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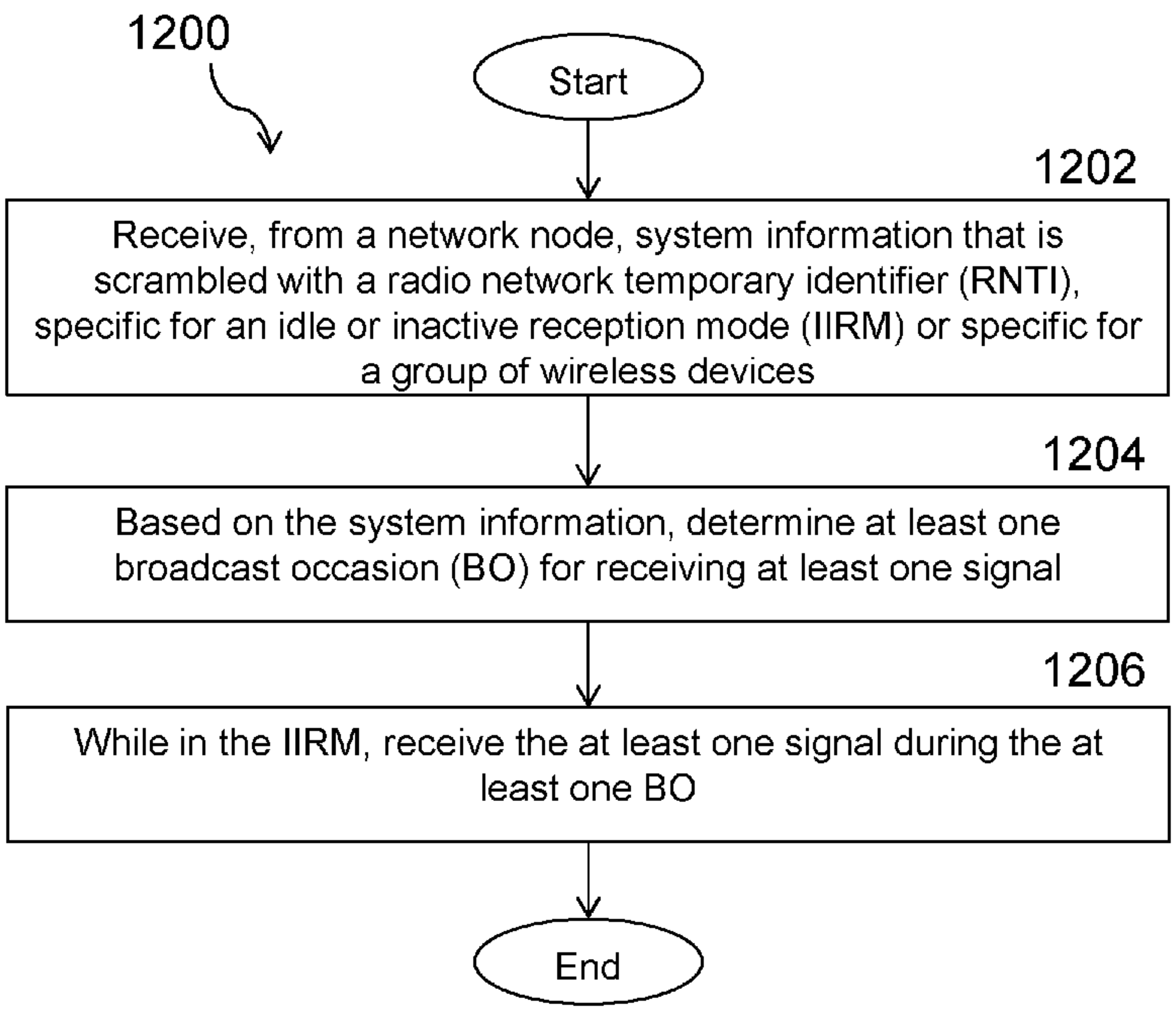

FIGURE 16

(57) Abstract: A method (1200) by a wireless device (110) includes receiving (1202), from a network node (160), system information that is scrambled with a radio network temporary identifier, RNTI, specific for an idle or inactive reception mode, IIRM, or specific for a group of wireless devices. Based on the system information, the wireless device determines (1204) at least one broadcast occasion, BO, for receiving at least one signal. While in the IIRM, the wireless device receives (1206) the at least one signal during the at least one BO.

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BROADCAST OCCASION FOR RECEIVING A SIGNAL

TECHNICAL FIELD

The present disclosure relates, in general, to wireless communications and, more particularly, systems and methods for determining a broadcast occasion for receiving a signal by a wireless device while in an idle or inactive reception mode (IIRM).

BACKGROUND

As part of 5G mobility management (5GMM), a New Radio (NR) paging mechanism allows the network to communicate a message or deliver data to user equipments (UEs) in 5GMM-registered or 5GMM-Idle state, which are known at tracking area level. Specifically, the paging is initiated, and paging area is maintained by core network (CN) during Radio Resource Control_IDLE (RRC_IDLE) state while the paging is initiated and Radio Access Network-based notification area (RNA) is maintained by NR Radio Access Network (NR RAN) during Radio Resource Control_INACTIVE (RRC_INACTIVE) state.

A UE in RRC_INACTIVE or IDLE is able to monitor the paging messages. A UE is registered in a tracking area or RNA and, therefore, the network sends the paging message in all the possible cells within the tracking area. In NR, the UE monitors Paging Occasions (POs) where the paging Downlink Control Indicator (DCI) can be sent once per cycle using Discontinuous Reception (DRX). In NR systems, the paging DCI is scrambled with a Paging-Radio Network Temporary Identifier (P-RNTI).

These paging DRX cycles are configured by the network:

- For CN-initiated paging, a default cycle is broadcast in system information (e.g., SIB1).
- For CN-initiated paging, a UE specific cycle can be configured by via Non-Access Stratum (NAS) signaling (Requested DRX parameters: 5GS DRX parameters).
- For RAN-initiated paging, a UE-specific cycle is configured via Radio Resource Control (RRC) signaling (RRC Release: SuspendConfig).

A UE in RRC_IDLE uses the shortest of the first two-cycles above, while a UE in RRC_INACTIVE uses the shortest of the three cycles. Furthermore, a UE in RRC_CONNECTED monitors the paging channels in any PO signaled in the system information (SI) message for any SI change indication and Public Warning System (PWS) notification.

The same paging message is created for Radio Access Network (RAN) or CN-initiated paging. The UE initiates RRC Connection Resume procedure upon receiving RAN-initiated paging. If the UE receives CN-initiated paging in RRC_INACTIVE state, the UE moves to RRC_IDLE and informs NAS.

A Paging Frame (PF) can contain several paging occasions or starting points for Paging Occasions (POs). The PF and PO for paging are determined by the following formulae in current NR:

- System Frame Number (SFN) for the PF is determined by the following value:
  (SFN + PF_offset) mod T = (T div N)*(UE_ID mod N)
- Additionally, index (i_s), indicating the index of the PO is determined by:
  i_s = floor (UE_ID/N) mod Ns

Whereby the specifications define the terms as follows:

SFN: System Frame Number

T: DRX cycle of the UE

N: number of total paging frames in T

Ns: Number of paging occasions for a PF

PF_offset: offset used for PF (Paging Frame) determination

T div N: indicates the remainder free division operation of T/N

Index(i_s): indicates the index of the PO for one of the multiple potential Paging Occasions

LTE Multimedia Broadcast Multicast Services (MBMS) reception based on Multimedia Broadcast multicast service Single Frequency Network (MBSFN) supports reception in idle mode

In LTE, MBMS reception is supported in RRC IDLE mode. Scheduling is not based on the Physical Downlink Control Channel (PDCCH) but on a combination of SIB13 and Multicast Control CHannel (MCCH). SIB13 defines which subframes are allocated for MBMS and the MBSFN areas, and for each, how to obtain the MCCH. All Multicast Channels (MCHs) within one MBSFN area use a common subframe allocation (CSA) pattern. Among the subframes defined by the CSA, consecutive subframes are allocated to the same MCH. The MCCH defines the CSA of the MBSFN area. A change notification for the MCCH is transmitted on the PDCCH.

Receive Only Mode (RoM) in LTE

The following scenarios are defined for LTE and taken from 3GPP TS 23.246 v16.1. This reception mode is an addition to the LTE MBMS idle mode reception.

In LTE the UEs can be in three different scenarios:

- Scenario 1: The UE receives both unicast and broadcast service from same Public Land Mobile Network (PLMN).
- Scenario 2 (The UE acts in RoM): the UE receives broadcast MBMS service without PLMN subscription over Evolved Universal Terrestrial Radio Access Network (E-UTRAN) without the need to access and register with the PLMN offering the MBMS service. A UE configured to operate in RoM camps on a network cell in an enhanced MBMS (eMBMS) Broadcast carrier, shall attempt to receive MBMS service based only on a standardised Temporary Mobile Group Identifier (TMGI) value range for RoM. The UE shall not attempt to receive MBMS service for TMGIs outside the standardized TMGI range. The UE shall refrain from any Mobility Management or other signalling with the network offering MBMS. The UE uses the acquired system information to receive MBMS broadcast. Use of RoM does not require Universal Subscriber Identity Module (USIM) for the UE.
- Scenario 3 (The UE acts in RoM with independent unicast): The UE receives unicast service from one serving PLMN (e.g. the PLMN for which it has unicast subscription) and receive MBMS service through a different PLMN. A UE may be configured as RoM with independent unicast using Enhanced Packet Service (EPS) bearer contexts. This configuration option allows a UE to operate as RoM for MBMS broadcast service, and independently follows regular NAS/RRC procedures for unicast service with a PLMN. This mode of operation requires

USIM and PLMN subscription to receive unicast service. No additional subscription or credentials are required to receive MBMS broadcast service.

FIGURE 1 illustrates Scenarios 2 and 3, as described above,

Any device that is equipped with a MBMS broadcast receiver and is configured to operate in RoM is able to receive the broadcast content, with the following characteristics:

- No PLMN credentials/subscription are required, as long as use of EPS unicast bearers is not required by the device.
- Without PLMN credentials/subscription, the UE can only access broadcast services without subscription.
- There is no need for the UE to support uplink.

The UE is preconfigured with all the necessary information for the UE to acquire the system information and receive MBMS service. This information includes:

- PLMN ID(s) that provide the MBMS service.
- TMGI(s): The TMGI is composed by an MBMS Service ID and a PLMN ID (Mobile Country Code/ Mobile Network Code (MCC/MNC)).
- In the case of the network providing MBMS service in MBMS transport only mode, the TMGI(s) for each MBMS service need to be configured in the UE.
- The UE may be configured to receive TMGI(s) via Service Announcement
- RAN specific information, User Service Description (USD).

Certain problems exist. For example, in the current LTE and NR standards, there is no method to page/signal a particular group of UEs, i.e., a subset of all UEs in the network or cell, at the same time or in a coordinated matter, and in a resource-efficient way.

In the current paging mechanism in NR, each UE is individually paged without the possibility to select a group of UEs by using the same transmitted signal. This is due to the nature of the paging message which is a function of the individual UE_ID, i.e., the message is specific for that particular UE. In some cases, e.g., for Vehicle-to-Anything (V2X) and National Security and Public Safety (NSPS) use cases, it is beneficial to include a paging mechanism that is able to address specific groups of UEs in a multicast manner.

Additionally, in the current NR standard, there is no broadcast or multicast supported. There is no mechanism so that all UEs in the cell or a group of UEs within the cell can receive an MBMS message, e.g., some sort of broadcast messages. One straightforward possibility is that these UEs receive these messages when they are in RRC_CONNECTED mode. This scenario leads to a constant/higher power consumption since the UEs need to be constantly in RRC_CONNECTED mode, which is more demanding in terms of energy than other RRC states like IDLE or INACTIVE where the UEs only need to monitor for transmissions at specific, and possibly predefined, times.

Additionally, if a UE or group of UEs is in RRC_IDLE or RRC_INACTIVE mode, they need to transition to RRC_CONNECTED mode before being able to receive any transmission other than paging or system information, which may lead to a higher latency in the communications and a potential cumbersome signaling if it is a highly dense scenario.

Furthermore, in the current NR technology, there is no possibility of having different DRX patterns coexisting for reception of different transmissions.

SUMMARY

Certain aspects of the present disclosure and their embodiments may provide solutions to these or other challenges. For example, according to certain embodiments, methods and systems are provided to signal a selected number of wireless devices such as user equipments (UEs), belonging to a particular group, at the same time (or in a coordinated manner).

According to certain embodiments, a method by a wireless device includes receiving, from a network node, system information that is scrambled with a radio network temporary identifier (RNTI) specific for an idle or inactive reception mode (IIRM) or specific for a group of wireless devices. Based on the system information, the wireless device determines at least one broadcast occasion (BO) for receiving at least one signal. While in the IIRM, the wireless device receives the at least one signal during the at least one BO.

According to certain embodiments, a wireless device includes processing circuitry configured to receive, from a network node, system information that is scrambled with a RNTI specific for an IIRM or specific for a group of wireless devices. Based on the system information, the processing circuitry determines at least one BO for receiving at least one signal. While in the IIRM, the processing circuitry receives the at least one signal during the at least one BO.

According to certain embodiments, a method by a network node includes determining at least one BO for transmitting at least one signal. The network node transmits, to a wireless device, system information that is scrambled with a RNTI specific for an IIRM or specific for a group of wireless devices. The system information indicates the at least one BO. While the wireless device is in the IIRM, the network node transmits the at least one signal to the wireless device during the at least one BO.

According to certain embodiments, a network node includes processing circuitry configured to determine at least one BO for transmitting at least one signal. The processing circuitry transmits, to a wireless device, system information that is scrambled with a RNTI specific for an IIRM or specific for a group of wireless devices. The system information indicates the at least one BO. While the wireless device is in the IIRM, the processing circuitry transmits the at least one signal to the wireless device during the at least one BO.

Certain embodiments may provide one or more of the following technical advantages. For example, one technical advantage may be that certain embodiments provide a definition of a group identity for a set of UEs, by selecting groups of UEs with the same specific geographical area or service requirements that can be signaled at the same time, facilitates an efficient design from the perspective of resource utilization. As such, a technical advantage may be that certain embodiments obtain an optimal scheme with respect to the allocated resources.

As still further example, one technical advantage may be that certain embodiments enable the reception of messages by a single or a group of UEs without transitioning from RRC IDLE/INACTIVE mode into RRC_CONNECTED mode. Accordingly, certain embodiments bring benefits in terms of battery consumption for particular UEs or groups of users.

As yet another example, a technical advantage may be that certain embodiments allow a particular set of UEs to be signaled to transition into IIRM of NR MBMS if they are in RRC_CONNECTED mode based on successful or unsuccessful HARQ reports received by the network. This may save power, for example.

As still another example, a technical advantage may be that certain embodiments enable a UE to have different IIRM_DRX scheduling profiles, i.e., a UE may belong to several groups at the same time or may be interested in different types of services with different priorities. This hierarchy of transmissions creates a more optimal scheduling for reception of broadcast/multicast messages in RRC IDLE/INACTIVE mode.

As yet another example, a technical advantage may be that certain embodiments increase the reception performance, i.e., reliability for the downlink, for the UEs in

IDLE/INACTIVE mode without using uplink from the UEs, i.e., there is no Hybrid Automatic Repeat Request (HARQ) protocol, and using the same amount of Physical Resource Blocks (PRBs) in the downlink that would be transmitted using normal HARQ operation.

As yet another example, a technical advantage may be that certain embodiments enable several coexisting Discontinuous Reception (DRX) schedules for the UEs. This may lead to optimized monitoring whenever the receiving UEs are interested in certain broadcast messages or services.

Other advantages may be readily apparent to one having skill in the art. Certain embodiments may have none, some, or all of the recited advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the disclosed embodiments and their features and advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

FIGURE 1 illustrates several scenarios defined for Long Term Evolution (LTE) taken from 3GPP TS 23.246 v16.1;

FIGURE 2 illustrates an exemplary scenario defining different Geo-Group Area Identifiers (GGAI) for User Equipments (UEs) within the same geographical location or requiring the same service, according to certain embodiments;

FIGURE 3 illustrates an example wireless network, according to certain embodiments;

FIGURE 4 illustrates an example network node, according to certain embodiments;

FIGURE 5 illustrates an example wireless device, according to certain embodiments;

FIGURE 6 illustrate an example user equipment, according to certain embodiments;

FIGURE 7 illustrates a virtualization environment in which functions implemented by some embodiments may be virtualized, according to certain embodiments;

FIGURE 8 illustrates a telecommunication network connected via an intermediate network to a host computer, according to certain embodiments;

FIGURE 9 illustrates a generalized block diagram of a host computer communicating via a base station with a user equipment over a partially wireless connection, according to certain embodiments;

FIGURE 10 illustrates a method implemented in a communication system, according to one embodiment;

FIGURE 11 illustrates another method implemented in a communication system, according to one embodiment;

FIGURE 12 illustrates another method implemented in a communication system, according to one embodiment;

FIGURE 13 illustrates another method implemented in a communication system, according to one embodiment;

FIGURE 14 illustrates an example method by a wireless device, according to certain embodiments;

FIGURE 15 illustrates an example virtual apparatus, according to certain embodiments;

FIGURE 16 illustrates another example method by a wireless device, according to certain embodiments;

FIGURE 17 illustrates another example virtual apparatus, according to certain embodiments;

FIGURE 18 illustrates an example method by a network node, according to certain embodiments;

FIGURE 19 illustrates another example virtual apparatus, according to certain embodiments;

FIGURE 20 illustrates another example method by a network node, according to certain embodiments; and

FIGURE 21 illustrates another example virtual apparatus, according to certain embodiments.

DETAILED DESCRIPTION

Some of the embodiments contemplated herein will now be described more fully with reference to the accompanying drawings. Other embodiments, however, are contained within the scope of the subject matter disclosed herein, the disclosed subject matter should not be construed as limited to only the embodiments set forth herein; rather, these embodiments are provided by way of example to convey the scope of the subject matter to those skilled in the art.

Generally, all terms used herein are to be interpreted according to their ordinary meaning in the relevant technical field, unless a different meaning is clearly given and/or is implied from the context in which it is used. All references to a/an/the element, apparatus, component, means, step, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any methods disclosed herein do not have to be performed in the exact order disclosed, unless a step is explicitly described as following or preceding another step and/or where it is implicit that a step must follow or precede another step. Any feature of any of the embodiments disclosed herein may be applied to any other embodiment, wherever appropriate. Likewise, any advantage of any of the embodiments may apply to any other embodiments, and vice versa. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following description.

In some embodiments, a more general term “network node” may be used and may correspond to any type of radio network node or any network node, which communicates with a UE (directly or via another node) and/or with another network node. Examples of network nodes are NodeB, MeNB, ENB, a network node belonging to MCG or SCG, base station (BS), multi-standard radio (MSR) radio node such as MSR BS, eNodeB, gNodeB, network controller, radio network controller (RNC), base station controller (BSC), relay, donor node controlling relay, base transceiver station (BTS), access point (AP), transmission points, transmission nodes, RRU, RRH, nodes in distributed antenna system (DAS), core network node (e.g. MSC, MME, etc.), O&M, OSS, SON, positioning node (e.g. E-SMLC), MDT, test equipment (physical node or software), etc.

In some embodiments, the non-limiting term user equipment (UE) or wireless device may be used and may refer to any type of wireless device communicating with a network node and/or with another UE in a cellular or mobile communication system. Examples of UE are target device, device to device (D2D) UE, machine type UE or UE capable of machine to machine (M2M) communication, PDA, PAD, Tablet, mobile terminals, smart phone, laptop embedded equipped (LEE), laptop mounted equipment (LME), USB dongles, UE category M1, UE category M2, ProSe UE, V2V UE, V2X UE, etc.

Additionally, terminologies such as base station/gNodeB and UE should be considered non-limiting and do in particular not imply a certain hierarchical relation between the two; in general, “gNodeB” could be considered as device 1 and “UE” could be considered as device 2 and these two devices communicate with each other over some radio channel. And in the following the transmitter or receiver could be either gNB, or UE.

According to certain embodiments, a mechanism is disclosed for paging or signaling a selected number of UEs, which may belong to a particular group or be associated with a particular group of users, at the same time (or in a coordinated manner). In a particular embodiment, a group of UEs may be defined with a common Paging Frame (PF) and common Paging Occasions (POs) for all the UEs within the group by including a common value for all the UEs within the group in the formulae for PF and PO.

Additionally, according to certain embodiments, a mechanism is disclosed for paging or signaling a particular group of users, within a certain geographical area or to a set of UEs interested on the same service using a newly defined NR group signalling/paging. Stated differently, a group of UEs may be defined or otherwise determined, and a Group_ID may be assigned to these UEs based on some (pre-)defined criterion, e.g., geographical area or same service requirements.

For example, in a particular embodiment, a mechanism is disclosed to page/signal a group of UEs defined by their geographical area or required service based on a group_ID. The group paging mechanism uses the previously defined group structure to optimally use the resources within the group of users. Because of this further categorization/grouping, a new Geo-Group Area Identifier (GGAI) generally smaller than a RAN area or Tracking Area Identity (TAI) is disclosed and provides a higher flexibility to the network. Additionally, a method is disclosed to coordinate the uplink access for the UEs within the group is developed.

In a particular embodiment, not all of the wireless devices in the network or in a cell may be a part of the group of wireless devices.

FIGURE 2 illustrates an exemplary scenario defining different GGAI for UEs within the same geographical location or requiring the same service. In a particular embodiment, the GGAI may be related to infrastructure such as, for example street corners. For example, group(s) of wireless devices or users may be defined within emergency zones for NSPS or intersections and parking lots for V2X. According to certain embodiments, a network node, such as a gNB, may define Geo-Group areas and generate a GGAI for each Geo-Group area.

Though certain embodiments describe the grouping of UEs based on geographical area, it is recognized that grouping according to geographical area is just one example for grouping UEs. The grouping of UEs may be based on other criteria.

According to certain embodiments, the group paging procedure described herein may be used as a baseline to define an RRC IDLE/INACTIVE reception mode (IIRM) of NR

MBMS. In the IIRM, the UEs may be able to listen to and receive periodic and aperiodic traffic. Thus, according to certain embodiments, a mechanism is disclosed that allows the wireless devices or groups of wireless devices, which may include UEs or group of UEs, in certain embodiments, to receive broadcast/multicast messages in IIRM without transitioning into RRC_CONNECTED mode. Stated differently, instead of transitioning into RRC CONNECTED mode, which happens in the current NR and legacy systems, the signaled UEs remain in RRC IDLE/INACTIVE mode and are able to receive the transmission.

According to a particular embodiment, the IIRM mode may be similar to the ordinary IDLE/INACTIVE mode defined by 3GPP with a new functionality to monitor a BO. As used herein, the term "IDLE/INACTIVE reception mode (IIRM)" is a new term. In a particular embodiment, while the UE in connected mode may monitor constantly for downlink transmissions, the UE in IIRM mode may, for example, only monitor in the BO.

According to certain embodiments, the triggering mechanism for transitioning into IIRM may be based on RRC or network messages received while the UEs are in RRC_CONNECTED mode. Additionally or alternatively, the triggering mechanism may be based on an uplink transmission or radio link monitoring (RLM) metrics. For example, in a particular embodiment, a method to trigger the IIRM mode may be defined based on a number of ACK/NACK not delivered. Certain embodiments may save power.

According to certain embodiments, a common time alignment may be defined for different UEs. For example, a common IIRM of NR MBMS DRX (IIRM_DRX) cycle for INACTIVE/IDLE UEs may be defined based on the (pre-)defined Group_ID. The IIRM_DRX may be used by UEs in the group for reception and/or listening of potential messages. Using this mechanism, the UEs belonging to the same group can check Broadcast Occasions (BO) at the same time or in a coordinated manner.

Since the UEs may not transition to RRC_CONNECTED mode, there may be no possibility of having HARQ. More specifically, there may be no connection established and, therefore, the uplink cannot be used. Accordingly, an implicit mechanism may be provided wherein the network may nevertheless decide to send retransmissions in a (pre-)determined way to increase the reliability. For example, transmissions may be repeated a certain number of times without use of HARQ.

According to certain embodiments, a wireless device, such as a UE, for example, can have different DRX profiles coexisting since the same UE can be part of different groups at the same time. In order to handle the different DRX profiles, a prioritization based on service or group location is described.

In a particular embodiment, different priorities are defined for the IIRM_DRX patterns in order to solve conflicts whenever different receptions or transmissions could collide.

As described above with reference to FIGURE 2, UEs may be grouped according to geographical areas such as GGAI. According to certain embodiments, the UEs may be registered in this area. These new Geo-Group areas may be typically smaller than a Radio Access Network-based notification area (RNA) or Tracking Area Identifier (TAI) defined in NR, in particular embodiments. To find out the UE position, some independent positioning method may be used. For example, a UE-internal Global Navigation Satellite System (GNSS) receiver or some 3GPP-based solution, or a combination of methods, may be used.

In order to track the position of each of the UEs, each UE may send its location to the network node. In particular embodiments, for example, each UE may send its location by means of Radio Resource Control (RRC) message in a periodic way or in an event-triggered fashion such as, for example, after moving a certain number of meters. In case the UE is within a pre-defined GGAI, the gNB may signal to the transmitting UE that it is in a GGAI and consequently the UE will start monitoring the corresponding PO and PF.

In other embodiments, the network node may signal to the UE the GGAI by means of the geo-area definition (polygon, radius, etc.) together with the GGAI, and the UE may determine whether it is in the specified geo-area and only then monitors the PO and PF.

In a particular embodiment, if a cell is covered by individual beams, then each beam may broadcast a GGAI and the UE can register with the network node when the UE selects the beam broadcasting a particular GGAI.

According to a particular embodiment, in the case where higher layers select the UEs which belong to the group with respect to their geographical location or required services, each of the UEs may receive the Group_ID in a unicast manner upon connection establishment. For example, each UE may receive the Group_ID the first time it gets into RRC_CONNECTED with this gNB, in a particular embodiment. In another embodiment, if the group is defined while the UE is already in RRC_CONNECTED, the UE may receive the Group_ID via unicast transmission.

According to another particular embodiment, the UEs may receive their Group_ID via a “PTM Group definition message” targeting all connected UEs, where a list of all UE_IDs that are part of the group (as defined by upper layers) is transmitted. To further reduce overhead, this list could be broadcast and may include some compression method in the way the list is defined such as, for example, including *ranges* of UE_IDs, e.g. UE_ID #N to UE_ID #M. The individual UEs may then react depending on whether they are part of the list or not. For large number of UEs, this may be more efficient than addressing individual UEs via unicast.

According to a particular embodiment, in case the group of UEs is (pre-)configured in the UE, such as, for example, a group of firefighters or policemen, without network involvement, the group information such as, for example, the Group_ID, may be shared with the gNB and higher layers by means of RRC messages sent via uplink by the UEs.

According to a particular embodiment, the previously defined Group_ID may have a similar design as the 5G Temporary Mobile Subscriber Identity (TMSI) for an individual UE and consist of 32 bits in order to allocate a sufficient number of groups.

In NR systems, the PF and PO associated to the legacy paging mechanism are determined by the UE_ID. According to certain embodiments described herein, a group paging mechanism may be implemented to address all the UEs in the group using the same transmission. Therefore, the PO and PF associated to a group paging are allocated as a function of the Group_ID or any common identifier for the (pre-)defined group

Another possibility is to replace the UE_ID in the following formulae by the Group_ID generated by the gNB or which has been (pre-)configured into the UEs as follows:

1. (SFN + PF_offset) mod T = (T div N)*(Group_ID mod N)
2. Index (i_s), indicating the index of the PO is determined by: i_s = floor (Group_ID/N) mod Ns

The UEs belonging to the same group may monitor the different POs where the group paging/signalling downlink control information (DCI) is sent once per cycle using the (pre-)configured DRX pattern for this specific group. As described herein, according to a particular embodiment, the group paging/signalling DCI may be scrambled using a new Group Paging RNTI (GP-RNTI) unique for each group. The GP-RNTI can work in parallel to the normal P-RNTI.

Using this mechanism, a group of UEs may be signalled simultaneously, i.e., a certain message is addressed to a pre-defined group of users. In a particular embodiment, a particular case of this signalling is disclosed which involves the group paging mechanism, i.e., UEs transition from IDLE/INACTIVE into CONNECTED mode.

According to a particular embodiment, for UEs which wake-up by listening to the group paging mechanism, i.e., UEs that can comprehend the DCI scrambled using a particular GP-RNTI, a time coordination mechanism is provided to distribute in time the uplink access of the group of UEs transitioning from IDLE/INACTIVE to CONNECTED mode. This may avoid congestion in the uplink due to a large number of UEs trying to connect at the same time. When a UE connects, the UE starts by performing the Random Access procedure. In the state-of-the-art NR, this does not imply a randomization in time.

- In a particular embodiment, the UEs within the same group may randomly select their Random Access opportunity based on some time distribution within a (pre-) defined time window [0, T] using e.g. a rectangular distribution.
- In another particular embodiment, in addition to the Group_ID, each UE may also be allocated an ACCESS_ID, which is used to ensure that all UEs connect in a time window, but not only with equal probability but in a way which deterministically ensures that an equal number of UEs connect per time unit during this connection time window. The ACCESS_ID may e.g., be a simple ordering, so that UEs with ACCESS_ID#1 connect first, followed by UEs with ACCESS_ID#2 etc. up to the UEs with the highest ACCESS_ID, which are the last to connect. Additionally, this ACCESS_ID can be created by mapping the UE_ID which is unique for each of the UEs within the group.

According to certain embodiments, in the IIRM of NR MBMS, a wireless device and/or a particular group of wireless devices, which may include UEs, in a particular embodiment, listen and/or receive broadcast (BC) or multicast (MC) messages while remaining in IDLE or INACTIVE mode. In this mode, the wireless devices may not have an uplink established with the network node, and the wireless devices may only be able to monitor BC/MC transmissions which are included in the Broadcast Occasion (BO) defined by paging-like messages. The BO could also be referred to as a broadcast opportunity. The paging-like messages may include any kind of messages intended for a specific group and may not have any specific properties other than that the paging-like messages indicate the BO. Whereas, a paging message is used to “wake-up” the UE, for example, to transition from idle/inactive to connected mode, these paging-like messages have a similar structure to paging messages but are not intended to "wake-up" the UEs. Rather, the paging-like messages are intended to indicate the BO to a specific group of inactive/idle UE(s).

According to certain embodiments, the BO is sent in a paging-like message (or something similar) or in system information because the UE does not listen to anything else in the IDLE/INACTIVE mode.

Since the wireless devices normally have no uplink channel activated/enabled when in idle/inactive mode, there is no possibility to signal whether transmitted information (such as a signal or message transmitted by a network node) was successfully or unsuccessfully received, e.g., ACK/NACK, using the HARQ feedback. Nevertheless, the network node may decide to send retransmissions in a (pre)determined way. The reason for this is to increase the time diversity, i.e., the same amount of physical resource blocks (PRBs) would be transmitted as without HARQ but distributed in time over several occasions. In some reception conditions, this may result in a very significant improvement in reception performance, although at the expense of increased latency. It will be appreciated that retransmission may for example be performed for all data transport blocks that are transmitted in the BOs.

According to certain embodiments, a common time alignment for reception, i.e., common IIRM_DRX cycle for INACTIVE/IDLE UEs, based on Group_ID for reception/listening of potential messages for the UEs in the group is defined so they all check for Broadcast Occasions (BO) contained in the system information, e.g., paging-like messages, sent by the network at the same time.

According to certain embodiments, the BO is controlled/signaled via system information. All the users in the group may have the same BO. The BO is received in the system information, and there it will be scrambled with an RNTI (which may for example be referred to as GP-RNTI) that is associated with (or based on) the Group ID. Alternatively, the system information block containing the BO information element is not scrambled with the GP-RNTI but the information element additionally contains the Group_ID.

The group wireless devices monitor the BO that they receive using System Information sent by the network node, which may include a gNB, in a particular embodiment. In case of BC/MC information for IDLE/INACTIVE UEs, the network informs the wireless devices using a message, e.g., paging-like messages, which is scrambled using the GP-RNTI. For messages that are scrambled using the GP-RNTI there are two potential outcomes after being decoded by the target UEs:

1. The message is scrambled using GP-RNTI and it is intended to be a group paging, i.e., the UE will transition into RRC_CONNECTED mode. In this case, the message contains the Group_ID, which determines the PO (Paging Occasions) and PF (Paging Frame) so the UE can monitor and decode them.
2. The message is scrambled using GP-RNTI and its goal is to transition the receiving UEs into IIRM. In this case, a field within the message signals that the UEs should move into IIRM and it includes the BO or it indicates that the BO are transmitted in the system information, in either case so the UE or the group of UEs can monitor it.

According to certain embodiments, for some geo-graphical areas, every UE that transitions into IDLE or INACTIVE mode may be (pre-)configured to go into IIRM by default within these areas.

According to a particular embodiment, the triggering of the IIRM by the network for a particular UE can be based on downlink HARQ, i.e., a (pre-)defined number of ACK/NACK is not received by the gNB or based on an Radio Link Management (RLM) notification. A motivation for doing so can be that in the case where the uplink from the UE to the gNB is anyways so bad that ACK/NACK message do not get through, it may not make sense for the UE to stay in RRC-connected, so it may transition to IIRM.

According to a particular embodiment, a triggering for UEs to move into IIRM is signaled by the network in unicast manner when the UE is in RRC_CONNECTED mode. This transition into IIRM is signaled using RRC messages or other network messages. Since the gNB has knowledge of the UEs in the cell, i.e., UEs which are under its coverage, it is possible to signal only a subset of the UEs so they transition to the IIRM mode.

According to a further particular embodiment, the network may decide that a subset of UEs do not move into IIRM, i.e., they do not receive information in RRC IDLE/INACTIVE mode, by signaling these particular UEs.

According to another particular embodiment, a UE may potentially listen to several different DRX patterns signalled in SIB, i.e., a UE can belong to different groups at the same time, in parallel to the legacy cell-specific paging.

Since the new data, i.e., BO, does not fit into the normal DRX scheduling created for the paging messages, the UEs may be configured by the network to have two (or more) different DRX scheduling, i.e., one for the normal PO and one or more for the BO. Alternatively, the reception in the BO does not require an additional DRX pattern, as the UE is just waking up for the BO which is fully specified by embodiments described above. The new IIRM_DRX scheduling can be signaled using RRC messages. The scheduling can be configured to support several retransmissions of the same packet.

According to a further particular embodiment, it is possible to define different priorities attached to the different IIRM_DRX scheduling patterns, so there is no collision of different BO. The priorities are defined based on service requirements, e.g., NSPS for critical services has the highest priority, or based on geographical location. This mechanism is required since the same UE could potentially belong to several groups at the same time. The priority of the DRX scheduling may be signaled in the RRC messages.

According to certain embodiments, the BO can be scrambled using a new IIRM-RNTI so only UEs in IIRM can decode it. If a UE goes into IDLE/INACTIVE mode, it automatically receives/selects the IIRM-RNTI so it can by default listen to IIRM BC/MC. The IIRM-RNTI can be sent once the UE joins the network for the first time so there is no need to transmit this information once the UE goes into IDLE/INACTIVE mode.

FIGURE 3 illustrates a wireless network, in accordance with some embodiments. Although the subject matter described herein may be implemented in any appropriate type of system using any suitable components, the embodiments disclosed herein are described in relation to a wireless network, such as the example wireless network illustrated in FIGURE 3. For simplicity, the wireless network of FIGURE 3 only depicts network 106, network nodes 160 and 160b, and wireless devices 110. In practice, a wireless network may further include any additional elements suitable to support communication between wireless devices or between a wireless device and another communication device, such as a landline telephone, a service provider, or any other network node or end device. Of the illustrated components, network node 160 and wireless device 110 are depicted with additional detail. The wireless network may provide communication and other types of services to one or more wireless devices to facilitate the wireless devices' access to and/or use of the services provided by, or via, the wireless network.

The wireless network may comprise and/or interface with any type of communication, telecommunication, data, cellular, and/or radio network or other similar type of system. In some embodiments, the wireless network may be configured to operate according to specific standards or other types of predefined rules or procedures. Thus, particular embodiments of the wireless network may implement communication standards, such as Global System for Mobile Communications (GSM), Universal Mobile Telecommunications System (UMTS), Long Term Evolution (LTE), and/or other suitable 2G, 3G, 4G, or 5G standards; wireless local area network (WLAN) standards, such as the IEEE 802.11 standards; and/or any other appropriate wireless communication standard, such as the Worldwide Interoperability for Microwave Access (WiMax), Bluetooth, Z-Wave and/or ZigBee standards.

Network 106 may comprise one or more backhaul networks, core networks, IP networks, public switched telephone networks (PSTNs), packet data networks, optical networks, wide-area networks (WANs), local area networks (LANs), wireless local area networks (WLANs), wired networks, wireless networks, metropolitan area networks, and other networks to enable communication between devices.

Network node 160 and wireless device 110 comprise various components described in more detail below. These components work together in order to provide network node and/or wireless device functionality, such as providing wireless connections in a wireless network. In different embodiments, the wireless network may comprise any number of wired or wireless networks, network nodes, base stations, controllers, wireless devices, relay stations, and/or any other components or systems that may facilitate or participate in the communication of data and/or signals whether via wired or wireless connections.

FIGURE 4 illustrates an example network node 160, according to certain embodiments. As used herein, network node refers to equipment capable, configured, arranged and/or operable to communicate directly or indirectly with a wireless device and/or with other network nodes or equipment in the wireless network to enable and/or provide wireless access to the wireless device and/or to perform other functions (e.g., administration) in the wireless network. Examples of network nodes include, but are not limited to, access points (APs) (e.g., radio access points), base stations (BSs) (e.g., radio base stations, Node Bs, evolved Node Bs (eNBs) and NR NodeBs (gNBs)). Base stations may be categorized based on the amount of coverage they provide (or, stated differently, their transmit power level) and may then also be referred to as femto base stations, pico base stations, micro base stations, or macro base stations. A base station may be a relay node or a relay donor node controlling a relay. A network node may also include one or more (or all) parts of a distributed radio base station such as centralized digital units and/or remote radio units (RRUs), sometimes referred to as Remote Radio Heads (RRHs). Such remote radio units may or may not be integrated with an antenna as an antenna integrated radio. Parts of a distributed radio base station may also be referred to as nodes in a distributed antenna system (DAS). Yet further examples of network nodes include multi-standard radio (MSR) equipment such as MSR BSs, network controllers such as radio network controllers (RNCs) or base station controllers (BSCs), base transceiver stations (BTSs), transmission points, transmission nodes, multi-cell/multicast coordination entities (MCEs), core network nodes (e.g., MSCs, MMEs), O&M nodes, OSS nodes, SON nodes, positioning nodes (e.g., E-SMLCs), and/or MDTs. As another example, a network node may be a virtual network node as described in more detail below. More generally, however, network nodes may represent any suitable device (or group of devices) capable, configured, arranged, and/or operable to enable and/or provide a wireless device with access to the wireless network or to provide some service to a wireless device that has accessed the wireless network.

In FIGURE 4, network node 160 includes processing circuitry 170, device readable medium 180, interface 190, auxiliary equipment 184, power source 186, power circuitry 187, and antenna 162. Although network node 160 illustrated in the example wireless network of FIGURE 4 may represent a device that includes the illustrated combination of hardware components, other embodiments may comprise network nodes with different combinations of components. It is to be understood that a network node comprises any suitable combination of hardware and/or software needed to perform the tasks, features, functions and methods disclosed herein. Moreover, while the components of network node 160 are depicted as single boxes located within a larger box, or nested within multiple boxes, in practice, a network node may comprise multiple different physical components that make up a single illustrated component (e.g., device readable medium 180 may comprise multiple separate hard drives as well as multiple RAM modules).

Similarly, network node 160 may be composed of multiple physically separate components (e.g., a NodeB component and a RNC component, or a BTS component and a BSC component, etc.), which may each have their own respective components. In certain scenarios in which network node 160 comprises multiple separate components (e.g., BTS and BSC components), one or more of the separate components may be shared among several network nodes. For example, a single RNC may control multiple NodeB's. In such a scenario, each unique NodeB and RNC pair, may in some instances be considered a single separate network node. In some embodiments, network node 160 may be configured to support multiple radio access technologies (RATs). In such embodiments, some components may be duplicated (e.g., separate device readable medium 180 for the different RATs) and some components may be reused (e.g., the same antenna 162 may be shared by the RATs). Network node 160 may also include multiple sets of the various illustrated components for different wireless technologies integrated into network node 160, such as, for example, GSM, WCDMA, LTE, NR, WiFi, or Bluetooth wireless technologies. These wireless technologies may be integrated into the same or different chip or set of chips and other components within network node 160.

Processing circuitry 170 is configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being provided by a network node. These operations performed by processing circuitry 170 may include processing information obtained by processing circuitry 170 by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored in the network node, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination.

Processing circuitry 170 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software and/or encoded logic operable to provide, either alone or in conjunction with other network node 160 components, such as device readable medium 180, network node 160 functionality. For example, processing circuitry 170 may execute instructions stored in device readable medium 180 or in memory within processing circuitry 170. Such functionality may include providing any of the various wireless features, functions, or benefits discussed herein. In some embodiments, processing circuitry 170 may include a system on a chip (SOC).

In some embodiments, processing circuitry 170 may include one or more of radio frequency (RF) transceiver circuitry 172 and baseband processing circuitry 174. In some embodiments, radio frequency (RF) transceiver circuitry 172 and baseband processing circuitry 174 may be on separate chips (or sets of chips), boards, or units, such as radio units and digital units. In alternative embodiments, part or all of RF transceiver circuitry 172 and baseband processing circuitry 174 may be on the same chip or set of chips, boards, or units.

In certain embodiments, some or all of the functionality described herein as being provided by a network node, base station, eNB or other such network device may be performed by processing circuitry 170 executing instructions stored on device readable medium 180 or memory within processing circuitry 170. In alternative embodiments, some or all of the functionality may be provided by processing circuitry 170 without executing instructions stored on a separate or discrete device readable medium, such as in a hard-wired manner. In any of those embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry 170 can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry 170 alone or to other components of network node 160 but are enjoyed by network node 160 as a whole, and/or by end users and the wireless network generally.

Device readable medium 180 may comprise any form of volatile or non-volatile computer readable memory including, without limitation, persistent storage, solid-state memory, remotely mounted memory, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), mass storage media (for example, a hard disk), removable storage media (for example, a flash drive, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer-executable memory devices that store information, data, and/or instructions that may be used by processing circuitry 170. Device readable medium 180 may store any suitable instructions, data or information, including a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by processing circuitry 170 and, utilized by network node 160. Device readable medium 180 may be used to store any calculations made by processing circuitry 170 and/or any data received via interface 190. In some embodiments, processing circuitry 170 and device readable medium 180 may be considered to be integrated.

Interface 190 is used in the wired or wireless communication of signalling and/or data between network node 160, network 106, and/or wireless devices 110. As illustrated, interface 190 comprises port(s)/terminal(s) 194 to send and receive data, for example to and from network 106 over a wired connection. Interface 190 also includes radio front end circuitry 192 that may be coupled to, or in certain embodiments a part of, antenna 162. Radio front end circuitry 192 comprises filters 198 and amplifiers 196. Radio front end circuitry 192 may be connected to antenna 162 and processing circuitry 170. Radio front end circuitry may be configured to condition signals communicated between antenna 162 and processing circuitry 170. Radio front end circuitry 192 may receive digital data that is to be sent out to other network nodes or wireless devices via a wireless connection. Radio front end circuitry 192 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 198 and/or amplifiers 196. The radio signal may then be transmitted via antenna 162. Similarly, when receiving data, antenna 162 may collect radio signals which are then converted into digital data by radio front end circuitry 192. The digital data may be passed to processing circuitry 170. In other embodiments, the interface may comprise different components and/or different combinations of components.

In certain alternative embodiments, network node 160 may not include separate radio front end circuitry 192, instead, processing circuitry 170 may comprise radio front end circuitry and may be connected to antenna 162 without separate radio front end circuitry 192. Similarly, in some embodiments, all or some of RF transceiver circuitry 172 may be considered a part of interface 190. In still other embodiments, interface 190 may include one or more ports or terminals 194, radio front end circuitry 192, and RF transceiver circuitry 172, as part of a radio unit (not shown), and interface 190 may communicate with baseband processing circuitry 174, which is part of a digital unit (not shown).

Antenna 162 may include one or more antennas, or antenna arrays, configured to send and/or receive wireless signals. Antenna 162 may be coupled to radio front end circuitry 190 and may be any type of antenna capable of transmitting and receiving data and/or signals wirelessly. In some embodiments, antenna 162 may comprise one or more omni-directional, sector or panel antennas operable to transmit/receive radio signals between, for example, 2 GHz and 66 GHz. An omni-directional antenna may be used to transmit/receive radio signals in any direction, a sector antenna may be used to transmit/receive radio signals from devices within a particular area, and a panel antenna may be a line of sight antenna used to transmit/receive radio signals in a relatively straight line. In some instances, the use of more than one antenna may be referred to as MIMO. In certain embodiments, antenna 162 may be separate from network node 160 and may be connectable to network node 160 through an interface or port.

Antenna 162, interface 190, and/or processing circuitry 170 may be configured to perform any receiving operations and/or certain obtaining operations described herein as being performed by a network node. Any information, data and/or signals may be received from a wireless device, another network node and/or any other network equipment. Similarly, antenna 162, interface 190, and/or processing circuitry 170 may be configured to perform any transmitting operations described herein as being performed by a network node. Any information, data and/or signals may be transmitted to a wireless device, another network node and/or any other network equipment.

Power circuitry 187 may comprise, or be coupled to, power management circuitry and is configured to supply the components of network node 160 with power for performing the functionality described herein. Power circuitry 187 may receive power from power source 186. Power source 186 and/or power circuitry 187 may be configured to provide power to the various components of network node 160 in a form suitable for the respective components (e.g., at a voltage and current level needed for each respective component). Power source 186 may either be included in, or external to, power circuitry 187 and/or network node 160. For example, network node 160 may be connectable to an external power source (e.g., an electricity outlet) via an input circuitry or interface such as an electrical cable, whereby the external power source supplies power to power circuitry 187. As a further example, power source 186 may comprise a source of power in the form of a battery or battery pack which is connected to, or integrated in, power circuitry 187. The battery may provide backup power should the external power source fail. Other types of power sources, such as photovoltaic devices, may also be used.

Alternative embodiments of network node 160 may include additional components beyond those shown in FIGURE 4 that may be responsible for providing certain aspects of the network node’s functionality, including any of the functionality described herein and/or any functionality necessary to support the subject matter described herein. For example, network node 160 may include user interface equipment to allow input of information into network node 160 and to allow output of information from network node 160. This may allow a user to perform diagnostic, maintenance, repair, and other administrative functions for network node 160.

FIGURE 5 illustrates an example wireless device 110. According to certain embodiments. As used herein, wireless device refers to a device capable, configured, arranged and/or operable to communicate wirelessly with network nodes and/or other wireless devices. Unless otherwise noted, the term wireless device may be used interchangeably herein with user equipment (UE). Communicating wirelessly may involve transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information through air. In some embodiments, a wireless device may be configured to transmit and/or receive information without direct human interaction. For instance, a wireless device may be designed to transmit information to a network on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the network. Examples of a wireless device include, but are not limited to, a smart phone, a mobile phone, a cell phone, a voice over IP (VoIP) phone, a wireless local loop phone, a desktop computer, a personal digital assistant (PDA), a wireless cameras, a gaming console or device, a music storage device, a playback appliance, a wearable terminal device, a wireless endpoint, a mobile station, a tablet, a laptop, a laptop-embedded equipment (LEE), a laptop-mounted equipment (LME), a smart device, a wireless customer-premise equipment (CPE). a vehicle-mounted wireless terminal device, etc. A wireless device may support device-to-device (D2D) communication, for example by implementing a 3GPP standard for sidelink communication, vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-everything (V2X) and may in this case be referred to as a D2D communication device. As yet another specific example, in an Internet of Things (IoT) scenario, a wireless device may represent a machine or other device that performs monitoring and/or measurements and transmits the results of such monitoring and/or measurements to another wireless device and/or a network node. The wireless device may in this case be a machine-to-machine (M2M) device, which may in a 3GPP context be referred to as an MTC device. As one particular example, the wireless device may be a UE implementing the 3GPP narrow band internet of things (NB-IoT) standard. Particular examples of such machines or devices are sensors, metering devices such as power meters, industrial machinery, or home or personal appliances (e.g. refrigerators, televisions, etc.) personal wearables (e.g., watches, fitness trackers, etc.). In other scenarios, a wireless device may represent a vehicle or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation. A wireless device as described above may represent the endpoint of a wireless connection, in which case the device may be referred to as a wireless terminal. Furthermore, a wireless device as described above may be mobile, in which case it may also be referred to as a mobile device or a mobile terminal.

As illustrated, wireless device 110 includes antenna 111, interface 114, processing circuitry 120, device readable medium 130, user interface equipment 132, auxiliary equipment 134, power source 136 and power circuitry 137. Wireless device 110 may include multiple sets of one or more of the illustrated components for different wireless technologies supported by wireless device 110, such as, for example, GSM, WCDMA, LTE, NR, WiFi, WiMAX, or Bluetooth wireless technologies, just to mention a few. These wireless technologies may be integrated into the same or different chips or set of chips as other components within wireless device 110.

Antenna 111 may include one or more antennas or antenna arrays, configured to send and/or receive wireless signals, and is connected to interface 114. In certain alternative embodiments, antenna 111 may be separate from wireless device 110 and be connectable to wireless device 110 through an interface or port. Antenna 111, interface 114, and/or processing circuitry 120 may be configured to perform any receiving or transmitting operations described herein as being performed by a wireless device. Any information, data and/or signals may be received from a network node and/or another wireless device. In some embodiments, radio front end circuitry and/or antenna 111 may be considered an interface.

As illustrated, interface 114 comprises radio front end circuitry 112 and antenna 111. Radio front end circuitry 112 comprise one or more filters 118 and amplifiers 116. Radio front end circuitry 114 is connected to antenna 111 and processing circuitry 120 and is configured to condition signals communicated between antenna 111 and processing circuitry 120. Radio front end circuitry 112 may be coupled to or a part of antenna 111. In some embodiments, wireless device 110 may not include separate radio front end circuitry 112; rather, processing circuitry 120 may comprise radio front end circuitry and may be connected to antenna 111. Similarly, in some embodiments, some or all of RF transceiver circuitry 122 may be considered a part of interface 114. Radio front end circuitry 112 may receive digital data that is to be sent out to other network nodes or wireless devices via a wireless connection. Radio front end circuitry 112 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 118 and/or amplifiers 116. The radio signal may then be transmitted via antenna 111. Similarly, when receiving data, antenna 111 may collect radio signals which are then converted into digital data by radio front end circuitry 112. The digital data may be passed to processing circuitry 120. In other embodiments, the interface may comprise different components and/or different combinations of components.

Processing circuitry 120 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software, and/or encoded logic operable to provide, either alone or in conjunction with other wireless device 110 components, such as device readable medium 130, wireless device 110 functionality. Such functionality may include providing any of the various wireless features or benefits discussed herein. For example, processing circuitry 120 may execute instructions stored in device readable medium 130 or in memory within processing circuitry 120 to provide the functionality disclosed herein.

As illustrated, processing circuitry 120 includes one or more of RF transceiver circuitry 122, baseband processing circuitry 124, and application processing circuitry 126. In other embodiments, the processing circuitry may comprise different components and/or different combinations of components. In certain embodiments processing circuitry 120 of wireless device 110 may comprise a SOC. In some embodiments, RF transceiver circuitry 122, baseband processing circuitry 124, and application processing circuitry 126 may be on separate chips or sets of chips. In alternative embodiments, part or all of baseband processing circuitry 124 and application processing circuitry 126 may be combined into one chip or set of chips, and RF transceiver circuitry 122 may be on a separate chip or set of chips. In still alternative embodiments, part or all of RF transceiver circuitry 122 and baseband processing circuitry 124 may be on the same chip or set of chips, and application processing circuitry 126 may be on a separate chip or set of chips. In yet other alternative embodiments, part or all of RF transceiver circuitry 122, baseband processing circuitry 124, and application processing circuitry 126 may be combined in the same chip or set of chips. In some embodiments, RF transceiver circuitry 122 may be a part of interface 114. RF transceiver circuitry 122 may condition RF signals for processing circuitry 120.

In certain embodiments, some or all of the functionality described herein as being performed by a wireless device may be provided by processing circuitry 120 executing instructions stored on device readable medium 130, which in certain embodiments may be a computer-readable storage medium. In alternative embodiments, some or all of the functionality may be provided by processing circuitry 120 without executing instructions stored on a separate or discrete device readable storage medium, such as in a hard-wired manner. In any of those particular embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry 120 can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry 120 alone or to other components of wireless device 110, but are enjoyed by wireless device 110 as a whole, and/or by end users and the wireless network generally.

Processing circuitry 120 may be configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being performed by a wireless device. These operations, as performed by processing circuitry 120, may include processing information obtained by processing circuitry 120 by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored by wireless device 110, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination.

Device readable medium 130 may be operable to store a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by processing circuitry 120. Device readable medium 130 may include computer memory (e.g., Random Access Memory (RAM) or Read Only Memory (ROM)), mass storage media (e.g., a hard disk), removable storage media (e.g., a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer executable memory devices that store information, data, and/or instructions that may be used by processing circuitry 120. In some embodiments, processing circuitry 120 and device readable medium 130 may be considered to be integrated.

User interface equipment 132 may provide components that allow for a human user to interact with wireless device 110. Such interaction may be of many forms, such as visual, audial, tactile, etc. User interface equipment 132 may be operable to produce output to the user and to allow the user to provide input to wireless device 110. The type of interaction may vary depending on the type of user interface equipment 132 installed in wireless device 110. For example, if wireless device 110 is a smart phone, the interaction may be via a touch screen; if wireless device 110 is a smart meter, the interaction may be through a screen that provides usage (e.g., the number of gallons used) or a speaker that provides an audible alert (e.g., if smoke is detected). User interface equipment 132 may include input interfaces, devices and circuits, and output interfaces, devices and circuits. User interface equipment 132 is configured to allow input of information into wireless device 110 and is connected to processing circuitry 120 to allow processing circuitry 120 to process the input information. User interface equipment 132 may include, for example, a microphone, a proximity or other sensor, keys/buttons, a touch display, one or more cameras, a USB port, or other input circuitry. User interface equipment 132 is also configured to allow output of information from wireless device

110, and to allow processing circuitry 120 to output information from wireless device 110. User interface equipment 132 may include, for example, a speaker, a display, vibrating circuitry, a USB port, a headphone interface, or other output circuitry. Using one or more input and output interfaces, devices, and circuits, of user interface equipment 132, wireless device 110 may communicate with end users and/or the wireless network and allow them to benefit from the functionality described herein.

Auxiliary equipment 134 is operable to provide more specific functionality which may not be generally performed by wireless devices. This may comprise specialized sensors for doing measurements for various purposes, interfaces for additional types of communication such as wired communications etc. The inclusion and type of components of auxiliary equipment 134 may vary depending on the embodiment and/or scenario.

Power source 136 may, in some embodiments, be in the form of a battery or battery pack. Other types of power sources, such as an external power source (e.g., an electricity outlet), photovoltaic devices or power cells, may also be used. wireless device 110 may further comprise power circuitry 137 for delivering power from power source 136 to the various parts of wireless device 110 which need power from power source 136 to carry out any functionality described or indicated herein. Power circuitry 137 may in certain embodiments comprise power management circuitry. Power circuitry 137 may additionally or alternatively be operable to receive power from an external power source; in which case wireless device 110 may be connectable to the external power source (such as an electricity outlet) via input circuitry or an interface such as an electrical power cable. Power circuitry 137 may also in certain embodiments be operable to deliver power from an external power source to power source 136. This may be, for example, for the charging of power source 136. Power circuitry 137 may perform any formatting, converting, or other modification to the power from power source 136 to make the power suitable for the respective components of wireless device 110 to which power is supplied.

FIGURE 6 illustrates one embodiment of a UE in accordance with various aspects described herein. As used herein, a user equipment or UE may not necessarily have a user in the sense of a human user who owns and/or operates the relevant device. Instead, a UE may represent a device that is intended for sale to, or operation by, a human user but which may not, or which may not initially, be associated with a specific human user (e.g., a smart sprinkler controller). Alternatively, a UE may represent a device that is not intended for sale to, or operation by, an end user but which may be associated with or operated for the benefit of a user (e.g., a smart power meter). UE 200 may be any UE identified by the 3rd Generation Partnership Project (3GPP), including a NB-IoT UE, a machine type communication (MTC) UE, and/or an enhanced MTC (eMTC) UE. UE 200, as illustrated in FIGURE 4, is one example of a wireless device configured for communication in accordance with one or more communication standards promulgated by the 3rd Generation Partnership Project (3GPP), such as 3GPP's GSM, UMTS, LTE, and/or 5G standards. As mentioned previously, the term wireless device and UE may be used interchangeable. Accordingly, although FIGURE 6 is a UE, the components discussed herein are equally applicable to a wireless device, and vice-versa.

In FIGURE 6, UE 200 includes processing circuitry 201 that is operatively coupled to input/output interface 205, radio frequency (RF) interface 209, network connection interface 211, memory 215 including random access memory (RAM) 217, read-only memory (ROM) 219, and storage medium 221 or the like, communication subsystem 231, power source 233, and/or any other component, or any combination thereof. Storage medium 221 includes operating system 223, application program 225, and data 227. In other embodiments, storage medium 221 may include other similar types of information. Certain UEs may utilize all of the components shown in FIGURE 6, or only a subset of the components. The level of integration between the components may vary from one UE to another UE. Further, certain UEs may contain multiple instances of a component, such as multiple processors, memories, transceivers, transmitters, receivers, etc.

In FIGURE 6, processing circuitry 201 may be configured to process computer instructions and data. Processing circuitry 201 may be configured to implement any sequential state machine operative to execute machine instructions stored as machine-readable computer programs in the memory, such as one or more hardware-implemented state machines (e.g., in discrete logic, FPGA, ASIC, etc.); programmable logic together with appropriate firmware; one or more stored program, general-purpose processors, such as a microprocessor or Digital Signal Processor (DSP), together with appropriate software; or any combination of the above. For example, the processing circuitry 201 may include two central processing units (CPUs). Data may be information in a form suitable for use by a computer.

In the depicted embodiment, input/output interface 205 may be configured to provide a communication interface to an input device, output device, or input and output device. UE 200 may be configured to use an output device via input/output interface 205. An output device may use the same type of interface port as an input device. For example, a USB port may be used to provide input to and output from UE 200. The output device may be a speaker, a sound card, a video card, a display, a monitor, a printer, an actuator, an emitter, a smartcard, another output device, or any combination thereof. UE 200 may be configured to use an input device via input/output interface 205 to allow a user to capture information into UE 200. The input device may include a touch-sensitive or presence-sensitive display, a camera (e.g., a digital camera, a digital video camera, a web camera, etc.), a microphone, a sensor, a mouse, a trackball, a directional pad, a trackpad, a scroll wheel, a smartcard, and the like. The presence-sensitive display may include a capacitive or resistive touch sensor to sense input from a user. A sensor may be, for instance, an accelerometer, a gyroscope, a tilt sensor, a force sensor, a magnetometer, an optical sensor, a proximity sensor, another like sensor, or any combination thereof. For example, the input device may be an accelerometer, a magnetometer, a digital camera, a microphone, and an optical sensor.

In FIGURE 6, RF interface 209 may be configured to provide a communication interface to RF components such as a transmitter, a receiver, and an antenna. Network connection interface 211 may be configured to provide a communication interface to network 243a. Network 243a may encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, network 243a may comprise a Wi-Fi network. Network connection interface 211 may be configured to include a receiver and a transmitter interface used to communicate with one or more other devices over a communication network according to one or more communication protocols, such as Ethernet, TCP/IP, SONET, ATM, or the like. Network connection interface 211 may implement receiver and transmitter functionality appropriate to the communication network links (e.g., optical, electrical, and the like). The transmitter and receiver functions may share circuit components, software or firmware, or alternatively may be implemented separately.

RAM 217 may be configured to interface via bus 202 to processing circuitry 201 to provide storage or caching of data or computer instructions during the execution of software programs such as the operating system, application programs, and device drivers. ROM 219 may be configured to provide computer instructions or data to processing circuitry 201. For example, ROM 219 may be configured to store invariant low-level system code or data for basic system functions such as basic input and output (I/O), startup, or reception of keystrokes from a keyboard that are stored in a non-volatile memory. Storage medium 221 may be configured to include memory such as RAM, ROM, programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic disks, optical disks, floppy disks, hard disks, removable cartridges, or flash drives. In one example, storage medium 221 may be configured to include operating system 223, application program 225 such as a web browser application, a widget or gadget engine or another application, and data file 227. Storage medium 221 may store, for use by UE 200, any of a variety of various operating systems or combinations of operating systems.

Storage medium 221 may be configured to include a number of physical drive units, such as redundant array of independent disks (RAID), floppy disk drive, flash memory, USB flash drive, external hard disk drive, thumb drive, pen drive, key drive, high-density digital versatile disc (HD-DVD) optical disc drive, internal hard disk drive, Blu-Ray optical disc drive, holographic digital data storage (HDDS) optical disc drive, external mini-dual in-line memory module (DIMM), synchronous dynamic random access memory (SDRAM), external micro-DIMM SDRAM, smartcard memory such as a subscriber identity module or a removable user identity (SIM/RUIM) module, other memory, or any combination thereof. Storage medium 221 may allow UE 200 to access computer-executable instructions, application programs or the like, stored on transitory or non-transitory memory media, to off-load data, or to upload data. An article of manufacture, such as one utilizing a communication system may be tangibly embodied in storage medium 221, which may comprise a device readable medium.

In FIGURE 6, processing circuitry 201 may be configured to communicate with network 243b using communication subsystem 231. Network 243a and network 243b may be the same network or networks or different network or networks. Communication subsystem 231 may be configured to include one or more transceivers used to communicate with network 243b. For example, communication subsystem 231 may be configured to include one or more transceivers used to communicate with one or more remote transceivers of another device capable of wireless communication such as another wireless device, UE, or base station of a radio access network (RAN) according to one or more communication protocols, such as IEEE 802.2, CDMA, WCDMA, GSM, LTE, UTRAN, WiMax, or the like. Each transceiver may include transmitter 233 and/or receiver 235 to implement transmitter or receiver functionality, respectively, appropriate to the RAN links (e.g., frequency allocations and the like). Further, transmitter 233 and receiver 235 of each transceiver may share circuit components, software or firmware, or alternatively may be implemented separately.

In the illustrated embodiment, the communication functions of communication subsystem 231 may include data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, near-field communication, location-based communication such as the use of the global positioning system (GPS) to determine a location, another like communication function, or any combination thereof. For example, communication subsystem 231 may include cellular communication, Wi-Fi communication, Bluetooth communication, and GPS communication. Network 243b may encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, network 243b may be a cellular network, a Wi-Fi network, and/or a near-field network. Power source 213 may be configured to provide alternating current (AC) or direct current (DC) power to components of UE 200.

The features, benefits and/or functions described herein may be implemented in one of the components of UE 200 or partitioned across multiple components of UE 200. Further, the features, benefits, and/or functions described herein may be implemented in any combination of hardware, software or firmware. In one example, communication subsystem 231 may be configured to include any of the components described herein. Further, processing circuitry 201 may be configured to communicate with any of such components over bus 202. In another example, any of such components may be represented by program instructions stored in memory that when executed by processing circuitry 201 perform the corresponding functions described herein. In another example, the functionality of any of such components may be partitioned between processing circuitry 201 and communication subsystem 231. In another example, the non-computationally intensive functions of any of such components may be implemented in software or firmware and the computationally intensive functions may be implemented in hardware.

FIGURE 7 is a schematic block diagram illustrating a virtualization environment 300 in which functions implemented by some embodiments may be virtualized. In the present context, virtualizing means creating virtual versions of apparatuses or devices which may include virtualizing hardware platforms, storage devices and networking resources. As used herein, virtualization can be applied to a node (e.g., a virtualized base station or a virtualized radio access node) or to a device (e.g., a UE, a wireless device or any other type of communication device) or components thereof and relates to an implementation in which at least a portion of the functionality is implemented as one or more virtual components (e.g., via one or more applications, components, functions, virtual machines or containers executing on one or more physical processing nodes in one or more networks).

In some embodiments, some or all of the functions described herein may be implemented as virtual components executed by one or more virtual machines implemented in one or more virtual environments 300 hosted by one or more of hardware nodes 330. Further, in embodiments in which the virtual node is not a radio access node or does not require radio connectivity (e.g., a core network node), then the network node may be entirely virtualized.

The functions may be implemented by one or more applications 320 (which may alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) operative to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein. Applications 320 are run in virtualization environment 300 which provides hardware 330 comprising processing circuitry 360 and memory 390. Memory 390 contains instructions 395 executable by processing circuitry 360 whereby application 320 is operative to provide one or more of the features, benefits, and/or functions disclosed herein.

Virtualization environment 300, comprises general-purpose or special-purpose network hardware devices 330 comprising a set of one or more processors or processing circuitry 360, which may be commercial off-the-shelf (COTS) processors, dedicated Application Specific Integrated Circuits (ASICs), or any other type of processing circuitry including digital or analog hardware components or special purpose processors. Each hardware device may comprise memory 390-1 which may be non-persistent memory for temporarily storing instructions 395 or software executed by processing circuitry 360. Each hardware device may comprise one or more network interface controllers (NICs) 370, also known as network interface cards, which include physical network interface 380. Each hardware device may also include non-transitory, persistent, machine-readable storage media 390-2 having stored therein software 395 and/or instructions executable by processing circuitry 360. Software 395 may include any type of software including software for instantiating one or more virtualization layers 350 (also referred to as hypervisors), software to execute virtual machines 340 as well as software allowing it to execute functions, features and/or benefits described in relation with some embodiments described herein.

Virtual machines 340, comprise virtual processing, virtual memory, virtual networking or interface and virtual storage, and may be run by a corresponding virtualization layer 350 or hypervisor. Different embodiments of the instance of virtual appliance 320 may be implemented on one or more of virtual machines 340, and the implementations may be made in different ways.

During operation, processing circuitry 360 executes software 395 to instantiate the hypervisor or virtualization layer 350, which may sometimes be referred to as a virtual machine monitor (VMM). Virtualization layer 350 may present a virtual operating platform that appears like networking hardware to virtual machine 340.

As shown in FIGURE 7, hardware 330 may be a standalone network node with generic or specific components. Hardware 330 may comprise antenna 3225 and may implement some functions via virtualization. Alternatively, hardware 330 may be part of a larger cluster of hardware (e.g. such as in a data center or customer premise equipment (CPE)) where many hardware nodes work together and are managed via management and orchestration (MANO) 3100, which, among others, oversees lifecycle management of applications 320.

Virtualization of the hardware is in some contexts referred to as network function virtualization (NFV). NFV may be used to consolidate many network equipment types onto industry standard high volume server hardware, physical switches, and physical storage, which can be located in data centers, and customer premise equipment.

In the context of NFV, virtual machine 340 may be a software implementation of a physical machine that runs programs as if they were executing on a physical, non-virtualized machine. Each of virtual machines 340, and that part of hardware 330 that executes that virtual machine, be it hardware dedicated to that virtual machine and/or hardware shared by that virtual machine with others of the virtual machines 340, forms a separate virtual network elements (VNE).

Still in the context of NFV, Virtual Network Function (VNF) is responsible for handling specific network functions that run in one or more virtual machines 340 on top of hardware networking infrastructure 330 and corresponds to application 320 in FIGURE 7.

In some embodiments, one or more radio units 3200 that each include one or more transmitters 3220 and one or more receivers 3210 may be coupled to one or more antennas 3225. Radio units 3200 may communicate directly with hardware nodes 330 via one or more appropriate network interfaces and may be used in combination with the virtual components to provide a virtual node with radio capabilities, such as a radio access node or a base station.

In some embodiments, some signaling can be affected with the use of control system 3230 which may alternatively be used for communication between the hardware nodes 330 and radio units 3200.

FIGURE 8 illustrates a telecommunication network connected via an intermediate network to a host computer in accordance with some embodiments.

With reference to FIGURE 8, in accordance with an embodiment, a communication system includes telecommunication network 410, such as a 3GPP-type cellular network, which comprises access network 411, such as a radio access network, and core network 414. Access network 411 comprises a plurality of base stations 412a, 412b, 412c, such as NBs, eNBs, gNBs or other types of wireless access points, each defining a corresponding coverage area 413a, 413b, 413c. Each base station 412a, 412b, 412c is connectable to core network 414 over a wired or wireless connection 415. A first UE 491 located in coverage area 413c is configured to wirelessly connect to, or be paged by, the corresponding base station 412c. A second UE 492 in coverage area 413a is wirelessly connectable to the corresponding base station 412a. While a plurality of UEs 491, 492 are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole UE is in the coverage area or where a sole UE is connecting to the corresponding base station 412.

Telecommunication network 410 is itself connected to host computer 430, which may be embodied in the hardware and/or software of a standalone server, a cloud-implemented server, a distributed server or as processing resources in a server farm. Host computer 430 may be under the ownership or control of a service provider or may be operated by the service provider or on behalf of the service provider. Connections 421 and 422 between telecommunication network 410 and host computer 430 may extend directly from core network 414 to host computer 430 or may go via an optional intermediate network 420. Intermediate network 420 may be one of, or a combination of more than one of, a public, private or hosted network; intermediate network 420, if any, may be a backbone network or the Internet; in particular, intermediate network 420 may comprise two or more sub-networks (not shown).

The communication system of FIGURE 8 as a whole enables connectivity between the connected UEs 491, 492 and host computer 430. The connectivity may be described as an over-the-top (OTT) connection 450. Host computer 430 and the connected UEs 491, 492 are configured to communicate data and/or signaling via OTT connection 450, using access network 411, core network 414, any intermediate network 420 and possible further infrastructure (not shown) as intermediaries. OTT connection 450 may be transparent in the sense that the participating communication devices through which OTT connection 450 passes are unaware of routing of uplink and downlink communications. For example, base station 412 may not or need not be informed about the past routing of an incoming downlink communication with data originating from host computer 430 to be forwarded (e.g., handed over) to a connected UE 491. Similarly, base station 412 need not be aware of the future routing of an outgoing uplink communication originating from the UE 491 towards the host computer 430.

FIGURE 9 illustrates a host computer communicating via a base station with a user equipment over a partially wireless connection in accordance with some embodiments.

Example implementations, in accordance with an embodiment, of the UE, base station and host computer discussed in the preceding paragraphs will now be described with reference to FIGURE 9. In communication system 500, host computer 510 comprises hardware 515 including communication interface 516 configured to set up and maintain a wired or wireless connection with an interface of a different communication device of communication system 500. Host computer 510 further comprises processing circuitry 518, which may have storage and/or processing capabilities. In particular, processing circuitry 518 may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Host computer 510 further comprises software 511, which is stored in or accessible by host computer 510 and executable by processing circuitry 518. Software 511 includes host application 512. Host application 512 may be operable to provide a service to a remote user, such as UE 530 connecting via OTT connection 550 terminating at UE 530 and host computer 510. In providing the service to the remote user, host application 512 may provide user data which is transmitted using OTT connection 550.

Communication system 500 further includes base station 520 provided in a telecommunication system and comprising hardware 525 enabling it to communicate with host computer 510 and with UE 530. Hardware 525 may include communication interface 526 for setting up and maintaining a wired or wireless connection with an interface of a different communication device of communication system 500, as well as radio interface 527 for setting up and maintaining at least wireless connection 570 with UE 530 located in a coverage area (not shown in FIGURE 9) served by base station 520. Communication interface 526 may be configured to facilitate connection 560 to host computer 510. Connection 560 may be direct or it may pass through a core network (not shown in FIGURE 9) of the telecommunication system and/or through one or more intermediate networks outside the telecommunication system. In the embodiment shown, hardware 525 of base station 520 further includes processing circuitry 528, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Base station 520 further has software 521 stored internally or accessible via an external connection.

Communication system 500 further includes UE 530 already referred to. Its hardware 535 may include radio interface 537 configured to set up and maintain wireless connection 570 with a base station serving a coverage area in which UE 530 is currently located. Hardware 535 of UE 530 further includes processing circuitry 538, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. UE 530 further comprises software 531, which is stored in or accessible by UE 530 and executable by processing circuitry 538. Software 531 includes client application 532. Client application 532 may be operable to provide a service to a human or non-human user via UE 530, with the support of host computer 510. In host computer 510, an executing host application 512 may communicate with the executing client application 532 via OTT connection 550 terminating at UE 530 and host computer 510. In providing the service to the user, client application 532 may receive request data from host application 512 and provide user data in response to the request data. OTT connection 550 may transfer both the request data and the user data. Client application 532 may interact with the user to generate the user data that it provides.

It is noted that host computer 510, base station 520 and UE 530 illustrated in FIGURE 9 may be similar or identical to host computer 430, one of base stations 412a, 412b, 412c and one of UEs 491, 492 of FIGURE 8, respectively. This is to say, the inner workings of these entities may be as shown in FIGURE 9 and independently, the surrounding network topology may be that of FIGURE 8.

In FIGURE 9, OTT connection 550 has been drawn abstractly to illustrate the communication between host computer 510 and UE 530 via base station 520, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Network infrastructure may determine the routing, which it may be configured to hide from UE 530 or from the service provider operating host computer 510, or both. While OTT connection 550 is active, the network infrastructure may further take decisions by which it dynamically changes the routing (e.g., on the basis of load balancing consideration or reconfiguration of the network).

Wireless connection 570 between UE 530 and base station 520 is in accordance with the teachings of the embodiments described throughout this disclosure. One or more of the various embodiments improve the performance of OTT services provided to UE 530 using OTT connection 550, in which wireless connection 570 forms the last segment. More precisely, the teachings of these embodiments may improve the data rate, latency, and/or power consumption and thereby provide benefits such as reduced user waiting time, relaxed restriction on file size, better responsiveness, and/or extended battery lifetime.

A measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring OTT connection 550 between host computer 510 and UE 530, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring OTT connection 550 may be implemented in software 511 and hardware 515 of host computer 510 or in software 531 and hardware 535 of UE 530, or both. In embodiments, sensors (not shown) may be deployed in or in association with communication devices through which OTT connection 550 passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above or supplying values of other physical quantities from which software 511, 531 may compute or estimate the monitored quantities. The reconfiguring of OTT connection 550 may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect base station 520, and it may be unknown or imperceptible to base station 520. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling facilitating host computer 510's measurements of throughput, propagation times, latency and the like. The measurements may be implemented in that software 511 and 531 causes messages to be transmitted, in particular empty or 'dummy' messages, using OTT connection 550 while it monitors propagation times, errors etc.

FIGURE 10 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGURES 8 and 9. For simplicity of the present disclosure, only drawing references to FIGURE 10 will be included in this section. In step 610, the host computer provides user data. In substep 611 (which may be optional) of step 610, the host computer provides the user data by executing a host application. In step 620, the host computer initiates a transmission carrying the user data to the UE. In step 630 (which may be optional), the base station transmits to the UE the user data which was carried in the transmission that the host computer initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In step 640 (which may also be optional), the UE executes a client application associated with the host application executed by the host computer.

FIGURE 11 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGURES 8 and 9. For simplicity of the present disclosure, only drawing references to FIGURE 11 will be included in this section. In step 710 of the method, the host computer provides user data. In an optional substep (not shown) the host computer provides the user data by executing a host application. In step 720, the host computer initiates a transmission carrying the user data to the UE. The transmission may pass via the base station, in accordance with the teachings of the embodiments described throughout this disclosure. In step 730 (which may be optional), the UE receives the user data carried in the transmission.

FIGURE 12 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGURES 8 and 9. For simplicity of the present disclosure, only drawing references to FIGURE 12 will be included in this section. In step 810 (which may be optional), the UE receives input data provided by the host computer. Additionally or alternatively, in step 820, the UE provides user data. In substep 821 (which may be optional) of step 820, the UE provides the user data by executing a client application. In substep 811 (which may be optional) of step 810, the UE executes a client application which provides the user data in reaction to the received input data provided by the host computer. In providing the user data, the executed client application may further consider user input received from the user. Regardless of the specific manner in which the user data was provided, the UE initiates, in substep 830 (which may be optional), transmission of the user data to the host computer. In step 840 of the method, the host computer receives the user data transmitted from the UE, in accordance with the teachings of the embodiments described throughout this disclosure.

FIGURE 13 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGURES 8 and 9. For simplicity of the present disclosure, only drawing references to FIGURE 13 will be included in this section. In step 910 (which may be optional), in accordance with the teachings of the embodiments described throughout this disclosure, the base station receives user data from the UE. In step 920 (which may be optional), the base station initiates transmission of the received user data to the host computer. In step 930 (which may be optional), the host computer receives the user data carried in the transmission initiated by the base station.

FIGURE 14 depicts a method 1000 by a wireless device 110, according to certain embodiments. At step 1002, the wireless device determines at least one BO for receiving at least one signal. While in an idle or inactive reception mode, the wireless device receives the at least one signal during the at least one BO, at step 1004. As used herein, the term signal is to be interpreted broadly. A signal may comprise/carry/convey information such as one or more messages and/or one or more bits.

According to particular embodiments, while in the IIRM of NR MBMS, a wireless device is able to receive/listen to periodic and aperiodic traffic. In this mode, instead of transitioning into RRC CONNECTED mode, which happens in the current NR and legacy systems, the signaled UEs remain in RRC IDLE/INACTIVE mode and are able to receive the transmission.

In a particular embodiment, the at least one signal comprises at least one periodic signal.

In a particular embodiment, the at least one signal comprises at least one aperiodic signal.

In a particular embodiment, the wireless device detects an occurrence of a trigger event and, in response to detecting the occurrence of the trigger event, transitions into the idle or inactive reception mode.

In a particular embodiment, the trigger event comprises a signal received from a network node.

In a particular embodiment, the trigger event comprising the signal received from the network node is a RRC message.

In a particular embodiment, the trigger event comprises occurrence/absence of ACK/NACK.

In a particular embodiment, the wireless device obtains information associating the wireless device with at least one group of wireless devices. In a further particular embodiment, the obtaining comprises receiving the information from a network node; or obtaining information stored in the wireless device; or determining the information.

In a particular embodiment, the information comprises at least one group identifier.

In a particular embodiment, the at least one BO is determined based on the information associating the wireless device with the at least one group of wireless devices.

In a particular embodiment, the at least one BO is the same for all wireless devices in the at least one group of wireless devices.

In a particular embodiment, the at least one BO is determined in response to a paging-like message transmitted to the at least one group of wireless devices.

In a particular embodiment, the wireless device is associated with a plurality of groups of wireless devices. Each of the groups of devices being associated with a respective DRX pattern. For each group of the plurality of groups, the wireless device monitors for the respective DRX pattern (or the wireless device monitors in accordance with the respective DRX pattern) associated with that group. In a further particular embodiment, each of the DRX patterns is assigned a priority.

In a particular embodiment, the wireless device receives system information from a network node and determining the at least one BO based on the system information.

In a particular embodiment, the wireless device transitions into the idle or inactive reception mode based on the system information.

In a particular embodiment, the wireless device determines that the wireless device is within a geographical area and transitions into the idle or inactive reception mode in response to determining that the wireless device is within the geographical area.

In a particular embodiment, the wireless device determines that the network node has not received more than a threshold number of HARQ messages and transitioning from a connected mode into the idle or inactive reception mode in response to determining that the network node has not received more than the threshold number of HARQ messages.

In a particular embodiment, the wireless device receives a radio resource control message and transitions into the idle or inactive reception mode in response to receiving the radio resource control message.

In a particular embodiment, the network node is a base station.

In a particular embodiment, at least one of the wireless devices in the group of wireless devices is a user equipment.

FIGURE 15 illustrates a schematic block diagram of a virtual apparatus 1100 in a wireless network (for example, the wireless network shown in FIGURE 3). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 110 or network node 160 shown in FIGURE 3). Apparatus 1100 is operable to carry out the example method described with reference to FIGURE 14 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 14 is not necessarily carried out solely by apparatus 1100. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 1100 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause determining module 1110, receiving module 1120, and any other suitable units of apparatus 1100 to perform corresponding functions according one or more embodiments of the present disclosure.

According to certain embodiments, determining module 1110 may perform certain of the determining functions of the apparatus 1100. For example, determining module 1110 may determines at least one broadcast occasion (BO) for receiving at least one signal.

According to certain embodiments, receiving module 1120 may perform certain of the receiving functions of the apparatus 1100. For example, receiving module 1120 may receive the at least one signal during the at least one BO while in an idle or inactive reception mode.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

FIGURE 16 depicts another method 1200 by a wireless device 110, according to certain embodiments. Method 1200 is similar to method 1000 and may include similar steps and features and may be considered a more particular embodiment of method 1000. The method begins at step 1202 when the wireless device 110 receives, from a network node 160, system information that is scrambled with a RNTI specific for an IIRM or specific for a group of wireless devices. Based on the system information, the wireless device 110 determines at least one BO for receiving at least one signal, at step 1204. At step 1206, while in the IIRM, the wireless device 110 receives the at least one signal during the at least one BO.

In a particular embodiment, the system information is scrambled with a RNTI specific for a group of wireless devices, and the wireless device 110 obtains association information associating the wireless device 110 with the group of wireless devices.

In a further particular embodiment, obtaining the association information may include receiving the association information from a network node 160 or obtaining the association information stored in the wireless device 110 or determining the association information.

In a further particular embodiment, the association information comprises at least one group identifier.

In a further particular embodiment, the at least one BO is determined based on the association information associating the wireless device 110 with the group of wireless devices.

In a particular embodiment, determining the at least one BO may include descrambling the system information using the association information associating the wireless device 110 with the group of wireless devices and determining the at least one BO based on the descrambled system information.

In a particular embodiment, the system information is scrambled with a RNTI specific for the IIRM, and determining the at least one BO may include descrambling the system information using the RNTI specific for the IIRM and determining the at least one BO based on the descrambled system information.

In a particular embodiment, the at least one BO is the same for all wireless devices in the group of wireless devices.

In a particular embodiment, the system information is a message transmitted to the group of wireless devices, and the at least one BO is determined based on the message. In a particular embodiment, the message may be a paging-like message.

In a particular embodiment, the wireless device 110 is associated with a plurality of groups of wireless devices, and each of the groups of wireless devices is associated with a respective DRX pattern. For each group of the plurality of groups, the wireless device 110 may monitor the respective DRX pattern associated with that group. In a further particular embodiment, each DRX pattern is assigned a priority.

In a particular embodiment, the wireless device 110 detects an occurrence of a trigger event and, in response to detecting the occurrence of the trigger event, transitions into the IIRM.

In a further particular embodiment, detecting the occurrence of the trigger event may include at least one of: determining that the wireless device is within a geographical area; determining that the network node has not received more than a threshold number of HARQ messages in a certain time period; receiving a signal from the network node; receiving the system information from the network node; receiving a RRC message from the network node; detecting an occurrence of an ACK from the network node; detecting an absence of the ACK from the network node; detecting an occurrence of a NACK from the network node; and/or detecting an absence of the NACK from the network node.

In a further particular embodiment, the wireless device may be in connected mode when detecting the occurrence of the trigger event. In another particular embodiment, the wireless device may be in an idle or inactive mode when detecting the occurrence of the trigger event.

In a particular embodiment, the at least one signal includes at least one periodic signal or at least one aperiodic signal.

In a particular embodiment, the wireless device 110 receives, from the network node 160, the RNTI specific for the IIRM or the group of wireless devices.

FIGURE 17 illustrates a schematic block diagram of a virtual apparatus 1300 in a wireless network (for example, the wireless network shown in FIGURE 3). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 110 or network node 160 shown in FIGURE 3). Apparatus 1300 is operable to carry out the example method described with reference to FIGURE 16 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 16 is not necessarily carried out solely by apparatus 1300. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 1300 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause first receiving module 1310, determining module 1320, second receiving module 1330, and any other suitable units of apparatus 1300 to perform corresponding functions according one or more embodiments of the present disclosure.

According to certain embodiments, first receiving module 1310 may perform certain of the receiving functions of the apparatus 1300. For example, first receiving module 1310 may receive, from a network node 160, system information that is scrambled with a RNTI specific for an IIRM or specific for a group of wireless devices.

According to certain embodiments, determining module 1320 may perform certain of the determining functions of the apparatus 1300. For example, based on the system information, determining 1320 may determine at least one BO for receiving at least one signal.

According to certain embodiments, second receiving module 1330 may perform certain of the receiving functions of the apparatus 1300. For example, while in the IIRM, the second receiving module 1330 may receive the at least one signal during the at least one BO.

FIGURE 18 depicts a method 1400 by a network node 160, according to certain embodiments. At step 1402, the network node determines at least one broadcast occasion (BO) for transmitting at least one signal. While a wireless device is in the idle or inactive reception mode, the network node transmits the at least one signal to the wireless device during the at least one BO, at step 1404.

According to particular embodiments, while in the idle or inactive reception mode (IIRM) of NR MBMS, a wireless device is able to receive/listen to periodic and aperiodic traffic. In this mode, instead of transitioning into RRC CONNECTED mode, which happens in the current NR and legacy systems, the signaled UEs remain in RRC IDLE/INACTIVE mode and are able to receive the transmission.

In a particular embodiment, the at least one signal comprises at least one periodic signal.

In a particular embodiment, the at least one signal comprises at least one aperiodic signal.

In a particular embodiment, the network node transmits another signal to the wireless device to trigger the wireless device to transition into the idle or inactive reception mode. In a further particular embodiment, the other signal transmitted to the wireless device to trigger the wireless device to transition into the idle or inactive reception mode comprises a radio resource control (RRC) message. In a further embodiment, the trigger comprises occurrence/absence of ACK/NACK

In a particular embodiment, the network node obtains information associating the wireless device with at least one group of wireless devices.

In a particular embodiment, the obtaining comprises receiving the information from a network node; or obtaining information stored in the wireless device; or determining the information.

In a particular embodiment, the information comprises at least one group identifier.

In a particular embodiment, the at least one BO is determined based on the information associating the wireless device with the at least one group of wireless devices.

In a particular embodiment, the at least one BO is the same for all wireless devices in the at least one group of wireless devices.

In a particular embodiment, the at least one BO is determined in response to a paging-like message transmitted to the at least one group of wireless devices.

In a particular embodiment, the wireless device is associated with a plurality of groups of wireless devices. each of the groups of devices is associated with a respective DRX pattern. In a particular embodiment, each of the DRX patterns is assigned a priority.

In a particular embodiment, the network node transmits system information to the wireless device, wherein the at least one BO is determined based on the system information.

In a particular embodiment, the network node configures the wireless device to transition into the idle or inactive reception mode based on the system information.

In a particular embodiment, the network node configures the wireless device to transition into the idle or inactive reception mode in response to determining that the wireless device is within the geographical area.

In a particular embodiment, the network node configures the wireless device to transition into the idle or inactive reception mode in response to receiving a radio resource control message, and the network node transmits the radio resource control message.

In a particular embodiment, the network node is a base station.

In a particular embodiment, at least one of the wireless devices in the group of wireless devices is a user equipment.

FIGURE 19 illustrates a schematic block diagram of a virtual apparatus 1500 in a wireless network (for example, the wireless network shown in FIGURE 3). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 110 or network node 160 shown in FIGURE 3). Apparatus 1500 is operable to carry out the example method described with reference to FIGURE 18 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 18 is not necessarily carried out solely by apparatus 1500. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 1500 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause determining module 1510, transmitting module 1520, and any other suitable units of apparatus 1500 to perform corresponding functions according one or more embodiments of the present disclosure.

According to certain embodiments, determining module 1510 may perform certain of the determining functions of the apparatus 1500. For example, determining module 1510 may determine at least one broadcast occasion (BO) for transmitting at least one signal.

According to certain embodiments, transmitting module 1520 may perform certain of the transmitting functions of the apparatus 1500. For example, transmitting module 1520 may transmit, while a wireless device is in the idle or inactive reception mode, the at least one signal to the wireless device during the at least one BO.

FIGURE 20 depicts another method 1600 by a network node 160, according to certain embodiments. Method 1600 is similar to method 1400 and may include similar steps and features. Method 1600 may be considered a more particular embodiment of method 1400. The method begins at step 1602 when the network node 160 determines at least one BO for transmitting at least one signal. At step 1604, the network node 160 transmits, to a wireless device 110, system information that is scrambled with a RNTI specific for an IIRM or specific for a group of wireless devices. The system information indicates the at least one BO. While the wireless device is in the IIRM, the network node 160 transmits the at least one signal to the wireless device 110 during the at least one BO, at step 1606.

In a particular embodiment, the system information is scrambled with a RNTI specific for a group of wireless devices, and the network node 160 obtains association information associating the wireless device 110 with the group of wireless devices.

In a further particular embodiment, obtaining the association information may include receiving the association information from a wireless device or obtaining the association information stored in the network node or determining the association information.

In a further particular embodiment, the network node 160 may transmit, to the wireless device 110, the association information associating the wireless device 110 with the group of wireless devices.

In a further particular embodiment, the association information comprises at least one group identifier.

In a further particular embodiment, the at least one BO is determined based on the association information associating the wireless device with the group of wireless devices.

In a further particular embodiment, the at least one BO is the same for all wireless devices in the group of wireless devices.

In a particular embodiment, the wireless device is associated with a plurality of groups of wireless devices, and each of the groups of wireless devices is associated with a respective DRX pattern. In a further particular embodiment, each DRX pattern is assigned a priority.

In a particular embodiment, the network node 160 configures the wireless device 110 to detect an occurrence of an event and transition into the IIRM based on detecting the occurrence of the event.

In a further particular embodiment, configuring the wireless device 110 to detect the occurrence of the event may include configuring the wireless device to perform at least one of: detecting that the wireless device 110 has received the system information; determining that the wireless device 110 is within a geographical area; detecting that the network node 160 has not received more than a threshold number of HARQ messages in a certain time period; detecting that the wireless device 110 has received a signal from the network node 160; detecting that the wireless device 110 has received a RRC message from the network node 160; detecting that the wireless device 110 has received an ACK from the network node 160; detecting that the wireless device 110 has not received an ACK from the network node 160; detecting that the wireless device 110 has received a NACK from the network node 160; and/or detecting that the wireless device 110 has not received a NACK from the network node 160.

In a particular embodiment, the at least one signal comprises at least one periodic signal or at least one aperiodic signal.

In a particular embodiment, the network node 160 transmits, to the wireless device 110, the RNTI specific for the IIRM or the group of wireless devices.

FIGURE 21 illustrates a schematic block diagram of a virtual apparatus 1700 in a wireless network (for example, the wireless network shown in FIGURE 3). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 110 or network node 160 shown in FIGURE 3). Apparatus 1700 is operable to carry out the example method described with reference to FIGURE 20 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 20 is not necessarily carried out solely by apparatus 1700. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 1700 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause first transmitting module 1720, determining module 1710, second transmitting module 1730, and any other suitable units of apparatus 1700 to perform corresponding functions according one or more embodiments of the present disclosure.

According to certain embodiments, determining module 1710 may perform certain of the determining functions of the apparatus 1700. For example, determining module 1710 may determine at least one BO for transmitting at least one signal.

According to certain embodiments, first transmitting module 1720 may perform certain of the transmitting functions of the apparatus 1700. For example, first transmitting module 1720 may transmit, to a wireless device 110, system information that is scrambled with a RNTI specific for an IIRM or specific for a group of wireless devices. The system information indicates the at least one BO.

According to certain embodiments, second transmitting module 1730 may perform certain other of the transmitting functions of the apparatus 1700. For example, while the wireless device is in the IIRM, second transmitting module 1730 may transmit the at least one signal to the wireless device 110 during the at least one BO.

EXAMPLE EMBODIMENTS

Example Embodiment 1. A wireless device comprising processing circuitry and a memory, the memory containing instructions executable by the processing circuitry whereby the wireless device is operative to perform any of the steps of any of Claims 1 to 18.

Example Embodiment 2. A wireless device, the wireless device comprising: processing circuitry configured to perform any of the steps of any of Claims 1 to 18; and power supply circuitry configured to supply power to the wireless device.

Example Embodiment 3. A network node configured to perform any of the steps of any of Claims 19 to 32.

Example Embodiment 4. A network node comprising processing circuitry and a memory, the memory containing instructions executable by the processing circuitry whereby the network node is operative to perform any of the steps of any of Claims 19 to 32.

Example Embodiment 5. A network node comprising processing circuitry and a memory, the memory storing instructions that when executed by the processing circuitry causes the network node to perform any of the steps of any of Claims 19 to 32.

Example Embodiment 6. A network node comprising: processing circuitry configured to perform any of the steps of any of Claims 19 to 32; power supply circuitry configured to supply power to the network node.

Example Embodiment 7. A user equipment (UE) for improving network efficiency, the UE comprising: an antenna configured to send and receive wireless signals; radio front-end circuitry connected to the antenna and to processing circuitry, and configured to condition signals communicated between the antenna and the processing circuitry; the processing circuitry being configured to perform any of the steps of any of Claims 1 to 18; an input interface connected to the processing circuitry and configured to allow input of information into the UE to be processed by the processing circuitry; an output interface connected to the processing circuitry and configured to output information from the UE that has been processed by the processing circuitry; and a battery connected to the processing circuitry and configured to supply power to the UE.

Example Embodiment 8. A communication system including a host computer comprising: processing circuitry configured to provide user data; and a communication interface configured to forward the user data to a cellular network for transmission to a user equipment (UE), wherein the cellular network comprises a base station having a radio interface and processing circuitry, the base station's processing circuitry configured to perform any of the steps of any of Claims 19 to 32.

Example Embodiment 9. The communication system of the previous example embodiment further including the base station.

Example Embodiment 10. The communication system of the previous 2 example embodiments, further including the UE, wherein the UE is configured to communicate with the base station.

Example Embodiment 11. The communication system of the previous 3 example embodiments, wherein: the processing circuitry of the host computer is configured to execute a host application, thereby providing the user data; and the UE comprises processing circuitry configured to execute a client application associated with the host application.

Example Embodiment 12. A method implemented in a communication system including a host computer, a base station and a user equipment (UE), the method comprising: at the host computer, providing user data; and at the host computer, initiating a transmission carrying the user data to the UE via a cellular network comprising the base station, wherein the base station performs any of the steps of any of Claims 19 to 32.

Example Embodiment 13. The method of the previous example embodiment, further comprising, at the base station, transmitting the user data.

Example Embodiment 14. The method of the previous 2 example embodiments, wherein the user data is provided at the host computer by executing a host application, the method further comprising, at the UE, executing a client application associated with the host application.

Example Embodiment 15. A user equipment (UE) configured to communicate with a base station, the UE comprising a radio interface and processing circuitry configured to performs the of the previous 3 example embodiments.

Example Embodiment 16. A communication system including a host computer comprising: processing circuitry configured to provide user data; and a communication interface configured to forward user data to a cellular network for transmission to a user equipment (UE), wherein the UE comprises a radio interface and processing circuitry, the UE's components configured to perform any of the steps of any of Claims 1 to 18.

Example Embodiment 17. The communication system of the previous example embodiment, wherein the cellular network further includes a base station configured to communicate with the UE.

Example Embodiment 18. The communication system of the previous 2 example embodiments, wherein: the processing circuitry of the host computer is configured to execute a host application, thereby providing the user data; and the UE's processing circuitry is configured to execute a client application associated with the host application.

Example Embodiment 19. A method implemented in a communication system including a host computer, a base station and a user equipment (UE), the method comprising: at the host computer, providing user data; and at the host computer, initiating a transmission carrying the user data to the UE via a cellular network comprising the base station, wherein the UE performs any of the steps of any of Claims 1 to 18.

Example Embodiment 20. The method of the previous example embodiment, further comprising at the UE, receiving the user data from the base station.

Example Embodiment 21. A communication system including a host computer comprising: communication interface configured to receive user data originating from a transmission from a user equipment (UE) to a base station, wherein the UE comprises a radio interface and processing circuitry, the UE's processing circuitry configured to perform any of the steps of any of Claims 22.

Example Embodiment 23. The communication system of the previous example embodiment, further including the UE.

Example Embodiment 24. The communication system of the previous 2 example embodiments, further including the base station, wherein the base station comprises a radio interface configured to communicate with the UE and a communication interface configured to forward to the host computer the user data carried by a transmission from the UE to the base station.

Example Embodiment 25. The communication system of the previous 3 example embodiments, wherein: the processing circuitry of the host computer is configured to execute a host application; and the UE's processing circuitry is configured to execute a client application associated with the host application, thereby providing the user data.

Example Embodiment 26. The communication system of the previous 4 example embodiments, wherein: the processing circuitry of the host computer is configured to execute a host application, thereby providing request data; and the UE's processing circuitry is configured to execute a client application associated with the host application, thereby providing the user data in response to the request data.

Example Embodiment 27. A method implemented in a communication system including a host computer, a base station and a user equipment (UE), the method comprising:

at the host computer, receiving user data transmitted to the base station from the UE, wherein the UE performs any of the steps of any of Claims 1 to 18.

Example Embodiment 28. The method of the previous example embodiment, further comprising, at the UE, providing the user data to the base station.

Example Embodiment 29. The method of the previous 2 example embodiments, further comprising: at the UE, executing a client application, thereby providing the user data to be transmitted; and at the host computer, executing a host application associated with the client application.

Example Embodiment 30. The method of the previous 3 example embodiments, further comprising: at the UE, executing a client application; and at the UE, receiving input data to the client application, the input data being provided at the host computer by executing a host application associated with the client application, wherein the user data to be transmitted is provided by the client application in response to the input data.

Example Embodiment 31. A communication system including a host computer comprising a communication interface configured to receive user data originating from a transmission from a user equipment (UE) to a base station, wherein the base station comprises a radio interface and processing circuitry, the base station's processing circuitry configured to perform any of the steps of any of Claims 19 to 32.

Example Embodiment 32. The communication system of the previous example embodiment further including the base station.

Example Embodiment 33. The communication system of the previous 2 example embodiments, further including the UE, wherein the UE is configured to communicate with the base station.

Example Embodiment 34. The communication system of the previous 3 example embodiments, wherein: the processing circuitry of the host computer is configured to execute a host application; the UE is configured to execute a client application associated with the host application, thereby providing the user data to be received by the host computer.

Example Embodiment 35. A method implemented in a communication system including a host computer, a base station and a user equipment (UE), the method comprising: at the host computer, receiving, from the base station, user data originating from a transmission which the base station has received from the UE, wherein the UE performs any of the steps of any of Claims 1 to 18.

Example Embodiment 36. The method of the previous example embodiment, further comprising at the base station, receiving the user data from the UE.

Example Embodiment 37. The method of the previous 2 example embodiments, further comprising at the base station, initiating a transmission of the received user data to the host computer.

Modifications, additions, or omissions may be made to the systems and apparatuses described herein without departing from the scope of the disclosure. The components of the systems and apparatuses may be integrated or separated. Moreover, the operations of the systems and apparatuses may be performed by more, fewer, or other components. Additionally, operations of the systems and apparatuses may be performed using any suitable logic comprising software, hardware, and/or other logic. As used in this document, “each” refers to each member of a set or each member of a subset of a set.

Modifications, additions, or omissions may be made to the methods described herein without departing from the scope of the disclosure. The methods may include more, fewer, or other steps. Additionally, steps may be performed in any suitable order.

Although this disclosure has been described in terms of certain embodiments, alterations and permutations of the embodiments will be apparent to those skilled in the art. Accordingly, the above description of the embodiments does not constrain this disclosure. Other changes, substitutions, and alterations are possible without departing from the spirit and scope of this disclosure.

CLAIMS

1. A method by a wireless device, the method comprising:

receiving, from a network node, system information that is scrambled with a radio network temporary identifier, RNTI, specific for an idle or inactive reception mode, IIRM, or specific for a group of wireless devices;

based on the system information, determining at least one broadcast occasion, BO, for receiving at least one signal;

while in the IIRM, receiving the at least one signal during the at least one BO.

2. The method of Claim 1, wherein the system information is scrambled with a RNTI specific for a group of wireless devices, the method further comprising obtaining association information associating the wireless device with the group of wireless devices.

3. The method of Claim 2, wherein obtaining the association information comprises:

receiving the association information from a network node; or

obtaining the association information stored in the wireless device; or

determining the association information.

4. The method of any one of Claims 2 to 3, wherein the association information comprises at least one group identifier.

5. The method of any one of Claims 2 to 4, wherein the at least one BO is determined based on the association information associating the wireless device with the group of wireless devices.

6. The method of any one of Claims 2 to 5, wherein determining the at least one BO comprises:

descrambling the system information using the association information associating the wireless device with the group of wireless devices; and

determining the at least one BO based on the descrambled system information.

7. The method of Claim 1, wherein the system information is scrambled with a RNTI specific for the IIRM, and wherein determining the at least one BO comprises:

descrambling the system information using the RNTI specific for the IIRM; and

determining the at least one BO based on the descrambled system information.

8. The method of any one of Claims 1 to 7, wherein the at least one BO is the same for all wireless devices in the group of wireless devices.

9. The method of any one of Claims 1 to 8, wherein the system information comprises a message transmitted to the group of wireless devices, and wherein the at least one BO is determined based on the message.

10. The method of any one of Claims 1 to 9, wherein the wireless device is associated with a plurality of groups of wireless devices, each of the groups of wireless devices being associated with a respective discontinuous reception ,DRX, pattern, and wherein the method further comprises, for each group of the plurality of groups, monitoring the respective DRX pattern associated with that group.

11. The method of Claim 10, wherein each DRX pattern is assigned a priority.

12. The method of any one of Claims 1 to 11, further comprising:
detecting an occurrence of a trigger event; and
in response to detecting the occurrence of the trigger event, transitioning into the IIRM.

13. The method of Claim 12, wherein detecting the occurrence of the trigger event comprises at least one of:
determining that the wireless device is within a geographical area;
determining that the network node has not received more than a threshold number of HARQ messages;
receiving a signal from the network node;
receiving the system information from the network node;
receiving a radio resource control, RRC, message from the network node;
detecting an occurrence of an acknowledgement, ACK, from the network node;
detecting an absence of the ACK from the network node;
detecting an occurrence of a negative acknowledgement, NACK, from the network node; and
detecting an absence of the NACK from the network node.

14. The method of any one of Claims 12 to 13, wherein the wireless device is in connected mode when detecting the occurrence of the trigger event.

15. The method of any one of Claims 12 to 13, wherein the wireless device is in an idle or inactive mode when detecting the occurrence of the trigger event.

16. The method of any one of Claims 1 to 15, wherein the at least one signal comprises at least one periodic signal or at least one aperiodic signal.

17. The method of any one of Claims 1 to 16, further comprising receiving, from the network node, the RNTI specific for the IIRM or the group of wireless devices.

18. A wireless device comprising processing circuitry configured to perform any one of the methods of Claims 1 to 17.

19. A method performed by a network node, the method comprising:

determining at least one broadcast occasion, BO, for transmitting at least one signal;

transmitting, to a wireless device, system information that is scrambled with a radio network temporary identifier, RNTI, specific for an idle or inactive reception mode, IIRM, or specific for a group of wireless devices, wherein the system information indicates the at least one BO;

while the wireless device is in the IIRM, transmitting the at least one signal to the wireless device during the at least one BO.

20. The method of Claim 19 , wherein the system information is scrambled with a RNTI specific for a group of wireless devices, the method further comprising obtaining association information associating the wireless device with the group of wireless devices.

21. The method of Claim 20, wherein the obtaining the association information comprises:

receiving the association information from a wireless device; or

obtaining the association information stored in the network node; or

determining the association information.

22. The method of any one of Claims 20 to 21, further comprising transmitting, to the wireless device, the association information associating the wireless device with the group of wireless devices.

23. The method of any one of Claims 20 to 21, wherein the association information comprises at least one group identifier.

24. The method of any one of Claims 20 to 23, wherein the at least one BO is determined based on the association information associating the wireless device with the group of wireless devices.

25. The method of any one of Claims 19 to 24, wherein the at least one BO is the same for all wireless devices in the group of wireless devices.

26. The method of any one of Claims 19 to 25, wherein the wireless device is associated with a plurality of groups of wireless devices, each of the groups of wireless devices being associated with a respective DRX pattern.

27. The method of Claim 26, wherein each DRX pattern is assigned a priority.

28. The method of any one of Claims 19 to 27, further comprising configuring the wireless device to detect an occurrence of an event and transition into the IIRM based on detecting the occurrence of the event.

29. The method of Claim 28, wherein configuring the wireless device to detect the occurrence of the event comprises configuring the wireless device to perform at least one of:

detecting that the wireless device has received the system information;

determining that the wireless device is within a geographical area;

detecting that the network node has not received more than a threshold number of HARQ messages;

detecting that the wireless device has received a signal from the network node;

detecting that the wireless device has received a radio resource control, RRC, message from the network node;

detecting that the wireless device has received an acknowledgement, ACK, from the network node;

detecting that the wireless device has not received an ACK from the network node;

detecting that the wireless device has received a negative acknowledgement, NACK, from the network node; and

detecting that the wireless device has not received a NACK from the network node.

30. The method of any one of Claims 19 to 29, wherein the at least one signal comprises at least one periodic signal or at least one aperiodic signal.

31. The method of any one of Claims 19 to 30, further comprising transmitting, to the wireless device, the RNTI specific for the IIRM or the group of wireless devices.

32. A network node comprising processing circuitry configured to perform any one of the methods of Claims 19 to 31.

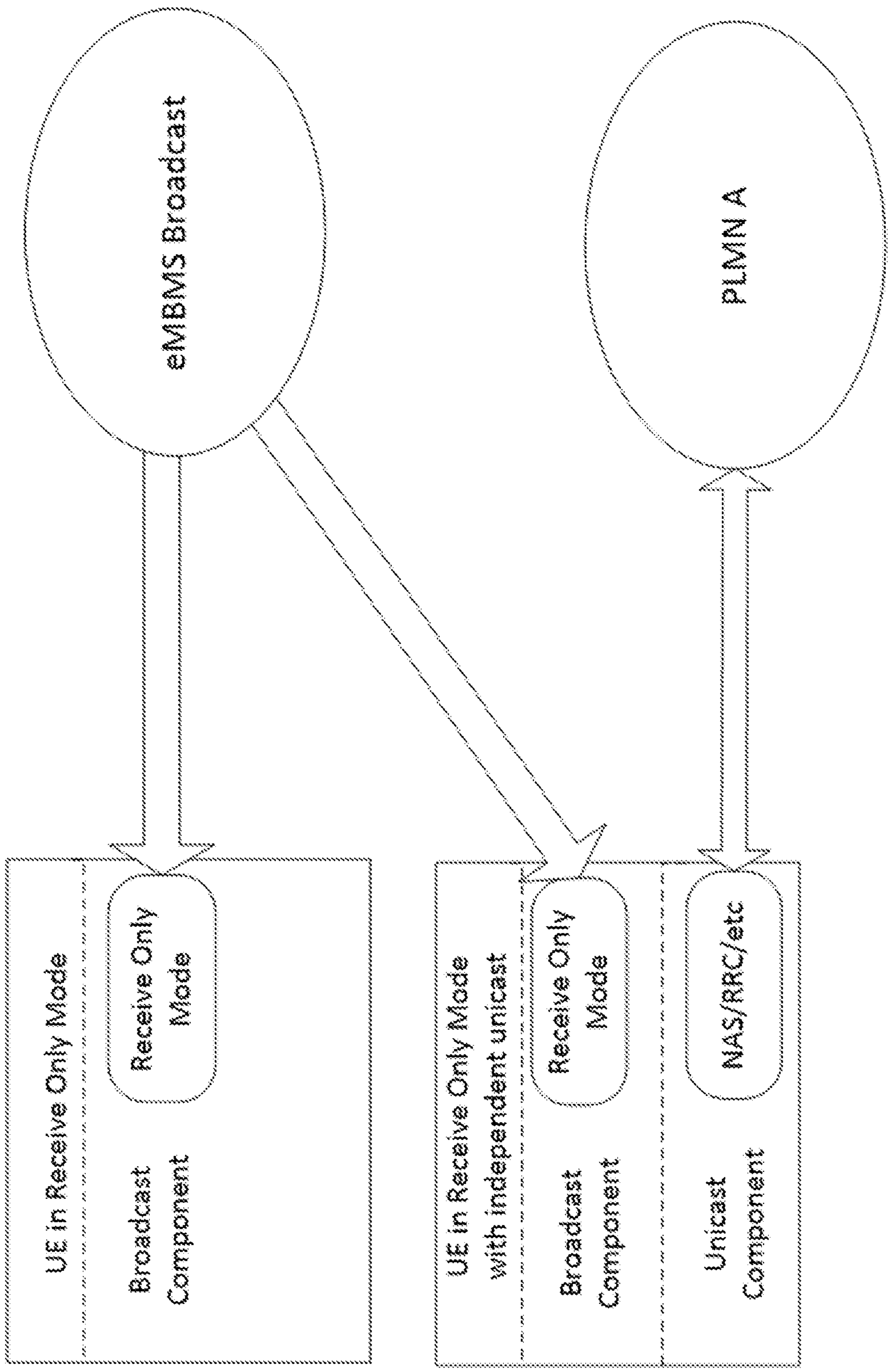

eMBMS Broadcast
PLMN A
UE in Receive Only Mode
Broadcast Component
Receive Only Mode
UE in Receive Only Mode with independent unicast
Broadcast Component
Receive Only Mode
Unicast Component
NAS/RRC/etc

FIGURE 1

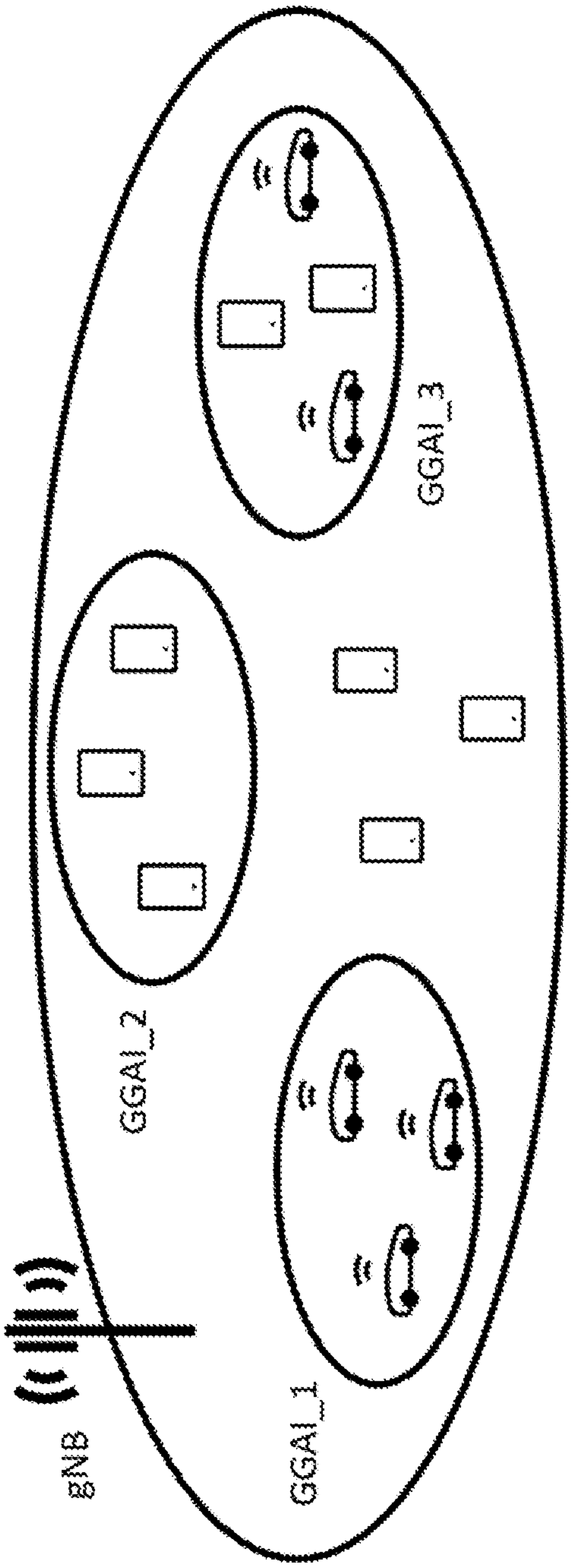


FIGURE 2

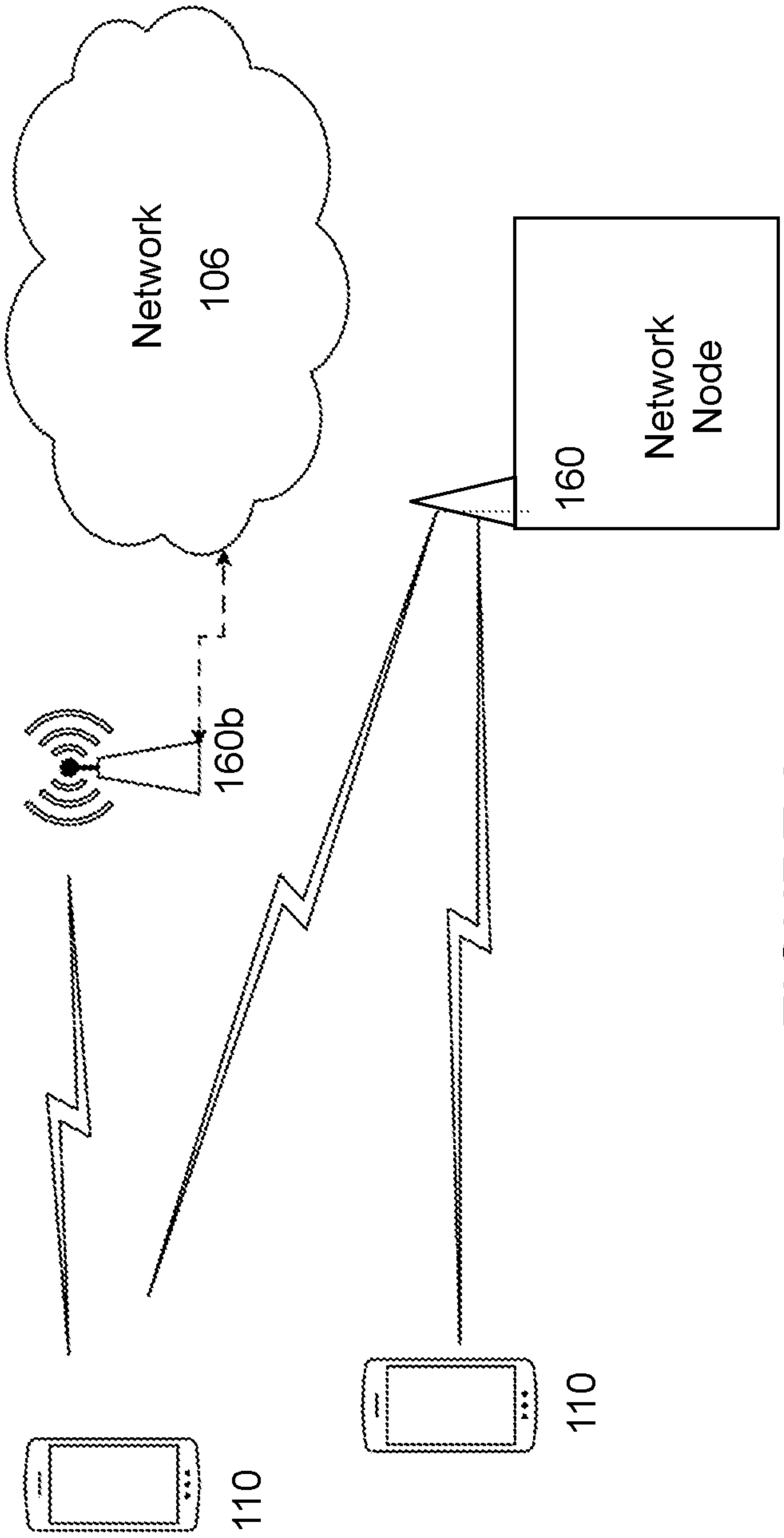


FIGURE 3

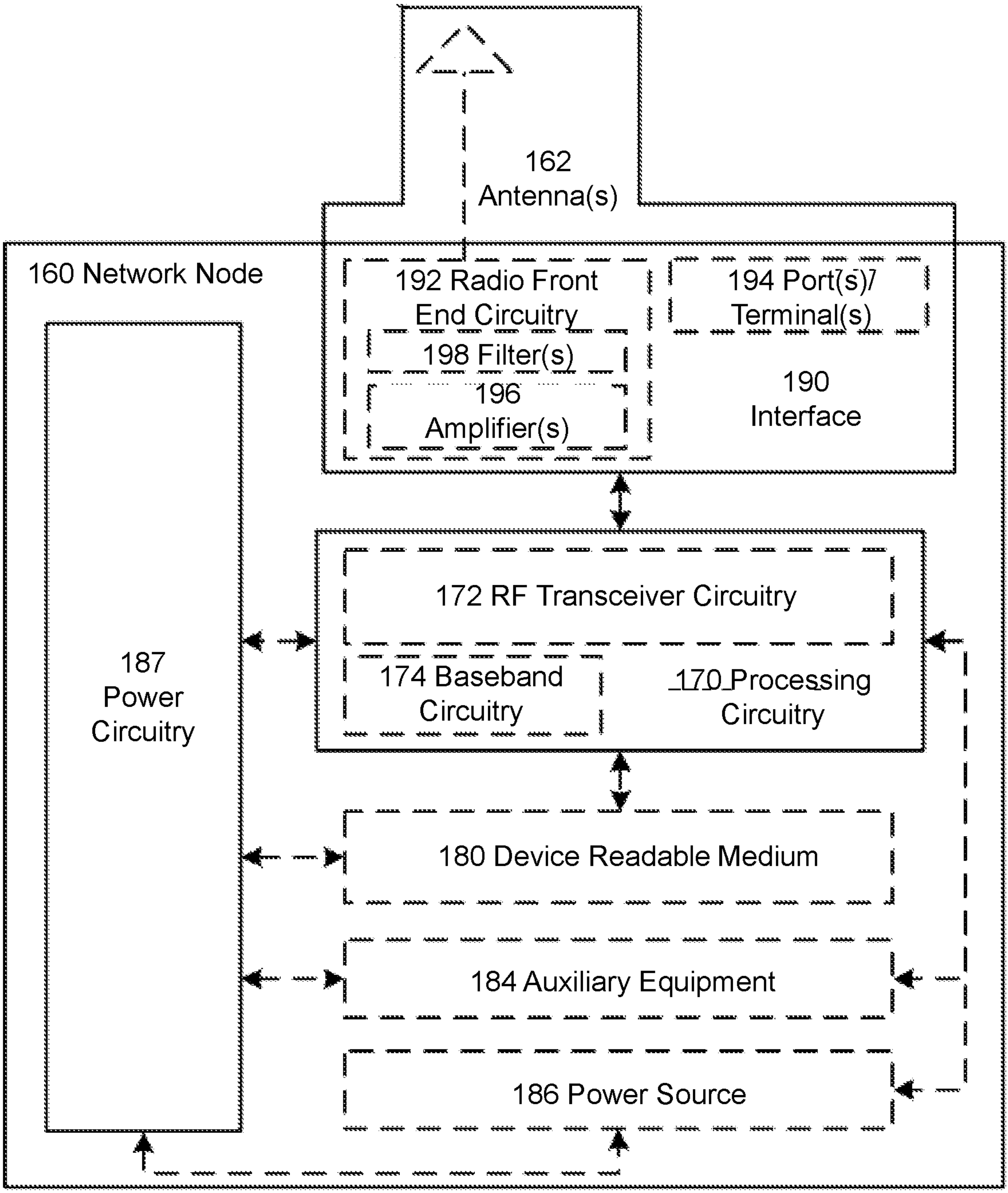

162
Antenna(s)
160 Network Node
192 Radio Front End Circuitry
194 Port(s)/ Terminal(s)
198 Filter(s)
196 Amplifier(s)
190 Interface
172 RF Transceiver Circuitry
174 Baseband Circuitry
170 Processing Circuitry
187 Power Circuitry
180 Device Readable Medium
184 Auxiliary Equipment
186 Power Source

FIGURE 4

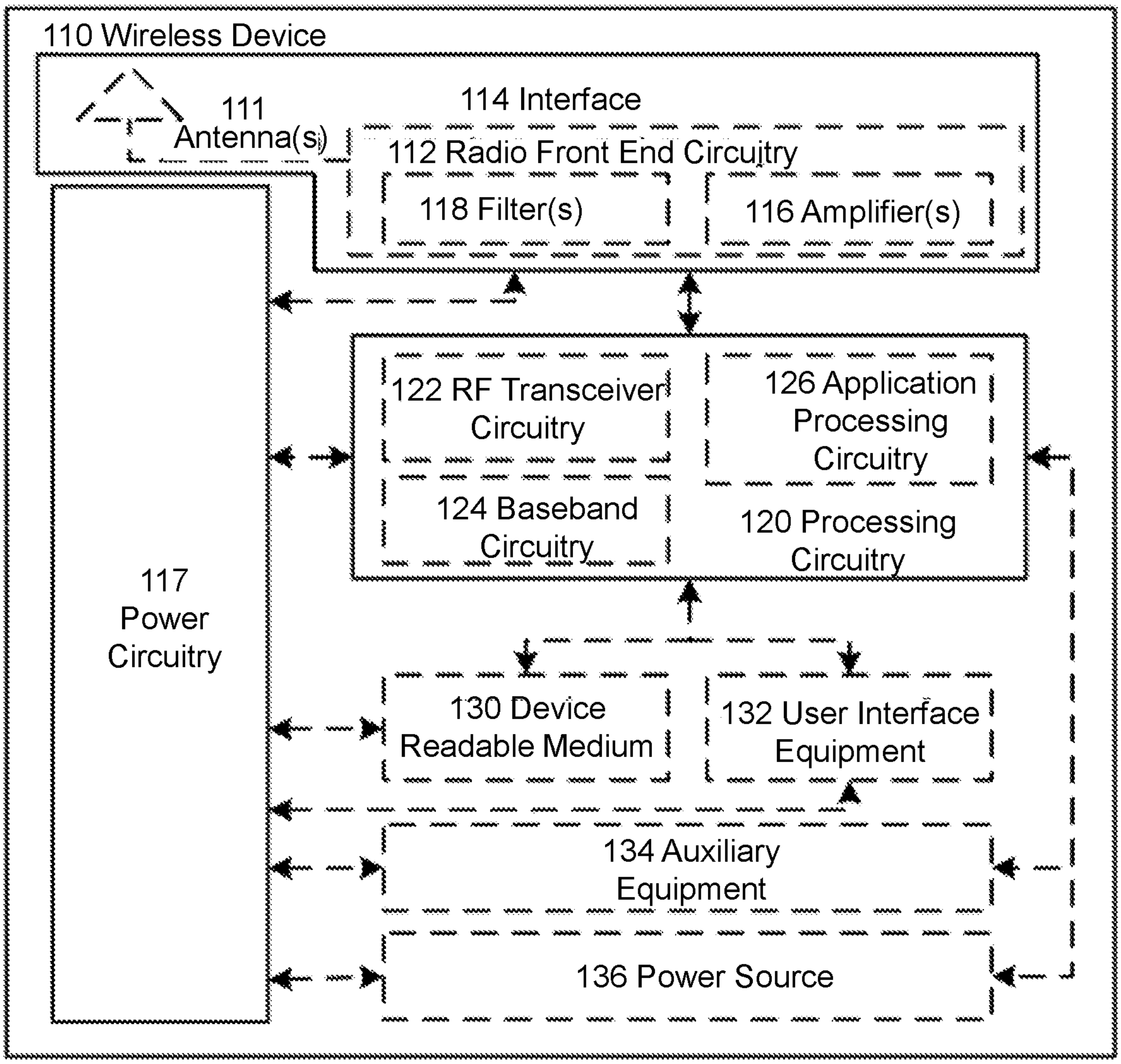

110 Wireless Device
111
Antenna(s)
114 Interface
112 Radio Front End Circuitry
118 Filter(s)
116 Amplifier(s)
122 RF Transceiver Circuitry
126 Application Processing Circuitry
124 Baseband Circuitry
120 Processing Circuitry
117
Power
Circuitry
130 Device Readable Medium
132 User Interface Equipment
134 Auxiliary Equipment
136 Power Source

FIGURE 5

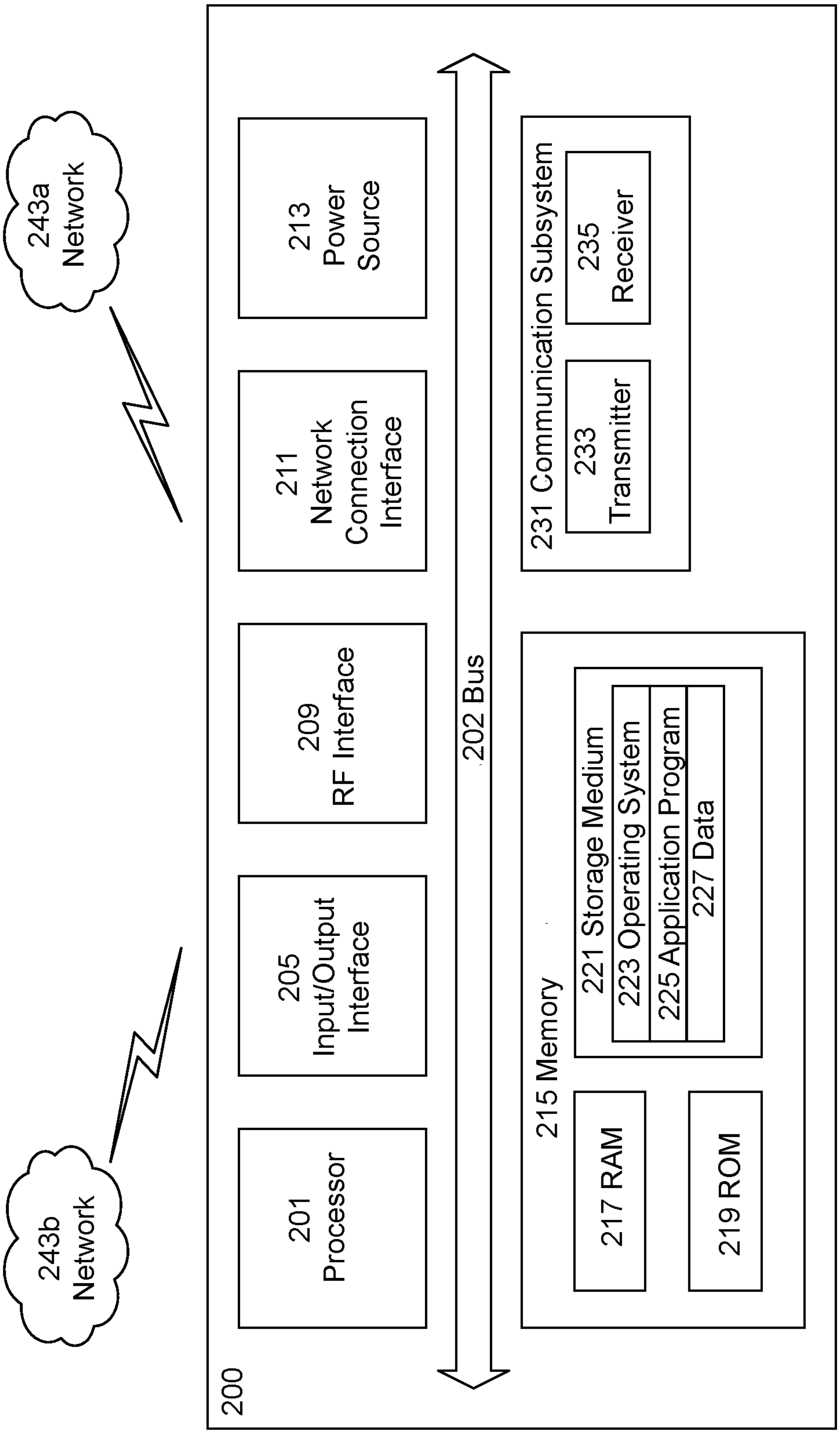

200
243a
Network
243b
Network
201
Processor
205
Input/Output
Interface
209
RF Interface
211
Network
Connection
Interface
213
Power
Source
202 Bus
215 Memory
217 RAM
219 ROM
221 Storage Medium
223 Operating System
225 Application Program
227 Data
231 Communication Subsystem
233
Transmitter
235
Receiver

FIGURE 6

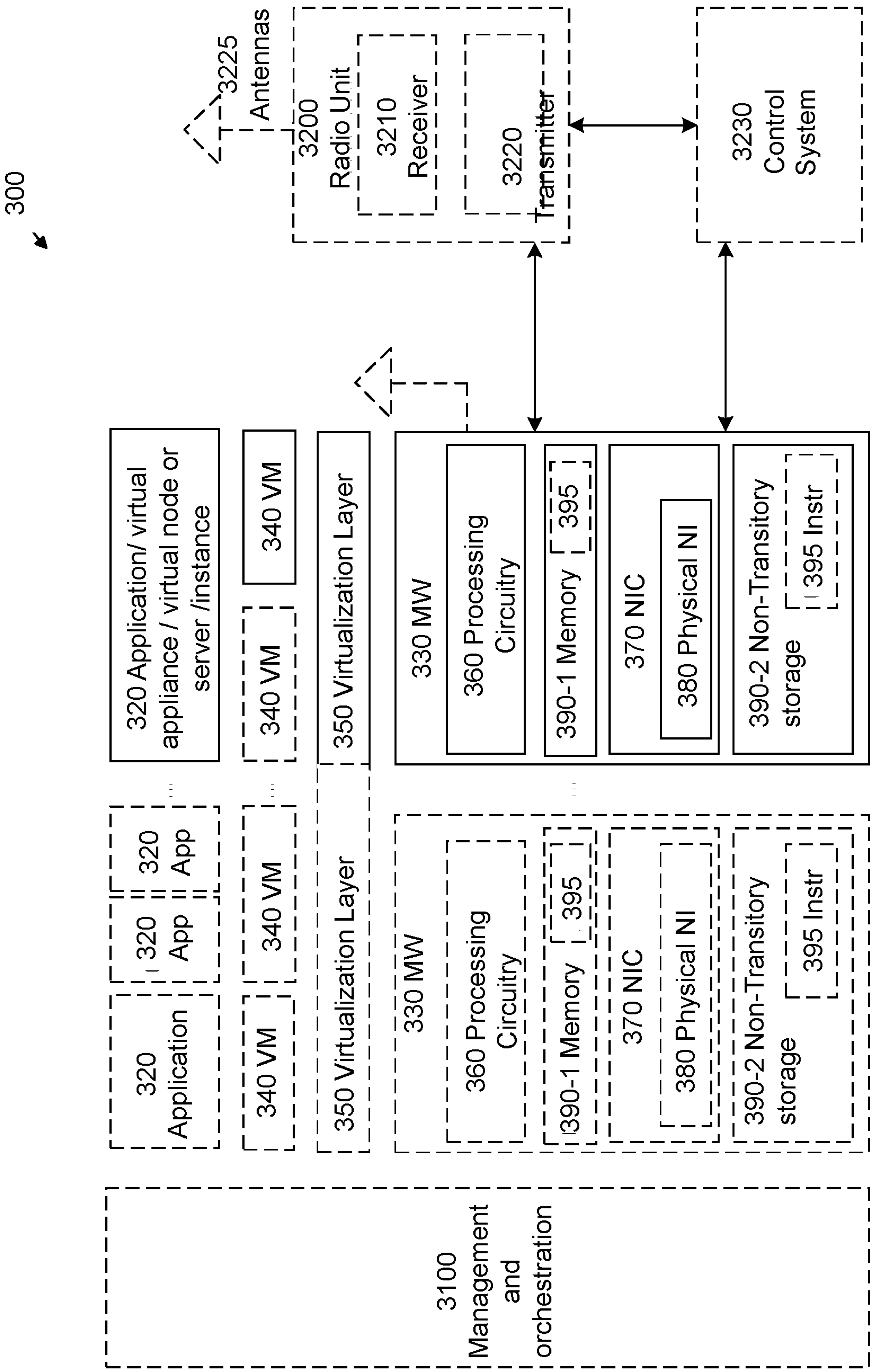

300
3225 Antennas
3200 Radio Unit
3210 Receiver
3220 Transmitter
3230 Control System
320 Application/ virtual appliance / virtual node or server /instance
340 VM
340 VM
350 Virtualization Layer
330 MW
360 Processing Circuitry
390-1 Memory
395
370 NIC
380 Physical NI
390-2 Non-Transitory storage
395 Instr
320 App
320 App
340 VM
350 Virtualization Layer
330 MW
360 Processing Circuitry
390-1 Memory
395
370 NIC
380 Physical NI
390-2 Non-Transitory storage
395 Instr
320 Application
340 VM
3100 Management and orchestration

FIGURE 7

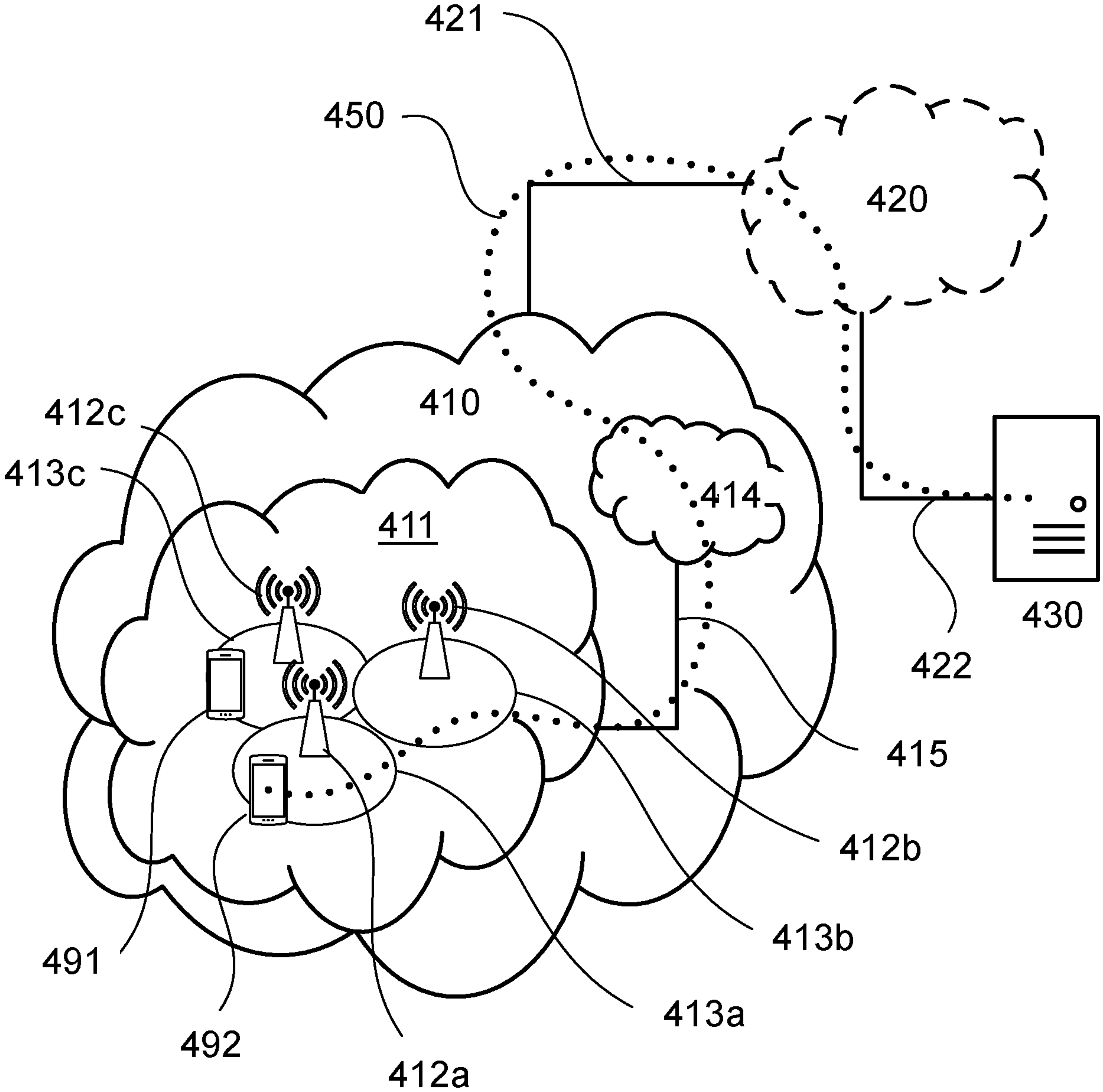

421
450
420
410
412c
413c
414
411
430
422
415
412b
413b
491
413a
492
412a

FIGURE 8

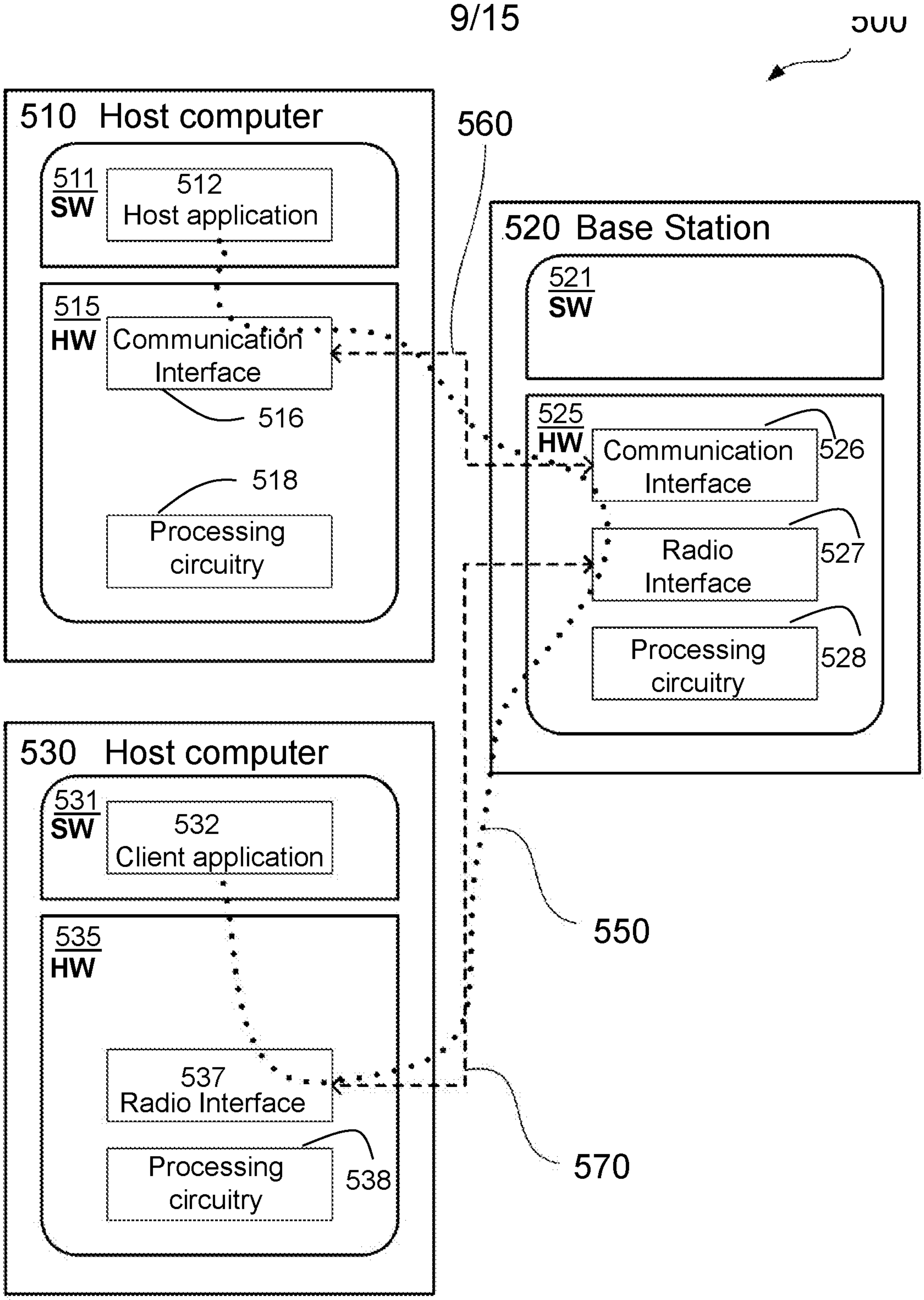

500
510 Host computer
511
SW
512
Host application
515
HW
Communication Interface
516
518
Processing circuitry
560
520 Base Station
521
SW
525
HW
Communication Interface
526
Radio Interface
527
Processing circuitry
528
530 Host computer
531
SW
532
Client application
535
HW
537
Radio Interface
Processing circuitry
538
550
570

FIGURE 9

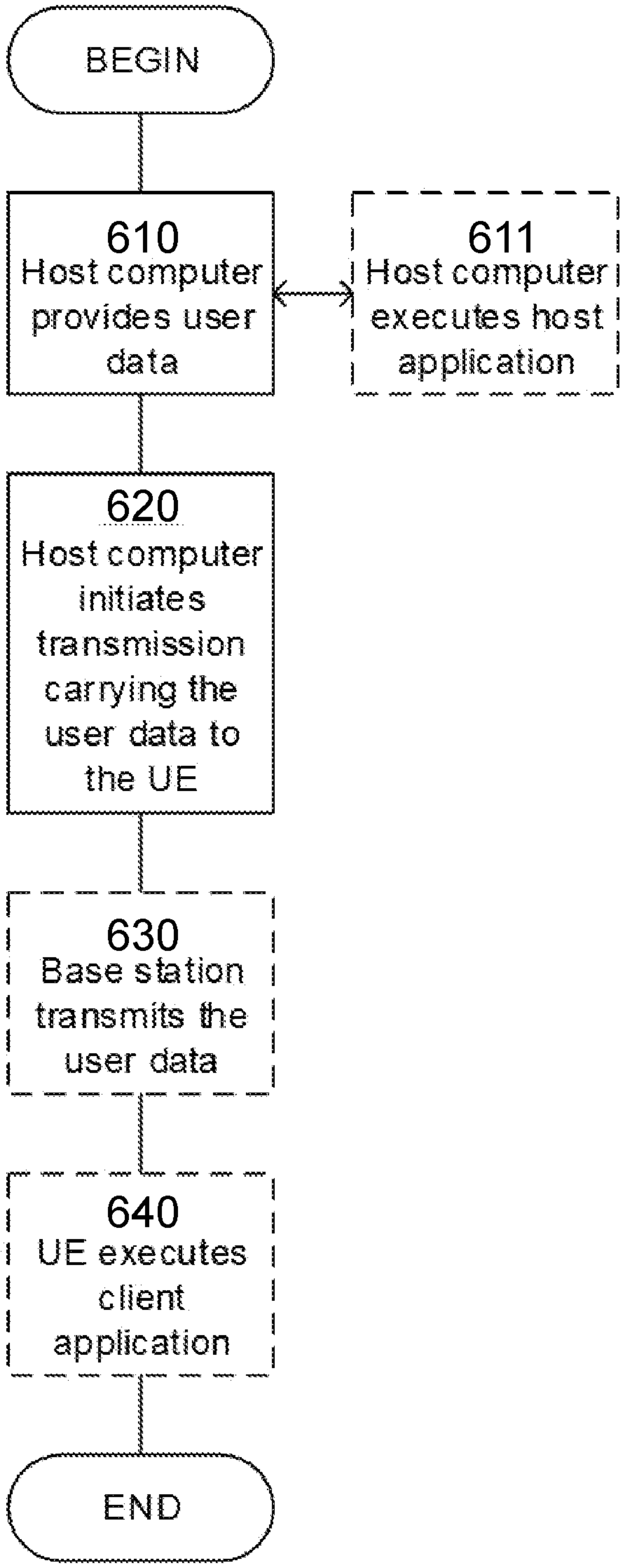


FIGURE 10

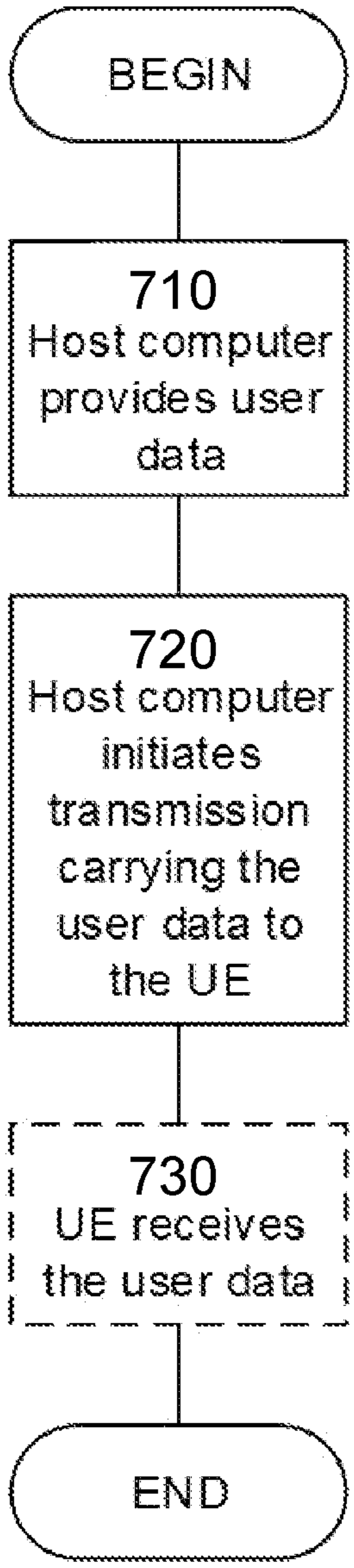
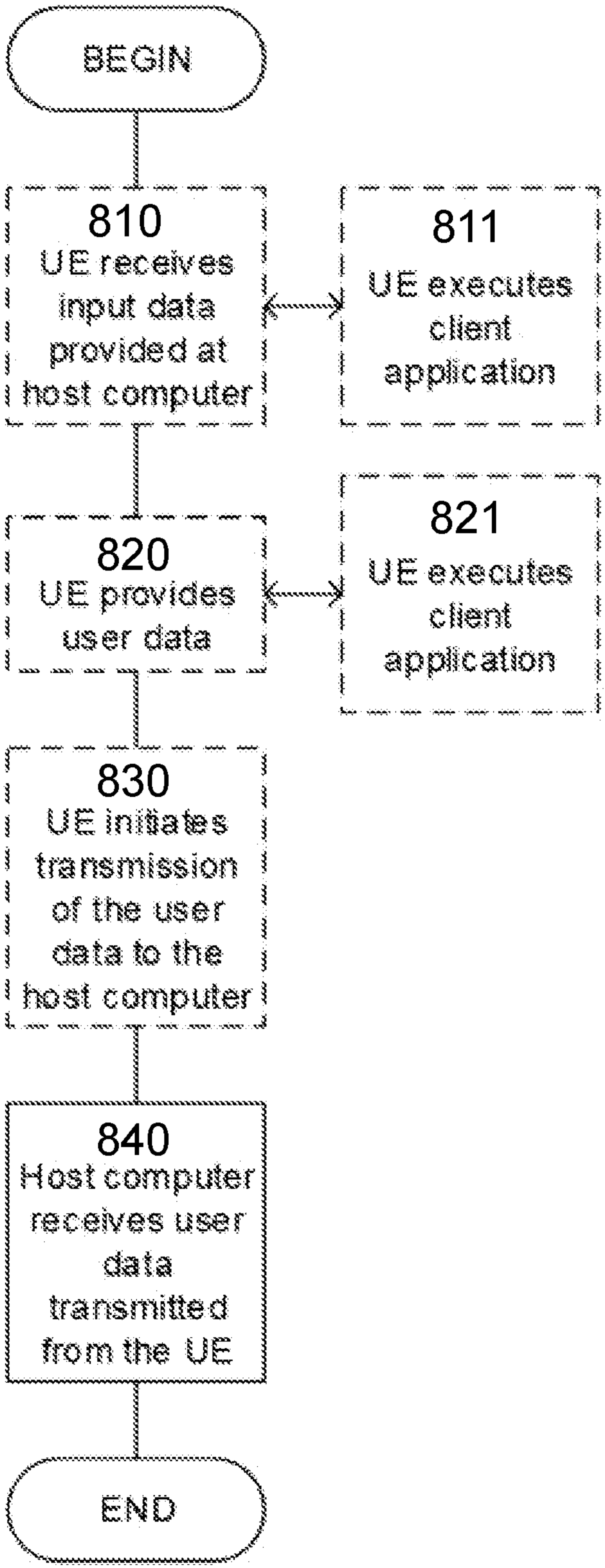


FIGURE 11



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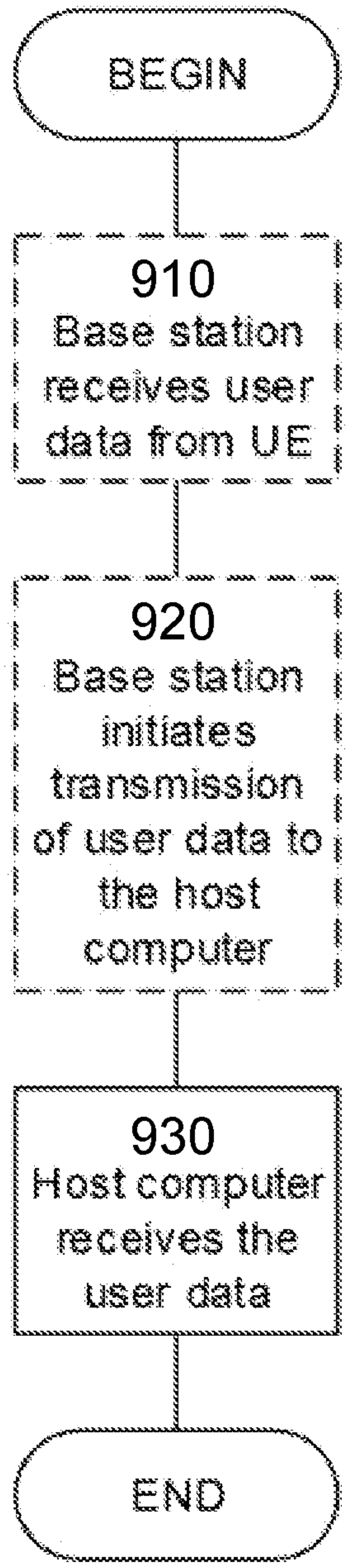
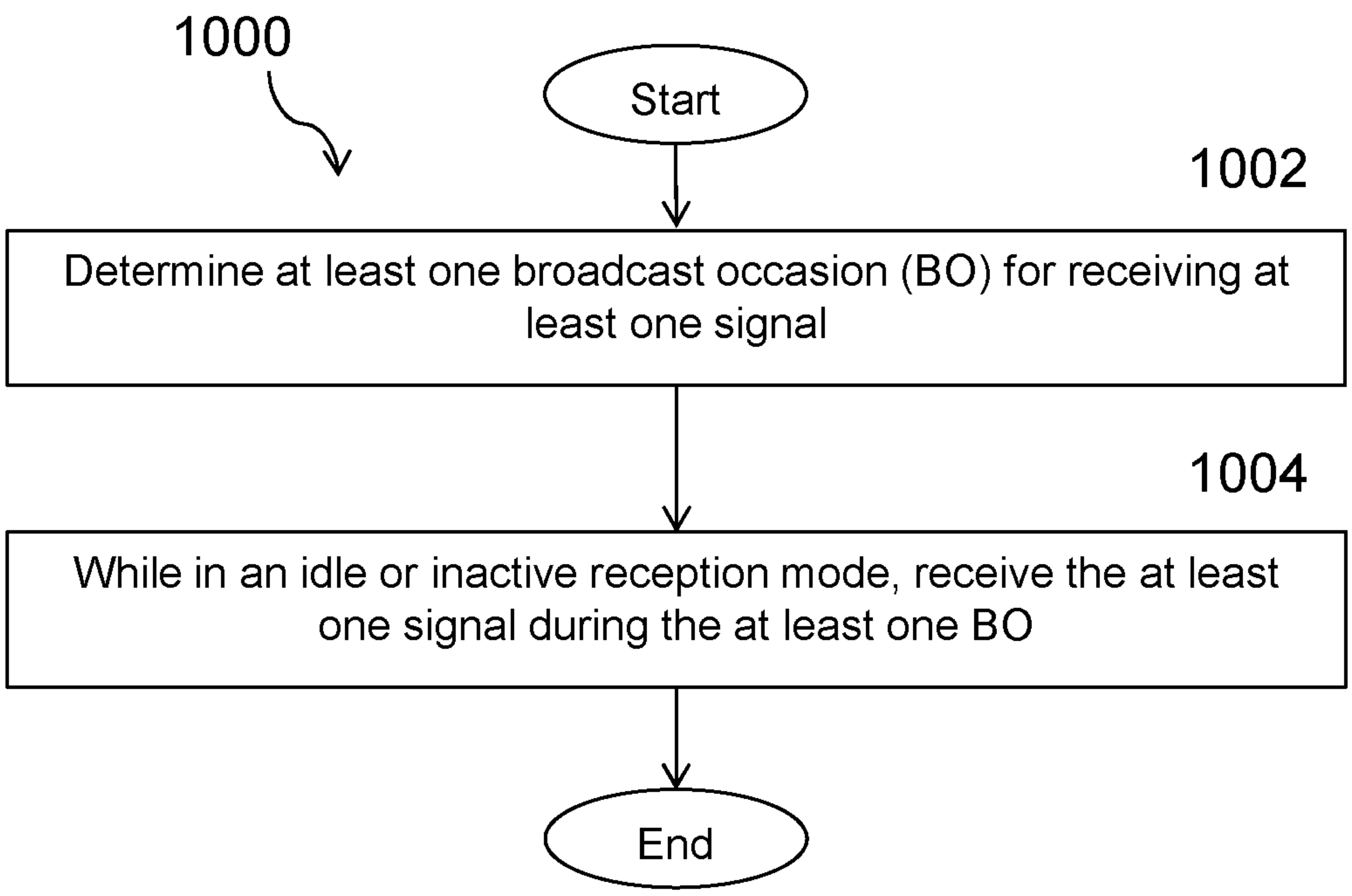


FIGURE 13



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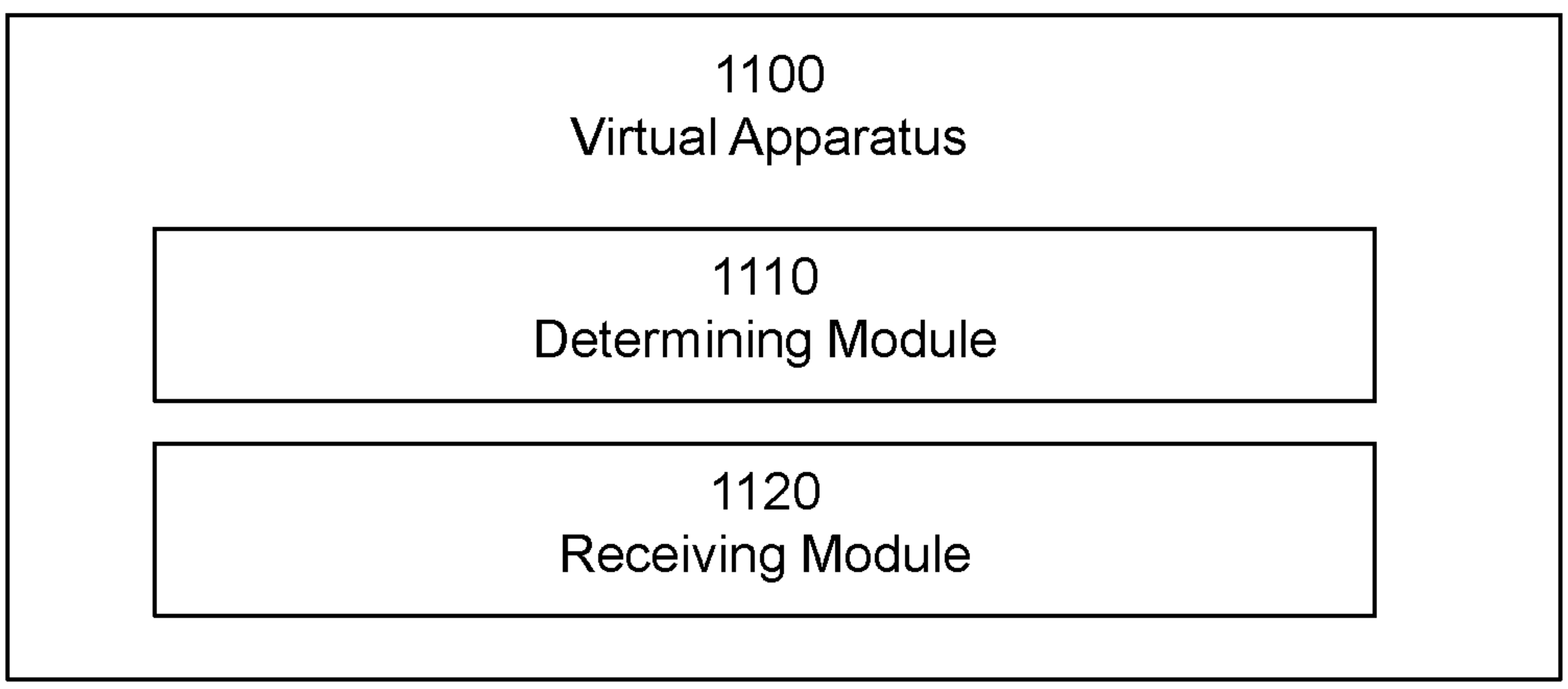

FIGURE 15

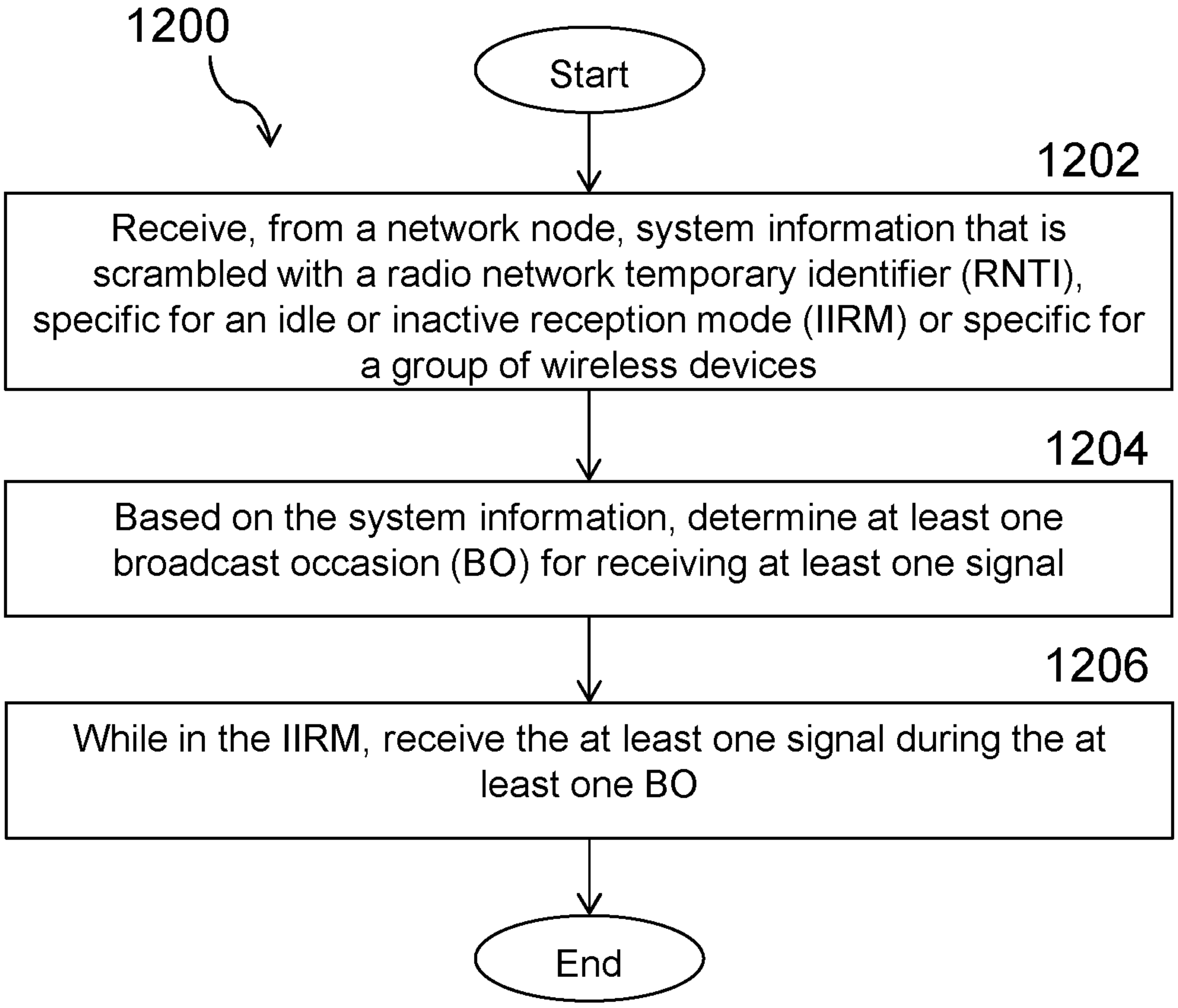

FIGURE 16

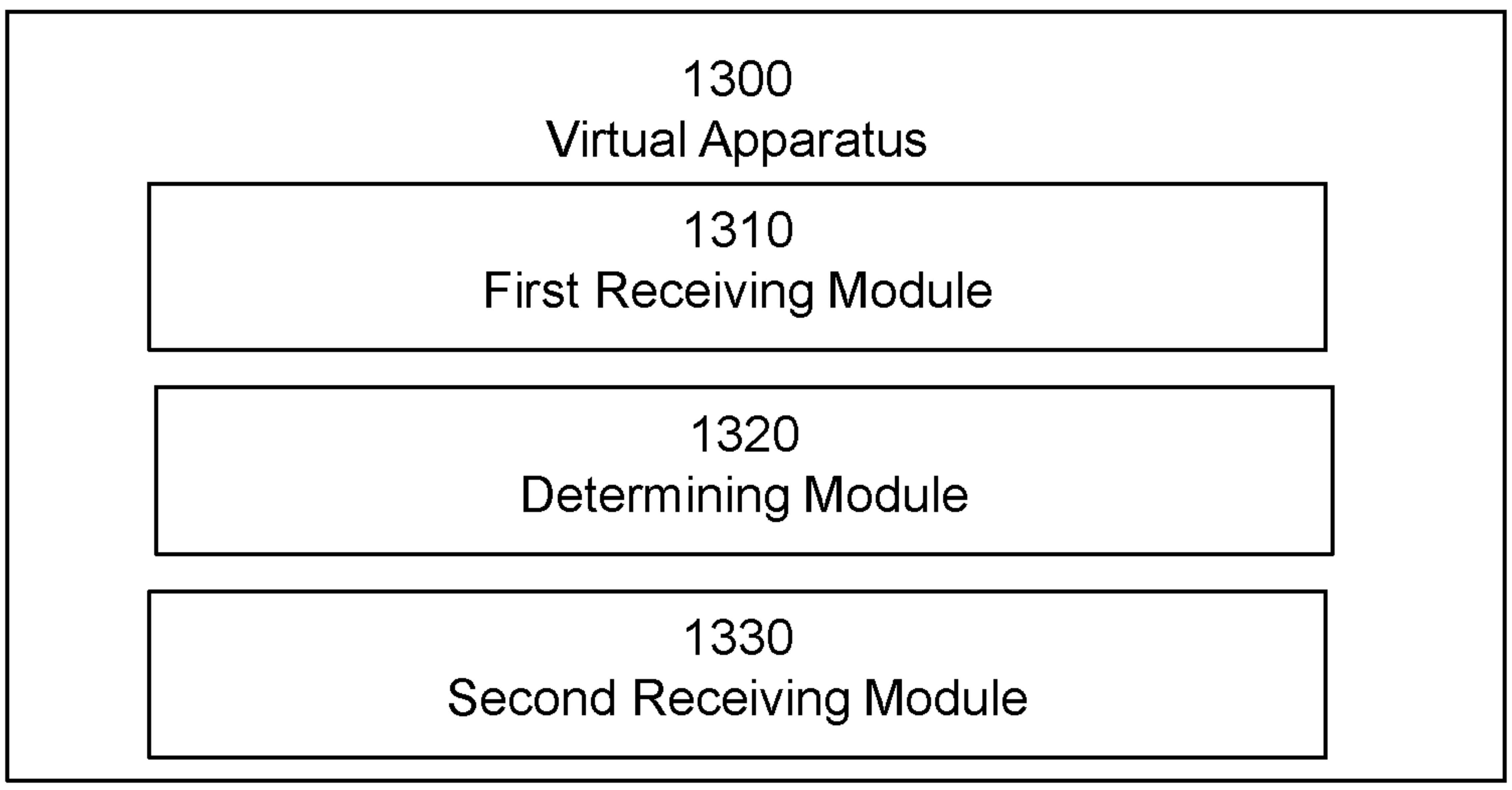

FIGURE 17

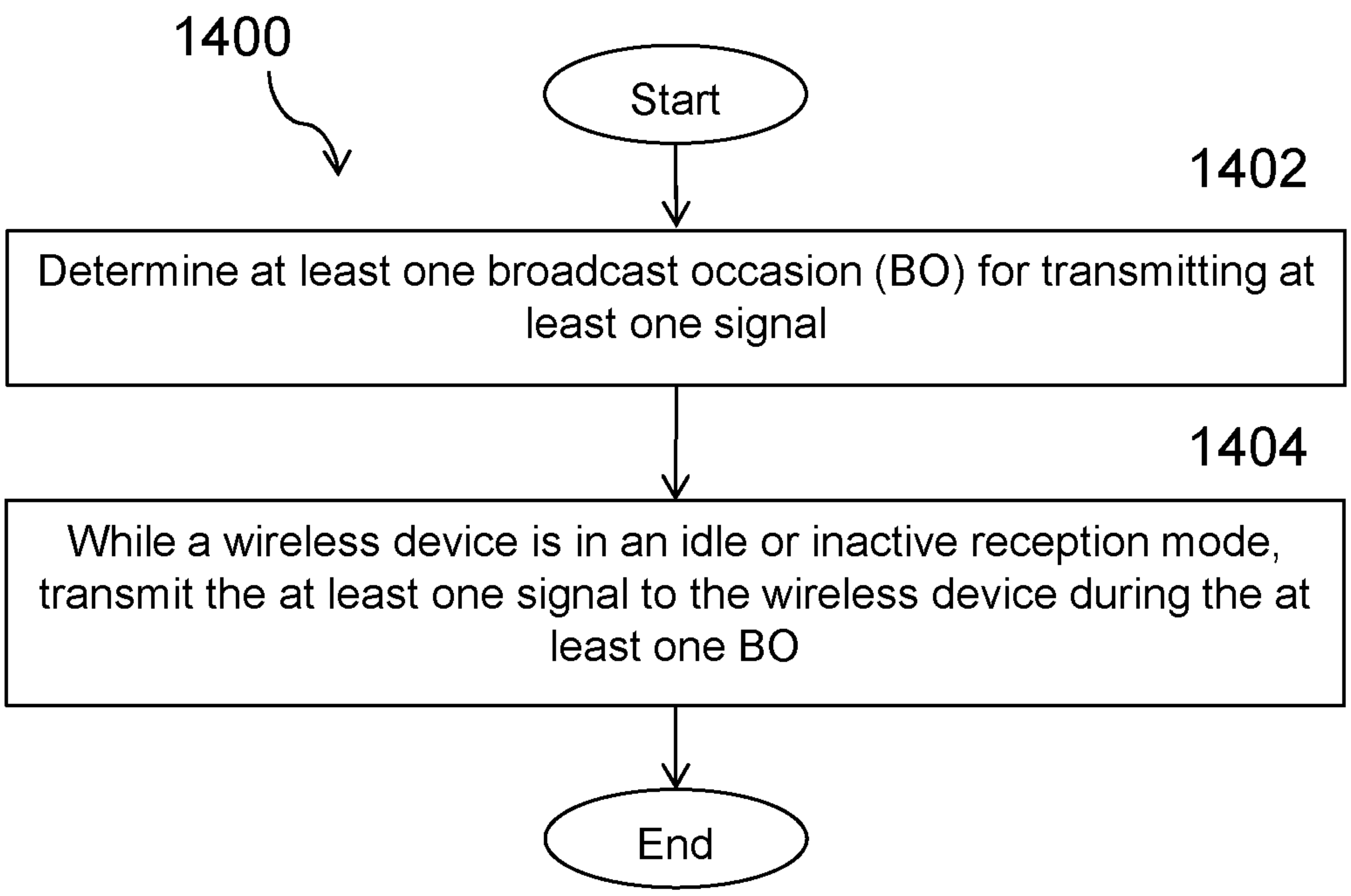

FIGURE 18

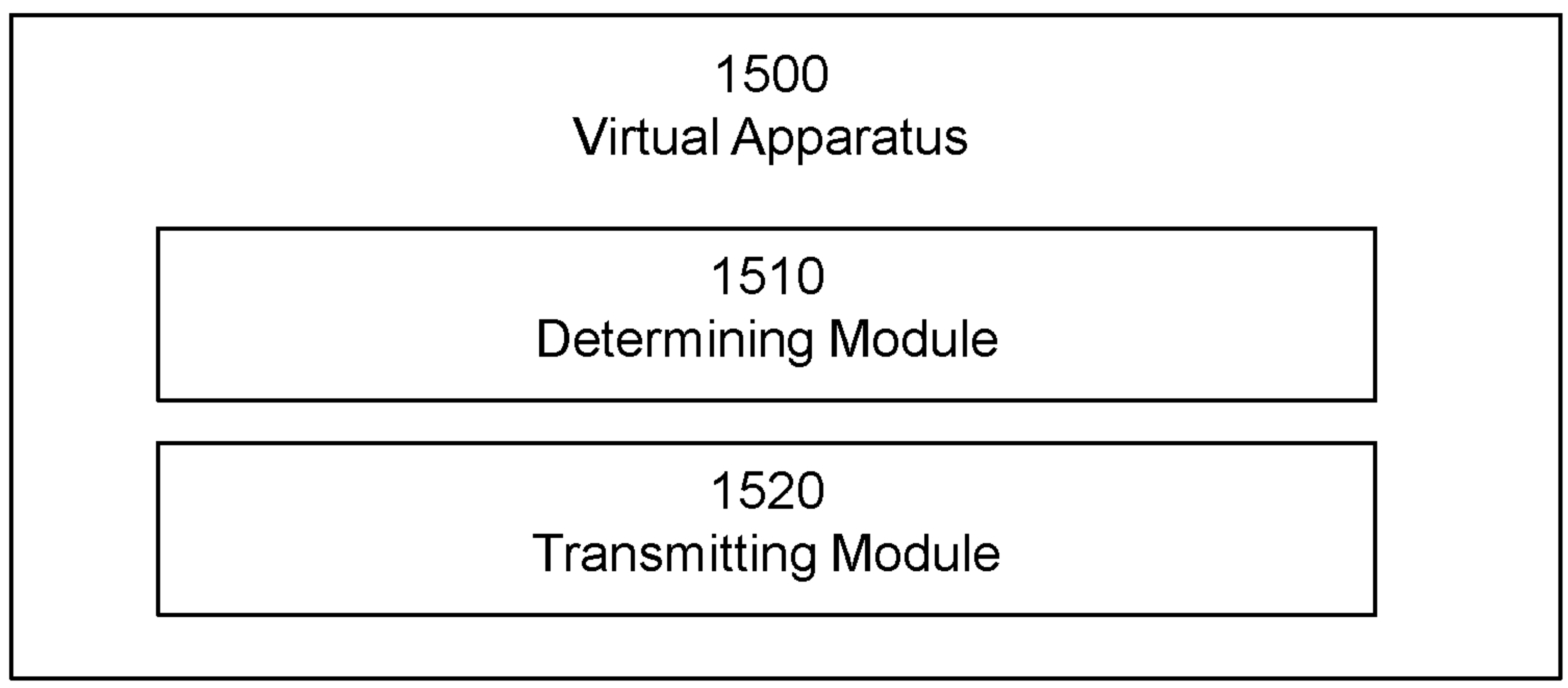

FIGURE 19

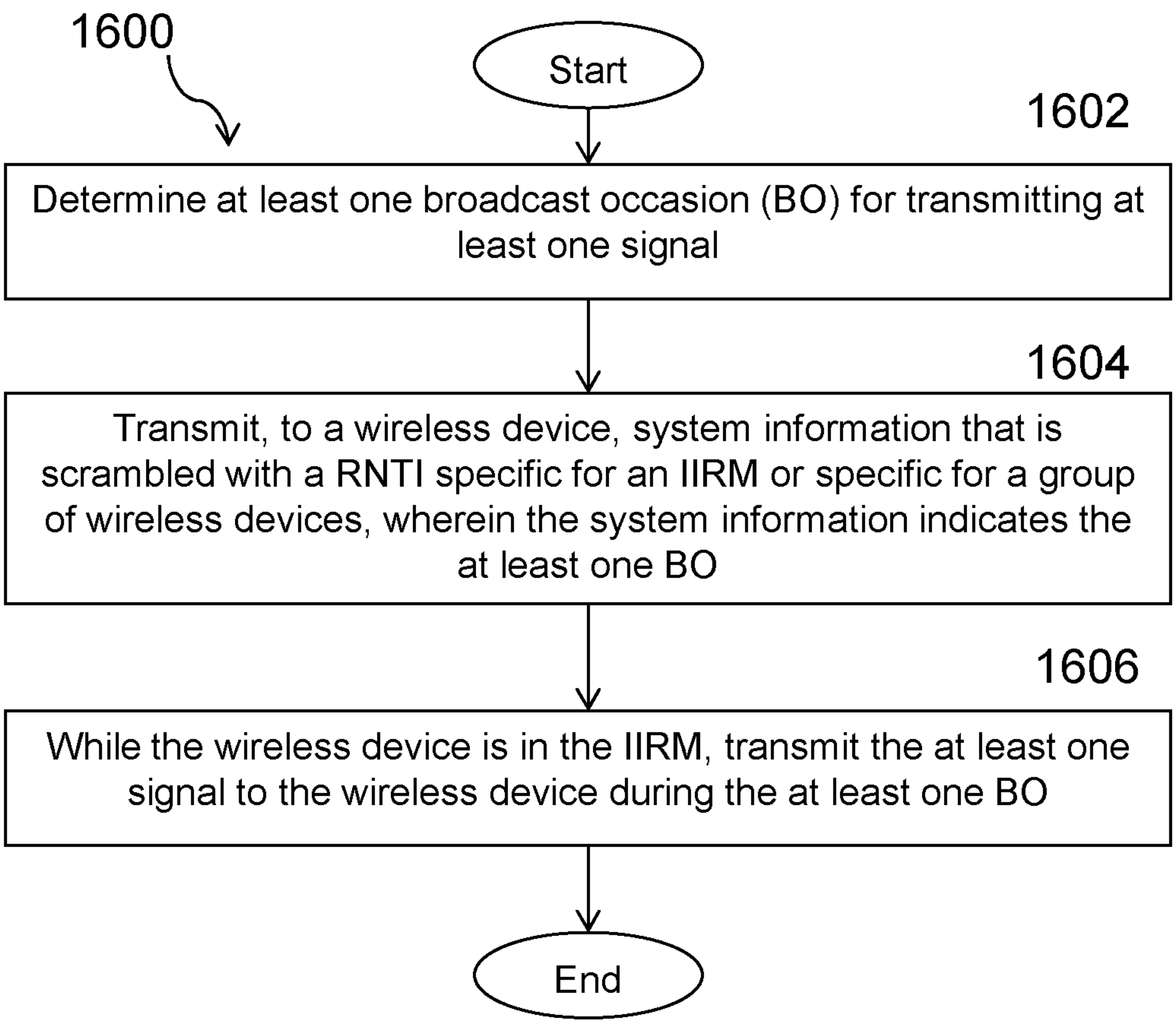

FIGURE 20

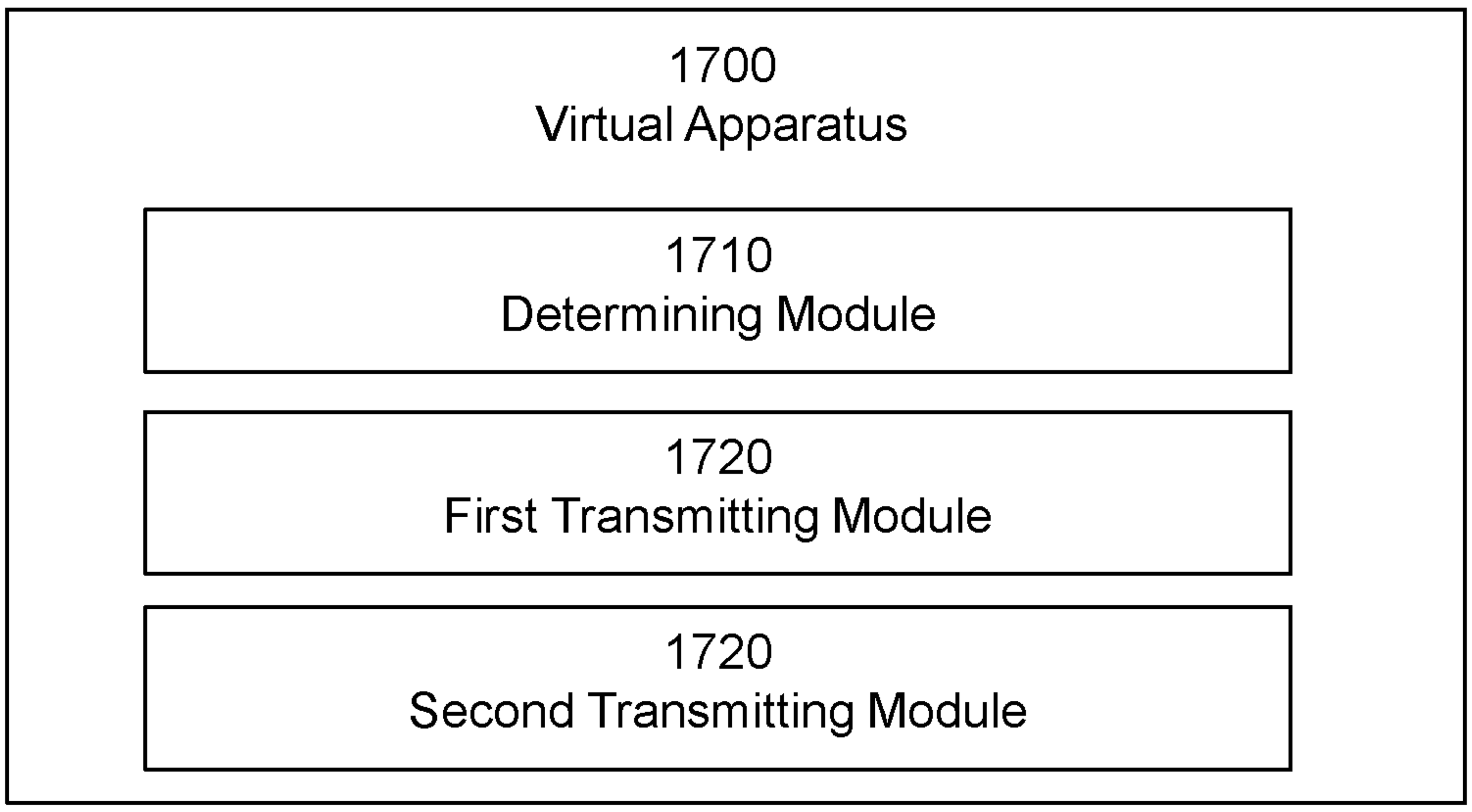

FIGURE 21

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2020/051180

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W68/02 H04W48/08
ADD. H04W76/27 H04W76/28

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)
H04W

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/155739 A2 (NOKIA CORP [FI]; NOKIA INC [US] ET AL.) 24 December 2008 (2008-12-24) paragraphs [0042] - [0052], [0055] - [0058], [0064], [0065]	1-32
X	GB 2 568 513 A (TCL COMMUNICATION LTD [CN]) 22 May 2019 (2019-05-22)	1-10, 12-26, 28-32
A	paragraphs [0021] - [0023], [0030], [0033], [0035], [0038], [0051] - [0053]	11,27
A	US 2019/297577 A1 (LIN QIONGJIE [US] ET AL) 26 September 2019 (2019-09-26) paragraphs [0117], [0133], [0134], [0164], [0165], [0244] paragraphs [0275] - [0279], [0327], [0330], [0597], [0598]	1-31

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 February 2021	19/02/2021

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer
Alonso Maleta, J

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SE2020/051180

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		US 2020275372 A1	27-08-2020
		WO 2019182428 A1	26-09-2019