



(51) International Patent Classification:

H04W 72/10 (2009.01) *H04W* 4/38 (2018.01)
H04B 7/185 (2006.01) *G16Y* 20/10 (2020.01)

(21) International Application Number:

PCT/SG2020/050021

(22) International Filing Date:

16 January 2020 (16.01.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

10201900392T 16 January 2019 (16.01.2019) SG

(71) Applicant: **NATIONAL UNIVERSITY OF SINGAPORE** [SG/SG]; 21 Lower Kent Ridge Road, Singapore 119077 (SG).

(72) Inventors: **NG, Zhen Ning**; c/o National University of Singapore, Faculty of Engineering, Department of Electrical and Computer Engineering, 21 Lower Kent Ridge Road, Singapore 119077 (SG). **LUO, Sha**; c/o National University of Singapore, Faculty of Engineering, Department of Electrical and Computer Engineering, 21 Lower Kent Ridge Road, Singapore 119077 (SG).

(74) Agent: **POH, Chee Kian, Daniel**; Marks & Clerk Singapore LLP, Tanjong Pagar, P O Box 636, Singapore 910816 (SG).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

(54) Title: COMMUNICATION GATEWAY APPARATUS, COMMUNICATION SYSTEM, DATA PACKET PROCESSING METHOD AND COMPUTER READABLE MEDIUM

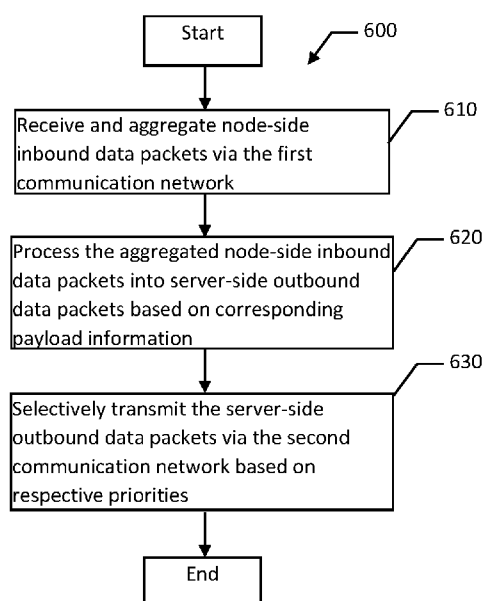


Figure 3

(57) Abstract: Communication gateway apparatus, communication system, data packet processing method and computer readable medium Disclosed is a data packet processing method (600). In a described embodiment, the data packet processing method (600) is performed by a communication gateway apparatus and comprises: receiving and aggregating inbound data packets from a plurality of communication devices of an Internet-of-Things (IoT) communication network; processing the aggregated inbound data packets into outbound data packets based on corresponding payload information of the aggregated inbound data packets, each outbound data packet having a respective priority; and selectively transmitting the outbound data packets through a satellite communication network based on the respective priorities of the outbound data packets. A communication gateway apparatus and communication system are also disclosed.

Published:

- *with international search report (Art. 21(3))*
- *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

Communication gateway apparatus, communication system, data packet processing method and computer readable medium

Technical field

5 The present invention relates to a communication gateway apparatus, a communication system, a data packet processing method and a computer readable medium.

Background

10 Internet-of-Things (IoT) nodes devices (such as sensor nodes) generate node data packets and require internet connections to transmit their node data to, for example, servers. For remote locations (e.g., rural areas), internet connections are usually unreliable or unavailable due to restrictions or non-existence of backhaul networks.

15

PCT Publication No. WO/2018/184900 ("space communication method for IoT services and corresponding space telecommunications system") discloses a system using satellites or High Altitude Platforms (HAPS) to serve as base stations for IoT networks. The HAPS serve as intermediate data relay stations to relay data communications between end node devices and satellites. However, such a system is inefficient.

It is desirable to provide a communication gateway apparatus, a communication system, a data packet processing method and a computer readable medium, which address at least one of the drawbacks of the prior art and/or to provide the public with a useful choice.

25

Summary

According to one aspect, there is provided a data packet processing method performed by a communication gateway apparatus, comprising: receiving and aggregating inbound data packets from a plurality of communication devices of an Internet-of-Things (IoT) communication network; processing the aggregated

30

inbound data packets into outbound data packets based on corresponding payload information of the aggregated inbound data packets, each outbound data packet having a respective priority; and selectively transmitting the outbound data packets through a satellite communication network based on the
5 respective priorities of the outbound data packets.

The described embodiment is particularly advantageous. By virtue of processing the inbound data packets into outbound data packets based on corresponding payload information with each outbound data packet having a
10 respective priority, outbound data packets of different priorities can be identified by the gateway apparatus. Moreover, by virtue of selective transmission of the outbound data packets based on the corresponding priorities, the outbound data packets of the high priorities can be prioritised for transmission by the gateway apparatus to the satellite communication network. This is particularly
15 advantageous where the gateway apparatus has intermittent or unreliable access to the satellite communication network.

Preferably, processing the aggregated inbound data packets into the outbound data packets may comprise assigning each outbound data packet with one of
20 high, medium and low priorities based on the corresponding payload information, selectively transmitting the outbound data packets may comprise transmitting each outbound data packet with the high priority followed by each outbound data packet with the medium priority through the satellite communication network, and selectively transmitting the outbound data packets
25 may comprise not transmitting each outbound data packet with the low priority through the satellite communication network.

This arrangement may be particularly useful. Availability of the satellite communication network may be affected by various factors and thus prioritised
30 transmission of outbound data packets with high priorities followed by those with medium priorities during, for example, short periods of satellite communication availability can increase the chance of successful reporting of

time-sensitive urgent information. This arrangement is also useful where a large amount of inbound data packets of different priorities is received. In particular, by selectively transmitting the outbound data packets, outbound data packets of low priority may not be transmitted, which reserves satellite communication
5 resources for the transmission of outbound data packets of normal and high priorities.

Processing the aggregated inbound data packets into the outbound data packets may comprise assigning each outbound data packet with a first priority
10 if a value derived from the corresponding payload information of the aggregated inbound data packets falls within a first range, and with a second priority if the value falls within a second range different from the first range. The value may represent a temperature, a sea level or a rate of position change.

15 Processing the aggregated inbound data packets into the outbound data packets may comprise including a bit representation of the corresponding priority in a header portion of each outbound data packet. With the bit representation in the header portion, outbound data packets of high priority may be transmitted through the satellite communication network in a prioritised
20 manner and may trigger an alarm.

The method may further comprise: storing each outbound data packet with the high priority and each outbound data packet with the medium priority in a data storage module. This arrangement may ensure availability of outbound data
25 packets of high and medium priorities in the event where the transmission of the outbound data packets of high and medium priorities through the satellite communication network fails.

The method may comprise storing each outbound data packet irrespective of
30 the respective priority.

The IoT communication network may be a Long Range Wide Area Network (LoRaWAN) communication network.

Alternatively, processing the aggregated inbound data packets into the
5 outbound data packets may comprise assigning each outbound data packet
with one of first and second priorities based on the corresponding priority
information, and selectively transmitting the outbound data packets may
comprise transmitting each outbound data packet with the first priority followed
by each outbound data packet with the second priority through the satellite
10 communication network. This arrangement may be useful in ensuring that
urgent or important data is prioritised over normal data for transmission.

Alternatively, processing the aggregated inbound data packets into the
outbound data packets may comprise assigning each outbound data packet
15 with one of first and second priorities based on the corresponding priority
information, transmitting the outbound data packets may comprise transmitting
each outbound data packet with the first priority through the satellite
communication network, and the method may further comprise not transmitting
each outbound data packet with the second priority through the satellite
20 communication network. This arrangement may advantageously ensure that
satellite communication resources are reserved for urgent or important data.
According to another aspect, there is provided a computer readable medium
comprising instructions for causing a data processing module to: receive and
aggregate inbound data packets from a plurality of communication devices of an
25 Internet-of-Things (IoT) communication network; process the aggregated
inbound data packets into outbound data packets based on corresponding
payload information of the aggregated inbound data packets, each outbound
data packet having a respective priority; and selectively transmit the outbound
data packets through a satellite communication network based on the
30 respective priorities of the outbound data packets.

The instructions for processing the aggregated inbound data packets into the outbound data packets may comprise instructions for causing the data processing module to assign each outbound data packet with one of high, medium and low priorities based on the corresponding payload information, the instructions for selectively transmitting the outbound data packets may comprise instructions for causing the data processing module to transmit each outbound data packet with the high priority followed by each outbound data packet with the medium priority through the satellite communication network, and the instructions for selectively transmitting the outbound data packets may comprise instructions for causing the data processing module to not transmit each outbound data packet with the low priority through the satellite communication network.

The instructions for processing the aggregated inbound data packets into the outbound data packets may comprise instructions for causing the data processing module to assign each outbound data packet with a first priority if a value derived from the corresponding payload information of the aggregated inbound data packets falls within a first range, and with a second priority if the value falls within a second range different from the first range. The value may represent a temperature, a sea level or a rate of position change.

The instructions for processing the aggregated inbound data packets into the outbound data packets may comprise instructions for causing the data processing module to include a bit representation of the corresponding priority in a header portion of each outbound data packet.

The computer readable medium may further comprise instructions for causing the data processing module to store each outbound data packet with the high priority and each outbound data packet with the medium priority in a data storage module.

The computer readable medium may further comprise instructions for storing each outbound data packet irrespective of the respective priority.

The IoT communication network may be a Long Range Wide Area Network
5 (LoRaWAN) communication network.

According to another aspect, there is provided a communication gateway apparatus comprising: a first network module configured to be associated with an Internet-of-Things (IoT) communication network; a second network module
10 configured to be associated a satellite communication network; and a data processing module coupled to the network modules, the data processing module being configured to: receive and aggregate inbound data packets via the first network module and from a plurality of communication devices of the IoT communication network; process the aggregated inbound data packets into
15 outbound data packets based on corresponding payload information of the aggregated inbound data packets, each outbound data packet having a respective priority; and selectively transmit the outbound data packets via the second network module and through a satellite communication network based on the respective priorities of the outbound data packets.

20

Preferably, the data processing module may be configured to assign each outbound data packet with one of high, medium and low priorities based on the corresponding payload information, the data processing module may be configured to transmit each outbound data packet with the high priority followed
25 by each outbound data packet with the medium priority via the second network module and through the satellite communication network, and the data processing module may be configured to not transmit each outbound data packet with the low priority via the second network module and through the satellite communication network.

30

The data processing module may be further configured to store each outbound data packet with the high priority and each outbound data packet with the medium priority in the data storage module.

- 5 The data processing module may be configured to assign each outbound data packet with a first priority if a value derived from the corresponding payload information of the aggregated inbound data packets falls within a first range, and with a second priority if the value falls within a second range different from the first range. The value may represent a temperature, a sea level or a rate of
10 position change.

The data processing module may be configured to include a bit representation of the corresponding priority in a header portion of each outbound data packet.

- 15 The first network module may be compatible with the Long Range Wide Area Network (LoRaWAN) specifications.

- It is preferred that the data processing module may be configured to receive and aggregate the inbound data packet, to process the aggregated inbound
20 data packets into the outbound data packets, and to selectively transmit the outbound data packets whilst the communication gateway apparatus is supported by a ground surface or a water surface.

- According to another aspect, there is provided a communication system
25 comprising: the communication gateway apparatus; the IoT communication network comprising the communication devices configured to be associated with the communication gateway apparatus; and the satellite communication network comprising a server configured to be associated with the communication gateway apparatus.

30

According to another aspect, there is provided a communication gateway apparatus comprising: a first network module configured to be associated with

an Internet-of-Things (IoT) communication network; a second network module configured to be associated a satellite communication network; and a data processing module coupled to the network modules, the data processing module being configured to receive inbound data packets via one of the network
5 modules and to transmit corresponding outbound data packets via the other of the network modules whilst the communication gateway apparatus is supported by a ground surface or a water surface.

The described embodiment is particularly advantageous. The communication
10 gateway apparatus provides a local IoT network to service end node devices in a remote area, which may be a land area or a sea area. The gateway apparatus in communication with the end node devices uses a satellite backhaul network to enable communication between the end node devices and a server via
15 satellites of the satellite backhaul network. Moreover, being supported by a ground surface or a water surface, the communication gateway apparatus is less susceptible to displacement by, for example, strong wind. This is advantageous because displacement of the communication gateway apparatus may adversely affect communication between the communication gateway
20 apparatus and end node devices. In addition, in contrast with the HAPS which cannot be deployed without permits for air space use, the communication gateway apparatus can be deployed conveniently without the need for a permit.

According to another aspect, there is provided a communication system comprising: the communication gateway apparatus; the IoT communication
25 network comprising a plurality of communication devices configured to be associated with the communication gateway apparatus; and the satellite communication network comprising a server configured to be associated with the communication gateway apparatus.

30 It is envisaged that features relating to one aspect may be applicable to the other aspects.

Brief Description of the drawings

Example embodiments will now be described hereinafter with reference to the accompanying drawings, wherein like parts are denoted by like reference numerals. Among the drawings:

5 Figure 1 shows a block diagram of some components of a communication gateway apparatus according to one embodiment of the present disclosure;

 Figure 2 shows a diagram of the gateway apparatus of Figure 1 in association with a plurality of end node devices through a LoRaWAN
10 communication network and with a plurality of satellites through a satellite communication network;

 Figure 3 shows steps of a method performed by the gateway apparatus of Figure 1; and

 Figure 4 shows steps of another method performed by the gateway
15 apparatus of Figure 1.

Detailed Description

Referring to Figure 1, a communication gateway apparatus 100 according to one embodiment of the present disclosure includes a data processing module
20 110, a first network module 120, a second interface module 130, a storage module 140, a power supply unit (PSU) 150, a battery module 160 and a power input module 170.

Figure 2 shows an example scenario in which the communication gateway
25 apparatus 100 is arranged directly on a ground surface in a remote rural land area. Moreover, the communication gateway apparatus 100 is shown to be associated with a plurality of end node devices 200 via an Internet-of-Things (IoT) communication network 300 and with a plurality of orbiting satellites 400 via a satellite communication network 500. The IoT communication network 300
30 in this embodiment is a Long Range Wide Area Network (LoRaWAN) communication network 300. Each node device 200 in this example is a sensor device, and is operable to sense, for example, temperature, position and

humidity for generating node data packets and to transmit the generated node data packets via the LoRaWAN communication network 300 to the gateway apparatus 100. The node data packets thus include sensor information. In other embodiments, the IoT communication network 300 may be any compatible non-
5 LoRaWAN communication network.

The first network module 120 in this embodiment is compatible with the LoRaWAN specifications, includes a LoRaWAN modem 122 (including an RF front end) and a LoRaWAN antenna 124 coupled to the LoRaWAN modem 122,
10 and is configured to be wirelessly associated with the LoRaWAN communication network 300 to enable communication between the gateway apparatus 100 and the end node devices 200 through the LoRaWAN communication network 300.

15 The second network module 130 in this embodiment is compatible with satellite communication specifications, includes a satellite communication modem 132 (including an RF front end) and a satellite antenna 134 coupled to the satellite communication modem 132, and is configured to be wirelessly associated with the satellite communication network 500 to enable communication of the
20 gateway apparatus 100 with a server (not shown) via the satellites 400 through the satellite communication network 500.

By utilising the satellite communication network 500, the gateway apparatus 100 can be deployed in a remote area. The satellites 400 and the second
25 network module 130 are configured in this embodiment to use a proprietary communication protocol to accommodate satellite constellation expansion. However, the satellites 400 and the second network module 130 may be configured in other embodiments to use any non-proprietary communication protocol to accommodate satellite constellation expansion.

30

The data processing module 110 is coupled to the first network module 120, the second network module 130 and the storage module 140. In this embodiment,

the data processing module 110 includes a Central Processing Unit (CPU) 112 and a LoRaWAN aggregator baseband processor 114 coupled to each other (via a Serial Peripheral Interface, SPI). The CPU 112 is further coupled to the satellite communication modem 132 (via a serial communication interface) and
5 the storage module 140. The aggregator baseband processor 114 is further coupled to the LoRaWAN modem 122.

In such a configuration, the data processing module 110 is configured to receive inbound data packets via one of the network modules 120, 130 and to transmit
10 corresponding outbound data packets via the other of the network modules 120, 130 whilst the communication gateway apparatus 100 is supported by the ground surface. In this embodiment, the communication gateway apparatus 100 is directly supported by the ground surface. More specifically, the components of the apparatus 100 are associated with a housing (not shown) of the
15 apparatus 100, and the housing is arranged directly on the ground surface.

The data processing module 110 in this embodiment is configured to perform a node reporting function and a node configuration function. Figure 3 shows steps of a method 600 corresponding to the node reporting function. Figure 4 shows
20 steps of a method 700 corresponding to the node configuration function.

With respect to the node reporting function, the apparatus 100 receives the inbound data packets (referred to below as “node-side inbound data packets”) via the LoRaWAN communication network 300 and transmits the corresponding
25 outbound data packets (referred to below as “server-side outbound data packets”) via the satellite communication network 500. In other words, the node-side inbound data packets in the context of the node reporting function are the node data packets transmitted by the end node devices 200 via the LoRaWAN communication network 300.

30

In relation to the node reporting function (see Figure 3), at step 610, the aggregator baseband processor 114 is configured to receive and aggregate the

node-side inbound data packets via the first network module 120 and through the LoRaWAN communication network 300 from the end node devices 200.

At step 620 following step 610, the CPU 112 is configured to process the aggregated node-side inbound data packets into the corresponding server-side outbound data packets based on corresponding payload information of the aggregated node-side inbound data packets, each outbound data packet having a respective priority. In this example, each server-side outbound data packet has one of high, medium and low priorities. That is, at step 620, the CPU 112 is further configured to assign each server-side outbound data packet with one of the high, medium and low priorities based on the corresponding payload information of the aggregated node-side inbound data packets. In this embodiment, at step 620, the CPU 112 is configured to assign each server-side outbound data packet with the high priority (a first priority) if a value derived from the corresponding payload information of the aggregated inbound data packets falls within a first range (e.g., not exceeding a lower threshold value), with the medium priority (a second priority) if the value falls within a second range (e.g., exceeding the lower threshold value and not exceeding a higher threshold value) different from the first range, and with the low priority (a third priority) if the value falls within a third range (exceeding the higher threshold value) different from the first and second ranges. Furthermore, the CPU 112 is further configured at this step to include (e.g., by way of tagging) a bit representation of the corresponding priority in a header portion of the respective server-side outbound data packet. With each server-side outbound data packet having one of the high, medium and low priorities (i.e., three states), two header bits may represent the respective priority. For example, bit values "00", "01" and "10" may represent the low, medium and high priorities, respectively. Server-side outbound data packets marked as having high priority in such a manner may be routed through the satellites 400 of the satellite communication network 500 to the server in a prioritised manner. The server may be configured to trigger an alarm based on the marked priority of each server-side outbound data packet received by the server.

At step 630 following step 620, the CPU 112 is further configured to selectively transmit the server-side outbound data packets via the second network module 130, through the satellite communication network 500 and via the satellites 400 to the server based on the respective priorities of the server-side outbound data packets. Specifically, in this example, the CPU 112 is configured to transmit, at step 630, the server-side outbound data packets with the high priorities prior to transmitting those with the medium priorities. That is, the CPU 112 is configured to transmit the server-side outbound data packets with the high priorities followed by those with the medium priorities. The CPU 112 is further configured to not transmit the server-side outbound data packets with the low priorities. Moreover, the CPU 112 is configured to transmit server-side outbound data packets with the same priorities in a first-come-first-served manner. For example, if two server-side outbound data packets have the same priorities, they are transmitted on a first-come-first-served manner in respect of their corresponding node-side inbound data packets.

In one example scenario, the end node devices 200 are arranged in a forest area to detect temperature to generate the node data packets (i.e., node-side inbound data packets). The CPU 112 of the gateway apparatus 100 processes the node-side inbound data packets received from the end node devices 200 into server-side outbound data packets having respective priorities. The gateway apparatus 100 further assigns each server-side outbound data packet with one of high, medium and low priorities based on corresponding payload information of the aggregated node-side inbound data packets. For instance, where each server-side outbound data packet corresponds to one of the end node devices 200, the CPU 112 may assign the server-side outbound data packet with the high priority if the value (e.g., representing a detected temperature) derived from the corresponding payload information of the node-side inbound data packets of the end node device 200 indicates an abnormal change of detected temperature, with the medium priority if the value indicates

a normal change of detected temperature, and with the low priority if the value indicate no change of detected temperature.

In another example scenario of cattle tracking, the end node devices 200 are
5 attached to or worn by respective cows to detect a rate of position change (e.g., by way of GPS). Where each server-side outbound data packet corresponds to one of the end node devices 200, the CPU 112 may assign the server-side outbound data packet with the high priority if a value (e.g., representing a rate of position change) derived from the corresponding payload information (e.g., time
10 and distance information) of the node-side inbound data packets from the end node device 200 indicate an abnormal rate of position change (e.g., greater than 35 km/h), with the medium priority if the value indicates a normal rate of position change (e.g., greater than 5 km/h and not greater 35 km/h), and with the low priority if the value indicates a low rate of position change (e.g., not
15 greater than 5 km/h).

In yet another example scenario, the end node devices 200 are deployed in open ocean to detect a tsunami event. Where each server-side outbound data packet corresponds to multiple ones of the end node devices 200, the CPU 112
20 may assign the server-side outbound data packet with the high priority if a value (e.g., representing a rise of sea level) derived from the corresponding payload information of the node-side inbound data packets from the multiple end node devices 200 indicates an abnormal rate of sea level change, with the medium priority if the value indicates a normal rate of sea level change, and with the low
25 priority if the value indicates no sea level change.

As can be understood from the above, the CPU 112 performs calculation or analysis upon the corresponding payload information in respect of each server-side outbound data packet and assigns a priority to the respective server-side
30 outbound data packet based on a result of calculation or analysis (in the above examples, the derived value). Such a calculation or analysis may, in other

embodiments, result in any suitable indication (e.g., Boolean) serving as a basis for determining priority.

In each of the above scenarios, an alarm or warning mechanism may be triggered at the server upon receipt of the server-side outbound data packets of the high priorities.

In this embodiment, the CPU 112 is further configured to store, between steps 620 and 630, the server-side outbound data packets in the storage module 140. This arrangement is useful where the satellite communication network 500 is temporarily unavailable. With such a configuration, the CPU 112 is configured to perform step 630 with the server-side outbound data packets stored in the storage module in response to the satellite communication network 500 becoming available. The selectively transmitted server-side outbound data packets (i.e., those with the high priorities and those with the medium priorities) may be optionally removed from the storage module 140.

In an alternative arrangement, the CPU 112 may be configured to store, after performing step 630, the server-side outbound data packets with the low priorities in the storage module 140. The CPU 112 may further be configured to store, after performing step 630, those with the high priorities and those with the medium priorities in the storage module 140. That is, the CPU 112 may store the server-side outbound data packets in the storage module 140 irrespective of the priorities. Moreover, the CPU 112 may be configured to overwrite old server-side outbound data packets with new ones in the event where the storage module 140 has no unused space.

The stored server-side outbound data packets may be retrieved on-site. This facilitates archiving and manual retrieval. Instead of accessing a large number of end node devices 200 to retrieve information represented by the server-side outbound data packets, the gateway apparatus 100 can be accessed to retrieve the same or similar information.

With respect to the node configuration function, the apparatus 100 receives the inbound data packets (referred to below as “server-side inbound data packets”) via the satellite communication network 500 and transmits the corresponding
5 outbound data packets (referred to below as “node-side outbound data packets”) via the LoRaWAN communication network 300. In the example of Figure 2, the server-side inbound data packets in the context of the node configuration function are configuration data packets transmitted by the server via the satellites 400 through the satellite communication network 500 for the purpose
10 of configuring the end node devices 200.

In relation to the node configuration function, at step 710, the CPU 112 is configured to receive the server-side inbound data packets (i.e., the configuration data packets) via the second network module 130 and through the
15 satellite communication network 500 via the satellites 400 from the server. At step 720 following step 710, the aggregator baseband processor 114 is configured to transmit the corresponding node-side outbound data packets via the first network module 120 through the LoRaWAN communication network 300 to the end node devices 200. In this embodiment, the server-side inbound
20 data packets serve as the node-side outbound data packets and are transmitted (relayed) on a first-come-first-served basis.

The configuration data packets transmitted by the server via the satellites 400 through the satellite communication network 500 are thus relayed by the
25 gateway apparatus 100 via the LoRaWAN communication network 300 to the node devices 200 to result in configuration of the node devices 200. Such configuration may take the example form of firmware update or reprogramming. For example, the configuration data packets may cause a change of frequency at which the node devices 200 generates and transmits the node data packets
30 by the node devices 200. Other parameters of the node devices 200 may be configured in such a manner.

The configuration data packets may correspond to one, some or all of the node devices 200. That is, configuration data packets may cause configuration of one, some or all of the node devices 200. In this embodiment, the node devices 200 have respective unique identification numbers. The configuration data packets
5 include at least one of the identification numbers of the node devices 200. The gateway apparatus 100 is configured to relay the configuration data packets to at least one of the node devices 200 corresponding to the at least one of the identification numbers included in the configuration data packets.

In this example, during periods of availability of the satellite communication
10 network 500 (e.g., before or after the performance of the node reporting function), the gateway apparatus 100 is configured to receive the configuration data packets (i.e., the server-side inbound data packets) from the server via the satellite communication network 500, and to store the received configuration data packets in the storage module 140. Once the configuration data packets
15 are received by the gateway apparatus 100, the gateway apparatus 100 is further configured to, in response to receipt of the node data packets from the node devices 200 corresponding to the configuration data packets, transmit the node configuration data packets (serving as the node-side outbound data packets) to the corresponding node devices 200.

20 More specifically, the gateway apparatus 100 registers the identification numbers of the end node devices 200 from which the node-side inbound data packets are received, and transmits the node-side outbound data packets to the end node devices 200 based on the registered identification numbers. In other
25 words, when one the end node devices 200 transmits the node-side inbound data packets to the gateway apparatus 100, if the configuration data packets stored at the gateway apparatus 100 corresponds to the registered identification number of said one of the end node devices 200, the gateway apparatus 100 transmits in response the configuration data packets to said one of the end
30 node devices 200.

In some scenarios, multiple instances of the communication gateway apparatuses 100 may be deployed and associated with the satellites 400. A record of correspondence relationships between each gateway apparatus 100 and the associated end node devices 200 may be maintained (e.g., stored on
5 the server or distributed among the satellites 400) to facilitate the performance of the node configuration function. More specifically, for the purpose of the node configuration function, if the end node devices 200 associated with a particular one of the gateway apparatuses 100 are to receive the configuration data packets, the satellites 400 may communicate, based on the record, the
10 configuration data packets only to the particular one of the gateway apparatuses 100. This reduces unnecessary communication resources consumption as the configuration data packets are forwarded only to the particular one of the gateway apparatuses 100 and not to the other ones of the gateway apparatuses 100.

15

The data processing module 110 in this embodiment is configured to perform the node configuration function after performing the node reporting function. That is, the node configuration function is performed following each performance of the node reporting function.

20

The storage module is configured to store instructions executable by the CPU 112 for causing the CPU 112 to perform steps 620, 630, 710.

The PSU 150 is configured to power the components 110-140 from the battery
25 module 160 and the power input module 170. The power input module 170 is configured to be associated with a power source (not shown) to supply power from the power source. With such a configuration, the power input module 170 provides an interface between the PSU 150 and the power source.

30 In this embodiment, the power source includes a solar panel. The solar panel collects and converts solar energy into an external supply current. This external supply current is provided through the power input module 170 to the PSU 150.

- The PSU 150 is configured to condition the external supply current prior to supplying the conditioned external supply current to the components 110-140. The PSU 150 is configured to receive a battery supply current from the battery module 160 in response to the conditioned external supply current being
- 5 insufficient to power the components 110-140, and to further supply an excess portion of the conditioned external supply current to the battery module 160 to charge the battery module 160 in response to the conditioned external supply current being sufficient to power the components 110-140.
- 10 The power input module 170 in this embodiment is configured to control the solar panel to maintain orientation at the sun to achieve a higher solar power generation efficiency. The battery module 160 of this embodiment has a life expectancy of five years and has specifications suitable for outdoor applications (e.g., high tolerance for extreme environmental conditions). The housing of the
- 15 apparatus 100 in this embodiment is weatherproof. In some embodiments, the gateway apparatus 100 may include the solar panel. In some embodiments, the power source associated with the power input module 170 may include, for example, AC mains.
- 20 The gateway apparatus 100 is arranged to receive, via the satellite communication network 500, configuration information (e.g., configuration information for the satellite modem 132) and to be configured accordingly. The configuration information is useful for ensuring compatibility of the apparatus 100 as changes (e.g., additions, deletions or changes of communication
- 25 protocols) are made to the satellites 400.

The gateway apparatus 100 allows IoT end node devices 200 to be deployed in remote areas. The gateway apparatus 100 is associated with (or provides) the LoRaWAN communication network 300, and performs the node reporting

30 function to receive and aggregate node data packets from the end node devices 200. In such a manner, edge computing is carried out to sieve or filter out data that is unnecessary for transmission back to the server. Processing time and

loading of the satellite communication infrastructure can thus be reduced. Moreover. The gateway apparatus 100 further performs the node configuration function to allow, for example, over the air (OTA) software reconfiguration of the end node devices 200, which eliminates or reduces the need for manual
5 reconfiguration of the end node devices 200 on-site. This provides convenience as the end node devices 200 may be located in land areas or sea areas that are difficult to access. Example applications may include livestock monitoring, forest fire monitoring, water quality monitoring and tsunami warning systems.

10 Other alternative arrangements are described below.

In some embodiments, the gateway apparatus 100 may be indirectly supported by the ground surface. For example, the gateway apparatus 100 may be supported by the roof of a building that is supported by the ground surface.

15

In some embodiments, the gateway apparatus 100 may be directly or indirectly supported by a water surface. For example, the gateway apparatus 100 may be supported by a floating vessel, and a compatible mounting device may be provided for the gateway apparatus 100.

20

The gateway apparatus 100 may be configured to store the node-side inbound data packets in the storage module 140.

In some embodiments, step 620 may include the CPU 112 determining the
25 priority of each server-side outbound data packet without adding any corresponding indication in the header portion of the respective server-side outbound data packet. In such embodiments, the determined respective priorities of the server-side outbound data packets may be used by the gateway apparatus 100 only to determine the order in which the server-side outbound
30 data packets are to be transmitted from the gateway apparatus 100. The determined priorities may not affect transmission or routing of the transmitted server-side outbound data packets by the satellites 400 of the satellite

communication network 500. That is to say, such server-side outbound data packets, once transmitted, may be routed by the satellites 400 without regard to the priorities determined by the gateway apparatus 100.

- 5 In other embodiments, the CPU 112 may be configured to assign each server-side outbound data packet with the respective priority based on a comparison of the value derived from the corresponding payload information of the aggregated inbound data packets with a threshold.
- 10 In another scenario of cattle tracking, the basis for determining priority can be a distance rather than a rate of position change.

Depending on applications, each server-side outbound data packet may correspond to multiple end node devices 200. For example, the CPU 112 may process the node-side inbound data packets of multiple end node devices 200 during a time period into the server-side outbound data packet. The CPU 112 may then assign the server-side outbound data packet with a high priority if corresponding payload information of the node-side inbound data packets from a certain number or percentage of the end node devices 200 (or a value derived from the corresponding payload information) indicates abnormality. This may be useful in reducing false alarm caused by a faulty end node device 200. In other words, depending on applications, each server-side outbound data packet may correspond to node-side inbound data packets from more than one end node device 200.

Claims

1. A data packet processing method performed by a communication gateway apparatus, comprising:

receiving and aggregating inbound data packets from a plurality of
5 communication devices of an Internet-of-Things (IoT) communication network;
processing the aggregated inbound data packets into outbound data
packets based on corresponding payload information of the aggregated inbound
data packets, each outbound data packet having a respective priority; and
10 selectively transmitting the outbound data packets through a satellite
communication network based on the respective priorities of the outbound data
packets.

2. The data packet processing method of claim 1,

wherein processing the aggregated inbound data packets into the
15 outbound data packets comprises assigning each outbound data packet with
one of high, medium and low priorities based on the corresponding payload
information,

wherein selectively transmitting the outbound data packets comprises
transmitting each outbound data packet with the high priority followed by each
20 outbound data packet with the medium priority through the satellite
communication network, and

wherein selectively transmitting the outbound data packets comprises not
transmitting each outbound data packet with the low priority through the satellite
communication network.

25

3. The data packet processing method of claim 1, wherein processing the
aggregated inbound data packets into the outbound data packets comprises
assigning each outbound data packet with a first priority if a value derived from
the corresponding payload information of the aggregated inbound data packets
30 falls within a first range, and with a second priority if the value falls within a
second range different from the first range.

4. The data packet processing method of claim 3, wherein the value represents a temperature, a sea level or a rate of position change.
5. The data packet processing method of any one of claims 1 to 4, wherein
5 processing the aggregated inbound data packets into the outbound data packets comprises including a bit representation of the corresponding priority in a header portion of each outbound data packet.
6. The data packet processing method of any one of claims 1 to 5, wherein the
10 IoT communication network is a Long Range Wide Area Network (LoRaWAN) communication network.
7. The data packet processing method of any one of claims 1 to 6, performed by
the communication gateway apparatus whilst the communication gateway
15 apparatus is supported by a ground surface or a water surface.
8. A computer readable medium comprising instructions for causing a data processing module to:
- receive and aggregate inbound data packets from a plurality of
20 communication devices of an Internet-of-Things (IoT) communication network;
process the aggregated inbound data packets into outbound data packets based on corresponding payload information of the aggregated inbound data packets, each outbound data packet having a respective priority; and
selectively transmit the outbound data packets through a satellite
25 communication network based on the respective priorities of the outbound data packets.
9. The computer readable medium of claim 8,
wherein the instructions for processing the aggregated inbound data
30 packets into the outbound data packets comprise instructions for causing the data processing module to assign each outbound data packet with one of high, medium and low priorities based on the corresponding payload information,

wherein the instructions for selectively transmitting the outbound data packets comprise instructions for causing the data processing module to transmit each outbound data packet with the high priority followed by each outbound data packet with the medium priority through the satellite

5 communication network, and

wherein the instructions for selectively transmitting the outbound data packets comprise instructions for causing the data processing module to not transmit each outbound data packet with the low priority through the satellite communication network.

10

10. The computer readable medium of claim 8, wherein the instructions for processing the aggregated inbound data packets into the outbound data packets comprise instructions for causing the data processing module to assign each outbound data packet with a first priority if a value derived from the corresponding payload information of the aggregated inbound data packets falls within a first range, and with a second priority if the value falls within a second range different from the first range.

15

11. The computer readable medium of claim 10, wherein the value represents a temperature, a sea level or a rate of position change.

20

12. The computer readable medium of any one of claims 8 to 11, wherein the instructions for processing the aggregated inbound data packets into the outbound data packets comprise instructions for causing the data processing module to include a bit representation of the corresponding priority in a header portion of each outbound data packet.

25

13. The computer readable medium of any one of claims 8 to 12, wherein the IoT communication network is a Long Range Wide Area Network (LoRaWAN) communication network.

30

14. A communication gateway apparatus comprising:

a first network module configured to be associated with an Internet-of-Things (IoT) communication network;

a second network module configured to be associated a satellite communication network; and

5 a data processing module coupled to the network modules, the data processing module being configured to:

receive and aggregate inbound data packets via the first network module and from a plurality of communication devices of the IoT communication network,

10 process the aggregated inbound data packets into outbound data packets based on corresponding payload information of the aggregated inbound data packets, each outbound data packet having a respective priority, and

selectively transmit the outbound data packets via the second network module and through a satellite communication network based on the
15 respective priorities of the outbound data packets.

15. The communication gateway apparatus of claim 14,

wherein the data processing module is configured to assign each outbound data packet with one of high, medium and low priorities based on the
20 corresponding payload information,

wherein the data processing module is configured to transmit each outbound data packet with the high priority followed by each outbound data packet with the medium priority via the second network module and through the satellite communication network, and

25 wherein the data processing module is configured to not transmit each outbound data packet with the low priority via the second network module and through the satellite communication network.

16. The communication gateway apparatus of claim 14, wherein the data
30 processing module is configured to assign each outbound data packet with a first priority if a value derived from the corresponding payload information of the

aggregated inbound data packets falls within a first range, and with a second priority if the value falls within a second range different from the first range.

17. The communication gateway apparatus of claim 16, wherein the value
5 represents a temperature, a sea level or a rate of position change.

18. The communication gateway apparatus of any one of claims 14 to 17,
wherein the data processing module is configured to include a bit representation
of the corresponding priority in a header portion of each outbound data packet.
10

19. The communication gateway apparatus of any one of claims 14 to 18,
wherein the IoT communication network is a Long Range Wide Area Network
(LoRaWAN) communication network.

15 20. The communication gateway apparatus of any one of claims 14 to 19,
wherein the data processing module is configured to receive and aggregate the
inbound data packet, to process the aggregated inbound data packets into the
outbound data packets, and to selectively transmit the outbound data packets
whilst the communication gateway apparatus is supported by a ground surface
20 or a water surface.

21. A communication system comprising:
the communication gateway apparatus of any one of claims 14 to 20;
the IoT communication network comprising the communication devices
25 configured to be associated with the communication gateway apparatus; and
the satellite communication network comprising a server configured to be
associated with the communication gateway apparatus.

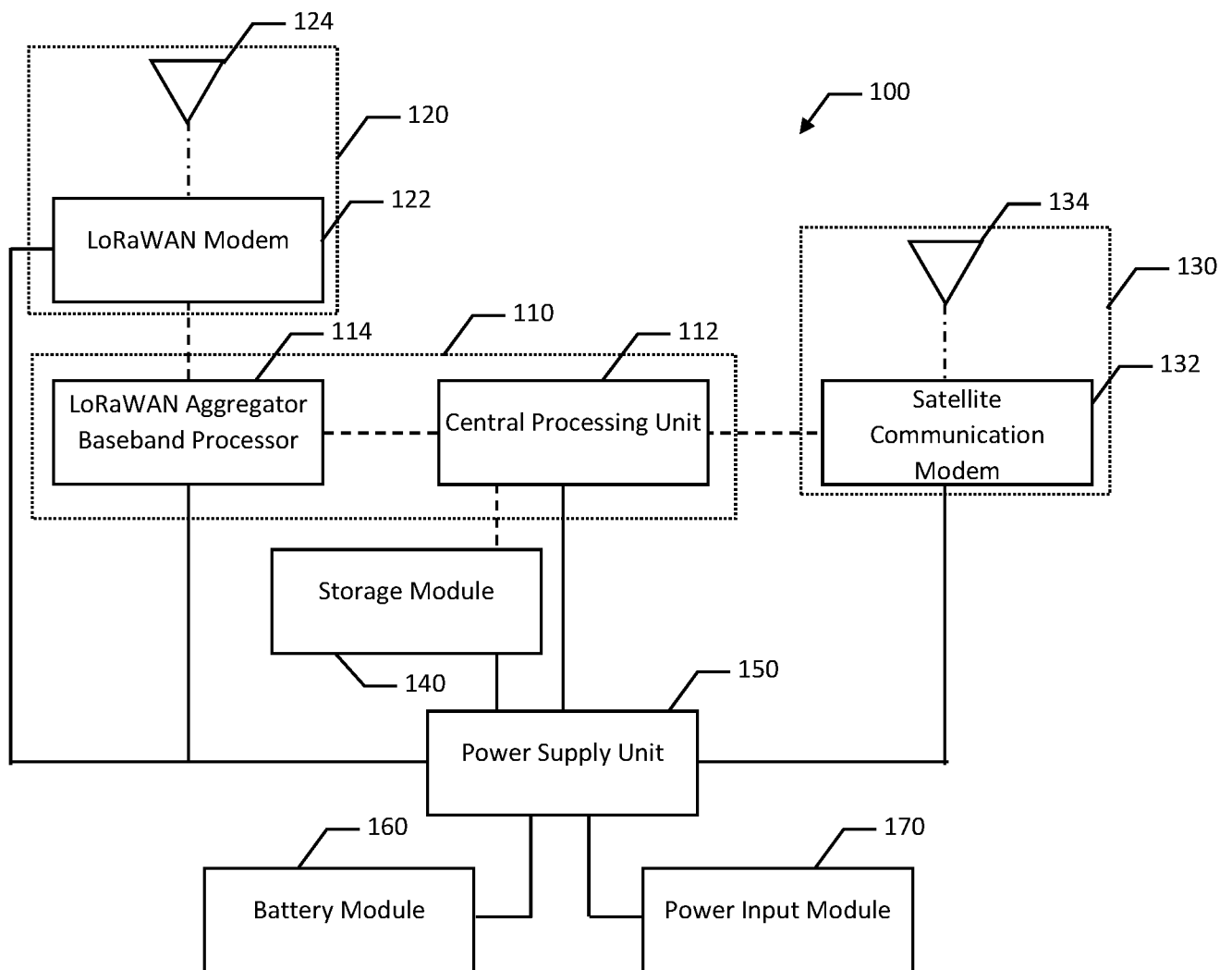
22. A communication gateway apparatus comprising:
30 a first network module configured to be associated with an Internet-of-
Things (IoT) communication network;

a second network module configured to be associated a satellite communication network; and

a data processing module coupled to the network modules, the data processing module being configured to receive inbound data packets via one of
5 the network modules and to transmit corresponding outbound data packets via the other of the network modules whilst the communication gateway apparatus is supported by a ground surface or a water surface.

23. A communication system comprising:

10 the communication gateway apparatus of claim 22;
the IoT communication network comprising a plurality of communication devices configured to be associated with the communication gateway apparatus;
and
the satellite communication network comprising a server configured to be
15 associated with the communication gateway apparatus.



- Power Supply Connection
- - - Data Connection
· · · · Radio Frequency Connection

Figure 1

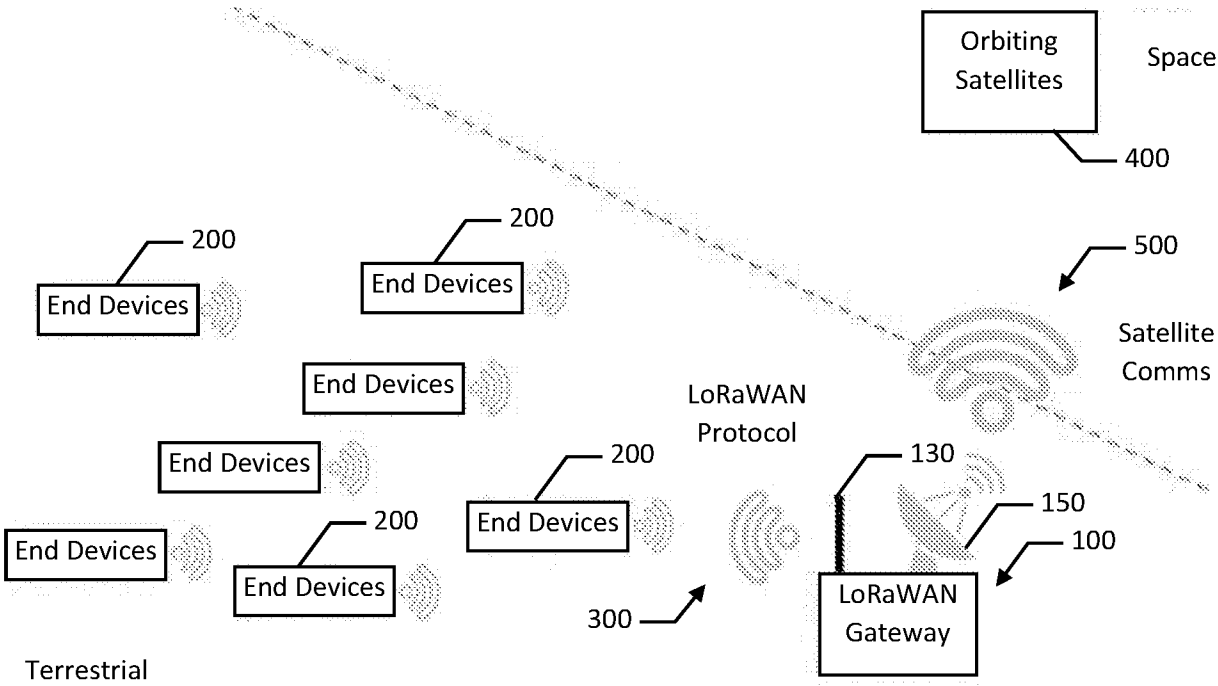


Figure 2

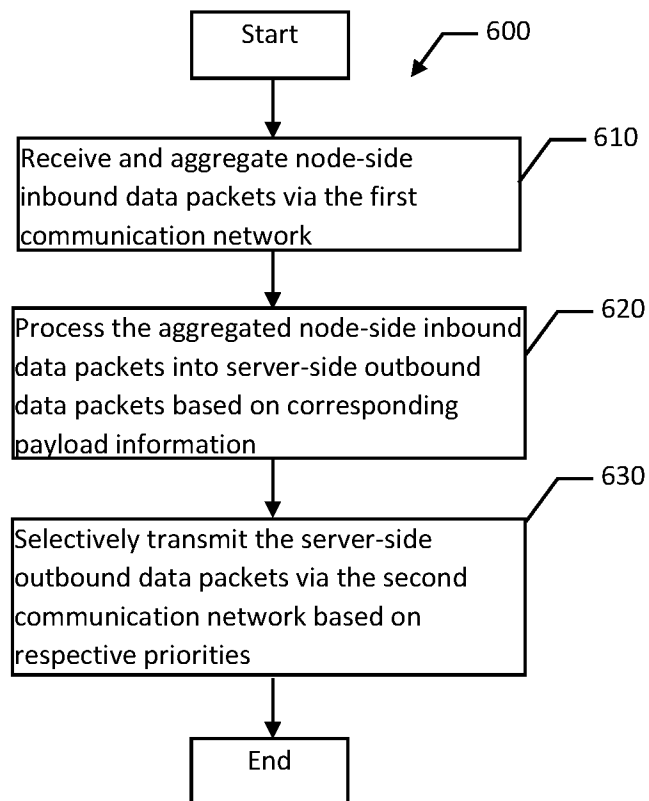


Figure 3

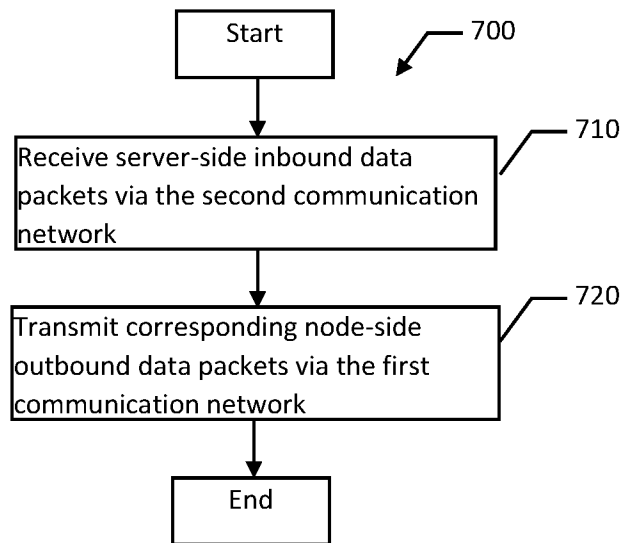


Figure 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2020/050021

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/10 (2009.01) H04B 7/185 (2006.01) H04W 4/38 (2018.01) G16Y 20/10 (2020.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W, H04B, G16Y

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

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

FamPat, IEEE, CNKI, Google scholar: nanosatellite, satellite, 卫星, space, gateway, 网关, aggregate, combine, 汇总, 合并, 聚合, 汇集, integrate, group, collect, merge, sensor, IOT, 物联网, internet of things, 传感器, data, 数据, priority, 优先, rank, preference, grade, order, payload, content, 有效载荷, 内容 and related search terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/0024677 A1 (GOPAL R. ET AL.) 22 January 2015 Fig. 2A, Paras. [0002], [0004], [0010], [0013], [0017], [0045]-[0048], [0053]-[0054], [0063], [0065]-[0067]	1-23
X	CN 107819675 A (HUNAN LINGXING SPACE INFORMATION TECHNOLOGY) 20 March 2018 Figs. 3-5, Paras. [0067], [0072], [0084]-[0087] of the original non-English language document (a machine translation is enclosed only for your reference)	22-23
X	KAWAMOTO Y. ET AL., Internet of Things (IoT): Present State and Future Prospects. <i>IEICE Transactions on Information and Systems</i> , 31 October 2014, Vol. E97-D, No. 10, pages 2568-2575 [Retrieved on 2020-03-12] <DOI: https://doi.org/10.1587/transinf.2013THP0009 > Fig. 2, Section 2.4	22-23

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

*Special categories of cited documents:

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

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

12/03/2020

(day/month/year)

Date of mailing of the international search report

24/03/2020

(day/month/year)

Name and mailing address of the ISA/SG

IPPOS Intellectual Property Office of Singapore
1 Paya Lebar Link, #11-03
PLQ 1, Paya Lebar Quarter
Singapore 408533

Email: pct@ippos.gov.sg

Authorized officer

Lu Liru (Dr)

IPOS Customer Service Tel. No.: (+65) 6339 8616

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2020/050021

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015/0024677 A1	22/01/2015	EP 3025439 A1 WO 2015/013216 A1	01/06/2016 29/01/2015
CN 107819675 A	20/03/2018	NONE	