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(54) Title: ACCESSING MULTIPLE ACCESS POINT NAMES BY AIRBORNE RADIO SYSTEM FOR OPTIMAL ROUTING TO GATEWAYS ALONG A FLIGHT PATH

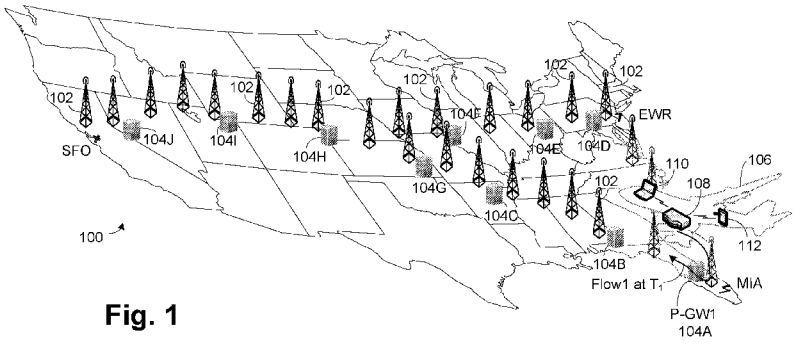


Fig. 1

(57) Abstract: An ABR-UE and Wi-Fi AP that connects with all P-GWs with APNs along a flight path and obtains an IP address from each one. When a user wishes to make a connection through the ABR-UE and Wi-Fi AP, the ABR-UE and Wi-Fi AP determines the closest P-GW and uses an IP address from that P-GW to NAT with a local IP address of the user's device so that communications then go through that nearest P-GW. The selected P-GW changes as the airplane flies and time elapses, the ABR-UE and Wi-Fi AP using the closest P-GW for any new connections.

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PATENT APPLICATION

TITLE: Accessing Multiple Access Point Names by Airborne Radio System for Optimal Routing to Gateways along a Flight Path

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application Serial No. 62/315,868 entitled "Accessing Multiple Access Point Names by Airborne Radio System for Optimal Routing to Gateways along a Flight Path," filed March 31, 2016, which is hereby incorporated by reference as if reproduced in its entirety.

[0002] This application is related to U.S. Patent Application Serial No. __/_____ entitled "Airborne Radio System That uses Nearest SAE-GW for Anchoring New Connections along the Flight Path and Tunnels Existing Connections," which is filed concurrently herewith and is hereby incorporated by reference as if reproduced in its entireties.

BACKGROUND

[0003] For data connectivity from moving aircraft two types of solutions exist, one that relies on satellite connection and another that uses an Air to Ground (ATG) network. The satellite-based solution is slow and has long latency, which makes it unsuitable for interactive or streaming services. The Air to Ground systems do not have satellite-like propagation delay and should be able to perform much better. The ATG network has a set of base stations spread across the terrestrial coverage, e.g. in case of United States the base stations will be from coast to coast along the flight paths. This is shown in Fig. 1 for two exemplary flight paths between Miami (MIA) and San Francisco (SFO) and Newark (EWR) and San Francisco. The ATG systems typically leverage 3G or 4G technologies, where an airborne radio (ABR) acts like a regular mobile handset or modem (user equipment or UE) for connecting to base stations and then base stations are connected to the terrestrial mobile network for connectivity to Internet or other networks. The ABR then acts as a modem connected

to a Wi-Fi access point, which then accepts connections from the laptops, tablets and cell phones on the aircraft.

[0004] The traditional mobile network was designed for mobility across neighborhoods, cities and regions for walkable and drivable use cases. Typically, the core network has a mobility anchor (packet data network gateway/gateway GPRS support node or P-GW/GGSN) in the region that connects to the Internet. The path from the UE is to radio towers (eNodeB or eNB). The eNB then connects to an S-GW (serving gateway) and then the S-GW connects to the P-GW/GGSN (mobility anchor), which is a gateway to an external network such as the Internet. In the context of an ATG network, the ABR-UE on the aircraft connects to radio towers in its vicinity. A group of the eNBs are then served by a nearby S-GW. The S-GW can connect to any P-GW depending on access point name (APN) based P-GW selection. Typically, for a service like Internet access, the nearest P-GW with Internet connectivity is selected.

[0005] When a UE first attaches to the mobile network (say upon power up), it requests connectivity to the external network (e.g. Internet) as identified by an APN (Access Point Name). The APN decides which P-GW/GGSN becomes anchor for the connecting UE. Typically, the name resolution of the APN will point to a nearby P-GW/GGSN that serves that APN. When a UE re-attaches to the mobile network (say due to powering down and then by powering up) or upon accessing new service as identified by a different APN, the UE gets to establish a new session/context with the P-GW. Depending on location or service sought, it may get connected to a different P-GW.

[0006] Once a UE establishes a session/context with the anchor (P-GW/GGSN), the internet protocol (IP) address of the UE is assigned by the P-GW/GGSN from the pool of IP addresses associated with that P-GW/GGSN and all data of the UE is routed through the anchor for the duration of connectivity, e.g. if a person attaches to network in city A and drives for a few hours to city B, his/her data flow will remained anchored through the P-GW/GGSN that it got connected to in city A. If the user was simply accessing the Internet, it would be more efficient to route the data through a P-GW/GGSN located closer to City B. However, due to the smaller distances involved, the additional delay due to such anchoring is not that big of an issue.

[0007] This situation completely changes in ATG systems, where the ABR-UE is typically connected to a Wi-Fi access point (AP) onboard and hundreds of users connect to the AP over the wireless local area network (WLAN), which then does network address translation (NAT) as part of its normal routing function and sends all data through the ABR-UE to the ground. Considering a coast-to-coast flight involves 5000km of distance, the ABR-UE will be connected to a base station near the departing airport and a nearby P-GW/GGSN. Then for the duration of the flight the ABR-UE will remain anchored to that P-GW near the originating airport. Given that coast-to-coast propagation delays are significant, ATG solutions also suffer from long delays and perform poorly for interactive services. The ATG service will have multiple regional datacenters with P-GWs. As an illustration, say a person watches 30 min. of video on a laptop soon after takeoff from SFO. Then the person takes a nap for 2 hours, then does Skype® chatting using the laptop for the next fifteen minutes and then in the last one hour of flight he/she takes an aerial video of the New York area using the smartphone to be emailed to a colleague in Maine. The way the ABR-UE to P-GW connection is setup, it is clear to see that the user experience will be progressively worse. Moreover, the same P-GW will be utilized for all of the flights taking off from nearby airports, making P-GWs near busy airports unnecessarily loaded, especially if many people in the flight use the service. Backhauling a lot of data across the continent is not only inefficient but expensive as well.

BRIEF DESCRIPTION OF THE FIGURES

[0008] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an implementation of apparatus and methods consistent with the present invention and, together with the detailed description, serve to explain advantages and principles consistent with the invention.

[0009] Figures 1-3 are block diagrams of an ATG network according to the present invention at different times.

[0010] Figure 4 is a flowchart of ABR-UE and Wi-Fi AP operation according to the present invention.

[0011] Figure 5 is a block diagram of an S-GW or P-GW.

[0012] Figure 6 is a block diagram of a combined ABR-UE and Wi-Fi access point according to the present invention.

[0013] Figure 7 is a block diagram of a separate ABR-UE and a separate Wi-Fi access point according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Fig. 1 is a representation of an ATG network 100. Various base stations 102, indicated by the radio towers, are positioned along the flight paths between MIA and SFO and EWR and SFO. Every few base stations 102 a P-GW 104A-J is shown for that group of base stations 102 for purposes of illustration. An airplane 106 is illustrated having an ABR-UE and Wi-Fi access point 108 that is connected to a laptop 110 and a tablet 112 by Wi-Fi. The S-GWs have not been shown for the sake of clarity. They can be collocated with the P-GW or can be deployed as a service architecture evolution gateway (SAE-GW).

[0015] Embodiments according to the present invention reduce the propagation delays and overloading of P-GWs near airports by utilizing a method initiated from the onboard Wi-Fi AP and ABR-UE 108. Assume there are (n) P-GWs 104A-J along the flight path that can provide access to Internet. At the time of startup, the ABR-UE 108 initiates access to the (n) APNs. Each APN points to a specific P-GW 104A-J along the way. This also means that the ABR-UE 108 gets (n) IP addresses, one from each P-GW 104A-J. When users connect to the Wi-Fi access point (AP) 108, the AP 108 assigns an IP address to the user device, such as a laptop 110 or tablet 112, and then NATs it to one of the ABR-UE IP addresses. By observing the time since the take-off, or by accessing the location on the flight map, the Wi-Fi AP 108 can simply select the ABR-UE IP address that is associated with the P-GW 104A-J closest to the aircraft for NATting purposes.

[0016] This is illustrated in Figures 1-3. In Fig. 1, the airplane 106 is leaving MIA bound for SFO. The ABR-UE and Wi-Fi AP 108 has been started and connected to P-GW1 104A. A flow1 is commenced as soon as possible after takeoff at time T1. Because P-GW1 104A is the closest P-GW, flow1 is connected to P-GW1 104A. In Fig. 2, time has elapsed to time T2 and the airplane 106 has progressed to being over Tennessee. A second user wishes to make a connection, in this case flow2. The closest

P-GW is now P-GW2 104C, so flow2 is routed to P-GW2 104C. Flow1 remains with P-GW1 104A at time T2. In Fig. 3, additional time has elapsed to time T3, with the airplane 106 now over Iowa or Nebraska. A third user wishes to make a connection, in this case flow3. The closest P-GW is now P-GW3 104H, so flow3 is assigned to use P-GW3 104H. Flow2 remains with P-GW2 104C and flow1 remains with P-GW1 104A.

[0017] The Wi-Fi AP 108 can extend this logic to new requests coming from the same user. Since it is NATting, every new flow coming from the new user or the same user can be optimally NATted to the ABR-UE IP address associated with the nearest P-GW 104A-J, e.g. a new HTTP request will have a unique 4-tuple of src-ip, dst-ip, src-port, dst-port which can be pointed to ABR-UE IP address3 (associated with P-GW3 104H) if that P-GW is closest to the aircraft 106. The returning traffic comes back to P-GW3 104H, which sends it back to ABR-UE 108, which forwards it to the Wi-Fi AP. The AP 108 looking at its NAT table sends it back to correct user.

[0018] In case a user starts a 6 hour movie at takeoff, this flow is connected to P-GW1 104A and remains connected there since there is no break. The user can deliberately break the connection and reestablish it for better user experience or authorize the Wi-Fi AP 108 to do that on his/her behalf. In this case, the Wi-Fi AP 108 may force an http redirect based on time and/or location, which connects to the closest P-GW 104A-J as explained earlier. This process continues until the flight lands.

[0019] This operation is illustrated in Fig. 4. In step 402 the ABR-UE and Wi-Fi AP 108 is turned on, the initial cellular connection is made, the access point is activated and flight information is obtained. In step 404 the ABR-UE and Wi-Fi AP 108 determines the P-GWs with APNs along the flight path. In step 406 the ABR-UE and Wi-Fi AP 108 obtain an IP address from each determined P-GW. With this, the ABR-UE and Wi-Fi AP 108 is ready for operation.

[0020] In step 408 the ABR-UE and Wi-Fi AP 108 determines if there is a Wi-Fi request, such as a request for a new transmission control protocol (TCP)/IP connection. The request can be a request to connect to a new IP address or a request for a new TCP port at an IP address that is used for an existing connection of the device. Conventionally this is done based on a message from a Wi-Fi AP program. If there is a Wi-Fi request, in step 410 the ABR-UE and Wi-Fi AP 108 determines the closest P-GW, based on time or flight path location, as noted above. In step 412, a

local IP address is assigned to the Wi-Fi request, if one is not already assigned to the requesting device, and a NAT relationship is made with an IP address from the nearest P-GW. This is a many-to-many NAT situation, the IP addresses from the various P-GWs to local, internal IP addresses. The Wi-Fi process would then continue normally.

[0021] In step 414 it is determined if it is time to reestablish any Wi-Fi connections to improve their performance. This step 414 is also performed if there is no Wi-Fi request in step 408. If it is time to reestablish a connection, in step 426 that connection is terminated. In step 418 the closest P-GW is determined and in step 420 the NAT relationship is changed so that the local IP address is now associated with an IP address from the closest P-GW. In step 422 a redirect is provided to the connected device so that the connection is reestablished. After step 422 or if it was not time to reestablish a connection in step 414, operation returns to step 408 waiting for a Wi-Fi request.

[0022] As noted above, the reestablishment is optional, in which case operation returns to step 408 after step 412 or if there is no Wi-Fi request in step 408.

[0023] This operation can also be done in a UE itself, where each connection to a different APN/P-GW appears as an IP interface and the UE can select the interface based on its location or DNS information. Similarly, high-speed trains can also implement this operation.

[0024] As known to one skilled in the art and shown in Fig. 5, S-GWs and P-GWs are complicated and expensive computer systems and packet routers, which include a processor 502, network interfaces or ports 508, a packet switch 506 for packet routing and a memory 504 to store programs and data. The operations, such as those described here, are performed by programs stored in the memory and executing on the processor. Because the structure and operation of an S-GW and a P-GW are so well known, further details of their construction, configuration and operation are not provided here.

[0025] Fig. 6 is an exemplary block diagram of a combined ABR-UE and Wi-Fi AP 600 according to the present invention. A processor 602 manages the operation and executes program contained in memory 606, such as flash memory. A RAM 604 provides working storage. A Wi-Fi network processor and RF chip 608 is connected to

the processor 602 and handles the Wi-Fi communications. An LTE modem and RF chip 610 is connected to the processor 602 and handles the cellular communications.

[0026] The memory 606 contains various programs executed on the processor 602. First is an operating system 612. Second is a W-Fi access point program 616 that performs the normal access point and Wi-Fi functions. An LTE program 614 that handles the cellular communications. An airborne program 618 handles the special operations of an ABR-UE and Wi-Fi access point, including most of the operations described herein including obtaining IP addresses from the P-GWs, providing the NAT operations and determining the closest P-GW. It is understood that the functions of the ABR-UE and Wi-Fi AP are substantially separate even though they may be located in the same device and share components, such as a processor, so that the functions may be referred to separately even though the ABR-UE and Wi-Fi AP are integrated into a single device.

[0027] The system 700 of Figure 7 is similar to the system 600 of Figure 6 except that the ABR-UE and Wi-Fi access point functions have been separated. The Wi-Fi access point 703 includes a processor 702A that manages the operation and executes program contained in memory 706A, such as flash memory. A RAM 704A provides working storage. A Wi-Fi network processor and RF chip 708 is connected to the processor 702A and handles the Wi-Fi communications. The memory 706A contains various programs executed on the processor 702A. First is an operating system 712. Second is a W-Fi access point program 716 that performs the normal access point and Wi-Fi functions. An airborne program 718A handles Wi-Fi access point special operations described herein including providing the NAT operations.

[0028] An ABR-UE 701 includes a processor 702B that manages the operation and executes program contained in memory 706B, such as flash memory. A RAM 704B provides working storage. An LTE modem and RF chip 710 is connected to the processor 702B and handles the cellular communications. The memory 706B contains various programs executed on the processor 702B. First is an operating system 712. Second is an LTE program 714 that handles the cellular communications. An airborne program 718B handles the ABR-UE special operations, including obtaining IP addresses from the P-GWs and determining the closest P-GW.

[0029] The Wi-Fi access point processor 702A is connected to the ABR-UE processor 702B so that the two processors can communicate. The airborne programs 718A and 718B contain the programs to allow this communication and the programs that handle the cooperative portions of operation.

[0030] It is understood that these are highly simplified block diagrams for illustration purpose and many different configurations can be developed by those skilled in the art and perform the operations described above.

[0031] By having the ABR-UE obtain IP addresses from P-GWs along the flight path, any new connections can be anchored or sent to the nearest P-GW as the airplane crosses the country, thus reducing back haul and congestion on P-GWs near airports. If desired, existing connections can be migrated to closer P-GWs to further reduce backhaul.

[0032] The above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments may be used in combination with each other. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein."

CLAIMS

1. A device comprising:

an airborne radio user equipment (ABR-UE) for location on an aircraft for communicating with a plurality of base stations located along a flight path and a plurality of packet data network gateways (P-GWs) associated with the plurality of base stations, the plurality of P-GWs also located along a flight path, each with an associated access point name (APN), with each P-GW having associated Internet protocol (IP) addresses; and

a Wi-Fi access point for location on the aircraft and coupled to the ABR-UE for connecting a plurality of user Wi-Fi devices located on the aircraft to the ABR-UE and for performing network address translation (NAT) operations,

wherein the ABR-UE and Wi-Fi access point cooperate to obtain an IP address for each of the plurality of P-GWs along the flight path and provide a connection between the nearest P-GW and a user Wi-Fi device when the user Wi-Fi device requests a first IP connection, the nearest P-GW changing as the aircraft proceeds along the flight path.

2. The device of claim 1, wherein the ABR-UE and the Wi-Fi access point cooperate further to force a redirect of an IP connection when the aircraft has proceeded along the flight path at least enough to have a different P-GW become the nearest P-GW.

3. The device of claim 1, wherein the ABR-UE and the Wi-Fi access point cooperate further to provide a connection between the nearest P-GW and the user Wi-Fi device when the user Wi-Fi device requests a second IP connection, the ABR-UE and Wi-Fi access point maintaining the first IP connection of the user Wi-Fi device with the P-GW to which it was originally connected even though such P-GW is no longer the nearest P-GW.

4. The device of claim 1, further comprising the aircraft on which the ABR-UE and the Wi-Fi access point are located.

5. The device of claim 4, further comprising:

the plurality of base stations located along the flight path of the aircraft, the flight path extending a multiplicity of kilometers; and

the plurality of packet data network gateways (P-GWs) associated with the plurality of base stations, the plurality of P-GWs also located along the flight path, each with an associated access point name (APN), with each P-GW having associated Internet protocol (IP) addresses.

6. The device of claim 1, further comprising:

the plurality of base stations located along the flight path of the aircraft, the flight path extending a multiplicity of kilometers; and

the plurality of packet data network gateways (P-GWs) associated with the plurality of base stations, the plurality of P-GWs also located along the flight path, each with an associated access point name (APN), with each P-GW having associated Internet protocol (IP) addresses.

7. A method comprising:

communicating, by an airborne radio user equipment (ABR-UE) located on an aircraft, with a plurality of base stations located along a flight path and a plurality of packet data network gateways (P-GWs) associated with the plurality of base stations, the plurality of P-GWs also located along a flight path, each P-GW with an associated access point name (APN), with each P-GW having associated Internet protocol (IP) addresses;

obtaining, by the ABR-UE, an IP address for each of a plurality of packet data network gateways (P-GWs); and

providing, by cooperation of the ABR-UE and a Wi-Fi access point located on the aircraft, the Wi-Fi access point coupled to the ABR-UE for connecting a plurality of user Wi-Fi devices located on the aircraft to the ABR-UE and for performing network address translation (NAT) operations, a connection between the nearest P-GW and a user Wi-Fi device when the user Wi-Fi device requests a first IP connection, the nearest P-GW changing as the aircraft proceeds along the flight path.

8. The method of claim 7, further comprising:

forcing, by the ABR-UE and the Wi-Fi access point, a redirect of an IP connection when the aircraft has proceeded along the flight path at least enough to have a different P-GW become the nearest P-GW.

9. The method of claim 7, further comprising:

providing, by the ABR-UE and the Wi-Fi access point, a connection between the nearest P-GW and the user Wi-Fi device when the user Wi-Fi device requests a second IP connection, the ABR-UE and Wi-Fi access point maintaining the first IP connection of the user Wi-Fi device with the P-GW to which it was originally connected even though such P-GW is no longer the nearest P-GW.

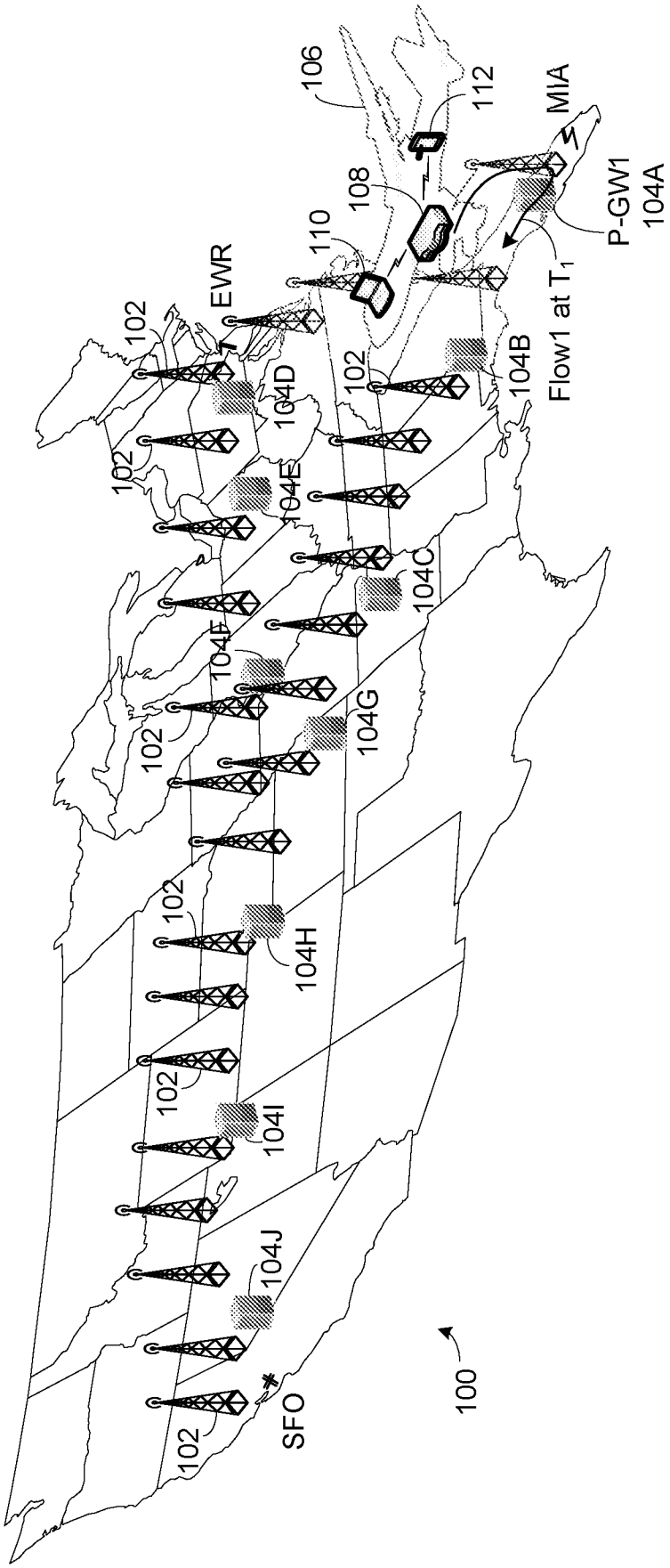

106
112
MIA
108
110
P-GW1
104A
EWR
Flow1 at T_1
102
104B
104D
104E
104C
104F
104G
104H
104I
104J
SFO
100

Fig. 1

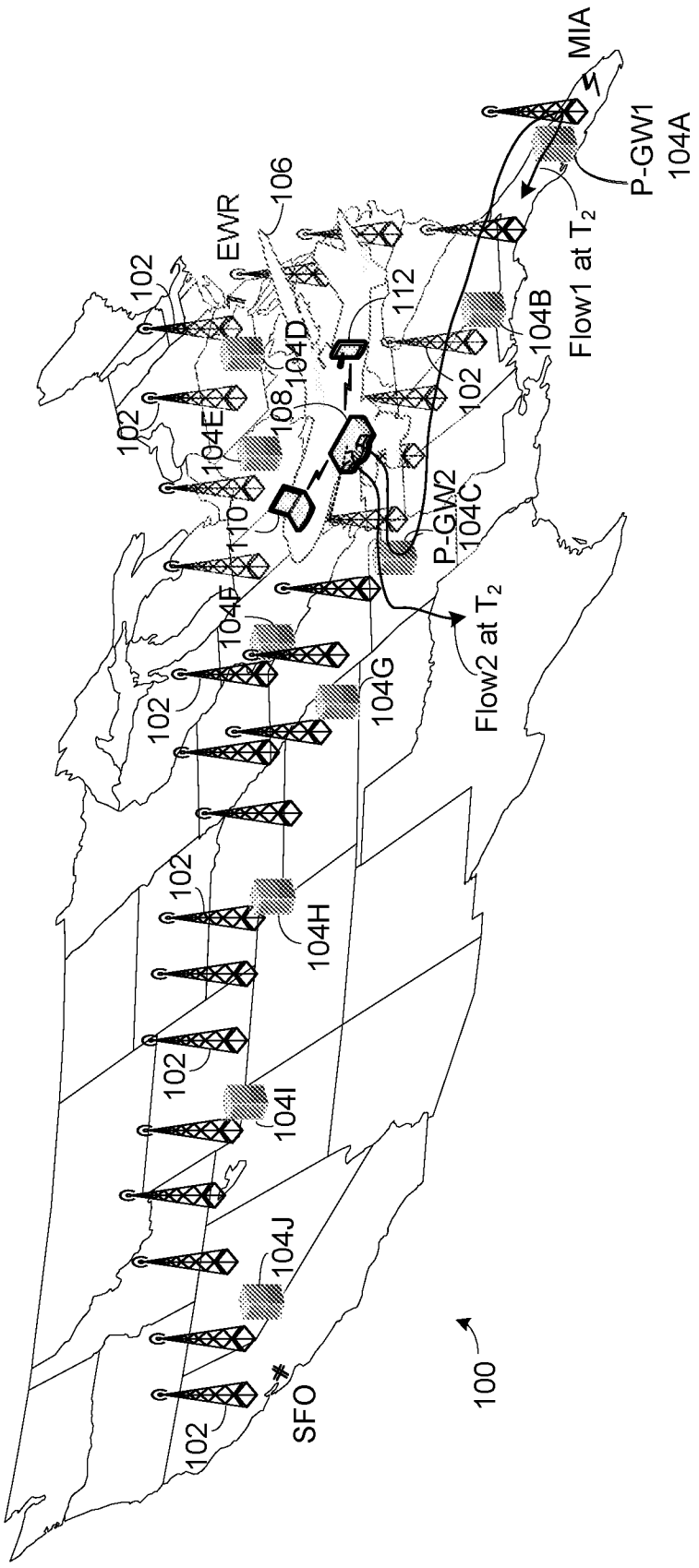

MIA
P-GW1
104A
Flow1 at T_2
EWR
106
102
112
104B
104D
108
104E
110
P-GW2
104C
Flow2 at T_2
104F
104G
104H
104I
104J
SFO
100

Fig. 2

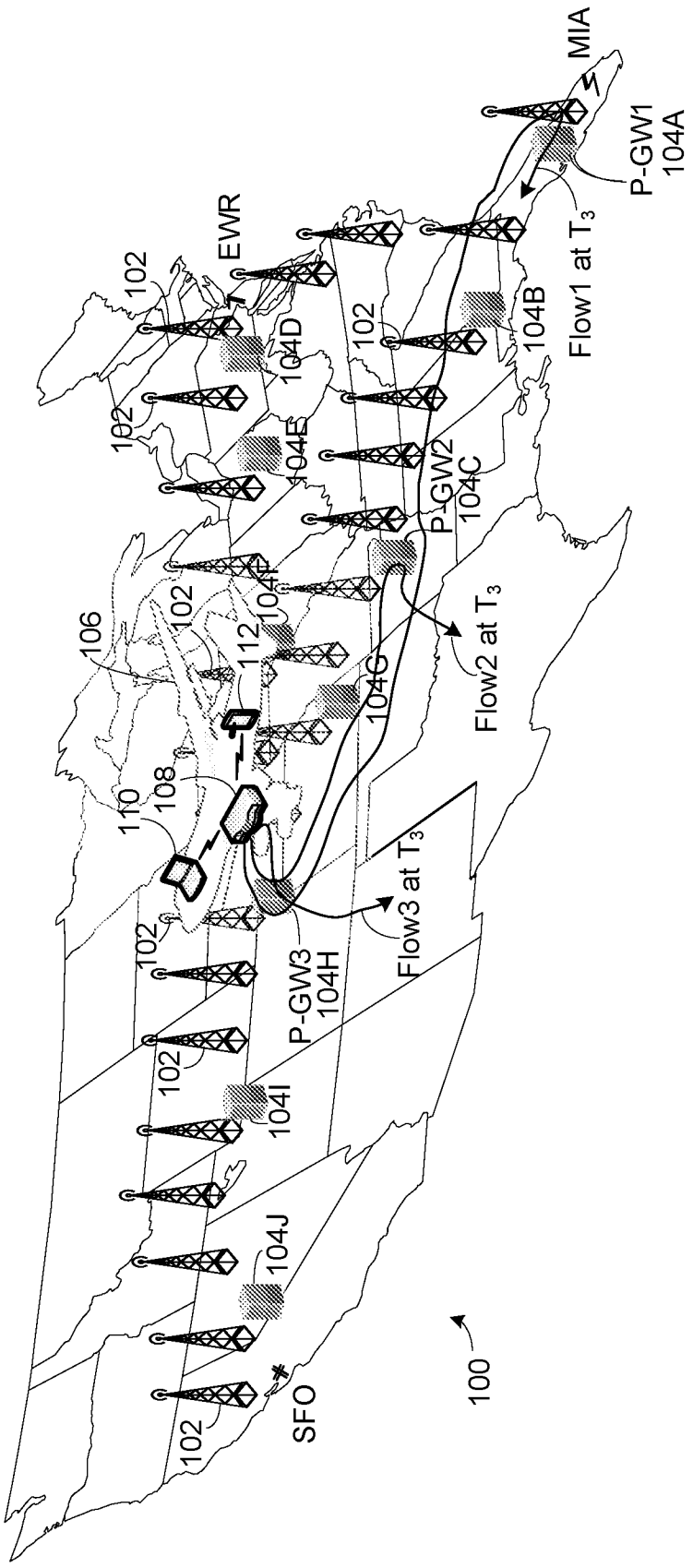

MIA
P-GW1
104A
Flow1 at T_3
EWR
102
104D
104B
102
102
104E
P-GW2
104C
102
104F
106
112
Flow2 at T_3
104G
110
108
Flow3 at T_3
102
P-GW3
104H
102
104I
104J
SFO
102
100

Fig. 3

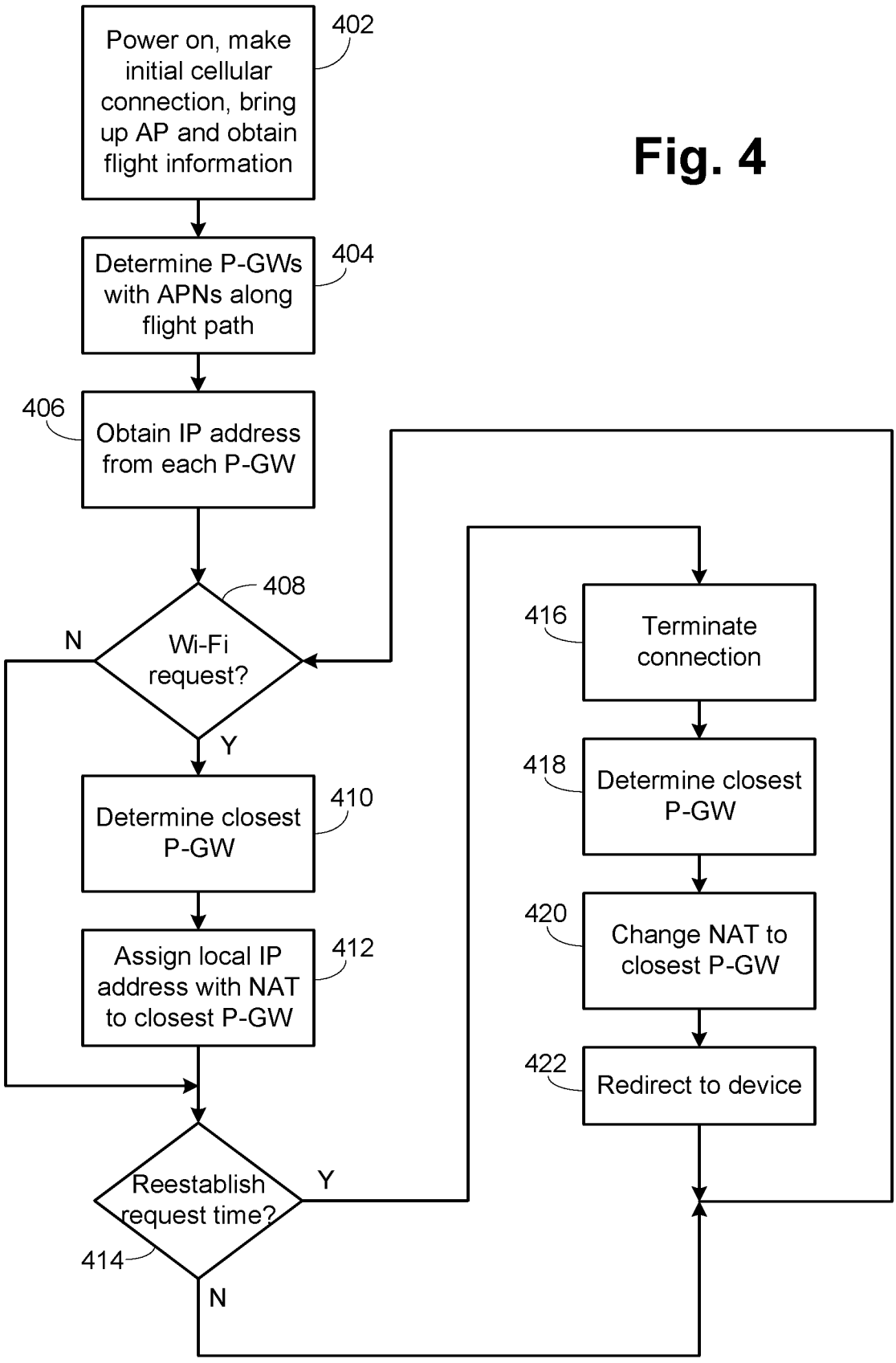

Power on, make initial cellular connection, bring up AP and obtain flight information
402
Determine P-GWs with APNs along flight path
404
406
Obtain IP address from each P-GW
408
Wi-Fi request?
N
Y
Determine closest P-GW
410
Assign local IP address with NAT to closest P-GW
412
Reestablish request time?
Y
414
N
416
Terminate connection
418
Determine closest P-GW
420
Change NAT to closest P-GW
422
Redirect to device

Fig. 4

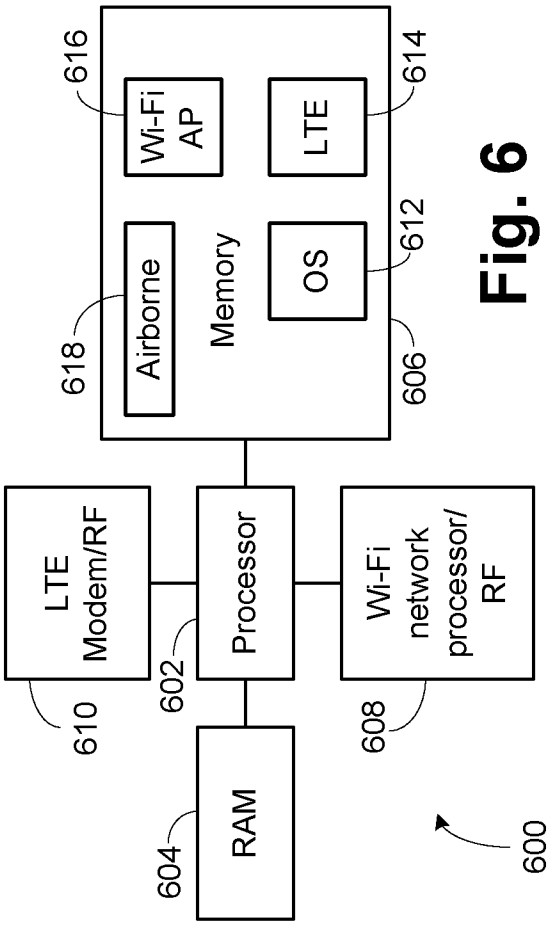


Fig. 6

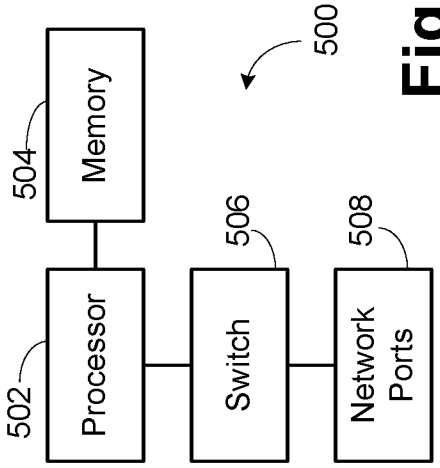


Fig. 5

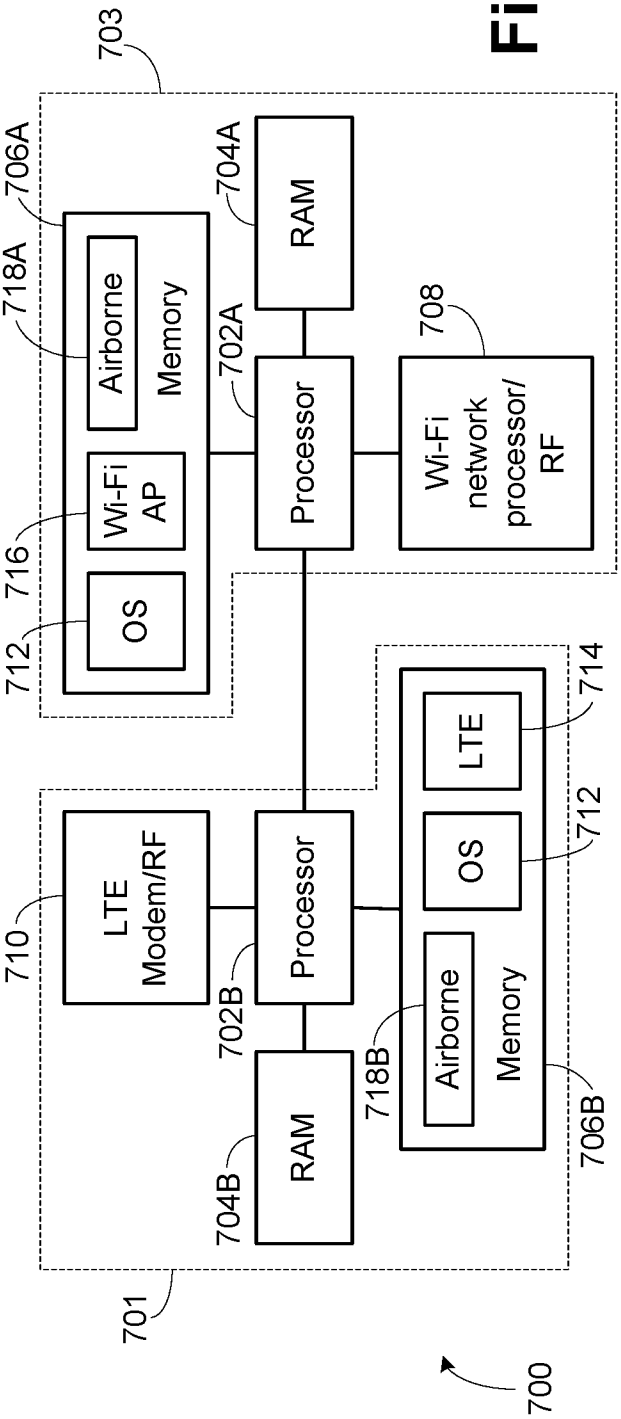


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/024576

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H04B 7/185; H04Q 7/20; H04W 4/02; H04W 12/08 (2017.01)
CPC - H01Q 3/24; H04B 7/18506; H04W 84/005; H04W 84/06 (2017.02)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 340/945; 370/338; 455/431 (keyword delimited)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009/0186611 A1 (STILES et al) 23 July 2009 (23.07.2009) entire document	1-9
Y	US 2009/0082013 A1 (ECKERT et al) 26 March 2009 (26.03.2009) entire document	1-9
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