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(54) **METHODS AND SYSTEMS FOR AUTOMATED ACTIVATION AND CONFIGURATION OF BROADBAND INCIDENT AREA NETWORKS (IANS)**

(71) Applicant: **MOTOROLA SOLUTIONS, INC**, Schaumburg, IL (US)

(72) Inventors: **David P Gurney**, Carpentersville, IL (US); **Bradley M Hiben**, Glen Ellyn, IL (US); **Stephen L Kuffner**, Algonquin, IL (US)

(73) Assignee: **MOTOROLA SOLUTIONS, INC.**, Schaumburg, IL (US)

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(51) **Int. Cl.**

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H04W 76/00	(2009.01)
H04W 4/02	(2009.01)
H04W 24/10	(2009.01)
H04W 4/22	(2009.01)

(52) **U.S. Cl.**
CPC ***H04W 76/007*** (2013.01); ***H04W 4/02*** (2013.01); ***H04W 4/22*** (2013.01); ***H04W 24/10*** (2013.01)

(58) **Field of Classification Search**
CPC H04W 76/007; H04W 4/02; H04W 24/10; H04W 4/22
USPC 455/404.1
See application file for complete search history.

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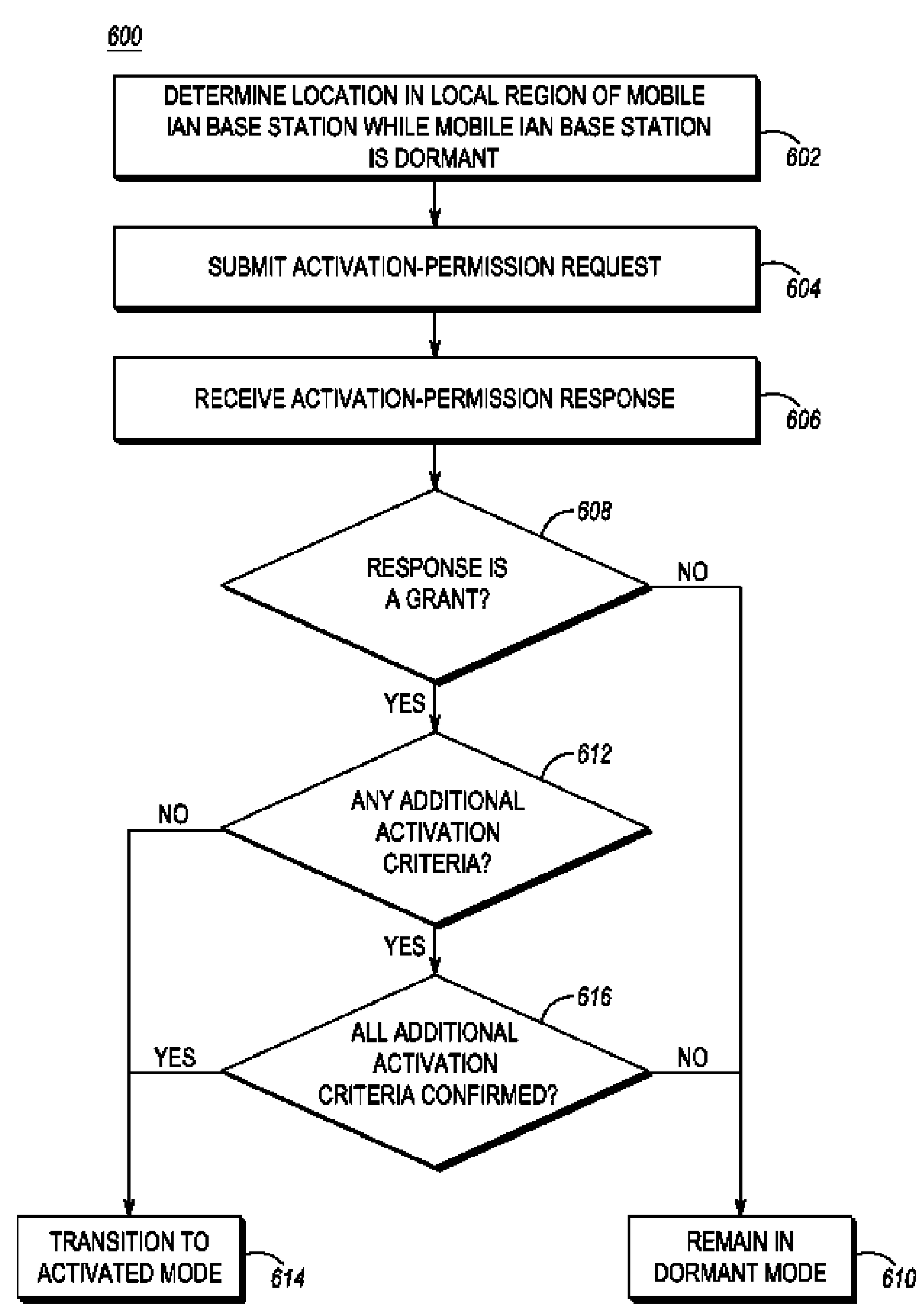
Primary Examiner — Nader Bolourchi
(74) *Attorney, Agent, or Firm* — Kenneth A. Haas

(57) **ABSTRACT**

Disclosed herein are methods and systems for automated activation and configuration of broadband LTE IANs. A mobile IAN base station, an activated mode and a dormant mode, determines at least one location in a local region of the mobile IAN base station while in the dormant mode. An activation-permission request is submitted to a geo-location-database (GDB) function, and the mobile IAN base station receives an activation-permission response. The response is based on an expected level of wide-area-network (WAN) coverage associated with the determined location. Responsive to receiving an activation-permission grant, the mobile IAN base station transitions to the activated mode. Responsive to not receiving an activation-permission grant, the mobile IAN base station remains in the dormant mode.

20 Claims, 8 Drawing Sheets



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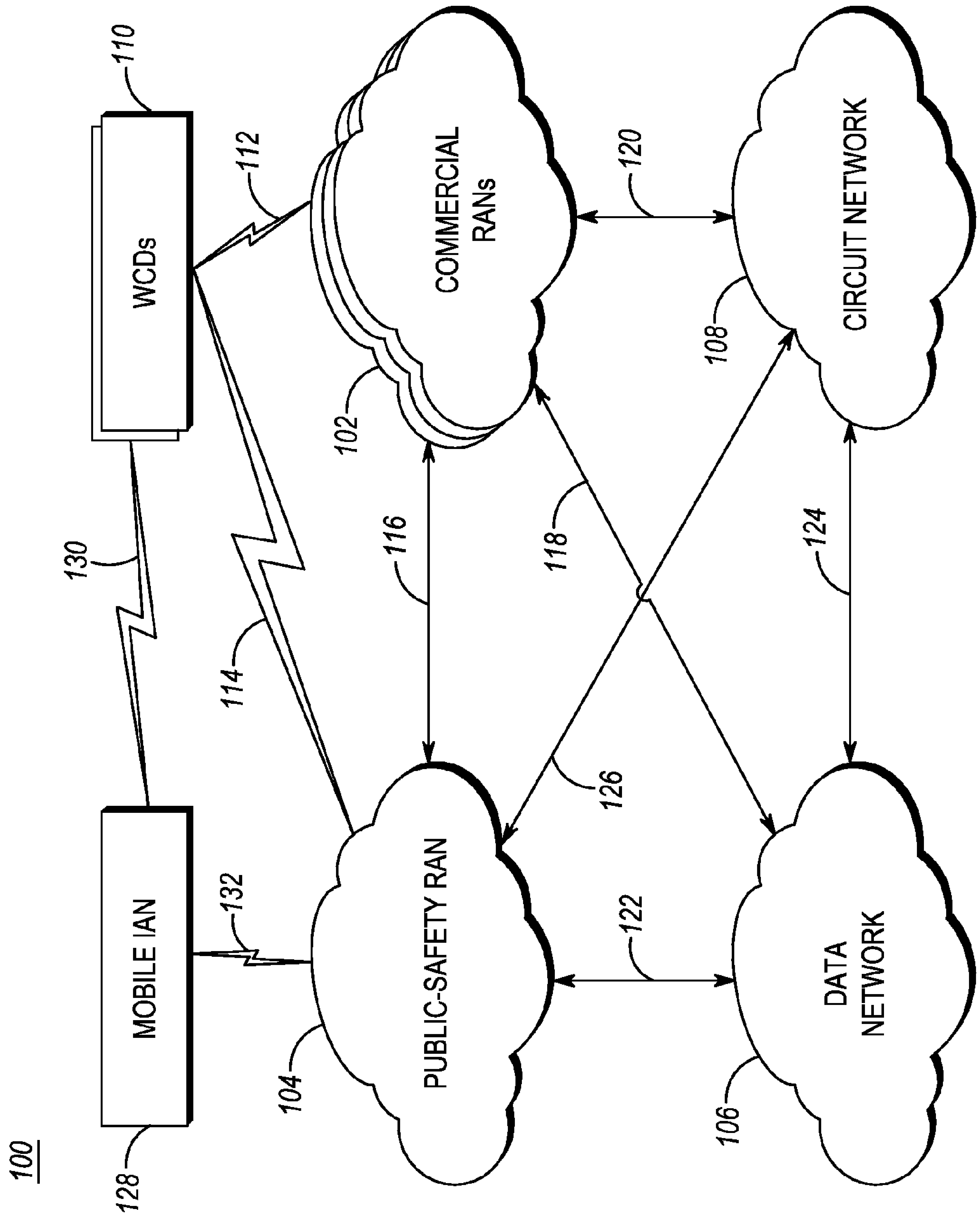

100
MOBILE IAN
128
WCDs
110
130
114
112
132
COMMERCIAL RANs
102
PUBLIC-SAFETY RAN
104
116
118
126
120
122
124
CIRCUIT NETWORK
108
DATA NETWORK
106

FIG. 1

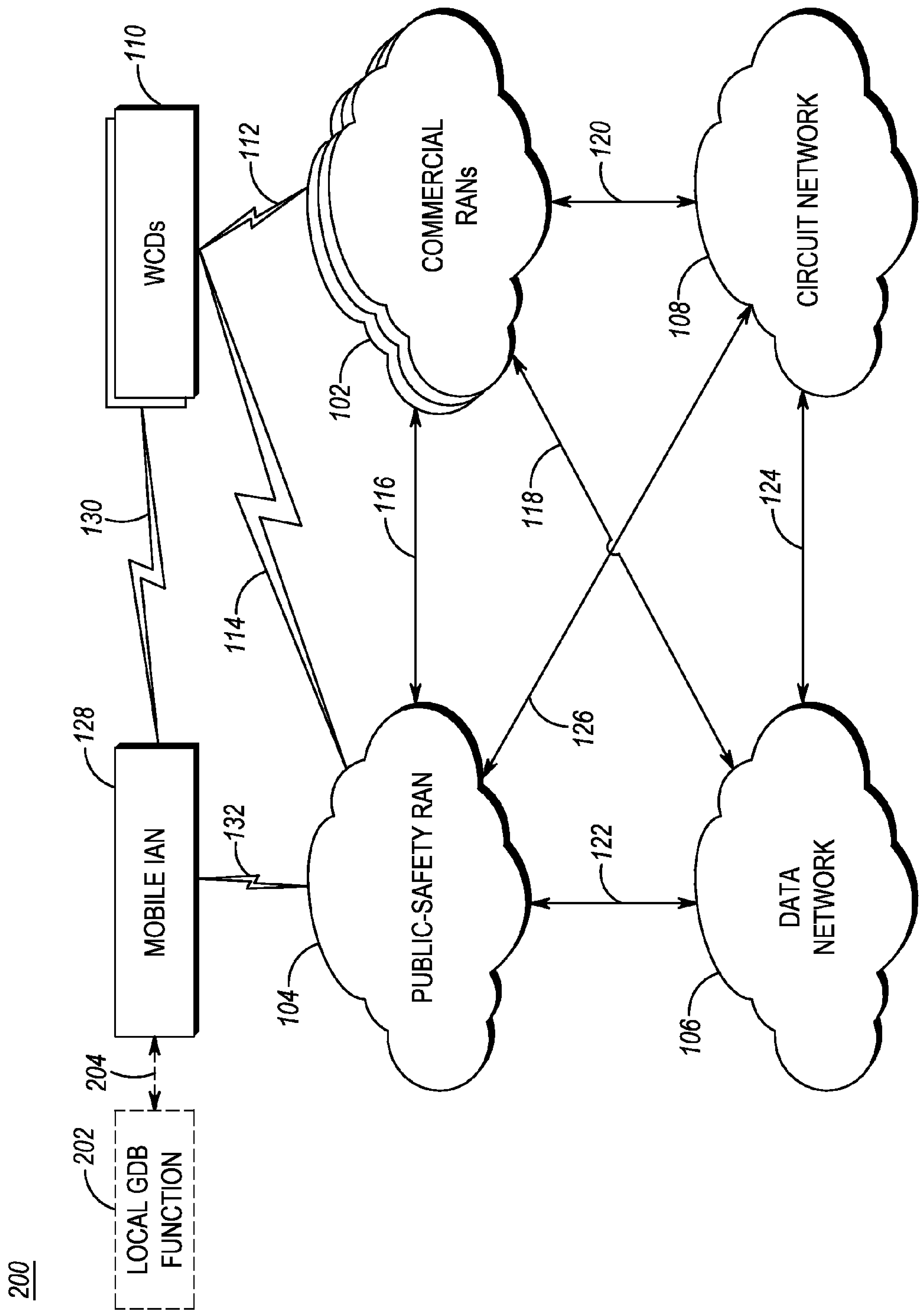

200
LOCAL GDB FUNCTION
202
204
MOBILE IAN
128
132
WCDs
110
112
130
114
COMMERCIAL RANs
102
PUBLIC-SAFETY RAN
104
116
118
126
120
122
124
CIRCUIT NETWORK
108
DATA NETWORK
106

FIG. 2

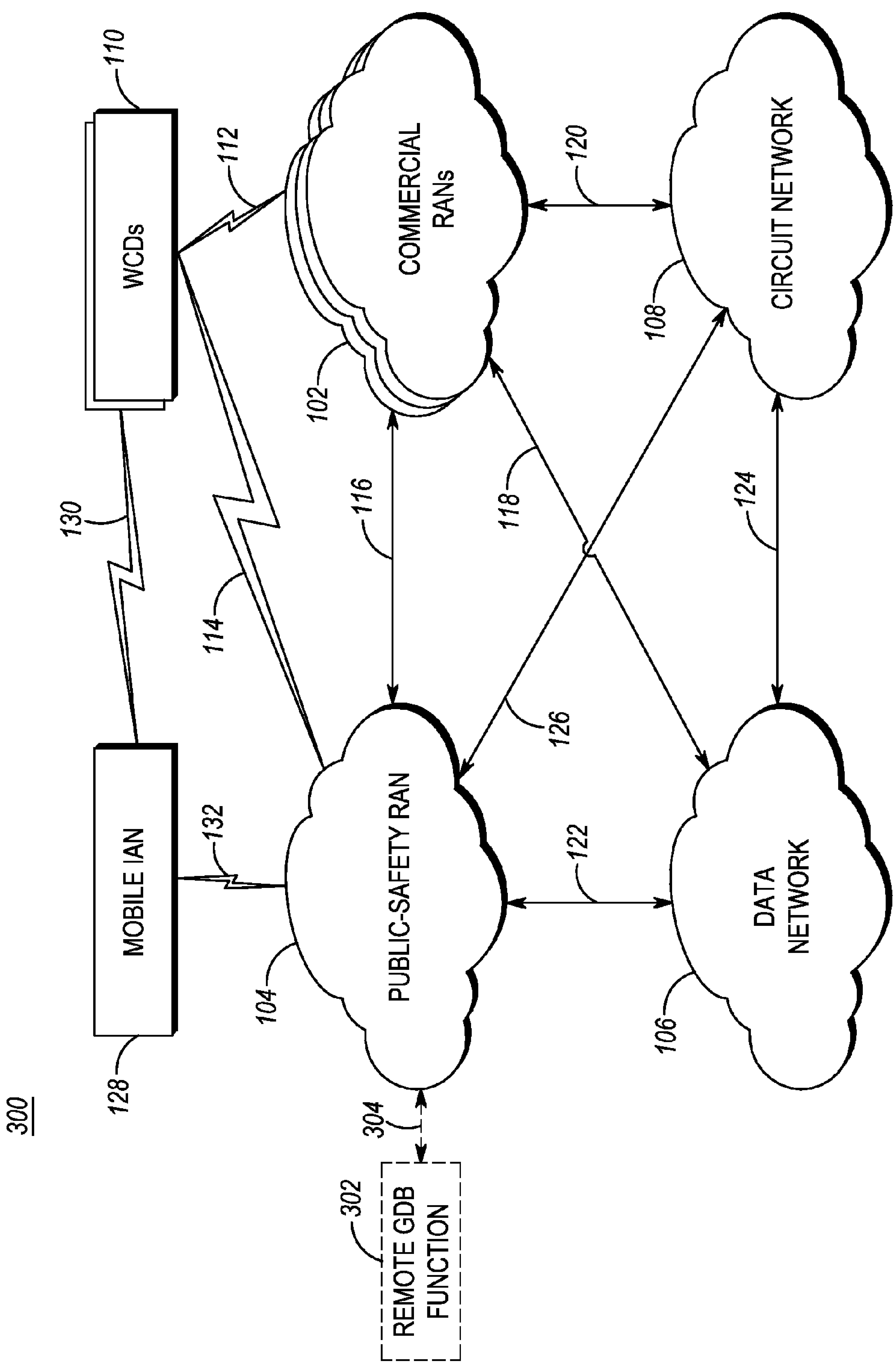
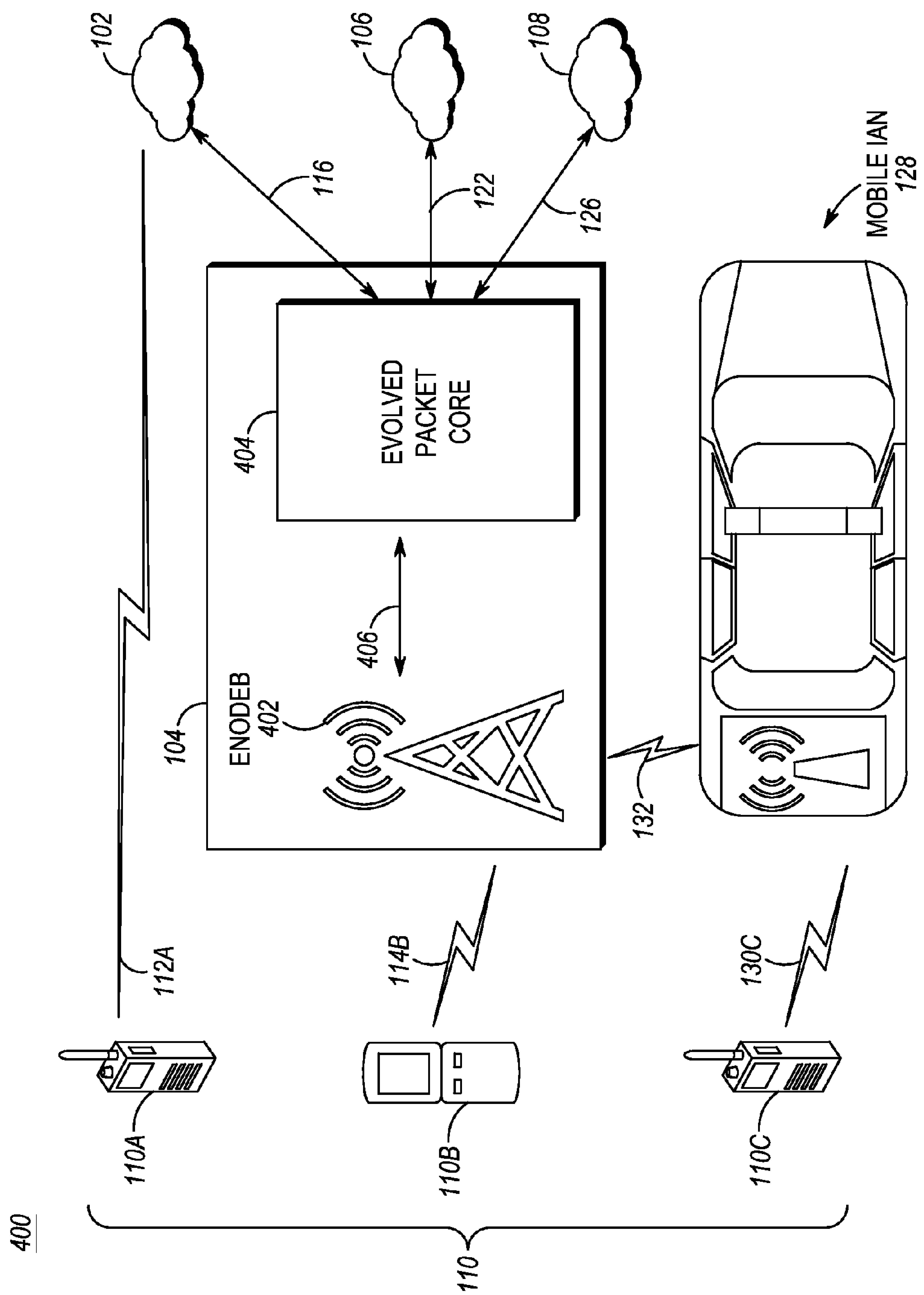

300
WCDs
110
112
COMMERCIAL RANs
102
120
CIRCUIT NETWORK
108
130
116
118
124
114
MOBILE IAN
128
132
PUBLIC-SAFETY RAN
104
126
122
DATA NETWORK
106
304
REMOTE GDB FUNCTION
302

FIG. 3



102
106
108
116
122
126
MOBILE IAN
128
EVOLVED PACKET CORE
404
406
ENODEB
402
104
132
112A
114B
130C
110A
110B
110C
110
400

FIG. 4

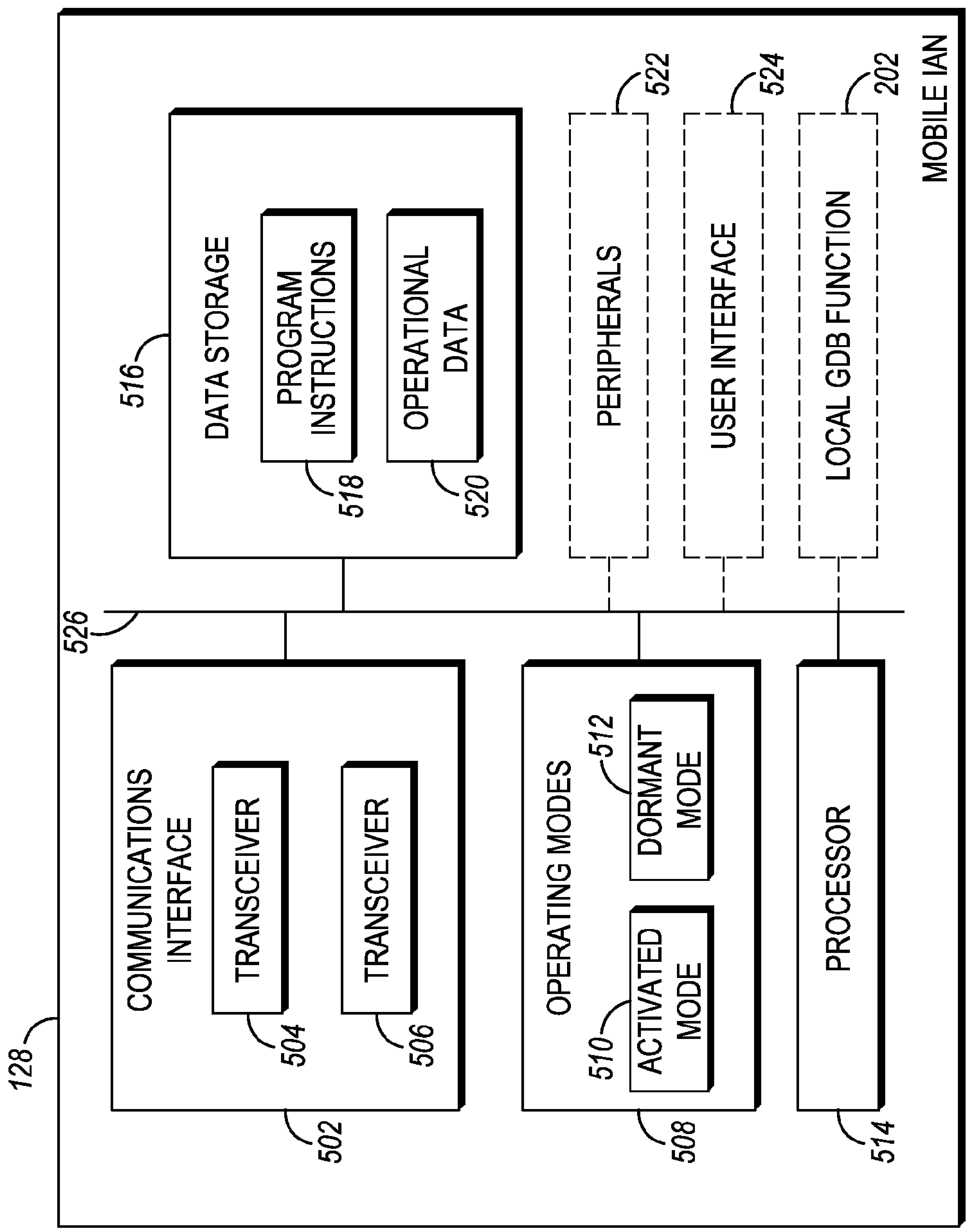

128
MOBILE IAN
COMMUNICATIONS INTERFACE
TRANSCEIVER
504
TRANSCEIVER
506
502
526
DATA STORAGE
516
PROGRAM INSTRUCTIONS
518
OPERATIONAL DATA
520
OPERATING MODES
ACTIVATED MODE
510
DORMANT MODE
512
508
PROCESSOR
514
PERIPHERALS
522
USER INTERFACE
524
LOCAL GDB FUNCTION
202

FIG. 5

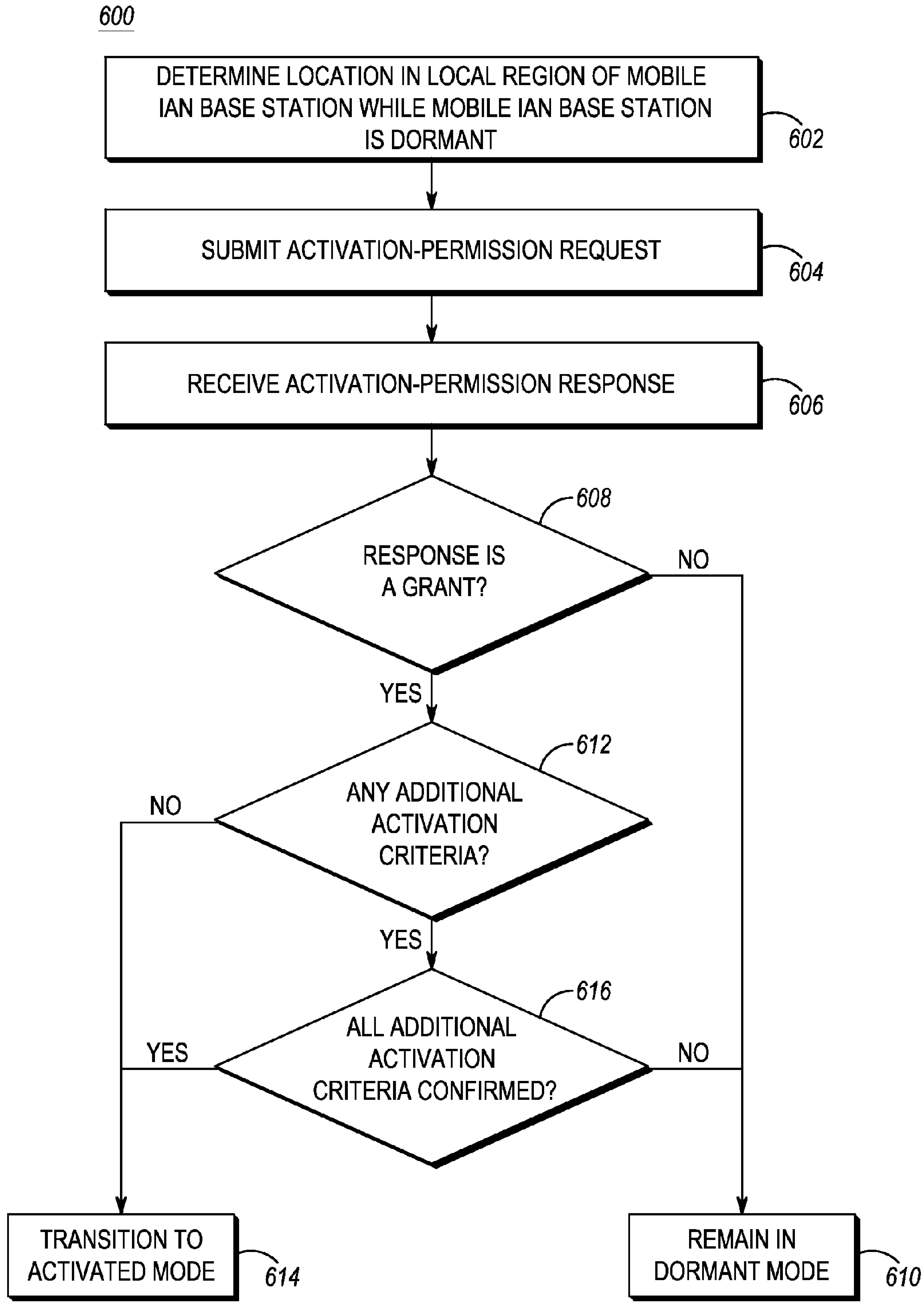

600
DETERMINE LOCATION IN LOCAL REGION OF MOBILE IAN BASE STATION WHILE MOBILE IAN BASE STATION IS DORMANT
602
SUBMIT ACTIVATION-PERMISSION REQUEST
604
RECEIVE ACTIVATION-PERMISSION RESPONSE
606
608
RESPONSE IS A GRANT?
NO
YES
612
ANY ADDITIONAL ACTIVATION CRITERIA?
NO
YES
616
ALL ADDITIONAL ACTIVATION CRITERIA CONFIRMED?
YES
NO
TRANSITION TO ACTIVATED MODE
614
REMAIN IN DORMANT MODE
610

FIG. 6

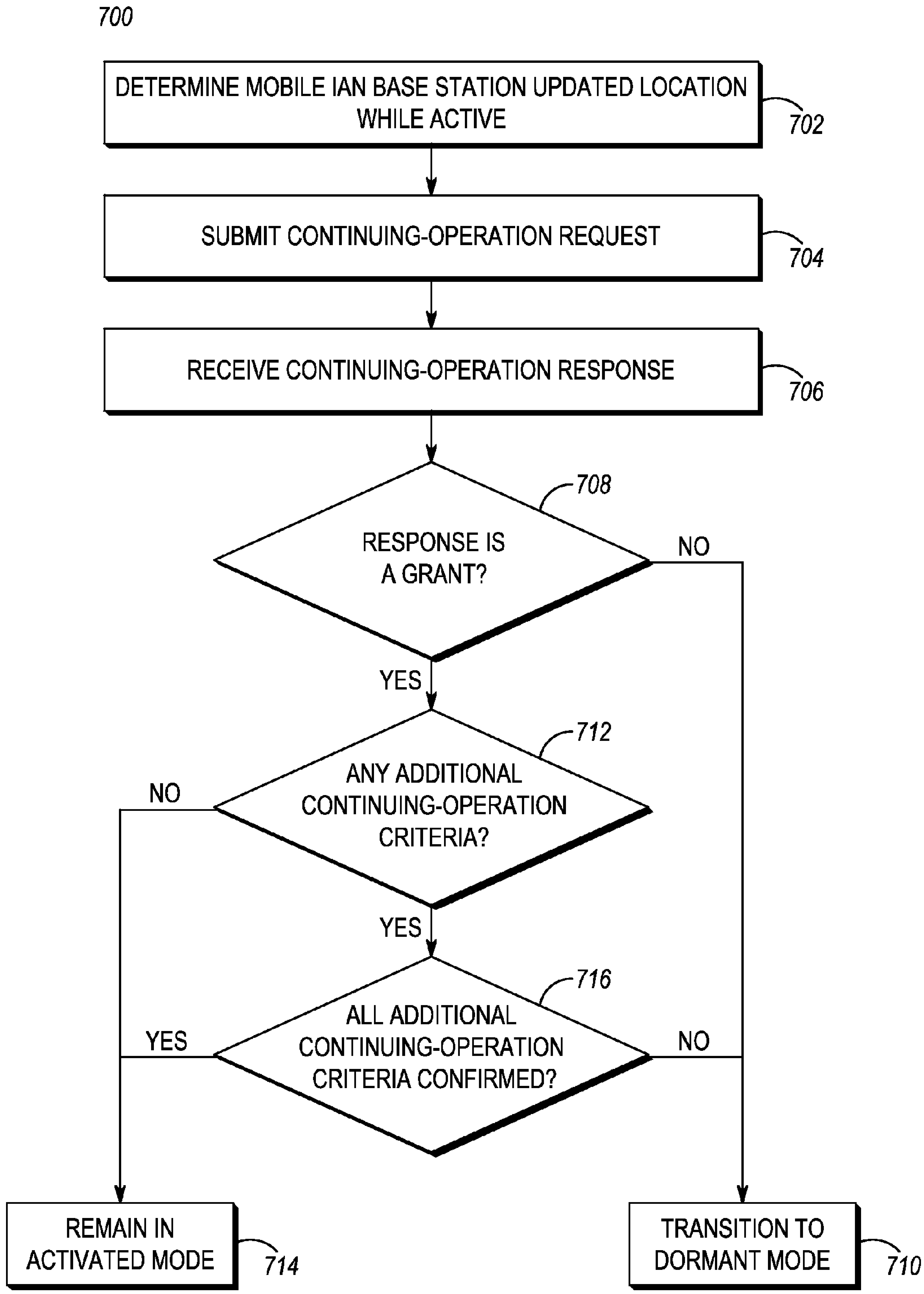

700
DETERMINE MOBILE IAN BASE STATION UPDATED LOCATION WHILE ACTIVE
702
SUBMIT CONTINUING-OPERATION REQUEST
704
RECEIVE CONTINUING-OPERATION RESPONSE
706
708
RESPONSE IS A GRANT?
NO
YES
712
ANY ADDITIONAL CONTINUING-OPERATION CRITERIA?
NO
YES
716
ALL ADDITIONAL CONTINUING-OPERATION CRITERIA CONFIRMED?
YES
NO
REMAIN IN ACTIVATED MODE
714
TRANSITION TO DORMANT MODE
710

FIG. 7

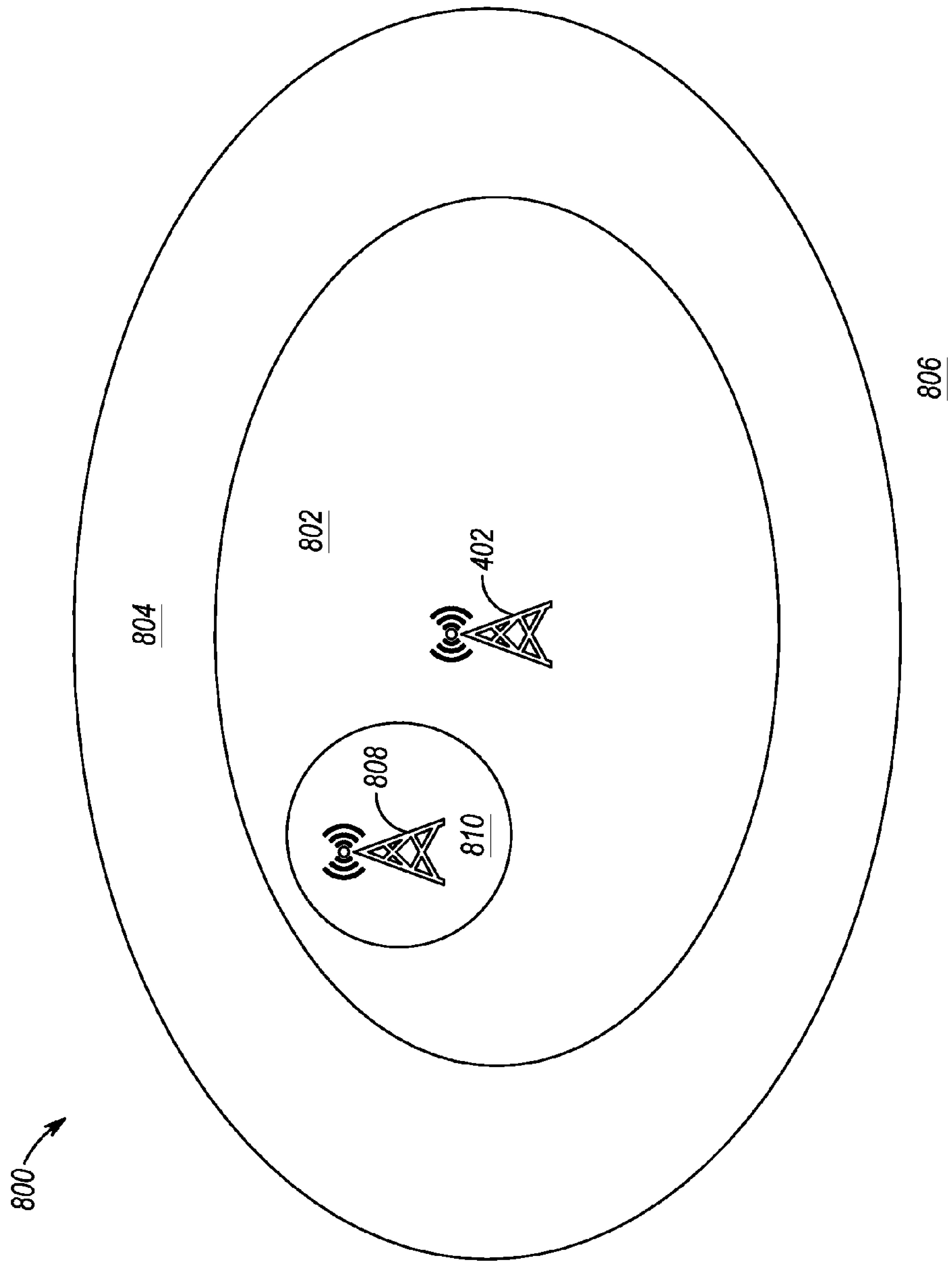


FIG. 8

METHODS AND SYSTEMS FOR AUTOMATED ACTIVATION AND CONFIGURATION OF BROADBAND INCIDENT AREA NETWORKS (IANS)

BACKGROUND OF THE INVENTION

It is important that public-safety responders have an adequate link to communication services (e.g., telephony, data services, and the like) when responding to an incident. However, the reality of the dynamic and mobile nature of the profession is that, in many instances, incidents occur outside of the range or coverage of the established radio access networks (RANs). In other cases, the available RAN signal may not have enough capacity to support the required public-safety mission. To facilitate communication between the responders and offsite utilities, incident area networks (IANs) are often set up using mobile base stations. These mobile base stations establish a link between a given wireless-communication device (WCD) (e.g., a handheld mobile radio) and a given network resource, typically using some standard for over-the-air communication, an example of which is 3GPP's Long Term Evolution (LTE), which is one example protocol for a type of wireless communication known as orthogonal frequency division multiplex (OFDM) communication. In addition to mobile radios, some examples of commonly used WCDs include cell phones, smartphones, dongles, tablets, notebook computers, laptop computers, and the like. And certainly many other examples of WCDs could be listed as well, as known to those having skill in the relevant art.

It is desirable for public-safety responders to be able to communicate with one another as efficiently as possible for at least the reason that the immediacy and efficacy with which public-safety responders can communicate with one another are quite often determinative of a positive outcome in public-safety incidents. For the sake of general efficiency and for optimized allocation of network resources, it is important that mobile base stations be coordinated with existing communication networks. Accordingly, for this reason and others, there is a need for methods and systems for automated activation and configuration of broadband IANs.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views, together with the detailed description below, are incorporated in and form part of the specification, and serve to further illustrate embodiments of concepts that include the claimed invention, and explain various principles and advantages of those embodiments.

FIG. **1** depicts a first example communication system, in accordance with an embodiment.

FIG. **2** depicts a second example communication system, in accordance with an embodiment.

FIG. **3** depicts a third example communication system, in accordance with an embodiment.

FIG. **4** depicts examples of aspects of the communication system of FIG. **1**, in accordance with an embodiment.

FIG. **5** depicts an example mobile IAN base station, in accordance with an embodiment.

FIG. **6** depicts a first example process, in accordance with an embodiment.

FIG. **7** depicts a second example process, in accordance with an embodiment.

FIG. **8** depicts a number of types of regions within which a mobile IAN base station could be activated, in accordance with at least one embodiment.

Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of embodiments of the present invention.

The apparatus and method components have been represented where appropriate by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments of the present invention so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein.

DETAILED DESCRIPTION OF THE INVENTION

Disclosed herein are methods and systems for an automated activation and configuration of broadband (e.g., LTE) IANs. As a general matter, an IAN is a rapidly deployable site (e.g., a mobile LTE base station, perhaps comprising an eNodeB, an enhanced packet core, and/or one or more other related network-entity functions) that can be quickly set up at an incident scene to provide enhanced coverage and/or capacity. As a non-limiting list of example deployments, an IAN can be utilized for coverage extension (e.g., to extend wide area cellular coverage), coverage creation (e.g., where no wide area cellular coverage is available), capacity off-loading and/or improvement (e.g., in areas where wide area coverage exists, but does not have sufficient capacity or throughput for a given situation (e.g., to properly service public-safety personnel at a location of a given public-safety incident)). IANs may utilize other in-band and/or out-of-band networks for backhaul (e.g., to reach the Internet or other servers, a core network, and/or the like). Furthermore, a typical IAN is capable of operating in a standalone fashion, or in conjunction with wide area networks. Moreover, in this disclosure, IANs are referred to equivalently as IAN base stations, mobile IAN base stations, mobile IANs, and the like.

One embodiment takes the form of a process carried out by a mobile IAN base station having an activated mode and a dormant mode. The process includes (i) determining at least one location in a local region of the mobile IAN base station while the mobile IAN base station is in the dormant mode, (ii) submitting to a geo-location-database (GDB) function an activation-permission request that includes at least the determined location for processing by the GDB function, (iii) receiving, from the GDB function, an activation-permission response associated with the submitted activation-permission request, wherein the received activation-permission response is based at least in part on an expected level of wide-area-network (WAN) coverage associated with the determined location, (iv) transitioning the mobile IAN base station to the activated mode in response to confirming each activation criterion in a set of one or more activation criteria, the set of activation criteria including the received activation-permission response being an activation-permission grant, and (v) remaining in the dormant mode in response to failing to confirm at least one activation criterion in the set of activation criteria. The local region generally encompasses the maximum expected IAN coverage area.

Another embodiment takes the form of a system that includes a wireless-communication interface, a processor, and data storage containing instructions executable by the processor for causing the system to carry out at least the functions described in the preceding paragraph.

Moreover, any of the variations and permutations described in the ensuing paragraphs and anywhere else herein can be implemented with respect to any embodiments, including with respect to any method embodiments and with respect to any system embodiments. Furthermore, this flexibility and cross-applicability of embodiments is present in spite of the use of slightly different language (e.g., process, method, steps, functions, set of functions, and the like) to describe and or characterize such embodiments.

In at least one embodiment the GDB function operates locally in the mobile IAN base station. The GDB function is described below.

In at least one embodiment, the GDB function utilizes a local cache of WAN-coverage data derived from a remote GDB function.

In at least one embodiment, the GDB function operates remote from the mobile IAN base station.

In at least one embodiment, the received activation-permission response is an activation-permission grant and the process further includes operating in accordance with the activation-permission grant. In at least one such embodiment, the activation-permission grant instructs the mobile IAN base station to operate at a full transmission power level (based on its operating location and GDB computations); in at least one such embodiment, the activation-permission grant instructs the mobile IAN base station as to permissible operating ranges with respect to one or more operating parameters, the one or more operating parameters including one or more of a transmit power level, a carrier frequency, a channel bandwidth, utilized resource blocks, and a time-frequency allocation. The general concept in specifying utilized resource blocks or a time-frequency allocation is to provide some level of orthogonality between the WAN-system signal and the IAN-system signal. Note that other forms of orthogonality or quasi-orthogonality could also be applied, such as spreading codes, space-time codes, antenna pattern/polarization, orbital angular momentum, and the like.

The GDB function may utilize co-, adjacent, and alternate channel interference protection ratios along with signal propagation modeling to compute a maximum allowed transmission power level for the IAN base station in order to avoid interference with other systems (including the WAN system, which may be operating co-channel). In general, the GDB function will compute the expected desired (e.g., WAN) signal power and the aggregate interference power at a given location to estimate a signal-to-noise-and-interference ratio (SINR), signal-to-noise ratio (SNR), or received signal strength indicator (RSSI) level of the desired signal.

These estimates reflect the expected WAN coverage level at any given operating location (in a local region), and can generally be pre-computed for an entire operating area or greater region. The GDB may also enforce a maximum allowed interference level with the WAN (and possibly other nearby radio systems) to avoid causing excessive interference to those systems at defined operating points or contours (which may limit the maximum allowed IAN power level based on its operating location). Note that RSSI values may include other related measures, like the reference signal received power (RSRP) value utilized in LTE systems. Likewise, related WAN-coverage-level estimates, such as the channel quality indicator (CQI) or block error rate (BLER) may also be predicted in the GDB function. The GDB function should typically take into account antenna heights of both the transmitter and receiver in the computations. WCD antenna height (and/or unit altitude) may also be taken into account in the computations.

In at least one embodiment, the expected level of WAN coverage comprises at least one of an expected WAN SINR, an expected WAN signal strength, an expected WAN loading level, and an expected WAN available-capacity level. That is, some general examples of WAN-performance measures include a predicted WAN SINR, RSSI, RSRP, system loading level, an indication of the available data-throughput capacity (e.g., CQI values), and the like. These performance levels may be related and/or specific to a given WCD or IAN operating location or locations, and may include the expected and/or actual performance levels of WCD or IAN equipment (e.g., sensitivity, selectivity, antenna gain, transmit power level, etc.). In addition, both desired and undesired (e.g., out-of-band) radio signals may be considered in the determination of the expected level of WAN coverage. In general, all of the nearby interfering signals should be modeled and accounted for in the GDB computations (as described below). And certainly other examples of expected WAN coverage or performance could be listed as well.

In at least one embodiment, the process further includes measuring an actual level of WAN coverage and the set of activation criteria further includes the measured actual level of WAN coverage being less than a predetermined WAN-coverage threshold. In at least one such embodiment, the measured actual level of WAN coverage being less than the predetermined WAN-coverage threshold corresponds to one or both of (i) a measured actual WAN SINR being less than a predetermined SINR threshold and (ii) a measured actual WAN signal strength being less than a predetermined signal-strength level. Additionally, as above, other WAN performance measures may be considered, such as the system loading level, available data-throughput capacity at a given location or locations, and the like.

In at least one embodiment, consideration (when determining whether or not to activate a given mobile IAN base station) is given to respective locations of other WAN clients (e.g., heavy and/or light and/or numerous WAN users), and further to location of such one or more users as compared with the IAN location. In instances in which no (or very few) WAN users are operating, activating a mobile IAN base station would not generally tend to compromise WAN capacity. However, in instances in which WAN usage is relatively heavy due to one or more users, the WAN performance in that area could be compromised by activation of an IAN. In those cases, it is generally desirable to coordinate WAN and IAN resource usage (e.g., of time-frequency resources) through the use of resource sharing techniques, such as through the use of extended Inter-Cell Interference Coordination (eICIC) techniques (in LTE systems). Almost Blank Subframes (ABS) may also be utilized (in LTE systems) to reduce interference between WAN and IAN systems. Activation of an IAN in such instances may result in WAN capacity being freed up for other users if such heavy WAN users can no longer be supported, and could instead or in addition result in one or more heavy WAN users being handed off to the IAN after it has been activated. And certainly numerous other example scenarios could be described as well, as will be evident to those having skill in the relevant art.

In at least one embodiment, the set of activation criteria further includes the mobile IAN base station having received a user instruction to transition to the activated mode. In at least one such embodiment, the mobile IAN base station received the user instruction via a user interface of the mobile IAN base station; in at least one such embodiment, the mobile

IAN base station received the user instruction from a user authorized to issue such an instruction.

In at least one embodiment, the set of activation criteria further includes the mobile IAN base station having received an activation instruction from a WAN. In such cases, the WAN may at least partially determine that it does not have the required amount of data-throughput capacity or signal coverage to meet the requested capacity or coverage for an incident scene. Note that incident scenes do not necessarily have to be large events, and could even be routine (e.g., daily) events that are better served by local radio coverage.

In at least one embodiment, the set of activation criteria further includes the mobile IAN base station having received an activation instruction from a mobile radio (or other WCD). In at least one such embodiment, the mobile IAN base station received the activation instruction from the mobile radio over a land-mobile-radio (LMR) channel. LMR radio channels are often narrow-band in nature (e.g., 25 kilohertz (kHz) channel bandwidth), and can often tolerate higher path losses (which typically translates into a longer communication range). This characteristic may make an LMR radio channel a useful signaling mechanism for activation of an IAN base station when there is limited or no coverage from a broadband WAN radio system. This applies to cases that use LMR to signal directly to the IAN base station (e.g., via direct-mode communications), as well as to cases that utilize LMR infrastructure (e.g., base stations or repeaters) to consequently signal to the IAN base station. In any case, a given mobile radio may determine that it has a poor connection quality, received signal level, throughput, SINR, SNR, and/or the like, and may responsively request that an IAN base station be activated.

In other embodiments, the IAN base station may receive an activation instruction based on user context. For example, if a given mobile IAN base station is located in a poor WAN-coverage area (e.g., near a building with known poor WAN coverage and/or low estimated SINR values), the IAN may automatically be activated once a user leaves an associated vehicle. This can be accomplished by any variety of technologies, including using short-range communications (e.g., Bluetooth or Wi-Fi) to detect when at least one of the users (e.g., a police officer) leaves the proximity of the car containing the IAN base station. In such a case, the IAN may responsively activate once the user is outside of some predefined range (or inside of a building), thus providing improved local coverage to the WCD user(s). And certainly numerous other example scenarios could be described here as well.

In at least one embodiment, the process further includes (i) receiving expected-WAN-coverage data (e.g., predictions of SINR, SNR, RSSI, and/or the like for one or more operating locations) from the GDB function, (ii) measuring an actual level of WAN coverage (e.g., SINR, SNR, RSSI, capacity values, and/or the like for, e.g., a representative user, a worst case of a survey of multiple users, and/or the like), and (iii) adapting the expected-WAN-coverage data with the measured actual level. Filtering of the measured values (using, e.g., moving average or finite impulse response filters) across time and users is also recommended to reduce spurious variations. In this case, the predictions of SINR, SNR, or RSSI values may be updated using a wide variety of adaption algorithms known in the art (e.g., least mean square, recursive least square, etc.) to adapt the GDB predictions to the measured actual (e.g., mean and standard deviation) values over time. There are many possible variants to the method, depending on the desired measurement intervals and adaption rates, among other considerations known to those of skill in the relevant art. Other related measures, such as RSRP values, CQI values, and/or the like may also be measured and compared to GDB-predicted values to update the values to improve accuracy. In general, predicted WAN coverage may refer to any number of performance measures, including RSSI, RSRP, SINR, SNR, RSSI, CQI, BLER, retransmission attempt values, and/or one or more other such measures.

Actual characteristics of the receiver system utilized to measure these values (e.g., antenna gains, polarization, measurement variance, etc.) may also be taken into account in updating the estimated values. In general, any value that helps to more accurately reflect the WAN coverage and/or connection quality (e.g., throughput level, error rate, retransmission rate, and/or the like) can be measured and compared to GDB predictions to update the prediction results.

In at least one embodiment, the process further includes (i) determining an updated capacity need and/or location of the mobile IAN base station while the mobile IAN base station is in the activated mode, (ii) submitting, to the GDB function, a continuing-operation request that includes the determined updated location for processing by the GDB function, (iii) receiving, from the GDB function, a continuing-operation response associated with the submitted continuing-operation request, wherein the received continuing-operation response is based at least in part on an expected level of WAN coverage associated with the determined updated capacity need and/or location, (iv) remaining in the activated mode in response to confirming each continuing-operation criterion in a set of one or more continuing-operation criteria, the set of continuing-operation criteria comprising the received continuing-operation response being a continuing-operation grant; and (v) transitioning the mobile IAN base station to the dormant mode in response to failing to confirm at least one continuing-operation criterion in the set of continuing-operation criteria.

In at least one embodiment, the GDB function formulates the activation-permission response based at least in part on information regarding one or more of a transmitter location, a transmitter power level, an antenna height, an antenna gain, an antenna polarization, an antenna pattern, and terrain data. The transmitter's effective isotropic radiated power (EIRP) level can be computed from these values in various directions by the GDB function. This is typically modeled for both desired and undesired WAN base station transmitters and IAN mobile transmitters, and can be performed to estimate both the uplink and downlink desired and aggregate undesired signal strengths. Thus, at any given location, the GDB function is able to compute a set of expected desired and undesired signal strengths, for potentially all of the transmitters (and receivers) in the system. This allows both a WAN coverage level to be estimated, and IAN transmitter operating parameters to be computed to avoid causing undue interference to WAN or other systems operating in the area. The use of eICIC or ABS interference reduction techniques (for LTE systems) may also be accounted for in the GDB computations.

In terms of computing the maximum allowable interference to WAN systems, the SINR or desired to undesired (D/U) signal ratio is typically modeled for the WAN system (transmitters and receivers), again based on transmitter and receiver locations. For example, in TV white space, incumbent transmitter signal strength is modeled in one-degree (radial) steps over varying propagation distances, taking into account the transmitter power level output (TPO) and antenna gain in each direction. Furthermore, antenna height above average terrain (HAAT) or above ground level (AGL) could be taken into account in the various GDB function predictions, as well as terrain data in signal-propagation modeling. One example of a signal-propagation model that takes into account terrain data is a Longley-Rice propagation model.

The extended HATA model is an example of a model that takes into account coarse terrain features and/or classifications (e.g., large urban, suburban, etc.). The receiver interference protection ratios (e.g., on co-, adjacent, and alternate channels) can also be taken into account when computing a maximum permissible IAN transmit power level to avoid causing harmful interference to other WAN systems (whether they be public-safety-related or commercial cellular systems).

Before proceeding with this detailed description, it is noted that the entities, connections, arrangements, and the like that are depicted in—and described in connection with—the various figures are presented by way of example and not by way of limitation. As such, any and all statements or other indications as to what a particular figure "depicts," what a particular element or entity in a particular figure "is" or "has," and any and all similar statements—that may in isolation and out of context be read as absolute and therefore limiting—can only properly be read as being constructively preceded by a clause such as "In at least one embodiment, . . . " And it is for reasons akin to brevity and clarity of presentation that this implied leading clause is not repeated ad nauseum in this detailed description.

It is also noted that the terms "mobile IAN base station" and "mobile IAN" are used interchangeably in the present description and figures.

FIG. **1** depicts an example communication system, in accordance with an embodiment. In particular, FIG. **1** depicts an example communication system **100** that includes one or more commercial RANs **102**, a public-safety RAN **104**, a data network **106**, a circuit network **108**, WCDs **110**, communication links **112**-**126**, a mobile IAN **128** and communication links **130** and **132** to the mobile IAN.

An example public-safety RAN **104** is discussed below in connection with FIG. **4**, though in general, each RAN **102** and the public-safety RAN **104** includes typical RAN elements such as base stations, base station controllers (BSCs), routers, switches, and the like, arranged, connected, and programmed to provide wireless service to user equipment (e.g., WCDs **110**) in a manner known to those of skill in the relevant art.

The public-safety RAN **104** may include one or more packet-switched networks and/or one or more circuit-switched networks, and in general functions to provide one or more public-safety agencies with any necessary computing and communication needs. Thus, the public-safety RAN **104** may include a dispatch center communicatively connected with the data network **106** and also with the circuit network **108**, for retrieving and transmitting any necessary public-safety-related data and communications. The public-safety RAN **104** may also include any necessary computing, data-storage, and data-presentation resources utilized by public-safety personnel in carrying out their public-safety functions. Moreover, the public-safety RAN **104** may include one or more network access servers (NASs), gateways, and the like for bridging communications to one or more other entities and/or networks, such as the commercial RANs **102**, the data network **106**, and the circuit network **108**, as representative examples.

The data network **106** may be, include, or be a part of the global network of networks typically referred to as the Internet. The data network **106** may be a packet-switched network, and entities (i.e., servers, routers, computers, and the like) that communicate over the data network **106** may be identified by a network address such as an Internet Protocol (IP) address. Moreover, the data network **106** may include one or more NASs, gateways, and the like for bridging communications to one or more other entities and/or networks, such as the commercial RANs **102**, the public-safety RAN **104**, and the circuit network **108**, as representative examples.

The circuit network **108** may be, include, or be a part of the circuit-switched telephone network commonly referred to as the public switched telephone network (PSTN), and in general functions to provide circuit-switched communications to various communication entities as is known in the relevant art. Moreover, the circuit network **108** may include one or more NASs, gateways, and the like for bridging communications to one or more other entities and/or networks, such as the commercial RANs **102**, the public-safety RAN **104**, and the data network **106**, as representative examples.

The mobile IAN **128** may comprise a mobile eNodeB (eNB) connected to a public-safety vehicle to transport the mobile eNB to different locations. The public-safety vehicle in conjunction with the mobile eNB can be used to establish an IAN, which in at least one embodiment provides local WCDs **110** with respective wireless-communication links to (or as part of) the public-safety RAN **104**. In this example, the mobile IAN **128** can be positioned and repositioned where needed by driving the public-safety vehicle to various incident locations. If an incident occurs in a place where there is no wireless service, the mobile IAN **128** can be transported to that area to facilitate its accompanying mobile eNB being used by nearby WCDs **110**. Certainly other possible uses and deployments of the mobile IAN **128** could be listed here. For example, a mobile IAN or eNB could be set up in a more permanent fashion to provide service over an area.

The depicted example communication system **100** includes communication links **112**-**126** and **130**-**132**, any one or more of which could include one or more wireless-communication links and/or one or more wired-communication links. In FIG. **1**, the communication links **112**, **114**, **130**, and **132** are depicted with respective lightning-bolt graphics; while this graphic typically denotes wireless communication, and does in this example as well, this is not to the exclusion of one or more of the other communication links **116**-**126** being or at least including wireless-communication links as well.

The WCDs **110** may be any suitable computing and communication devices configured to engage in wireless communication with the RANs **102** over the air interface **112**, the public-safety RAN **104** over the air interface **114**, and/or the mobile IAN **128** over the air interface **130**, as is known to those in the art. Some example WCDs **110** are discussed below in connection with the various figures. Example WCDs **110** include mobile radios, portable radios, mobile phones, smart phones, tablet computers, laptop computers, personal digital assistants, connected wearable accessories, and the like.

As can be seen in FIG. **1**, the communication link **112** (as mentioned above) connects the commercial RANs **102** and the WCDs **110**, the communication link **114** (as mentioned above) connects the public-safety RAN **104** and the WCDs **110**, the communication link **116** connects the commercial RANs **102** and the public-safety RAN **104**, the communication link **118** connects the commercial RANs **102** and the data network **106**, the communication link **120** connects the commercial RANs **102** and the circuit network **108**, the communication link **122** connects the public-safety RAN **104** and the data network **106**, the communication link **124** connects the data network **106** and the circuit network **108**, the communication link **126** connects the public-safety RAN **104** and the circuit network **108**, the communication link **130** connects the WCDs **110** and the mobile IAN **128**, and the communication link **132** connects the mobile IAN **128** to the public-safety RAN **104**. This arrangement is provided purely by way of example, as other arrangements could be implemented by those of skill in the relevant art in various different contexts.

FIG. **2** depicts an example communication system, in accordance with an embodiment. In particular, FIG. **2** depicts an example communication system **200**. The example communication system **200** includes the components of the example communication system **100**, a local geo-location database (GDB) function **202**, and a communication link **204**. A GDB function utilizes the location of the mobile IAN to predict poor reception areas, predict WAN coverage/capacity, predict interference, and/or perform one or more additional functions, perhaps including one or more of the additional functions described herein.

In various embodiments, the GDB function operates locally with the mobile IAN, utilizes a local cache of WAN-coverage data derived from a remote GDB function, or operates remote from the mobile IAN. The local cache of WAN coverage data may be represented by any of the measures mentioned herein (e.g., predicted SINR, SNR, RSSI, RSRP, CQI, BLER values), and/or it may be stored as low-resolution data (e.g., one-bit values) per location to indicate whether those values are above or below a threshold. The WAN-coverage data may be further compressed by any number of algorithms known in the art (e.g., run-length encoding, Huffman encoding, variable spatial resolution encoding, discrete cosine transforms (DCT) encoded, etc.) to reduce the required cache storage size.

It is noted that the functions described by one version of the GDB function (e.g. a local GDB function) may also be executed by another version (e.g. a remote GDB function) of the GDB function, as known by those with skill in the art. The remote GDB function may comprise a server on the infrastructure side of the network. In the example communication system **200**, the GDB function is the local GDB function **202**. The local GDB function is connected by the communication link **204**, which could take the form of a data cable, a wireless connection, or could instead represent integration of the mobile IAN **128** and the local GDB function **202** in a single device. Wireless communications to the remote GDB function could occur over any of a variety of connections, including a wide area cellular network (either in-band or out-of-band), a local area network (e.g., Wi-Fi), or via a narrowband LMR data channel (as described above), as examples.

FIG. **3** depicts an example communication system, in accordance with an embodiment. In particular, FIG. **3** depicts an example communication system **300**. The example communication system **300** includes the components of the example communication system **100**, a remote GDB function **302**, and a communication link **304**. The remote GDB function **302** is capable of carrying out the functions of any GDB function described in this disclosure. The communication link **304** provides a communication path between the remote GDB function **302** and the public-safety RAN **104**. The communication link **304** could take the form of or include a data cable or a wireless communication link, and the remote GDB function could be embodied as a standalone server or integrated as a functional component of another system, among other possible implementations.

FIG. **4** depicts examples of aspects of the communication system of FIG. **1**, in accordance with an embodiment. FIG. **4** depicts the communication system **400**, which is a detailed view of portions of the example communication system **100** of FIG. **1**. The example communication system **400** shows more detail regarding some example WCDs **110**, an example public-safety RAN **104**, and a mobile IAN **128**. And it is noted that a similar figure could be depicted with an example commercial RAN **102** instead of the example public-safety RAN **104**.

In particular, FIG. **4** depicts the public-safety RAN **104** as including an eNB (labeled "eNodeB" in FIG. **4**) **402**, which communicates directly or indirectly with an evolved packet core (EPC) **404** over a communication link **406**. As is the case with each of the links mentioned above, and as is the case with any of the links mentioned anywhere else in this disclosure, the communication link **406** may be or include one or more wireless-communication links and/or one or more wired-communication links, as deemed suitable by those of skill in the art in a given context.

In at least one embodiment, the eNB **402** includes the hardware and software (and/or firmware) necessary for the eNB **402** to function as an eNodeB, a NodeB, a base station, a base transceiver station (BTS), a WiFi access point, and/or the like, as known to those having skill in the relevant art. In some instances, the eNB **402** in the example RAN **104** also includes functionality typically associated in the art with entities that are often referred to by terms such as BSCs, radio network controllers (RNCs), and the like. Also, while one eNB **402** is depicted by way of example in FIG. **4**, any suitable number of eNBs could be deployed as deemed suitable by those of skill in the relevant art. As mentioned above, the mobile IAN **128** may include both eNB and EPC functionality. It may also include a Home Subscriber Server (HSS), which handles security and authentication functions. Typical eNB functions that are implemented may include physical (PHY) layer functions (e.g., modulation/demodulation, coding, etc.), media access control (MAC), radio link control (RLC), radio resource control (RRC), and related functions, such as the packet data convergence protocol (PDCP) functions. Typical EPC functions that are implemented may include a mobility management entity (MME), a serving gateway (SGW), a packet gateway (PGW), related functions (e.g., all required Non-Access Stratum (NAS) signaling) as well as related application services, such as group/dispatch voice communications, push-to-talk (PTT) services, or video services. These functions combined may allow completely isolated IAN operation, for operation where other communications means may not be available. This allows typical WCD user equipment (e.g., broadband smartphones or subscriber radios) to be utilized when outside of typical cellular WAN coverage. In other cases, even when the IAN is not isolated from other networks, it may be advantageous to keep much of the data traffic local to the incident scene, thereby offloading data traffic from the other (e.g., WAN) networks.

In general, the eNB **402** is an entity that, on one side (i.e., the wireless-network side (interface)), engages in wireless communications over the air interface **114** (or **114**B in FIG. **4**) with one or more WCDs **110** according to a protocol such as LTE or the like and, on the other side (i.e., the "backhaul" side), engages in communications with the EPC **404** via the communication link **406**, to facilitate communications between various WCDs **110** and networks such as the networks **102**, **106**, and **108**, as examples.

The EPC **404** may include one or more network entities such as one or more MMEs, one or more SGWs, one or more packet data network (PDN) gateways (PGWs), one or more evolved packet data gateways (ePDGs), one or more HSSs, one or more access network discovery and selection functions (ANDSFs), and/or one or more other entities deemed suitable for a given implementation by those of skill in the relevant art. Moreover, these entities may be configured and interconnected in a manner known to those of skill in the relevant art to provide wireless service to the WCDs **110** via the eNB **402**, and to bridge such wireless service with various transport networks. In general, a commercial RAN and a public-safely RAN may each provide wireless service according to a protocol such as LTE, WiFi, APCO P25, TETRA, digital mobile radio (DMR) and/or the like. These examples are provided for illustration and not by way of limitation; moreover, those of skill in the art are aware of variations among different protocols and among different implementations of a given protocol, and of similarities across different protocols.

The WCDs are generally able to operate over any of the available RANs. The example communication system **400** includes three example wireless-communication devices **110**: the wireless-communication devices **110**A, **110**B, and **110**C, and the wireless communication links **112**A, **114**B, and **130**C. The WCD **110**A is connected to the commercial RAN **102** via the link **112**A, the WCD **110**B is connected to the public-safety RAN **104** via the link **114**B, and the WCD **110**C is connected to the mobile IAN **128** via the link **130**C. The WCDs may be configured to operate over specific networks (via a SIM card and HSS provisioning).

It is noted that the present disclosure depicts systems and methods according to which a mobile IAN base station interoperates with a public-safety RAN. However, one with skill in the relevant art can apply the systems and methods of this application with the mobile IAN base station operating with any suitable type of RAN (e.g., a commercial RAN). Additionally, the mobile IAN base station could be a commercial mobile base station, and need not be dedicated to public-safety service. One of the primary goals of the IAN is to provide enhanced coverage and capacity to the WAN. WANs often have coverage holes, interference zones, and/or fringe reception areas that are difficult and/or expensive to address utilizing WAN base station equipment. The mobile IAN provides significant coverage enhancement to the WAN. Having reliable communications coverage over a very wide area is important to public-safety users.

FIG. **5** depicts an example mobile IAN base station, in accordance with an embodiment. In particular, FIG. **5** depicts the components of the example mobile IAN **128**. In the depicted embodiment, the mobile IAN **128** includes a communications interface **502**, a first transceiver **504**, a second transceiver **506**, operating-mode parameters **508**, activated-mode parameters **510**, dormant-mode parameters **512**, a processor **514**, data storage **516**, program instructions **518**, operational data **520**, optional peripherals **522**, an optional user interface **524**, a communication bus **526**, and an optional local GDB function **202**.

The communication interface **502** includes the first transceiver **504** and the second transceiver **506**. Each of the first transceiver **504** and the second transceiver **506** can be configured (e.g., tuned) to receive and transmit on one of a set of channels. The communication interface **502** may be configured to be operable for communication according to one or more wireless-communication protocols, some examples of which include LMR, LTE, APCO P25, ETSI DMR, TETRA, WiFi, Bluetooth, and the like. The communication interface **502** may also include one or more wired-communication interfaces (for communication according to, e.g., Ethernet, USB, and/or one or more other protocols). As such the communication interface **502** may include any necessary hardware (e.g., chipsets, antennas, Ethernet interfaces, etc.), any necessary firmware, and any necessary software for conducting one or more forms of communication with one or more other entities as described herein.

The operating-mode parameters **508** includes parameters for the activated mode (i.e., the activated-mode parameters **510**) and the dormant mode (i.e., the dormant-mode parameters **512**). The operating-mode parameters **508** control the functions and operations of the mobile IAN in the activated mode and the dormant mode. Some example parameters include transmit power level, carrier frequency, channel bandwidth, utilized resource blocks, and time-frequency allocation. In at least one embodiment, the operating-mode parameters **508** are configurable (e.g., user-configurable and/or network-administrator-configurable).

The processor **514** may include one or more processors of any type deemed suitable by those of skill in the relevant art, some examples including a general-purpose microprocessor and a dedicated digital signal processor (DSP).

The data storage **516** may take the form of any non-transitory computer-readable medium or combination of such media, some examples including flash memory, read-only memory (ROM), and random-access memory (RAM) to name but a few, as any one or more types of non-transitory data-storage technology deemed suitable by those of skill in the relevant art could be used. As depicted in FIG. **5**, the data storage **516** contains program instructions **518** executable by the processor **514** for carrying out various functions described herein, and further is depicted as containing operational data **520**, which may include any one or more data values stored by and/or accessed by the example mobile base station **128** in carrying out one or more of the functions described herein.

The peripherals **522** may include any mobile base station accessory, component, or the like that is accessible to and useable by the mobile IAN base station **128** during operation. Example peripherals **522** include a GPS receiver, an altimeter, or similar location-determination peripherals. The peripherals **522** are optional as some embodiments do not require additional peripherals to determine the mobile IAN location. In some such embodiments without the optional peripherals, the location of the mobile IAN is determined by a user input, by detecting nearby wireless communication networks, by receiving a message from one or more network entities (e.g., utilizing time difference of arrival or angle of arrival techniques), and/or by any other method known by those with skill in the relevant art.

The user interface **524** may include one or more input devices (a.k.a. components and the like) and/or one or more output devices (a.k.a. components and the like). With respect to input devices, the user interface **524** may include one or more touchscreens, buttons, switches, microphones, and the like. With respect to output devices, the user interface **524** may include one or more displays, speakers, light emitting diodes (LEDs), and the like. Moreover, one or more components (e.g., an interactive touchscreen and display) of the user interface **524** could provide both user-input and user-output functionality. Other user interface components (e.g., a PTT button) could also be present, as known to those of skill in the art. The user interface **524** may also be remote to the mobile IAN, and can include a user interface on a wireless communication device. In some embodiments, the mobile IAN **128** does not include a user interface.

The local GDB function **202** carries out the functions described in more detail in conjunction with FIGS. **5-6**. In some embodiments, the mobile IAN **128** does not include a local GDB function **202**. In some such embodiments, the mobile IAN **128** communicates via the communications interface **502** with a remote GDB function.

The various components of the mobile radio **128** are all communicatively coupled with one another via a communication bus **526** (or other suitable communication connection, network, or the like).

FIG. **6** depicts a first example process, in accordance with an embodiment. In particular, FIG. **6** depicts the example process **600**. The example mobile IAN **128** of FIG. **5** can be used to execute the steps of the example process **600**.

In step **602**, at least one location in a local region of the mobile IAN is determined while in the dormant mode. By way of example, a mobile IAN peripheral **522** (e.g., a GPS receiver) can be used to determine the mobile IAN location, or the potential operating locations of WCDs in the local region that could utilize the IAN. Hence, the locations of areas nearby the IAN (e.g., nearby buildings, etc.) may also be submitted to the GDB function to determine whether any nearby areas (where a WCD user may operate) would have poor WAN coverage or throughput. This may assist a first responder in completing their task in the local area, where additional coverage or capacity may be needed.

In step **604**, the mobile IAN submits to the GDB function an activation-permission request that includes at least the determined location for processing by the GDB function. In some embodiments, the mobile IAN **128** submits the request to a local GDB function (e.g., local GDB function **202**), a local GDB function that utilizes a local cache of WAN coverage data derived from a remote GDB function, or a remote GDB function (e.g., remote GDB function **302**).

In step **606**, the mobile IAN receives, from the GDB function, an activation-permission response associated with the submitted activation-permission request. The received activation-permission response is based at least in part on an expected level of WAN coverage associated with the determined location and the communication/capacity need.

At the decision box **608**, the mobile IAN determines whether the activation-permission response is an activation-permission grant. If the activation-permission response is not an activation-permission grant, the mobile IAN (at **610**) remains in the dormant mode (e.g., operates in accordance with the dormant-mode parameters **512**).

If, at **608**, the activation-permission response is an activation-permission grant, the mobile IAN determines (at **612**) whether there are additional activation criteria. If there are not any other activation criteria, the mobile IAN transitions (at **614**) to the activated mode (e.g., operates in accordance with the activated-mode parameters **510**).

If there are one or more additional activation criteria, the mobile IAN then determines (at **616**) whether all such additional activation criteria are confirmed. Additional activation criteria may include user input, user proximity, or user signaling (e.g., as described above). If all such additional activation criteria are confirmed, the mobile IAN transitions (at **614**) to the activated mode; otherwise, the mobile IAN (at **610**) remains in the dormant mode.

In some embodiments wherein the received activation-permission response is an activation grant, the process further includes operating in accordance with the activation-permission grant. In at least one embodiment, operating in accordance with the activation-permission grant includes configuring the activated-mode parameters **510**. In some embodiments, the activation-permission grant instructs the mobile IAN to operate at a full transmission power level; in some embodiments, the activation-permission grant instructs the mobile IAN as to permissible operating ranges with respect to one or more operating parameters. The one or more operating parameters may include one or more of transmit power level, carrier frequency, channel bandwidth, utilized resource blocks, and time-frequency allocation.

In some embodiments, the expected level of WAN coverage comprises at least one of an expected WAN SINR, an expected WAN signal strength, an expected WAN loading level, or an expected WAN available capacity. The GDB function utilizes the expected level of WAN coverage to determine optimal mobile IAN operating parameters. The optimal mobile IAN operating parameters may take into consideration interference with nearby WAN systems, coordination with nearby WAN systems (e.g., utilizing resource sharing), and the ability to add useful capacity to the local incident scene, among other possibilities. In some such embodiments, the activation-permission response is an activation-permission grant when either one or both of the expected WAN SINR and WAN signal strength are less than a first and a second predetermined threshold, respectively. In one example, a first threshold, associated with the expected WAN SINR, is set at or near 6 dB, and the second threshold, associated with the WAN signal strength, is set at or near −90 dBm. Either or both of the first and second thresholds could be programmable or configurable (either locally by the user and/or remotely by the network) in practice. Actual values implemented in practice may depend on the desired throughput levels and/or the interference/noise floors present in the system (which may vary based on operating time and/or implementation requirements, objectives, and/or the like).

In some embodiments, the process further includes measuring an actual level of WAN coverage, and the set of activation criteria further includes the measured actual level of WAN coverage being less than a predetermined WAN-coverage threshold. The predetermined WAN-coverage threshold may be determined by the GDB function to optimize the mobile IAN's performance. In some such embodiments, the measured actual level of WAN coverage being less than the predetermined WAN-coverage threshold corresponds to one or both of (i) a measured actual WAN SINR being less than a predetermined SINR threshold and (ii) a measured actual WAN signal strength being less than a predetermined signal-strength level. And certainly other possible example implementations could be listed here, as described above.

In some embodiments, the set of activation criteria further includes the mobile IAN base station having received a user instruction to transition to the activated mode. Using the example mobile IAN **128** of FIG. **5**, the user instruction to transition to the activated mode may be received via the user interface **524**.

In some embodiments wherein the set of activation criteria further includes the mobile IAN base station having received a user instruction to transition to the activated mode, the received user instruction is from a user authorized to issue such an instruction. The authorized user may be an incident commander, a public-safety official, or any other user with appropriate authorization. The mobile IAN may include authentication devices and methods to ensure that users have appropriate authorization. The authentication devices and methods may include password protection, biometric verification, or any other device(s) and/or method(s) known by those with skill in the relevant art.

In some embodiments, the set of activation criteria further includes the mobile IAN having received an activation instruction from a mobile radio. The activation instruction from the mobile radio may include a manual activation instruction (such as a user activating the mobile IAN from the mobile radio) or an automatic activation instruction (such as the mobile radio automatically sending an activation instruction responsive to a public safety officer leaving a public safety vehicle or a police officer withdrawing a firearm from a holster). The mobile radio may be any of the WCDs **110** described herein. In such embodiments, the received activation instruction from a mobile radio may be received over an LMR channel. The GDB function may record such locations (e.g., locations nearby those to users in a building that have poor coverage) for future reference, to enable potential IAN operation. In general, the term WAN coverage may refer to any number of measures, including RSSI, RSRP, SINR, SNR, RSSI, CQI, BLER, retransmission attempt values, and/or one or more other such measures.

In some embodiments, the process further includes (i) receiving expected-WAN-coverage data from the GDB function, (ii) measuring an actual level of WAN coverage, and (iii) adapting the expected-WAN-coverage data with the measured actual level of the WAN coverage. In such embodiments, adapting the expected-WAN-coverage data may include overwriting expected-WAN-coverage data entirely, adapting the expected-WAN-coverage data partially (e.g., using a weighted average or adaptive filter), or by any other method of updating the expected-WAN-coverage data of a GDB function as known by those with skill in the relevant art.

In some embodiments, the GDB function formulates the activation-permission response based at least in part on the information regarding one or more of a transmitter location, a radiated power level, an antenna height, an antenna gain, an antenna polarization, an antenna pattern, terrain data, and any other piece of relevant information known by those with skill in the relevant art. Such information may pertain to one or more WAN transmitters, one or more IAN transmitters, and/or one or more transmitters of any other type.

FIG. **7** depicts a second example process, in accordance with an embodiment. In particular, FIG. **7** depicts an example process **700**. The example mobile IAN **128** of FIG. **5** can be used to execute the steps of the example process **700**.

In step **702**, the location of the mobile IAN is determined while in the activated mode. By way of example, a mobile IAN peripheral **522** (e.g., a GPS receiver) can be used to determine the mobile IAN location.

In step **704**, the mobile IAN submits to the GDB function a continuing-operation request that includes at least the determined location for processing by the GDB function. In some embodiments, the mobile IAN **128** submits the request to a local GDB function (e.g., local GDB function **202**), a local GDB function that utilizes a local cache of WAN coverage data derived from a remote GDB function, or a remote GDB function (e.g., remote GDB function **302**).

In step **706**, the mobile IAN receives, from the GDB function, a continuing-operation response associated with the submitted continuing-operation request. The received continuing-operation response is based at least in part on an expected level of WAN coverage and communications need associated with the determined location.

At the decision box **708**, the mobile IAN determines whether the continuing-operation response is a continuing-activation grant. If the continuing-operation response is not a continuing-operation grant (step **710**), the mobile IAN transitions to the dormant mode (e.g., operates in accordance with the dormant-mode parameters **512**).

If the continuing-operation response is a continuing-operation grant (step **712**), the mobile IAN determines whether there are additional continuing-operation criteria. If there are no other continuing-operation criteria (step **714**), the mobile IAN remains in the activated mode (e.g., operates in accordance with the activated-mode parameters **510**).

If there are additional continuing-operation criteria, the mobile IAN then determines whether all additional continuing-operation criteria are confirmed (step **716**). If all additional continuing-operation criteria are confirmed, the mobile IAN remains in the activated mode (step **714**), otherwise, the mobile IAN transitions to the dormant mode (step **710**).

The example method **700** permits the mobile IAN to remain in the active mode in various circumstances such as but not limited to the mobile IAN moving to a new location, a second mobile IAN activating, and other circumstances. For example, one deployed and activated IAN may be instructed to power down (or otherwise enter its respective dormant mode) when a second, better located IAN arrives on scene to serve the current users; in other instances, multiple IANs may cooperate as a coordinated multipoint (CoMP) network to enhance (e.g., in-building) coverage and/or capacity. The mobile IAN may receive an updated continuing-operations grant that includes updated operating parameters (e.g., transmit power level, frequency, and/or the like). The updated operating parameters reflect selected operating parameters for the mobile IAN. Thus, the GDB function may also consider more than one IAN operating simultaneously in the overall system (e.g., consider the aggregate interference levels from multiple IAN transmitters).

FIG. **8** depicts a number of types of regions within which a mobile IAN base station could be activated, in accordance with at least one embodiment. In particular, FIG. **8** depicts an example terrain map **800** that includes a center region or main coverage area **802**, a fringe coverage region **804**, an outlying region **806**, and a coverage-hole region **810**. Note that a coverage hole region may be due to weak desired WAN signal strength (e.g., due to shadowing or indoor WCD usage), or due to interference from other transmitters or systems (resulting in a low desired SINR). The other transmitters or systems may be either in-band or out-of-band (e.g., adjacent channel) systems.

The central region **802** represents an area where coverage from the eNB **402** of RAN **104**, which may be a public-safety eNB operating on LTE band B14, is generally expected to be strong (e.g., above a given threshold level of SINR and/or one or more other metrics), although it is noted that the coverage-hole region **810** is a coverage hole in the region **802** where, for example, mobile radios attempting to communicate with the eNB **402** may struggle to do so based on a near-far problem caused by the eNB **808**, which may be a commercial eNB operating on LTE band B13, which is adjacent to B14. The fringe region **804** surrounds both the center region **802** and the coverage-hole region **810**. Desired WAN signal strength or SINR is generally poor in the fringe coverage region. Similarly, the outlying region **806** surrounds all three of the center region **802**, the fringe region **804**, and the coverage-hole region **810**. Desired WAN signal strength or SINR is generally very poor or non-existent in the outlying coverage region. IAN operation in these areas is generally referred to as an isolated or stand-alone operational scenario.

In at least one embodiment, a mobile IAN base station that is situated in the center region **802** (but not within the coverage-hole region **810**) may be activated to increase the capacity of the public-safety RAN **104**, offload traffic from the public-safety RAN **104**, and/or for one or more other reasons. Whatever the reason or reasons for activation, the mobile IAN base station may be activated in a manner that compliments—and at a minimum does not interfere significantly with—operation of the public-safety RAN **104**. Resource sharing (e.g., of time-frequency resources) may be utilized to minimize interference between the IAN and WAN systems. The use of interference reduction or coordination techniques (e.g., eICIC or ABS) may also be employed in this region, with a potential reduction of the maximum allowed IAN base station transmit power level (as discussed above) to reduce the interference impact to WAN systems.

In at least one embodiment, a mobile IAN base station that is situated in the coverage-hole region **810** may be activated to extend the coverage of the public-safety RAN **104** to nearby mobile radios, and/or for one or more other reasons, and may be configured to activate in a manner that does not interfere with either the operation of the public-safety RAN **104** or the commercial RAN of which the eNB **808** may be a part (as described above).

In at least one embodiment, a mobile IAN base station that is situated in the fringe region **804** may be activated to extend coverage to and/or improve coverage for one or more mobile radios that are communicating or at least attempting to communicate over the public-safety RAN **104**, and/or for one or more other reasons. The techniques utilized in the center region **802** may also be employed here (e.g., IAN transmit power level reduction, resource sharing, and/or interference coordination techniques), though likely to a lesser extent, since the IAN is operating further away from the WAN transmitter/system.

In at least one embodiment, a mobile IAN base station that is situated in the outlying region **806** may be activated to provide coverage to mobile radios that would otherwise not be able to communicate over the public-safety RAN **104**, to provide communication links and services among those more remotely located mobile radios themselves, and/or for one or more other reasons. Due to being outside the coverage area (i.e., outside both the center region **802** and the fringe region **804**), a mobile IAN base station that is situated in the outlying region **806** may be activated using full transmission power, among other possible settings. And certainly numerous other example types of regions and example configurations in such regions could be listed here. The IAN may also be operating on a more permanent basis in these areas.

In the foregoing specification, specific embodiments have been described. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the invention as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present teachings.

The benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential features or elements of any or all the claims. The invention is defined solely by the appended claims including any amendments made during the pendency of this application and all equivalents of those claims as issued.

Moreover in this document, relational terms such as first and second, top and bottom, and the like may be used solely to distinguish one entity or action from another entity or action without necessarily requiring or implying any actual such relationship or order between such entities or actions. The terms "comprises," "comprising," "has," "having," "includes," "including," "contains," "containing," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises, has, includes, contains a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element preceded by "comprises . . . a," "has . . . a," "includes . . . a," "contains . . . a" does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises, has, includes, contains the element. The terms "a" and "an" are defined as one or more unless explicitly stated otherwise herein. The terms "substantially," "essentially," "approximately," "about," or any other version thereof, are defined as being close to as understood by one of ordinary skill in the art, and in one non-limiting embodiment the term is defined to be within 1%, in another embodiment within 5%, in another embodiment within 1% and in another embodiment within 0.5%. The term "coupled" as used herein is defined as connected, although not necessarily directly and not necessarily mechanically. A device or structure that is "configured" in a certain way is configured in at least that way, but may also be configured in ways that are not listed.

It will be appreciated that some embodiments may be comprised of one or more generic or specialized processors (or "processing devices") such as microprocessors, digital signal processors, customized processors and field programmable gate arrays (FPGAs) and unique stored program instructions (including both software and firmware) that control the one or more processors to implement, in conjunction with certain non-processor circuits, some, most, or all of the functions of the method and/or apparatus described herein. Alternatively, some or all functions could be implemented by a state machine that has no stored program instructions, or in one or more application specific integrated circuits (ASICs), in which each function or some combinations of certain of the functions are implemented as custom logic. Of course, a combination of the two approaches could be used.

Moreover, an embodiment can be implemented as a computer-readable storage medium having computer readable code stored thereon for programming a computer (e.g., comprising a processor) to perform a method as described and claimed herein. Examples of such computer-readable storage mediums include, but are not limited to, a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a ROM (Read Only Memory), a PROM (Programmable Read Only Memory), an EPROM (Erasable Programmable Read Only Memory), an EEPROM (Electrically Erasable Programmable Read Only Memory) and a Flash memory. Further, it is expected that one of ordinary skill, notwithstanding possibly significant effort and many design choices motivated by, for example, available time, current technology, and economic considerations, when guided by the concepts and principles disclosed herein will be readily capable of generating such software instructions and programs and ICs with minimal experimentation.

The Abstract of the Disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

The invention claimed is:

1. A method carried out by a mobile incident-area-network (IAN) base station having a plurality of selectable operating modes, the plurality of selectable operating modes including an activated mode and a dormant mode, the method comprising:

determining at least one location in a local region of the mobile IAN base station while the mobile IAN base station is in the dormant mode;

submitting, to a geo-location-database (GDB) function, an activation permission request that includes the determined at least one location for processing by the GDB function;

receiving, from the GDB function, an activation-permission response associated with the submitted activation-permission request, wherein the received activation-permission response is based at least in part on an expected level of wide area-network (WAN) coverage associated with the determined at least one location;

transitioning the mobile IAN base station to the activated mode in response to confirming each activation criterion in a set of one or more activation criteria, the set of one or more activation criteria comprising the received activation-permission response being an activation-permission grant; and

remaining in the dormant mode in response to failing to confirm at least one activation criterion in the set of one or more activation criteria.

2. The method of claim **1**, wherein the GDB function operates locally in the mobile IAN base station.

3. The method of claim **1**, wherein the GDB function utilizes a local cache of WAN-coverage data derived from a remote GDB function.

4. The method of claim **1**, wherein the GDB function operates remote from the mobile IAN base station.

5. The method of claim **1**, the method further comprising:

operating in accordance with the activation-permission grant.

6. The method of claim **5**, wherein the activation-permission grant instructs the mobile IAN base station to operate at a full transmission power level.

7. The method of claim **5**, wherein the activation-permission grant instructs the mobile IAN base station as to permissible operating ranges with respect to one or more operating parameters, the one or more operating parameters including one or more of transmit power level, carrier frequency, channel bandwidth, utilized resource blocks, and time-frequency allocation.

8. The method of claim **1**, wherein the expected level of WAN coverage comprises at least one of an expected WAN signal-to-noise-and-interference ratio (SINR), an expected WAN signal strength, an expected WAN loading level, and an expected WAN available-capacity level.

9. The method of claim **1**, further comprising:

measuring an actual level of WAN coverage,

wherein the set of one or more activation criteria further comprises the measured actual level of WAN coverage being less than a predetermined WAN-coverage threshold.

10. The method of claim **9**, wherein the measured actual level of WAN coverage being less than the predetermined WAN-coverage threshold corresponds to one or both of (i) a measured actual WAN signal-to-noise-and-interference ratio (SINR) being less than a predetermined SINR threshold and (ii) a measured actual WAN signal strength being less than a predetermined signal-strength level.

11. The method of claim **1**, wherein the set of one or more activation criteria further comprises the mobile IAN base station having received a user instruction to transition to the activated mode.

12. The method of claim **11**, wherein the mobile IAN base station received the user instruction via a user interface of the mobile IAN base station.

13. The method of claim **11**, wherein the mobile IAN base station received the user instruction from a user authorized to issue such an instruction.

14. The method of claim **1**, wherein the set of one or more activation criteria further comprises the mobile IAN base station having received an activation instruction from a WAN.

15. The method of claim **1**, wherein the set of one or more activation criteria further comprises the mobile IAN base station having received an activation instruction from a mobile radio.

16. The method of claim **15**, wherein the mobile IAN base station received the activation instruction from the mobile radio over a land mobile radio (LMR) channel.

17. The method of claim **1**, further comprising:

receiving expected-WAN-coverage data from the GDB function;

measuring an actual level of WAN coverage; and

adapting the expected-WAN-coverage data with the measured actual level of the WAN coverage.

18. The method of claim **1**, further comprising:

determining an updated location of the mobile IAN base station while the mobile IAN base station is in the activated mode;

submitting, to the GBD function, a continuing operation request that includes the determined updated location for processing by the GDB function;

receiving, from the GDB function, a continuing-operation response associated with the submitted continuing-operation request, wherein the received continuing operation response is based at least in part on an expected level of WAN coverage associated with the determined updated location;

remaining in the activated mode in response to confirming each continuing operation criterion in a set of one or more continuing-operation criteria, the set of one or more continuing-operation criteria comprising the received continuing-operation response being a continuing-operation grant; and

transitioning the mobile IAN base station to the dormant mode in response to failing to confirm at least one continuing-operation criterion in the set of one or more continuing operation criteria.

19. The method of claim **1**, wherein the GDB function formulates the activation-permission response based at least in part on information regarding one or more of a transmitter location, a radiated power level, an antenna height, an antenna gain, an antenna polarization, an antenna pattern, and terrain data.

20. A mobile incident-area network (IAN) base station having a plurality of selectable operating modes, the plurality of selectable operating modes including an activated mode and a dormant mode, the mobile IAN base station comprising:

a wireless-communication interface;

a processor; and

a non-transitory computer readable medium containing instructions executable by the processor for causing the mobile IAN base station to carry out a set of functions, the set of functions comprising:

determining at least one location in a local region of the mobile IAN base station while the mobile IAN base station is in the dormant mode;

submitting, to a geo-location-database (GDB) function, an activation permission request that includes the determined at least one location for processing by the GDB function;

receiving, from the GDB function, an activation-permission response associated with the submitted activation-permission request, wherein the received activation permission response is based at least in part on an expected level of wide-area-network (WAN) coverage around the determined at least one location;

transitioning the mobile IAN base station to the activated mode in response to confirming each activation criterion in a set of one or more activation criteria, the set of one or more activation criteria comprising the received activation-permission response being an activation-permission grant; and

remaining in the dormant mode in response to failing to confirm at least one activation criterion in the set of one or more activation criteria.

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