that the remote device has a name of "thermometer" and an IP address of 192.168.8.1. The gateway **400** may identify or access the remote device using the name or IP address. The data adapter data **508** of the first row indicates that "machine adapter" may be used to adapt the data from the format of the "thermometer" (e.g., formats **153**, **155**, **157**) to the

common format **151**. The service data **510** indicates that the remote device has a service (e.g., services **172**, **174**, **176**) called "send data." The service data **510** may include information regarding the type of service and how to call the service on the device. An application module **102** may use this "send data" service to tell the "thermometer" to send temperature readings to the gateway **400**. The service data **510** may also include information for the gateway **400** to identify that a communication from the device is from this service. For example, the gateway **400** may determine that a communication from the "thermometer" is from the "send data" service based on port of the of the network interface (e.g., network interfaces **192**, **194**, **196**), or, as another example, there may be identifying text.

The protocol adapter data **512** indicates that an "OPC adapter" may be used to communicate with the "thermometer." The application data **514** indicates that "process sensor data" is an application module **102** that accesses the "thermometer". Process sensor data may be an application module **102**, which is described in conjunction with FIG. **7**, where sensor data is received, fused, and then stored on a remote server, and where the results are reported to a mobile device. In a similar fashion rows two and three of Table 1 provide a device configuration **505** for a "backendserver.com" and a "mobile".

The application configuration table **516** is shown by way of example to include application data **518**, device data **520**, and service data **522**. The application data **518** may indicate an application module (e.g. application module **102**) and may indicate other configuration data regarding the application module such as how large the application module is, where the application module is stored on the gateway **400**, whether the application module is stored on a remote server, where to get updates for the application module, a security level of the application, etc. The device data **520** may indicate one or more devices (e.g., the devices **142**, **144**, **146**) associated with the application module. For example, the device data **520** may indicate which devices the application module has accessed and how the application module accessed the device (e.g. received data, sent data, or accessed a service), and how to call the application module for a particular device (e.g., different parameters to call the application may be used depending on the device). The device referred to in device data **520** may have a device configuration in the device configuration table **504**.

The service data **522** may indicate one or more services (e.g., the services **172**, **174**, **176**) associated with the application module. For example, the service data **522** may indicate which services the application module has accessed and how the application module accessed the service. The service may have a services configuration **525** in the service configuration table **524**. Additionally, the service data **522** may indicate a preference or required service for the application module. For example, the application module may request a service (e.g. to store data) from the services selector module **406**, and the services selector module **406** may determine which service to access for the application module based on the service data **522** for that application module.

TABLE 2

APPLICATION CONFIGURATION TABLE

APPLICATION DATA	DEVICE DATA	SERVICE DATA
process sensor data	thermometer 192.168.8.1; Backendserver.com, 192.168.8.102; mobile, 192.168.8.193	send data, store, mobile app

Table 2 illustrates an example of the application configuration table of FIG. **5** with one application configuration for "process sensor data". The application data **518** may be the name of application module "process sensor data". The "process sensor data" application module may an application module **102** as described in conjunction with FIG. **7**. The application data **518** may include data related to how to run the application module and may include security information for the application module. The device data **520** may be "thermometer", which may be a device as described above. The device data **520** may also include "backend server", which may be a backend server device. For example, "backend server" may be the second device **144** as described in conjunction with FIG. **7**. The device data **520** may also include "mobile", which be the third device **146** as described in conjunction with FIG. **7**. The service data **522** may include "send data", which may be associated with the "thermometer" as described above, "store", which may be associated with the "backend server", and "mobile app", which may be services associated with the "mobile". The services may have entries in the service configuration table **524**.

The service configuration table **524** is shown by way of example to include service data **526**, device data **528**, and application data **530**. The service data **526** may indicate a specific service (e.g., services **172**, **174**, **176**) or a general type of service, and may indicate other configuration data regarding the service such as security information needed to access the service. The device data **528** may indicate devices (e.g., devices **142**, **144**, **146**) where the service may be accessed. The devices may have entries in the device configuration table **504**. The application data **520** may indicate application modules (e.g., application modules **102**) that have accessed the service or, in some embodiments, that have permission to access the service. The application data **530** may include an application module to call if the service makes a call to the gateway **400**, which may be configured to access the service configuration table **524** to determine which application module **102** to invoke for the service.

TABLE 3

SERVICES CONFIGURATION TABLE

SERVICE DATA	DEVICE DATA	APPLICATION DATA
send data	thermometer 192.168.8.1	processor sensor data
Store	backendserver.com, 192.168.8.102	processor sensor data
mobile app	mobile 192.168.8.193	processor sensor data

Table 3 illustrates an example of the services configuration table of FIG. **5**. The service data **518** may be "send data", which is the name of the service. The device data **528** may be "thermometer", which may be a device that provides

the service as described above. The device may be a device such as the first device **142** as described in conjunction with FIG. **7**. The application data **530** may be "process sensor data" as described above. The application data **530** may include security information for the application module **102** that indicates whether the application can access the service, and, in some embodiments, how the application may access the service. Similarly, "store" and "mobile app" are described in Table 3.

Returning to FIG. **4**, in example embodiments, the protocol adapter selector module **404** is configured to select a corresponding protocol adapter module **111** to use to communicate with a remote device (e.g. devices **142**, **144**, **146**). For example, the gateway **400** may receive a communication from a device **142**, **144**, **146**. The protocol adapter selector module **404** may identify which device **142**, **144**, **146** sent the communication by the device data **506**. For example, from Table 1, the received communication may have an IP address associated with it of 192.168.8.102. The protocol adapter selector module **108** may then determine that the received communication is from device "backendserver-.com". The protocol adapter selector module **404** may then determine from protocol adapter data **512** of Table 1 that the appropriate protocol adapter is an HTTP protocol adapter module. Similarly, the protocol adapter selector module **402** may also be configured to determine which protocol adapter module **111** to select for a communication from the gateway **400**.

In example embodiments, the data adapter selector module **402** is configured to select a corresponding data adapter module **110** to use to convert data **152**, **154**, **156** between the common data format **151**, and the format (e.g. formats **153**, **155**, **157**) used by a corresponding remote device (e.g., devices **142**, **144**, and **146**). For example, the data adapter selector module **402** may be configured to select a corresponding data adapter module **110** to convert data between the common data format **151** and one of the first format **153**, the second format **155**, or the third format **157** using the configuration table **103** to select the corresponding data adapter module **110**. For example, referring to Table 1, the data adapter selector module **402** may select "machine adapter" to adapt data received from a "thermometer".

The service selector module **406** may be configured to select an appropriate service (e.g., services **172**, **174**, **176**) for an application module **102** to call. For example, an application module **102**, "process sensor data", may request a service to store "thermometer" sensor data. The service selector module **406** may search the service configuration table **524** for a service to store the "thermometer" sensor data and retrieve the "store" service configuration **525**, and determine from this that "store" service from "backend-server.com" is appropriate.

The application selector module **408** may be configured to select an appropriate application module **102** for a received communication using the configuration table **103**. For example, the gateway **400** may receive a communication from a device (e.g., devices **142**, **144**, **146**), and the protocol adapter selector module **404** may determine which device the communication was received from. The application selector module **408** may then access the device configuration **505** and determine an appropriate application module **102** to call to process the received communication. As example, the gateway **400** may receive a communication. The protocol adapter selector module **404** may determine from Table 1 that the communication is from the "thermometer", and then the application selector module **408** may determine that the appropriate application module **102** to call to process the received communication is "process sensor data." The application will then process the communication from the device. For example, the gateway **400** may receive a communication from a "thermometer" to store data. The application selector module **408** may select the "process sensor data" to respond to the request from the "thermometer" to store data. The "process sensor data" may then access an appropriate service to store the data from the "thermometer".

FIG. **6** illustrates a method **600**, in accordance with an example embodiment, for converting data at a gateway from a first data format to a second data format using a common data format. The method **600** may be deployed on the gateways **170** and **400** and, accordingly, are described merely by way of example with reference thereto. FIG. **7** illustrates an example deployment of the method **600** in the system **100** of FIG. **1** and the system **200** of FIG. **2**.

The method **600** starts at operation **601** and then continues at operation **602** where a communication is received in a first protocol from a first system or device where the communication includes data in a first format. For example, referring to FIGS. **1**, **2**, and **3**, the first system **142** may send data **152** in the first format **153** using the first protocol **162** as shown by communication **132** (see FIGS. **1** and **7**). Thereafter, as shown at operation **604**, the gateway services module **108** (see FIG. **2**) determines a corresponding protocol adapter module **111** to process the communication. In example embodiments, the gateway services module **108** uses the configuration table **103** (see FIG. **5**) to select the corresponding protocol adapter module **111**.

The method **600** continues at operation **606** wherein a corresponding data adapter module (e.g., one of the data adapter modules **110**) is selected to convert the data in the first format **153** to data in the common data format **151** (see operation **608** and FIG. **7**). One or more of the application module(s) **102** may then process that data and provide an associated service. For example, the first format **153** may be a proprietary format with meta-characters for collecting data from industrial machines that may be converted into Extensible Markup Language (XML) as the common data format **151**.

As shown in operation **610**, upon receipt of a request from a second device (e.g., the second device **144**) to receive data, the method **600** may then select a second protocol adapter (e.g., from the protocol adapter modules **111** and select a second data adapter (e.g., from the data adapter modules **110**), corresponding to the second device (e.g., the device **144**) as shown at operation **612**. In example embodiments, the gateway services module **108** uses the configuration table **103** (see FIG. **5**) to select the corresponding protocol adapter module **111** and data adapter module(s) **110**.

The method **600** then continues at operation **612** with the relevant data is converted from the common data format **151** (e.g., XML) to the second data format (see operation **614**). Thereafter, the converted data is communicated using the selected protocol adapter to the second device (e.g., the second device **144**) as shown at operation **616**. The data sent to the second device **144** may be fused data and the method **600** may then end at operation **618**.

In an example embodiment, the application module(s) **102** create fused data after, for example, receiving the data from the first device **142**. When the device **142** forms a component or part of an industrial machine. As shown by way of example in FIG. **8**, data **802** may be sent from the first device **142** to the gateway **170** where it is processed in accordance with the method **600**. Thereafter, the data may be processed into fused data. The fused data may then be

converted (see operation **804**) and communicated (see operation **806**) to the second device **144** where it may be persisted in a database. In addition, the fused data may be converted (see operation **808**) and communicated (see operation **810**) to a third device **146** in the form of a mobile device. The data may then be processed or viewed using a mobile application running on the mobile device. In an example embodiment, the mobile application may allow a user to control operation of one or more industrial machines. The second device **144** may be a server system that maintains records of the operation of the industrial machine(s). Accordingly, in the given example, the gateway **170** can facilitate communications to/from various different devices that use different protocols.

In example embodiments, the gateways **170**, **400** are located or provided at edge devices where an edge device is a device that provides an entry point into a network (e.g. switches, routers, multiplexers). Accordingly, functionality performed by the application module(s) **102** takes place at an edge device. As the gateways **170**, **200** have a plurality of data adapter modules **110** and a plurality of protocol adapter modules **111**, interfacing of different devices using different data format and protocol can be done at the edge device.

FIG. **9** illustrates a further method, in accordance with an example embodiment, for communicating data to a remote device from a gateway with a common data format for applications. The method **900** may be deployed on the gateways **170**, **200** and, accordingly, are described merely by way of example with reference thereto. In the method **900** the device (e.g., one of more of the devices **142**, **144**, **146**) is a device such as a server system, mobile device, or machine component.

The method **900** optionally begins at operation **902** with search for a device. For example, the gateway **170** may listen for beacon frames from devices or actually send out queries regarding devices that the gateway **170** may communicate with. For example, in an embodiment, the gateway **170** may be a home or factor gateway which may discover all the active devices that the gateway may communicate with.

The method **900** continues at operation **903** with establishing a connection with a device as shown at operation **903**. An appropriate data adapter module (e.g., an adapter module **142**) and protocol adapter module (e.g., one of the protocol adapter modules **111**) may be identified and selected to effect communication with the device. In example embodiments, the gateway **170**, **400** may establish secure communications with the device. In example embodiments, the gateway engine module **106** determines the appropriate data adapter module based on calling the gateway services module **108**. For example, the gateway services module **108** may look up the system or a service associated with the system in the configuration table **103**, and determine the appropriate data adapter module (e.g., selected from the data adapter modules **110**) based on the system or service required.

Thereafter, the method **900** continues at operation **904** and determines whether or not to notify an application. For example, the gateway services module **108** may determine whether or not to notify an application module **102** of the establishment of a connection with the device (e.g., the first device **142**, second device **144**, or third device **146**). In example embodiments, the gateway service module **108** or gateway engine module **106** may access the configuration table **103** that indicates whether or not to notify an application module **102** upon establishment of a connection with the device (see decision operation **906**).

The method **900** then continues at operation **906** with notify application. If it is determined that the application is to be notified, a notification is sent to the application (see operation **908**) and the method proceeds to operation **910**. If, however, the application does not need to be notified then the method proceeds directly to operation **910**. In operation **910**, the method **900** determines whether or not data has been received.

Thereafter, the method **900** continues at decision operation **910** where a determination is made to determine whether or not data is received from the device. If no data has been received, then the method **900** proceeds directly to operation **916** where a determination is made whether or not a request for data is to be sent to the device. However, if data has been received from the device, the data is then sent to the relevant application (e.g., one of the application module(s) **102**) for processing. In example embodiments, the gateway services module **108** or the gateway engine module **106** determines whether or not data has been received from the devices **142**, **144**, **146** and, for example, stored as new data (e.g., data **150**) in the common data format **151**. The method the proceeds to operation **916**.

As shown at decision operation **918**, if a request fir data has been received, then the requested data may be sent to the device (see operation **920**), if, however, a request has not been received, then the method **900** proceeds to operation **922** where the method **900** terminates. The method **90**) may return to operation **901** and execute continually while the gateway is active.

FIG. **10** illustrates a gateway **1000**, in accordance with an example embodiment, to convert data using a common data format. The gateway **1000** may be deployed in the gateways **170**, **400** and, accordingly, is described merely by way of example with reference thereto. The gateway **1000** is shown to include user applications **102**, built-in applications and services **1004**, protocol and data adapters **1006**, gateway services **1024**, a gateway engine module **1032**, an Open Service Gateway initiative (OSGi) container and framework services **1046**, and a JAVA runtime engine **1048**.

The various components of the gateway **1000** may be arranged in a stack where the user applications and services **1002** are at the top of the stack. These user applications and services **1002** interact with the different layers of the stack. However, the user applications and services **1002** do not necessarily depend on the built-in applications and services **1004**. In example embodiments, the user applications and services **1002** include application modules similar to, or the same as, the application modules **102**. When included, the application modules **102** have access to data in a common data format (e.g., the common data format **151**) communicated via the gateway services **1024**.

The gateway services **1024** may include a plurality of gateway services such as, for example, a cloud gateway **1026** (e.g., machine to cloud (C2M)), a mobile gateway **1028** (e.g., machine to human (M2H)), a machine gateway **1030** (machine-to-machine gateway (M2M)), and various other gateways. Accordingly, the protocol and data adapters **1006** are shown to include a cloud adapter, a mobile adapter **1009** and machine adapters **1018**. It will be appreciated that other data and protocol adapters may also be provided. The functionality performed by the protocol and data adapters **1006** may be similar or the same as the functionality performed by the data adapter modules **110** and the protocol adapter modules **111** and, optionally, use configuration table similar to the configuration table **103**. The gateway services **1024** may be configured to provide centralized configuration, monitoring, and automatic management of the adapters

1010, 1012, 1014, 1016, 1020, 1022 that run as plug-ins within the example gateways 1026, 1028, 1030.

The cloud adapters 1008 include an Hypertext Transfer Protocol and/or Hypertext Transfer Protocol secure (HTTP(S)) client 1010 and a web-socket client 1012 configured to communicate with the cloud gateway 1008. In a similar fashion, the mobile adapters 1009 include an HTTP (S) client 1014 and a web-socket client 1016 configured to communicate with the mobile gateway 1028, and the machine adapters 1018 include an object linking and embedding (OLE) for process control (OPC) unified architecture (UA) (OPC UA) 1020 and a Modicum bus (MODBUS) 1022 configured to communicate with the machine gateway 1030. In an example embodiment, the protocol and adapters 1006 provide a single interface to the user applications and services 1002. In an example embodiment, the gateway 1000 performs one of more of the methods and functionality described herein before. For example, the gateway 1000 may form part of the system 100 and perform the methods 600 and 900.

In example embodiments, the built-in applications and services 1004 include applications that solve common needs, such as data aggregation, modeling, persistence, monitoring, alarm generation, and so on. In example embodiments, the user applications and services 1002 may call the built-in applications and services 1004. Third party developers or users may make use of the built-in applications and services 1004 in developing proprietary (or otherwise) applications modules.

As mentioned above, the gateway 1000 may be deployed in the system 100. Accordingly, the cloud adapters 1008, the mobile adapters 1009, and the machine adapters 1018 can be configured to communicate using protocols and data models, with the first system 142, the second system 144, or the third system 146 (see FIG. 1).

The OPC UA 1020 may be implemented by an application that is used by the machine gateway 1030 to communicate with a server that complies with the OPC UA specification. For example, the first device 142 may operate in accordance with OPC UA specifications and the machine gateway 1030 may use the OPC UA 1020 machine adapter 1018 to communicate with the first device 142. The MODBUS 1022 is an application that may be used by the machine gateway 1030 to communicate in accordance with the MODBUS standard with a server or device that operates in accordance with the MODBUS standard.

In example embodiments, the adapters 1010, 1012, 1014, 1016, 1020, and 1022 can also read/write data and subscribe for data updates from servers or devices (e.g., the first device 142, the second device 144, and the third device 146).

In example embodiments, the gateway services 1024 are configured to send and receive data to servers or devices such as the first device 142, the second device 144, and the third device 146.

In example embodiments, the gateway engine 1032 includes core services modules 1034. The core services modules 1034 are shown by way of example to include a resource management module 1036, a configuration management module 1038, an application management module 1040, a security management module 1042, and a message logging module 1044. In example embodiments, gateway engine module 1032 is configured to provide a runtime environment and to manage one or more of the gateway services 1024, the protocol and data adapters 1006, the built-in applications and services 1004, and the user applications and services 1002. In example embodiments, the gateway engine 1032 uses an OSGi framework and various OSGi framework services to manage the lifecycle of the user applications and services 1002. In example embodiments the gateway 1000 is developed using the JAVA runtime engine 1048.

Further to the core services module 1034, the resource management module 1036 may be configured to manage the various resources of the gateway 1000. For example, the resource management module 1036 may manage the memory allocation (e.g., memory allocation for the common data format 151). In example embodiments, the configuration management module 1038 manages the configuration of the gateway 1000, and the application management module 1040 manages the applications and services in the user application and services 1002. The security management 1042 module may be configured to manage the security of communications and message logging module 1044 may log messages.

FIG. 11 illustrates a gateway 1100 with a common data format, in accordance with another example embodiment. Illustrated in FIG. 11 are a gateway 1100, common data format area 1110, a machine network interface device 192, a server network interface device 194, a mobile network interface device 196, first conversion 1152, a second conversion 1154, a third conversion 1156, application framework 104, gateway services 108, server gateway 1120, machine gateway 1122, and mobile gateway 1124.

In example embodiments, the common data format area 1110 includes gateway engine module 1108, application modules 102, and data 150, which has a common data format 151. In example embodiments, the common data format area 1110 provides an environment where application modules 102 may operate on data 150 and send and receive data of a different format from external systems. The gateway engine module 1108 may be configured to receive and send data 150 to one or more of the gateways 1120, 1122, and 1124. In some embodiments, the gateway engine module 1108 may be configured as disclosed in conjunction with FIG. 2.

The gateways 1120, 1122, 1124 provide a gateway 1120, 1122, 1124 between the common data format area 1110 and an external system. The protocol adapter modules 1101, 1103, 1105, and the data adapter modules 1102, 1104, 1106 provide an abstraction between data domains of devices 142, 144, 146 (see FIG. 1) and the application modules 102.

The server data adapter module 1102, the machine data adapter module 1104, and the third adapter module 1106 take data in a different format from external systems and convert 1152, 1154, 1156 the data in a different format into the common data format 151. The server data adapter module 1102, the machine data adapter 1104, and the mobile data adapter 1106 may be configured to use communication protocols for the external systems. In example embodiments, the gateways 1120, 1122, 1124 may be modular so that additional gateways 1120, 1122, and 1124 can be added to the gateway 1100.

In example embodiments, the application framework 104 provides an application programming interface (API) to access the gateway services 108. In example embodiments, the server data adapter 1102, the machine data adapter 1104, the mobile data adapter 1106, the gateway engine module 1108, and the application modules 102 use the API provided by the application framework 104. In example embodiments, the gateway services 108 uses Open Service Gateway initiative (OSGi) and a Java® runtime environment.

The systems and methods described herein may facilitate connectivity and communication between industrial data systems/machines, cloud-based services, and mobile appli-

cations. In an example embodiment, connectivity between networked devices (e.g., mobile devices) and industrial systems where the industrial system is isolated within separate control networks may be facilitated. In example embodiments, example deployments of the technology described herein may be in resource-constrained devices that can be integrated into existing systems and networks. This may allow real-time data to flow from the industrial systems/machines into cloud-based services and mobile device users without disrupting existing data flow. The systems and methods described herein may be combined with low cost hardware platform, similar to Raspberry Pi devices, BeagleBone Black devices, or the like, and provide a plug-in gateway hub on top of an existing infrastructure.

In example embodiments, the gateway **170**, **400**, **1100** has the technical effect of processing data on an edge device so that the data does not have to be sent to a server to be processed. In example embodiments, the gateway **170**, **400**, **1100** has the technical effect of enabling application modules **102** to be developed using a common data format **151** independent of the data formats of different systems first system **142**, the second system **144**, and the third system **146**. In example embodiments, the gateway **170**, **400**, **1100** has the technical effect of enabling application modules **102** to be developed independent of the data protocols first protocol **162**, the second protocol **164**, and the third protocol **166** of the different systems first system **142**, the second system **144**, and the third system **146**, respectively. In example embodiments, the gateway **170**, **400**, **1100** has the technical effect of enabling devices to be added to the gateway **170**, **1100** by adding data adapter modules **110**, **1102**, **1104**, and **1106**.

FIG. **12**A is a block diagram illustrating a mobile device **1250**, according to an example embodiment. The mobile device **1250** may be a device described herein such as (e.g., device **142**, **144**, **146**). The mobile device **1250** may include a processor **1258**. The processor **1258** may be any of a variety of different types of commercially available processors suitable for mobile devices (for example, an XScale architecture microprocessor, a Microprocessor without Interlocked Pipeline Stages (MIPS) architecture processor, or another type of processor). The processor **1258** may include application(s) **1260**. The application(s) **1260** may be partially or wholly hardwired as part of the processor **1258**. A memory **1266**, such as a Random Access Memory (RAM), a Flash memory, or other type of memory, is typically accessible to the processor. In an example embodiment, the memory **1266** may partially be ROM. The memory **1266** may be adapted to store an OS **1268**, data **1272**, as well as application(s) **1260**. The application(s) **1260** may be partially or wholly hardwired and partially or wholly resident in the memory **1266**. The application(s) **1260** may be an application such as a service **172**, **174**, **176** (see FIG. **3**), which may be an application on the mobile device **1250**. The data **1272** may include data such as data **708** (see FIG. **7**) and communications mode **120**. The processor **1258** may be coupled, either directly or via appropriate intermediary hardware, to a display **1254** and to one or more input/output (I/O) devices **1262**, such as a keypad, a touch panel sensor, a microphone, and the like. Similarly, in some example embodiments, the processor **1258** may be coupled to a transceiver **1264** that interfaces with an antenna **1252**. The transceiver **1264** may be configured to both transmit and receive cellular network signals, wireless data signals, or other types of signals via the antenna **1252**, depending on the nature of the mobile device **1250**. In this manner, the communications **132**, **134**, **136** (see FIG. **1**) with the cloud **182**, **184**, **186** may be established. Further, in some configurations, a global positioning system (GPS) receiver **1256** may also make use of the antenna **1252** to receive GPS signals. Each of display **1254**, transceiver **1264**, GPS receiver **1256**, processor **1258**, memory **1266**, I/O devices, and antenna **1252** may be connected to an interconnect **1295** and/or connected (not illustrated) to one or more of each other. The interconnect **1295** may be one or more communications systems such as a bus or other hardware to enable communication, which may even be each component individually wired to the other components the component communicates with.

FIG. **12**B is a block diagram of a machine or apparatus in the example form of a computer system **1200** within which instructions for causing the machine or apparatus to perform any one or more of the methods disclosed herein may be executed. In alternative example embodiments, the machine operates as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine may operate in the capacity of a server or a client machine in server-client network environment, or as a peer machine in a peer-to-peer (or distributed) network environment. The machine may be a personal computer (PC), a wearable device, a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a cellular telephone, a web appliance, a network router, switch or bridge, an edge device, a gateway, a gateway, or another machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

The example computer system **1200** includes one or more processors **1202** (e.g., a central processing unit (CPU), a graphics processing unit (GPU), or both), a main memory **1204** and a static memory **1206**, which communicate with each other via a bus **1208**. In example embodiments, the computer system **1200** includes a display unit **1210** (e.g., a liquid crystal display (LCD) or a cathode ray tube (CRT)). In example embodiments, the computer system **1200** also includes an alphanumeric input device **1212** (e.g., a keyboard), a user interface (UI) navigation device **1214** (e.g., a mouse), mass storage **1216**, a signal generation device **1218** (e.g., a speaker), and a network interface device **1220**. In example embodiments, the network interface device **1220** includes a transmit/receive element **1230**. In example embodiments, the transmit/receive element **1230** is referred to as a transceiver. The transmit/receive element **1230** may be configured to transmit signals to, or receive signals from, other systems such as, referring to FIG. **1**, first systems **142**, second system **144**, and third system **146**. In example embodiments, the transmit/receive element **1230** may be an antenna configured to transmit and/or receive RF signals. In an example embodiment, the transmit/receive element **1230** may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In an example embodiment, the transmit/receive element **1230** may be configured to transmit and receive both RF and light signals. It will be appreciated that the transmit/receive element **1230** may be configured to transmit and/or receive any combination of wireless signals.

The mass storage **1216** includes a machine-readable medium **1222** on which is stored one or more sets of

instructions and data structures (e.g., software) **1224** embodying or used by any one or more of the methods or functions described herein.

For example, the instructions **1224** may include application module **102**, data **150**, application framework **104**, gateway engine module **106**, gateway services **108**, data adapters **110**, and/or an implementation of any of the method steps described herein. The instructions **1224** may be modules. The instructions **1224** may also reside, completely or at least partially, within the main memory **1204**, static memory **1206**, and/or within the one or more processors **1202** during execution thereof by the computer system **1200**, with the main memory **1204** and the one or more processors **1202** also constituting machine-readable media. The instructions **1224** may be implemented in a hardware module.

While the machine-readable medium **1222** is shown in an example embodiment to be a single medium, the term "machine-readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more instructions or data structures. The term "machine-readable medium" shall also be taken to include any tangible medium that is capable of storing, encoding or carrying instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. The term "machine-readable medium" shall accordingly be taken to include, but not be limited to, solid-state memories, and optical and magnetic media. Specific examples of machine-readable media include non-volatile memory, including by way of example, semiconductor memory devices (e.g., Erasable Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and compact disk read only memory (CD-ROM) and digital video disc-read only memory (DVD-ROM) disks.

The instructions **1224** may further be transmitted or received over a communications network **1228** using a transmission medium. The instructions **1224** may be transmitted using the network interface device **1220** and any one of a number of well-known transfer protocols (e.g., hypertext mark-up protocol (HTTP)). Examples of communication networks include a local area network (LAN), a wide-area network (WAN), the Internet, mobile telephone networks, Plain Old Telephone (POTS) networks, and wireless data networks (e.g., WiFi and WiMax networks). The term "transmission medium" shall be taken to include any intangible medium that is capable of storing, encoding, or carrying instructions for execution by the machine, and includes digital or analog communications signals or other intangible media to facilitate communication of such software.

In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B." "B but not A," and "A and B," unless otherwise indicated. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended; that is, a system, device, article, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," and so forth are used merely as labels, and are not intended to impose numerical requirements on their objects.

Certain example embodiments are described herein as including logic or a number of components, modules, applications, agents, or mechanisms. Modules may constitute either software modules (e.g., code embodied on a machine-readable medium or in a transmission signal) or hardware modules. A hardware module is a tangible unit capable of performing certain operations and may be configured or arranged in a certain manner. In example embodiments, one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware modules of a computer system (e.g., a processor or a group of processors) may be configured by software (e.g., an application or application portion) as a hardware module that operates to perform certain operations as described herein.

In various example embodiments, a hardware module may be implemented mechanically or electronically. For example, a hardware module may comprise dedicated circuitry or logic that is permanently configured (e.g., as a special-purpose processor, such as a field programmable gate array (FPGA) or an application-specific integrated circuit (ASIC)) to perform certain operations. A hardware module may also comprise programmable logic or circuitry (e.g., as encompassed within a general-purpose processor or other programmable processor) that is temporarily configured by software to perform certain operations. It will be appreciated that the decision to implement a hardware module mechanically, in dedicated and permanently configured circuitry, or in temporarily configured circuitry (e.g., configured by software) may be driven by cost and time considerations.

Accordingly, the term "hardware module" should be understood to encompass a tangible entity, be that an entity that is physically constructed, permanently configured (e.g., hardwired) or temporarily configured (e.g., programmed) to operate in a certain manner and/or to perform certain operations described herein. Considering example embodiments in which hardware modules are temporarily configured (e.g., programmed), each of the hardware modules need not be configured or instantiated at any one instance in time. For example, where the hardware modules comprise a general-purpose processor configured using software, the general-purpose processor may be configured as respective different hardware modules at different times. Software may accordingly configure a processor, for example, to constitute a particular hardware module at one instance of time and to constitute a different hardware module at a different instance of time.

Hardware modules can provide information to, and receive information from, other hardware modules. Accordingly, the described hardware modules may be regarded as being communicatively coupled. Where multiple of such hardware modules exist contemporaneously, communications may be achieved through signal transmission (e.g., over appropriate circuits and buses) that connect the hardware nodules. In example embodiments in which multiple hardware modules are configured or instantiated at different times, communications between such hardware modules may be achieved, for example, through the storage and retrieval of information in memory structures to which the multiple hardware modules have access. For example, one hardware module may perform an operation and store the output of that operation in a memory device to which it is

communicatively coupled. A further hardware module may then, at a later time, access the memory device to retrieve and process the stored output. Hardware modules may also initiate communications with input or output devices, and can operate on a resource (e.g., a collection of information).

The various operations of example methods described herein may be performed, at least partially, by one or more processors that are temporarily configured (e.g., by software) or permanently configured to perform the relevant operations. Whether temporarily or permanently configured, such processors may constitute processor-implemented modules that operate to perform one or more operations or functions. The modules referred to herein may, in some example embodiments, comprise processor-implemented modules.

Similarly, the methods described herein may be at least partially processor-implemented. For example, at least some of the operations of a method may be performed by one or processors or processor-implemented modules. The performance of certain of the operations may be distributed among the one or more processors, not only residing within a single machine, but deployed across a number of machines. In some example embodiments, the processor or processors may be located in a single location (e.g., within a home environment, an office environment or as a server farm), while in other example embodiments the processors may be distributed across a number of locations.

The one or more processors may also operate to support performance of the relevant operations in a "cloud computing" environment or as a "software as a service" (SaaS). For example, at least some of the operations may be performed by a group of computers (as examples of machines including processors), with these operations being accessible via a network (e.g., the Internet) and via one or more appropriate interfaces (e.g., APIs).

Example embodiments may be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. Example embodiments may be implemented using a computer program product, for example, a computer program tangibly embodied in an information carrier, for example, in a machine-readable medium for execution by, or to control the operation of, data processing apparatus, for example, a programmable processor, a computer, or multiple computers.

In example embodiments, operations may be performed by one or more programmable processors executing a computer program to perform functions by operating on input data and generating output. Method operations can also be performed by, and apparatus of example embodiments may be implemented as, special purpose logic circuitry (e.g., a FPGA or an ASIC).

This written description uses examples to disclose some example embodiments, including the best mode, and also to enable any person skilled in the art to practice the disclosed embodiments, including making and using any devices or systems and performing any incorporated methods. The patentable scope is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A gateway comprising:

memory to store data in a common data format to be operated on by a plurality of applications resident at the gateway;

a plurality of network interfaces, each network interface configured to interface at least one application to a remote device via a network;

a plurality of protocol adapters coupled to a corresponding network interface, each protocol adapter configured to communicate with the remote device using a communication protocol of the remote device;

a plurality of data adapters, each data adapter configured to convert data between a format of a corresponding remote device and the common data format;

a protocol selector module configured to select a protocol adapter of the plurality of protocol adapters, a selected protocol adapter corresponding to the remote device with which communication is to be established, the selecting of the protocol adapter based on a device configuration table, the device configuration table mapping protocol adapter data to a plurality of devices, the plurality of devices including the remote device;

a data adapter selector module configured to select a data adapter of the plurality of data adapters, a selected data adapter corresponding to the remote device with which communication is established using the selected protocol adapter, the selecting of the data adapter based on the device configuration table, the device configuration table mapping device adapter data to the plurality of devices; and

a service selector module configured to select an application module from the plurality of applications for processing of a communication that is to be received from the remote device, the selecting of the application module based on the device configuration table, the device configuration table mapping service data to the plurality of devices.

2. The gateway of claim **1**, wherein the plurality of network interfaces includes a machine interface, a cloud interface, and a mobile interface.

3. The gateway of claim **1**, wherein the protocol selector module is further configured to select a mobile protocol adapter to interface with a remote mobile device, a machine protocol adapter to interface with a remote machine, and a server protocol adapter to interface with a remote server, and wherein the data adapter selector module is further configured to select a mobile data adapter, machine data adapter, and server data adapter.

4. The gateway of claim **1**, wherein the plurality of protocol adapters and the plurality of data adapters provide an abstraction between data domains defined by the plurality of remote devices and the plurality of applications.

5. The gateway of claim **1**, further comprising an application configuration table comprising a plurality of application configurations and a services configuration table comprising a plurality of service configurations.

6. The gateway of claim **5**, further comprising:

a gateway engine module configured to search via one or more of the plurality of network interfaces for a new remote device, to generate a new device configuration for the new remote device, and to report the new remote device to an application of the plurality of applications.

7. The gateway of claim **5**, wherein the protocol selector module is further configured to determine a device configuration of the plurality of device configurations based on a network address of a received communication from the

remote device, and configured to select the selected protocol adapter based on the device configuration of the remote device.

8. The gateway of claim **7**, further comprising:

an application selector module configured to select an application module of a plurality of application modules based on the device configuration of the remote device, wherein the selected application module is configured to processes data included in the received communication.

9. The gateway of claim **7**, wherein the data adapter selector module is further configured to select the selected data adapter using the device configuration of the remote device.

10. The gateway of claim **7**, wherein the protocol selector module is further configured to group the received communication with previously received communications based on a group indication of the device configuration of the remote device.

11. The gateway of claim **10**, wherein the remote device is a machine control device, and wherein an application of the plurality of applications is configured to control the machine control device based on user input from a mobile device via a mobile interface, and further configured to store data from the machine control device on a remote server via a cloud interface.

12. The gateway of claim **1**, wherein the service selector module is further configured to receive a request to access a service from the remote device, to determine a device configuration of the plurality of device configurations based on a network address of a received request from the remote device, and to select the requested service from the plurality of services based on the plurality of service configurations and the device configuration.

13. The gateway of claim **1**, wherein the selected data adapter module is further configured to convert the data between the format of the corresponding remote device and the common data format by using a first portion of the data in the format corresponding to the remote device to convert a second portion of the data in the format corresponding to the remote device, wherein the first portion of the data is metadata describing the second portion of the data.

14. The gateway of claim **1**, further comprising:

an application frame module configured to provide an application programming interface (API) for accessing services provided by the gateway system to the plurality of applications.

15. A method comprising:

storing data in a common data format to be operated on by a plurality of applications;

providing a plurality of network interfaces, each network interface interfacing at least one application to a remote device via a network;

providing a plurality of protocol adapters coupled to a corresponding network interface, each protocol adapter communicating with the remote device using a communication protocol of the remote device;

providing a plurality of data adapters, each data adapter converting data between a format of a corresponding remote device and the common data format;

selecting a protocol adapter from a plurality of protocol adapters for a remote device with which communication is to be established, the selecting of the protocol adapter based on a device configuration table, the device configuration table mapping protocol adapter data to a plurality of devices, the plurality of devices including the remote device, selecting a data adapter of the plurality of data adapters using the selected protocol adapter, the selecting of the data adapter based on the device configuration table, the device configuration table mapping device adapter data to the plurality of devices; and

selecting an application module from a plurality of applications resident at a gateway for processing of a communication that is to be received from the remote device, the selecting of the application module based on the device configuration table, the device configuration table mapping service data to the plurality of devices.

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