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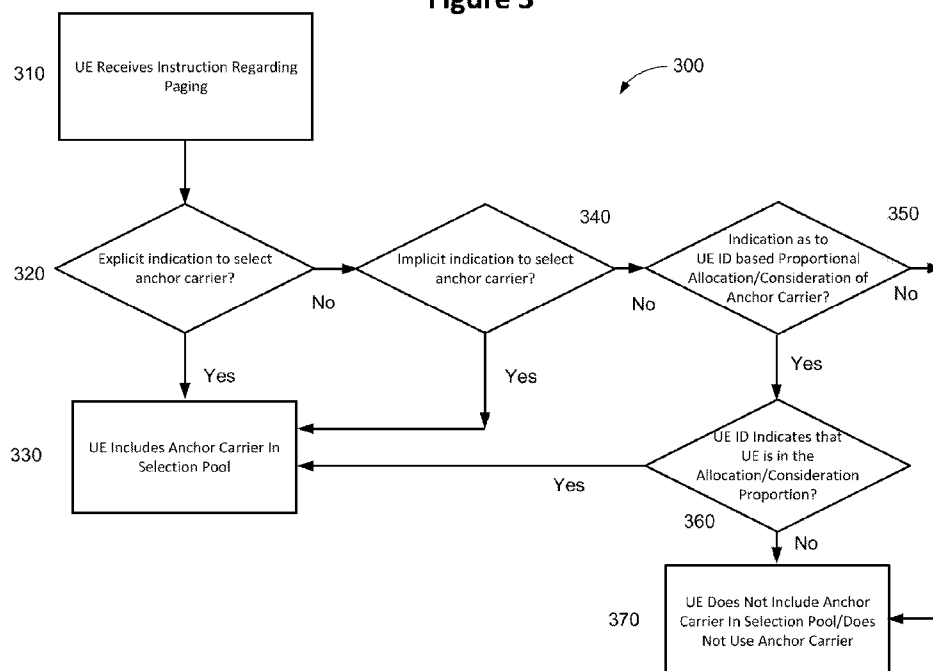
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(54) Title: SUPPORT OF IDLE MODE PAGING IN NON-ANCHOR CARRIER

Figure 3



(57) Abstract: Embodiments of the present disclosure may identify a User Equipment (UE) that supports non-anchor carriers for monitoring of paging. The UE may include transceiver circuitry to receive paging configuration messages in a cellular communications network, and paging carrier selection circuitry, coupled to the transceiver circuitry, to process the paging configuration messages, where the message includes information regarding: available carriers for monitoring paging in idle mode, and an anchor carrier indication including an indication as to whether an anchor carrier should be selected. The UE may select a carrier on which to monitor paging in idle mode, based, at least in part, on the information.



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SUPPORT OF IDLE MODE PAGING IN NON-ANCHOR CARRIER

Related Applications

This application claims benefit of U.S. Provisional Patent Application No. 62/373,888, filed on August 11, 2016, and U.S. Provisional Patent Application No. 62/414,478, filed on October 28, 2016, each of which is hereby incorporated by reference herein in its entirety.

Technical Field

Various embodiments generally may relate to the field of wireless communications, and in particular to the support of idle mode paging on a non-anchor carrier.

Background

The Third Generation Partnership Project (3GPP) introduced a Narrow-Band Internet-of-Things (NB-IoT) design into its Release 13 specifications of the Long-Term Evolution (LTE) wireless mobile communications standard. The 3GPP LTE NB-IoT specifications define a Radio Access Technology (RAT) for a Cellular Internet-of-Things (CIoT) based on a non-backward-compatible variant of the evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (E-UTRA) standard, specifically tailored towards improved indoor coverage, support for a massive number of low throughput devices, low delay sensitivity, ultra-low device complexity and cost, low device power consumption and (optimized) network architecture.

Furthermore, the NB-IoT system is being designed to support low complexity devices that support only 180 kHz User Equipment (UE) Radio Frequency (RF) bandwidth for both downlink (DL) and uplink (UL) communications, in three different modes of operation: stand-alone deployment, NB-IoT deployment in the guard band of an LTE carrier, and NB-IoT deployed in-band. A NB-IoT carrier generally includes one legacy LTE Physical Resource Block (PRB) for in-band mode and its equivalent in stand-alone/guard-band modes, corresponding to a system bandwidth of 180kHz.

However, it is also possible to support multi-carrier operation (MCO) for NB-IoT systems such that more than a single 180 kHz carrier is available for the network to configure the UE to other than the anchor carrier. Thus, a UE upon Radio Resource Control (RRC) connection establishment (or if it is supported/applicable, in future RRC Connection Reconfigurations), may be directed to another NB-IoT carrier via dedicated RRC signaling to retune from the current carrier to an additional DL or UL NB-IoT carrier in order to receive or transmit, respectively. According to agreements at the Radio Access

Network1 (RAN1) 2nd ad-hoc meeting on NB-IoT, held in March of 2016, [RAN1 Chairman's notes, RAN1 2nd ad-hoc meeting on NB-IoT, March 2016], the following was provided as regards multi-carrier operation:

- Any combination, i.e., inband+inband, inband+guardband, and guardband+guardband should be allowed for NB-IoT multi-carrier operation with the constraint that both guard-bands and the in-band are associated with the same LTE donor cell, i.e., the total span cannot exceed 110 PRBs from the same FFT;
- No support of NB-IoT multi-carrier operation for standalone mode with either guard-band or in-band mode of operation;
- Standalone+standalone should be allowed for NB-IoT multi-carrier operation with the constraint that the total frequency span cannot exceed 20MHz and both NB-IoT carriers are synchronized, i.e., the time alignment error shall not exceed the minimum requirement for intra-band contiguous carrier aggregation in TS 36.104;
- On Physical Resource Blocks (PRBs) different than the NB-IoT carrier on which the UE has received Narrow Band Primary Synchronization Signals/Secondary Synchronization Signals (NB-PSS/SSS), Narrow Band-Physical Broadcast Channel (NB-PBCH) and System Information Block (SIB) transmissions, the NB-IoT UE does not rate match around NB-PBCH and NB-PSS/SSS, i.e., the mapping of narrow band physical downlink control channels/physical downlink shared channel (NB-PDCCH/PDSCH) symbols to REs occurs without consideration of NB-PSS/SSS/PBCH.

Thus, according to agreements made by 3GPP RAN Working Group1 (WG1) and Working Group2 (WG2), a Release-13 UE directed to an additional carrier may only use the additional carrier for unicast traffic. All common control message transmissions, including procedures such as random access (RA) and paging, are to be performed only on the anchor carrier.

Brief Description of the Drawings

Embodiments will be readily understood by the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference numerals designate like structural elements. Embodiments are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings. Figure 1 illustrates an example network that includes a user equipment (UE) and an evolved NodeB (eNB), in accordance with various embodiments.

Figure 2 illustrates an example network that includes a plurality of eNBs, in accordance with various embodiments.

Figure 3 illustrates an overview of the operational flow of a process for determining whether to consider an anchor carrier for monitoring paging for a UE, in accordance with

5 various embodiments.

Figure 4 illustrates an overview of the operational flow of a process for sending carrier configuration information to a UE capable of monitoring paging on a non-anchor carrier, in accordance with various embodiments.

Figure 5 illustrates an electronic device, in accordance with various embodiments.

10 Figure 6 illustrates a computer system, in accordance with various embodiments.

Detailed Description

In embodiments, a User Equipment (UE) that supports non-anchor carriers for monitoring of paging may be provided. The UE may include transceiver circuitry to receive paging configuration messages in a cellular communications network, and paging
15 carrier selection circuitry, coupled to the transceiver circuitry, to process the paging configuration messages, where the message includes information regarding: available carriers for monitoring paging in idle mode, and an anchor carrier indication including an indication as to whether an anchor carrier should be selected. The UE may select a carrier on which to monitor paging in idle mode, based, at least in part, on the information.

20 The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the various aspects of
25 various embodiments. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the various embodiments may be practiced in other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the various embodiments with unnecessary detail.

30 Various operations may be described as multiple discrete actions or operations in turn, in a manner that is most helpful in understanding the claimed subject matter. However, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations may not be performed in the order of presentation. Operations described may be performed in a

different order than the described embodiment. Various additional operations may be performed or described operations may be omitted in additional embodiments.

For the purposes of the present disclosure, the phrases "A or B," "A and/or B," and "A/B" mean (A), (B), or (A and B).

5 The description may use the phrases "in an embodiment," or "in embodiments," which may each refer to one or more of the same or different embodiments. Furthermore, the terms "comprising," "including," "having," and the like, as used with respect to embodiments of the present disclosure, are synonymous.

10 As used herein, including in the claims, the term "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the
15 circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

As used herein, a reference to "Rel-14 UEs" includes UEs compatible with Release 14 or later releases.

20 As used herein, including the claims, a NB-IoT carrier is referred to as an "anchor carrier" if it carries Narrowband Primary and Secondary Synchronization Signals (NPSS/NSSS), Narrowband Physical Broadcast Channel (NPBCH), Narrowband System Information Block Type 1 (SIB1-NB), and other Narrowband System Information (SI) messages (NB-SI). Also the anchor carrier is the carrier that a UE camps on during idle mode. Otherwise, a carrier is termed as a "non-anchor carrier."

25 Figure 1 illustrates an example network 100 that includes user equipment (UE) 105 and an evolved NodeB (eNB) 110, in accordance with various embodiments. In embodiments, the network 100 may be a third generation partnership project (3GPP) Long Term Evolution (LTE), LTE Advanced (LTE-A) LTE-Unlicensed (LTE-U), fifth generation (5G) network, and/or a new radio (NR) network. In other embodiments, the
30 network 100 may be some other type of wireless communication network.

As shown in Figure 1, the UE 105 may include transceiver circuitry 120, which may also be referred to as a multi-mode transceiver chip. The transceiver circuitry 120 may be configured to transmit and receive signals using one or more protocols such as LTE, LTE-A, LTE-U, 5G, and/or NR protocols. Specifically, the transceiver circuitry 120

may be coupled with one or more of a plurality of antennas 160 of the UE 105 for communicating wirelessly with other components of the network 100, e.g., eNB 110 over radio link 115. The antennas 160 may be powered by the transceiver circuitry 120, for example, by a power amplifier, which may be a component of the transceiver circuitry 120 as shown in Figure 1, or separate from but coupled with the transceiver circuitry 120. In one embodiment, the power amplifier may provide the power for all transmissions on the antennas 160. In other embodiments, there may be multiple power amplifiers on the UE 105. The use of multiple antennas 160 may allow for the UE 105 to use transmit diversity techniques such as spatial orthogonal resource transmit diversity (SORTD), multiple-input multiple-output (MIMO), or full-dimension MIMO (FD-MIMO).

In certain embodiments the transceiver circuitry 120 may include transmit circuitry 125 configured to cause the antennas 160 to transmit one or more signals from the UE 105, and receive circuitry 130 configured to process signals received by the antennas 160. In some embodiments, the transmit circuitry 125 and the receive circuitry 130 may be implemented as a single communication circuitry. In other embodiments, the transmit circuitry 125 and the receive circuitry 130 may be implemented in separate chips or modules, for example, one chip including the receive circuitry 130 and another chip including the transmit circuitry 125. In some embodiments, the transmitted or received signals may be cellular signals transmitted to or received from eNB 110 or network 100. In some embodiments, where multiple carriers are available to the UE for paging, the received signals may be paging configuration messages, which direct or offer choices to a UE as to which carrier to use for paging, as described in detail below.

It is noted that paging configuration messages from the SIB are received by a RadioResourceConfiguration (RRC) layer of a UE. Additionally, selection of a paging carrier may also be performed by the RRC layer within the UE. Thus, in some embodiments, transceiver circuitry 120 may include or be coupled with paging carrier selection circuitry 135 to receive and process messages from eNBs and network 100. These messages may include idle mode paging messages, physical Paging Channel messages, RRC messages, *SystemInformationBlockType1 (SIB1)* messages, *SystemInformation (SI)* messages, Narrowband Primary and Secondary Synchronization Signals (NPSS/NSSS), Narrowband Physical Broadcast Channel (NPBCH), Narrowband System Information Block Type 1 (SIB1-NB), and other Narrowband System Information (SI) messages (NB-SI). These messages may further include Physical Downlink Control Channel (PDCCH) messages, Physical Downlink

Shared Channel (PDSCH) messages, Physical Uplink Shared Channel (PUSCH) messages, or the like. In embodiments, the UE may be a Release-14 UE or other UE capable of monitoring paging on non-anchor carriers. Thus, it may receive a list of carriers available for paging from eNB 110 or network 100. The list may include an anchor carrier
5 and one or more non-anchor carriers. In embodiments, paging carrier selection circuitry 135 may process paging messages received by transceiver circuitry 120, and may select a carrier for monitoring paging from a set of available carriers based, at least in part, on information in the paging messages. In some embodiments, the transceiver circuitry 120 and the paging carrier selection circuitry 135 may be provided in a single chip or apparatus
10 within UE 105.

Similar to UE 105, eNB 110 may include transceiver circuitry 140. The transceiver circuitry 140 may be further coupled with one or more of a plurality of antennas 165 of the eNB 110 for communicating wirelessly with other components of the network 100, e.g., UE 105 over radio link 115. The antennas 165 may be powered by a power amplifier, or
15 may be a separate component of the eNB 110. In one embodiment, the power amplifier may provide the power for all transmissions on the antennas 165. In other embodiments, there may be multiple power amplifiers on the eNB 110. The use of multiple antennas 165 may allow for the eNB 110 to use transmit diversity techniques such as SORTD, MIMO, or FD-MIMO. In certain embodiments the transceiver circuitry 140 may contain both
20 transmit circuitry 145 configured to cause the antennas 165 to transmit one or more signals from the eNB 110, and receive circuitry 150 to process signals received by the antennas 165. In other embodiments, the transceiver circuitry 140 may be replaced by transmit circuitry 145 and receive circuitry 150 which are separate from one another (not shown). In some embodiments, the eNB 110 may include messaging circuitry 155, to generate and
25 process messages to and from other eNBs, network 100 and UEs 105, including paging messages.

In some embodiments, the electronic device of Figure 1 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof.

30 Figure 2 illustrates an example network 200 that includes a plurality of eNBs, in accordance with various embodiments. For example, the network 200 may include a plurality of eNBs such as eNBs 210a, 210b, 210c, and 210d. In embodiments, respective eNBs 210a-d may be similar to eNB 110. The network 200 may also include a UE 205, which may be similar to UE 105. In embodiments, the UE 105 may be able to

communicate with the eNBs 210a-d over radio links 215a, 215b, 215c, 215d, which may be similar to radio link 115. It will be understood that although network 200 is shown to have four eNBs, in embodiments network 200 may have greater or fewer eNBs.

5 In general, the support of MCO for NB-IoT assumed the presence of a single anchor carrier where multiple carriers are being configured for NB-IoT deployment.

However, in 3GPP Release-14 eN-BIOT, the scope of the Work Item (WI) allows common control message transmissions, such as random access and paging, to also be performed on a non-anchor carrier.

10 As a result of this new option, it may be useful to provide techniques as to when and how a Release-14 UE may utilize non-anchor carriers.

In embodiments, the main issues on selecting a carrier for monitoring paging are as follows.

First, as noted above, in Release-13 UEs, idle mode paging is always performed on the anchor carrier. An eNB has to transmit the paging for Release-13 UE in the anchor
15 carrier. Thus, in a given network, at a given time, as long as there are significant numbers of Release-13 UEs, a carrier that can be used as anchor will most likely be more loaded than a carrier that can only be used as non-anchor carrier.

Second, if the anchor and non-anchor carriers are all in-band, the situation is very similar to enhanced Machine Type Communications (eMTC), where the non-anchor
20 Physical Resource Blocks (PRBs) are equivalent to paging narrowband in eMTC (e.g., the paging configuration, such as nB and Discontinuous Reception (DRX) cycle are the same across the carriers). In the case that the non-anchor carriers are different from the anchor carrier (e.g., a mixed deployment), the Resource Elements (REs) of Physical Downlink Shared Channel/ Physical Downlink Control Channel (PDSCH/PDCCH) for guard-band
25 and in-band are different. In fact, there may be up to 50%, e.g., 152 REs in guard-band mode vs. 100 REs in in-band mode, assuming three symbols reserved for LTE PDCCH, the presence of 4-port LTE CRS, and 2-port Narrowband Reference Signals (N-RS). Moreover, different carriers may have different power boosting, and the maximum amount of repetitions required for paging may be different for different carriers. As a result, the
30 paging configuration (i.e., the number of repetitions for NPDCCH for paging, etc.) may be different for each carrier.

Embodiments may generally relate to how the UE selects the carrier to monitor paging when PDSCH for paging can be transmitted on a non-anchor carrier (such as in a Release-14 - or higher - UE). Specifically, embodiments relate to how the UE may select

among NB-IoT carriers (one anchor carrier and one or more non-anchor carriers) to monitor paging, taking into consideration the above.

Paging, as noted above, is mostly a Radio Resource Control (RRC) procedure in which a network will wake up an idle UE if there is some data for it. The UE needs to be
 5 awakened, for example, for multiple reasons such as downlink data, change of system information, warnings (e.g., earthquake or Tsunami warnings), or instructions to fall back to lower access technologies like Code Division Multiple Access (CDMA). In all these cases the UE needs to be woken up if it has entered an RRC IDLE mode.

Thus, one of the important activities performed by a UE during RRC Idle mode is
 10 listening to paging messages. The UE should listen to paging messages to learn about incoming calls, system information changes, and ETWS (Earthquake and Tsunami Warning Service) notifications for ETWS-capable UEs.

In embodiments, the UE knows when to look for paging messages because it is informed about the paging cycle during an initial attach process as part of system
 15 information transmitted in, for example, a system information block type 2 (SIB2) transmission. Once it knows about the paging cycle, it may momentarily wake up during the onset of the paging cycle, check if there are any paging messages for it, and then return to sleep if there are none. If there are paging messages for the UE, it may then react by triggering an RRC connection request message.

20 It is noted that in eMTC, multiple narrowband resources (for example, 6 PRBs) may be used to transmit paging. A UE will select one of the narrowband resources to monitor for idle-mode paging based on a Paging Narrowband (PNB) calculation, as follows:

$$\text{PNB} = \text{floor}(\text{UE_ID}/(\text{N} * \text{Ns})) \bmod \text{Nn},$$

25 where:

T: DRX cycle of the UE;

nB: 4T, 2T, T, T/2, T/4, T/8, T/16, T/32, T/64, T/128, and T/256;

N: min(T, nB);

Ns: max(1, nB/T);

30 Nn: number of paging narrowbands provided in system information;

UE_ID: International Mobile Subscriber Identity (IMSI) mod 16384, if Paging Radio Network Temporary Identifier (P-RNTI) is monitored on MTC Physical Downlink Control Channel (MPDCCH); and

nB may be a cell-specific parameter that indicates a number of paging occasions or intervals in a cell specific Discontinuous Reception (DRX) cycle.

It is noted, however, that the above PNB calculation does not take into account the following restrictions for NB-IoT:

5 A. In Release-13, the idle mode paging is always performed on the anchor carrier. The eNB has to transmit the paging for Rel-13 UE in the anchor carrier. Thus, a carrier that can be used as anchor will most likely be more loaded than a carrier that can only be used as non-anchor carrier (due to all of the Rel-13 UEs in the network using the former).

10 B. If the anchor and non-anchors are all in-band, the situation may be very similar to eMTC where the non-anchor PRBs are equivalent to paging narrowband in eMTC (e.g. the paging configurations such as nB and DRX cycles are the same across all carriers). However, in the case where the non-anchors are different from the anchor, e.g., a mixed deployment, the respective Resource Elements (REs) of PDSCH/PDCCH for each
15 of guard-band and in-band are different, and different carriers can have different power boosting. Moreover, the maximum amount of repetitions required for paging may be different for different carriers and, hence, the paging configuration (e.g., at least the nB and DRX cycle) can also be different for each carrier.

Various embodiments are next described to address the restrictions for NB-IoT set
20 forth in (A) and (B) immediately above.

Support of Paging Transmissions in Multiple NB-IoT Carriers

As mentioned above, a Release-13 NB-IoT UE will only monitor paging in the anchor NB-IoT carrier (which is the carrier where the UE camps on in idle mode, reads
25 master information block (MIB) and SIB and monitors paging). With paging transmission also possible over a non-anchor carrier, a Release-14 NB-IoT UE has the choice of selecting the carrier for monitoring paging.

I. Embodiment No. 1 (addresses issue A)

30 In embodiments, the uneven distribution due to Release-13 UEs always using the anchor carrier may be addressed as follows. To address issue A described above, an eNB should be able to indicate to a Release-14 UE whether it is possible to take into consideration the anchor carrier in the selection of a carrier for paging. In embodiments, this indication may be sent on the SIB, as it may only be useful for idle mode UE. For

example, SIB2, which contains the common channel configuration, may, in embodiments, be the SIB to contain such an indication. In embodiments, in terms of SIB2 signaling, such an indication may be added as an extension in the extension marker, as shown in the example Abstract Syntax Notation (ASN.1) code provided below (added content in bold and slightly enlarged text):

```
-- ASN1START
```

```
RadioResourceConfigCommonSIB-NB-r13 ::= SEQUENCE {
    rach-ConfigCommon-r13          RACH-ConfigCommon-NB-r13,
    bccch-Config-r13               BCCCH-Config-NB-r13,
    pcch-Config-r13               PCCH-Config-NB-r13,
    np-rach-Config-r13             NP-RACH-ConfigSIB-NB-r13,
    np-dsch-ConfigCommon-r13       NP-PDSCH-ConfigCommon-NB-r13,
    np-psch-ConfigCommon-r13       NP-USCH-ConfigCommon-NB-r13,
    dl-Gap-r13                    DL-GapConfig-NB-r13          OPTIONAL,
    Need OF
    uplinkPowerControlCommon-r13   UplinkPowerControlCommon-NB-r13,
    ...
    [{pcch-Config-v14xx            PCCH-Config-NB-v14xx        OPTIONAL --
    Need OF
    11
    }
    BCCCH-Config-NB-r13 ::=
        modificationPeriodCoeff-r13 SEQUENCE {
        ENUMERATED {n16, n32, n64, n128}
        }
    PCCH-Config-NB-r13 ::=
        defaultPagingCycle-r13 SEQUENCE {
        nB-r13 ENUMERATED {
            fourT, twoT, oneT, halfT, quarterT,
            one16thT, one32ndT, one64thT,
            one128thT, one256thT, one512thT,
            spare3, spare2, spare11,
            np-dsch-NumRepetitionPaging-r13 ENUMERATED {
                r1, r2, r4, r8, r16, r32, r64, r128,
                r256, r512, r1024, r2048,
                spare4, spare3, spare2, spare11
            }
        }
    PCCH-Config-NB-v14xx ::= SEQUENCE {
        ** Alt#1: Explicit indication whether Anchor carrier should be selected by
        Rel-14 UE for monitoring of paging
        considerAnchorCarrierForPaging BOOLEAN,
        listOfNonAnchorCarriersForPaging ListOfNonAnchorCarriersForPaging
        ** Alt#2: Implicit indication whether Anchor carrier should be selected by
        Rel-14 UE for monitoring of paging
        listOfCarriersForPaging ListOfCarriersForPaging
        ** Alt#3: Indication on the proportion of Rel-14 UEs that should consider
        Anchor carrier for paging
```

```

    proportionAnchorCarrierForPaging      ENUMERATED {1, 2, 4, 8, 16,
infinity},
    listOfNonAnchorCarriersForPaging      ListOfNonAnchorCarriersForPaging
5  }
-- ASN1STOP

```

As shown in the example ASN.1 code provided above, in embodiments, there may
 10 be three alternatives for such an added indication:

Alternative No. 1:

In embodiments, an explicit indication may be made to a UE as to whether the
 anchor carrier should be assumed by Rel-14 UEs as one of the candidate carriers for
 15 monitoring paging. In this alternative, the cell may explicitly indicate whether the Rel-14
 UEs (and, as noted above, future UEs having even higher release numbers) can select the
 anchor carrier for paging. If the indication is "TRUE," the UE may include the anchor
 carrier as one of the carriers (including the indicated list of non-anchor carriers for paging)
 that may be selected for monitoring paging. If the indication is "FALSE," the UE will only
 20 select from the indicated list of non-anchor carriers for monitoring of paging.

Alternative No. 2:

In a second alternative, there may be an implicit indication whether the anchor
 carrier should be assumed by Rel-14 UEs as a possible candidate carrier for monitoring
 25 paging. In this alternative, the cell may implicitly indicate the anchor carrier in the list of
 possible carriers for paging. The UE may then use the list for selecting the carrier for
 monitoring of paging, as described below in Embodiment No. 2.

Alternative No. 3:

In a third alternative, there may be an indication as to the proportion of Rel-14 UEs
 30 that should consider the anchor carrier for monitoring paging. In embodiments, this value
 may be provided in a variable "*proportionAnchorCarrierForPaging*," as shown above,
 which may have values such as {1, 2, 4, 8, 16, infinity}. Based on the enumerated value of
 this variable, the following calculation may be made by a Rel-14 UE, based on the value
 35 of the UE's ID:

If $(UE_ID \bmod proportionAnchorCarrierForPaging) = 0$, the Rel-14 UE with the UE ID should include the anchor carrier into the list of carriers for selection for paging monitoring.

If $proportionAnchorCarrierForPaging = 1$, all or 100% of the Rel-14 UEs will consider the anchor carrier for paging monitoring.

If $proportionAnchorCarrierForPaging = 2$, 50% of the Rel-14 UEs will consider the anchor carrier for paging monitoring.

.....

If $proportionAnchorCarrierForPaging = 16$, 6.25% of the Rel-14 UEs will consider the anchor carrier for paging monitoring.

If $proportionAnchorCarrierForPaging = \text{Infinity}$, it would mean No Rel-14 UEs will consider the anchor carrier for paging monitoring.

It is noted that, in embodiments, integers that are not powers of two may also be used as values of *proportionAnchorCarrierForPaging*, and may thus determine other proportions of the Rel-14 UEs that should consider the anchor carrier. In embodiments, once a UE knows that an anchor carrier should be considered, it may then decide which paging carrier to use as described in detail below.

Alternative No. 4:

In embodiments, in a fourth alternative, a flag indication may be added when sending to the UE the information regarding each carrier (whether anchor or not) to indicate whether or not it is possible to use that specific carrier for paging. For example, a *ListOfCarriersForPaging* (as shown in Alternative 2, in the example ASN.1 code provided above) may be built, including all carriers, and a flag may indicate whether each carrier is suitable for paging or for other operations that are suitable for MCO (as explained in the two notes below). This fourth alternative is actually a variant of Alternatives 1 and 2, because the UE is told whether or not a given non-anchor carrier may be used.

In an alternative embodiment, this information may be defined as part of a bitmap, as opposed to as part of the information for each carrier in the carrier list.

Alternative No. 5:

In embodiments, in a fifth alternative, paging may be distributed amongst the paging carriers (including both anchor and non-anchor carriers for paging) with a different percentage of UEs assigned to each carrier. Assuming that the UEs are assigned uniformly

across the International Mobile Subscriber Identities (IMSI), in embodiments, a formula for the NB-IoT Paging Carrier (NB-PC) can be defined as:

NB-PC is the smallest number satisfying the following equation:

5

$$UE_ID < \text{maximum number of UE_ID} * (W(1) + W(2) + \dots + W(NB-PC)),$$

where NB-PC is the range of integers 1..Nn, Nn is a number of paging carriers provided in the system information, and $W(i)$ is weighted distribution factor of Nn paging carriers, where $(W(1) + W(2) + \dots + W(Nn)) = 100\%$.

10

In embodiments, this may ensure that a different percentage of the UEs are assigned to each carrier based on the weighting configured for the carrier for paging.

It is noted that the maximum number of UE_ID, for example, may be: for MTC (or if P-RNTI is monitored on MPDCCH), maximum number of UE_ID = 16384, and for NB-IoT (or if P-RNTI is monitored on Narrowband Physical Downlink Control Channel (NPDCCH), the maximum number of UE_ID = 4096.

15

In embodiments, the granularity of the weighting factor may be derived based on the maximum number of paging carriers. In eMTC, the maximum number of paging narrowband may be 16. In embodiments, this may also be used as a possible value for the NB-IoT. Thus, in such embodiments, the weight granularity may be $1/16 = 0.0625$ or 6.25%. Thus, in embodiments, the range of the weight (W) for a paging carrier (say i) may be in increments of 1/16th, as follows:

20

$$W(i) = \text{ENUMERATED } \{6.25\%, 12.50\%, 18.75\%, \dots, 100\%\}$$

25

It is noted that the reason for different weightings amongst the various available carriers is that each of the paging carriers (anchor or non-anchor) may not be the same. As noted above, if the anchor and non-anchor carriers are all in-band, the situation is very similar to enhanced Machine Type Communications (eMTC), where the non-anchor Physical Resource Blocks (PRBs) are equivalent to paging narrowband in eMTC (e.g., the paging configuration, such as nB and Discontinuous Reception (DRX) cycle are the same across the carriers). In the case that the non-anchor carriers are different from the anchor carrier (e.g., a mixed deployment), and the Resource Elements (REs) of Physical

30

Downlink Shared Channel/ Physical Downlink Control Channel (PDSCH/PDCCH) for guard-band and in-band are different. In fact, there may be up to 50%, e.g., 152 REs in guard-band mode vs. 100 REs in in-band mode, assuming three symbols reserved for LTE PDCCH, the presence of 4-port LTE CRS, and 2-port Narrowband Reference Signals (N-
 5 RS). Moreover, different carriers may have different power boosting, and the maximum amount of repetitions required for paging may be different for different carriers. As a result, in embodiments, each carrier may be unequal to the other available carriers, and may be loaded differently.

In embodiments, an example modified ASN.1 message directing this weight range
 10 may be as follows (additional language provided in bold), sent from the network to the UE:

RadioResourceConfigCommonSIB-NB information element

```
-- ASN1START
15 RadioResourceConfigCommonSIB-NB-r13 ::= SEQUENCE {
    rach-ConfigCommon-r13          RACH-ConfigCommon-NB-r13,
    pccch-Config-r13                PCCCH-Config-NB-r13,
    pccch-Config-r13                PCCCH-Config-NB-r13,
    nprach-Config-r13              NPRACH-ConfigSIB-NB-r13,
    npdsch-ConfigCommon-r13        NPDSCH-ConfigCommon-NB-r13,
    npusch-ConfigCommon-r13        NPUSCH-ConfigCommon-NB-r13,
    dl-Gap-r13                      DL-GapConfig-NB-r13          OPTIONAL,
20 Need OF
    uplinkPowerControlCommon-r13    UplinkPowerControlCommon-NB-r13,
    ...,
    [[ nprach-Config-v1350          NPRACH-ConfigSIB-NB-v1350    OPTIONAL
25 Need OR
    ]],
    [[
30     pccch-Config-v14xx           PCCCH-Config-NB-v14xx        OPTIONAL
    ]],
    Need OR
    []
35 }

BCCR-Config-NB-r13 ::=
    modificationPeriodCoeff-r13    ENUMERATED {n16, n32, n64, n128}
40 }

PCCCH-Config-NB-r13 ::=
    defaultPagingCycle-r13         ENUMERATED {rf128, rf256, rf512, rf1024},
    nb-r13                         ENUMERATED {
45     fourT, twoT, oneT, halfT, quarterT,
        one16thT, one32ndT, one64thT,
        one128thT, one256thT, one512thT,
50     spare3, spare2, spare1},
    npdcch-NumRepetitionPaging-r13 ENUMERATED {
        r1, r2, r4, r8, r16, r32, r64, r128,
        r256, r512, r1024, r2048,
55     spare4, spare3, spare2, spare1}
}

PCCCH-Config-NB-v14xx ::=
    pccch-ConfigNonAnchorCarrierList-r14 SEQUENCE (SIZE (1.. maxNonAnchorPagingCarriers-
    NB-r14)) OF PCCCH-ConfigNonAnchorCarrier-NB-r14
```

```

weightPagingCarrierList-r14          SEQUENCE (SIZE (1.. maxNonAnchorPagingCarriers-
NB-r14+1)) OF PagingCarrierWeightFactor-NB-r14  OPTIONAL,  -- need OR
5
{
PCCH-ConfigNonAnchorCarrier-NB-r14 ::= SEQUENCE {
    dl-CarrierIndex          INTEGER (1..maxDL-NonAnchorCarriers-NB-r14),
    npdcch-NumRepetitionPagingNonAnchorCarrier-r14  ENUMERATED {
10      r1, r2, r4, r8, r16, r32, r64, r128, r256,
      r512, r1024, r2048, spare4, spare3, spare2,
      spare1}
    }
PagingCarrierWeightFactor-NB-r14 ::= ENUMERATED{6dot25, 12dot5, 18dot75, ..., 100}
15
-- ASN1STOP

```

20 It is noted that the fields used in the example modification to ASN.1 message presented above of npdcch-NumRepetitionPagingNonAnchorCarrier-r14, and weightPagingCarrierList-r14, have the following meanings, as set forth in TS36.331:

<i>RadioResourceConfigCommonSIB-NB field descriptions</i>	
<i>npdcch-NumRepetitionPagingNonAnchorCarrier</i>	Maximum number of repetitions for NPDCCH common search space (CSS) for paging in non-anchor carrier, see TS 36.213 [23, 16.6]. If it is not present, the maximum number of repetitions for NPDCCH common search space for paging in non-anchor carrier is the same as in anchor carrier.
<i>weightPagingCarrierList</i>	Contains the paging distribution weight for each paging carrier. The first element corresponds to the paging distribution weight for the anchor carrier, the second element corresponds to the first non-anchor carrier and so on. If it is not present, the paging is uniformly distributed over all paging carrier.

Generalize to MCO Operations

25 It is noted that the various alternatives described above may also be generalized to refer to any kind of MCO operation, and not only for paging. For example, in embodiments, the indications may refer to which carrier to use for paging, Random Access Channel (RACH), SI broadcast and/or multicast. In addition, the provided carrier information may also be used by a connected mode UE, not being restricted to a UE in
30 idle mode.

For example, upon establishing the connection, a UE shall have a valid record of the SI, therefore UE's dedicated signaling could be reduced taking advantage of the information of the other carriers being broadcast. Different options could include, e.g., (1) upon establishing the connection or during reconfiguration certain signaling (such as
35 index) can be used to indicate which of the SI broadcasted carrier information should be used by the UE; (2) if more than one carrier could be used while the UE is connected (similar to eMTC, the NB-IoT connected UEs can hop across different NB-IoT frequencies), this information could be indicated in relation to the broadcasted carrier

information. Alternatively, further information can also be added or changed via the dedicated signaling, e.g., for the configuration of the USS NPDCCH.

Rel-13 NB-IoT UEs do not receive any broadcast information while connected, more over if it were to be received, it can only do so on the anchor carrier. Therefore, allowing the eNB to send this kind of information on the non-anchor carriers may allow the UE to potentially receive the information (if it were defined this way). Moreover, connected mode UEs might be configured to decode specific SI sent on a specific carrier. For example, there might be only minimal SI information that is needed while the UE is connected, such as, Commercial Mobile Alert System/Earthquake and Tsunami Warning System (CMAS/ETWS) (if defined on NB-IoT).

Thus, the main SI may still be on the anchor but some specific SI-related information may be scheduled on all or some of the non-anchor carriers for connected mode UEs or any UE monitoring that carrier. This may be scheduled, for example, based on the SIB1-NB sent in the anchor carrier (even when it is sent in the non-anchor carrier).

It is further noted that term “MCO” also refers to the fact that different carriers may be used. This may refer to a UE being (re)configured to a specific different carrier, as well as there being defined frequency hopping (FH) for use across multiple carriers. The embodiments described hereinabove may be applicable to both cases.

Figure 3 illustrates an overview of an operational flow of a process 300 for determining whether to consider an anchor carrier for monitoring paging in accordance with various embodiments.

As illustrated, process 300 may include operations performed at blocks 310-370. The operations may be performed, e.g., by the various elements of apparatus 120 earlier described with reference to Figure 1. For example, in embodiments, the operations may be performed by transceiver circuitry 120 and paging selection circuitry 135. Process 300 may begin at block 310, where the UE receives an instruction regarding paging from a network. The instruction received by the UE may be sent by an eNB. At query block 320, it may be determined if the instruction regarding paging received at block 310 has an explicit indication to select an anchor carrier. If Yes, then process 300 may move to block 330, where the UE may include the explicitly-indicated anchor carrier in its selection pool, and process 300 may terminate. It is here noted that, as in the case of block 330, in general the results of process 300 are whether or not the UE includes an anchor carrier in its selection pool, and not which carrier it may select from that pool. The actual process used by the UE to select amongst the various members of its selection pool is described

below, in connection with Embodiment 2, and Fig. 4.

Continuing with reference to Figure 3, if No at query block 320, then process 300 may move to query block 340, where it may be determined whether an implicit indication to select an anchor carrier was included in the message regarding paging of block 310.

5 This may take the form of the cell implicitly indicating the anchor carrier in the list of possible carriers for paging, as described above in Alternative 2. If Yes at query block 340, then process 300 may move to block 330, as described above. If No, however, at query block 340, and thus neither of Alternative 1 or Alternative 2 is the case, then process 300 may proceed to block 350, for a third query. At block 350 it may be determined
10 whether the instruction regarding paging includes an indication of a proportional allocation of UEs to an anchor carrier, or whether consideration of an anchor carrier for paging by a certain proportion (e.g., fraction) of UEs was indicated. In both cases (either allocation or consideration within a selection pool) the selection may be a function of the UE's ID, as in Alternatives 3 and 5, described above.

15 If Yes at query block 350, then process 300 may move to query block 360. At block 360 it may be determined whether the UE ID indicates that the UE is in the allocation/consideration proportion. Thus, the UE may determine, based on its ID, whether it is allocated to use the anchor carrier or whether the UE should consider monitoring the anchor carrier for paging messages. If Yes at query block 360, then process 300 may
20 move to block 330, as described above, and process 300 may then terminate. If No, however, at query block 360, then process 300 may proceed to block 370, where process 300 may exclude the anchor carrier from the selection pool.

II. Embodiment No. 2 (addresses issue B)

25 As noted above, a second issue, besides that of whether to consider a non-anchor carrier for paging, is which carrier to choose once a set of possible carriers has been received. In embodiments, as regards a UE selecting which carrier to use for monitoring paging, two cases are considered. In a first case, Case 1, only one paging configuration is needed for both the anchor and the non-anchor carriers, as they use the same paging
30 configuration. In a second case, Case 2, the paging configuration of the non-anchor carriers may be different than that of the anchor carrier.

Case 1

In embodiments, for Case 1, legacy signaling on the Paging Control Channel (PCCH) configuration may be sufficient. Thus, in embodiments, it is only necessary to send the anchor carrier information in a PCCH configuration message, as all carriers (including the non-anchor carriers) will use the same PCCH configuration. Such a PCCH message may be as follows:

```

PCCH-Config-NB-r13 ::=
    defaultPagingCycle-r13
    nB-r13
    one8thT,
    one16thT, one32ndT, one64thT,
    one128thT, one256thT, one512thT,
    one1024thT,
    spare3, spare2, spare1},
    npdcch-NumRepetitionPaging-r13
    ENUMERATED {
    r1, r2, r4, r8, r16, r32, r64, r128,
    r256, r512, r1024, r2048,
    spare4, spare3, spare2, spare1}
    ;

```

In this case, the legacy calculation for Paging Frame (PF) and Paging Occasion (PO), as provided above, may be used.

The calculation used by an eMTC UE to determine which carrier to select may, in embodiments, be reused to consider the list of carriers for NB-IoT paging. This list of potential carriers may or may not include the anchor carrier depending on which alternative of Embodiment 1 is implemented, as described above.

One Narrowband Paging Carrier (NB-PC) may be one narrowband resource on which the UE may perform the paging message reception. In embodiments, NB-PC may thus determine the index of *ListOfNonAnchorCarriersForPaging* or *ListOfCarriersForPaging*. In embodiments, if P-RNTI is monitored on the Narrowband Physical Downlink Control Channel (NPDCCH), and if the UE supports Narrow Band Packet Normal Bursts (NB-PNB) over a non-anchor carrier (e.g., the UE is a Rel-14 NBIOT UE), the NB-PNB may then be determined by the following equation:

$$PNB = \text{floor}(UE_ID / (N * N_s)) \bmod N_n,$$

where:

N_n is the maximum number of carriers configured for the cell;

N is the number of paging frames; and

Ns is the number of paging occasions in a paging frame for paging monitoring (which includes total number of non-anchor carriers for paging but may or may not include the anchor carrier, as described above in Embodiment No. 1).

In embodiments, the UE_ID may be changed to take into consideration the
5 maximum PF, PO and also the PNB, as follows:

IMSI mod 4096, if P-RNTI is monitored on NPDCCH but UE does not support PNB over non-anchor carrier; or

IMSI mod (4096*maximum number of NB-PC configurable), if P-RNTI is monitored on NPDCCH and UE supports PNB over non-anchor carrier.

10

In embodiments, the RRC signaling (*ListOfNonAnchorCarriersForPaging* or *ListOfCarriersForPaging*) for each of the carriers in SIB2 message for Paging may be as follows (only the downlink (DL) configuration of the carrier being needed for paging):

```

15 DL-CarrierConfigDedicated-NB-r13 ::= SEQUENCE {
    dl-CarrierFreq-r13          CarrierFreq-NB-r13,
    downlinkBitmapNonAnchor-r13 CHOICE {
        useNoBitmap-r13        NULL,
        useAnchorBitmap-r13    NULL,
20    explicitBitmapConfiguration-r13 DL-Bitmap-NB-r13,
        spare                   NULL
    } OPTIONAL, -- Need ON
    dl-GapNonAnchor-r13        CHOICE {
        useNoGap-r13           NULL,
25    useAnchorGapConfig-r13    NULL,
        explicitGapConfiguration-r13 DL-GapConfig-NB-r13,
        spare                   NULL
    } OPTIONAL, -- Need ON
    inbandCarrierInfo-r13      SEQUENCE {
30    samePCI-Indicator-r13      CHOICE {
        samePCI-r13            SEQUENCE {
            indexToMidPCH-r13  INTEGER (-55..54)
        },
        differentPCI-r13       SEQUENCE {
35    extra-NomCRS-Ports-r13    ENUMERATED {same, four}
        }
    }
    extraControlRegionSize-r13 OPTIONAL, -- Cond anchor-guardband
40    ...                       ENUMERATED {n1, n2, n3}
    ...                       OPTIONAL, -- Cond non-anchor-inband
}

```

Case 2:

As noted above, in a second case the paging configuration of the non-anchor
45 carriers may be different than that of the anchor carrier. As a result, in such a situation, the following PCCH configuration may need to be included for each carrier. There are two possibilities, next described:

(i) One possibility for the Case 2 situation is that defaultPagingCycle and nB are different as regards handling the different NPDCCH and Narrowband Physical Downlink Shared Channel (NPDSCH) repetitions for paging. It is here recalled that nB is a cell specific parameter that indicates the number of paging occasions or intervals in a cell specific Discontinuous Reception (DRX) cycle. Configuration of the nB value depends on
 5 paging capacity desired in a cell. The larger the value of nB, the larger the paging capacity. Likewise, the smaller the paging capacity, the smaller the value of nB.

```

10 PCCH-Config-NB-r13 ::= SEQUENCE {
    defaultPagingCycle-r13 ENUMERATED {rf128, rf256, rf512, rf1024},
    nB-r13 ENUMERATED {
        fourT, twoT, oneT, halfT, quarterT,
15 one16thT, one32ndT, one64thT,
        one128thT, one256thT, one512thT,
        one1024thT,
        spare3, spare2, spare1},
    npdsch-NewRepetitionPaging-r13 ENUMERATED {
20 r1, r2, r4, r8, r16, r32, r64, r128,
    r256, r512, r1024, r2048,
    spare4, spare3, spare2, spare1}
  
```

In embodiments, in order to reduce the amount of signaling (PCCH configuration for each carrier), the following techniques may be used:

25 Allow PCCH configuration of the non-anchor carrier to be the same as the Anchor Carrier

```

ListOfNonAnchorCarriersForPaging ::= SEQUENCE (SIZE (1..maxCarrierForPaging)) OF
NonAnchorCarriersForPaging
30 NonAnchorCarriersForPaging ::= SEQUENCE {
    dl-CarrierConfigForPaging-r14 DL-CarrierConfig-NB-r13 OPTIONAL,
    pcch-Config-r14 CHOICE {
        sameasAnchor NULL
35        different PCCH-Config-NB-r13
    }
  
```

The PCCH configuration may be part of the field in the list of carriers for monitoring paging and instead of providing the full PCCH configuration, the

```

40 ListOfNonAnchorCarriersForPaging ::= SEQUENCE (SIZE (1..maxCarrierForPaging)) OF
NonAnchorCarriersForPaging
NonAnchorCarriersForPaging ::= SEQUENCE {
    dl-CarrierConfigForPaging-r14 DL-CarrierConfig-NB-r13 OPTIONAL,
45    pcch-Config-r14 CHOICE {
        sameasAnchor NULL
        sameasNonAnchor INTEGER (1..maxCarrierForPaging)
        different PCCH-Config-NB-r13
    }
  
```

50 It is here noted that the indication of the PCCH configuration may also be implicitly understood that the specific carrier is used for MCO with paging.

Again, it is noted that in this case, the same legacy formulation as Case 1 for PF and PO may be used and the PCCH configuration used for the calculation will be based on the carrier selected. As regards determination of a carrier, in embodiments, the formulation may be the same as Case 1 but it may use the PCCH configuration of the carrier that provides the maximum $N \cdot N_s$. The PF, PO and PNB calculation may be as follows:

NB-PC calculation: $NB-PC = \text{floor} (UE_ID / \max(N_i \cdot N_{s_i})) \bmod N_n$

PF calculation: $SFN \bmod T_{NB-PC} = (T_{NB-PC} \text{ div } N_{NB-PC}) \cdot (UE_ID \bmod N_{NB-PC})$

PO calculation: $i_s = \text{floor}(UE_ID / N_{NB-PC}) \bmod N_{SNB-PC}$

where the index i is the indexing of the carrier in the list of carrier for paging monitoring and N_i and N_{s_i} are calculated based on the paging configuration (nB and DRX cycle) of the carrier index i , $\max(N_i \cdot N_{s_i})$ is the maximum of the product of N and N_s among the carriers that are configured for paging monitoring and N_n is the number of NB-IoT carriers configured for paging monitoring in the cell.

In embodiments, once the carrier index NB-PC is determined, the PF and PO calculation may be based on the PCCH configuration of the carrier index NB-PC (e.g. T_{NB-PC} , nB_{NB-PC} which derived N_{NB-PC} and N_{SNB-PC}).

Another formulation for the NB-PC calculation may take into consideration different deployments, which may result in some carriers having more REs available and different power boosting. In this case, the UE will not be stuck in the same paging carrier. One example of such formulation may be as follows:

$NB-PC = \text{floor} ((UE_ID + HSFN) / \max_i (N_i \cdot N_{s_i})) \bmod N_n$.

(ii) Another possible scenario for Case 2 is that the defaultPagingCycle and nB are the same across the carriers for paging monitoring, and only the npdcch-NumRepetitionPaging are different.

In this scenario, in embodiments, the PCCH configuration may be the same between different NB-IoT carriers for paging, with the sole exception of the maximum number of repetitions of NPDCCH in NPDCCH CSS-Type1.

Accordingly, in this embodiment, only the value of npdcch-NumRepetitionPaging may be different across paging carriers, and the eNodeB may be expected to configure an appropriate common value for nB and defaultPagingCycle for all carriers -- most likely

based on the carrier requiring maximum number of repetitions due to fewer available REs per subframe, lack of power boosting, etc.

In embodiments, this may simplify the scheduling considerations at the eNodeB as it would not need to account for different paging durations any cycles across carriers.

5 In embodiments, this may enable the eNB to optimize the maximum number of repetitions a UE needs to consider for monitor of paging Downlink Control Information (DCI) in Type1-CSS for NPDCCH, thereby optimizing UE power consumption. Considering the most typical case wherein there are no paging DCIs being transmitted, the UE can benefit from a reduction in the maximum number of repetitions for NPDCCH
10 candidates in the search space.

In this case, in embodiments, the NB-PC, PF and PO calculations may be the same as those used for Case 1, as described above.

Figure 4 illustrates an overview of the operational flow of a process 400 for sending, by the network (e.g., by an eNB), paging configuration information to the UE in
15 accordance with various embodiments.

As illustrated, process 400 may include operations performed at blocks 410-470. The operations may be performed e.g., by the various elements of apparatus 140 earlier described with reference to Figure 1. Process 400 may begin at query block 410, where the eNB, in preparing to send configuration information to a Release-14 UE (which it
20 knows is a Release-14 UE given the *UERadioPagingInformation-NB* message it received, as described below), determines if the PCCH configuration for non-anchor carriers is the same as for anchor carriers. If Yes, this is the situation of Case 1 of Embodiment 2, and then process 400 may move to block 430. At block 430 the eNB may send only the PCCH configuration for the anchor carrier. The UE may thereby understand
25 that, given a list of carriers and receipt of only one PCCH configuration, the configurations are the same across all carriers. Process 400 may then terminate at block 430.

If, however, it was No at query block 410, then process 400 may move to query block 420, where it may be determined whether the PCCH paging parameters *nB* and
30 *defaultPagingCycle* are different between the anchor carrier and some or even all of the non-anchor carriers. If Yes at query block 420, this is the situation of Case 2 of Embodiment 2, as described above, and then process 400 may move to query block 440, where it may be determined whether the PCCH paging parameters *nB* and *defaultPagingCycle* are different across all of the non-anchor carriers as well. If Yes, then

process 400 may move to block 445, where it may send both the values of nB and defaultPagingCycle for each carrier to the UE, and process 400 may terminate at block 445. If, however, a No is returned at query block 440, then process 400 may move to block 470, where it may send an abbreviated set of configuration data, as follows. At block 470 process 400 may send to the UE, for each non-anchor carrier, an indication as to whether it has the same configuration as (i) the anchor carrier (recall at query block 420 there may be some matching between some non-anchor carriers and the anchor carrier), or (ii) another non-anchor carrier. Process 400 may then terminate at block 470.

Returning now to query block 420, if No is returned, then this may be the situation of Case 2 of Embodiment 2 where defaultPagingCycle and nB are the same across carriers, but npdcch-NumRepetitionPaging is different. Process 400 may thus move to query block 450 to determine if that is the case. If Yes, then process 400 may move to block 460, where the eNB may be expected to optimize the maximum number of repetitions the UE needs to consider, thereby optimizing UE power consumption, as described above. Process 400 may terminate at 460. It is here noted that there is no "No" option at query block 450, inasmuch as if PCCH configuration parameters nB and defaultPagingCycle are the same, and npdcch-NumRepetitionPaging are not different, this is the situation of block 410, described above.

Advise eNB If A Release-14 Type UE

In embodiments, a UE may advise a network that the UE is capable of monitoring paging on a non-anchor carrier. In order for the eNB to know whether the UE is a Rel-13 or Rel-14 NB-IOT UE, either (i) the UE category (if different between Rel-13 and Rel-14) or (ii) the radio paging capability of a UE may be provided transparently in a *UERadioPagingInformation-NB* message to the MME to be provided to the eNB in S1 paging when paging the UE. In embodiments, this may be as follows:

UERadioPagingInformation-NB message

```
-- ASN1START
UERadioPagingInformation-NB ::= SEQUENCE {
    criticalExtensions      CHOICE {
        cl                  CHOICE {
            ueRadioPagingInformation-r13
            spare3 NULL, spare2 NULL, spare1 NULL
        },
        criticalExtensionsFuture SEQUENCE {}
    }
}
```

```

UERadioPagingInformation-NB-IEs ::= SEQUENCE {
    ue-RadioPagingInfo-r13 OCTET STRING (CONTAINING UE-RadioPagingInfo-NB-
5    r13),
    nonCriticalExtension SEQUENCE {}
    OPTIONAL
}
-- ASN1STOP

```

10 *UE-RadioPagingInfo-NB*

The *UE-RadioPagingInfo-NB* IE contains UE NB-IoT capability information needed for paging.

15 *UE-RadioPagingInfo-NB* information element

```

-- ASN1START
UERadioPagingInfo-NB-r13 ::= SEQUENCE {
20    ue-Category-NB-r13 ENUMERATED {nb1} OPTIONAL,
    ...,
    ** Approach#1: New UE category for Rel-14 NBIOT UE
    [{ ue-Category-NB-r14 ENUMERATED {nb2} OPTIONAL
    }]
25    ** Approach#2: Whether the UE supports paging reception on non-anchor carrier
    [{ SupportOfNonAnchorPaging ENUMERATED {TRUE} OPTIONAL
    }]
    ;
30 -- ASN1STOP

```

Upon receiving a S1 paging with the container UERadioPagingInformation-NB message, the eNB may then determine whether it is paging a Rel-13 NBIOT UE or a Rel-14 NBIOT UE.

35 In embodiments, the MCO operation for paging may be defined as a Rel-14 UE radio capability that may either be mandatory or optional for any UE. Thus, this new feature may be used by any UE that supports this feature.

Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Figure 5 illustrates, for one embodiment, 40 example components of an electronic device 500. In embodiments, the electronic device 500 may be implemented, be incorporated into, or otherwise be a part of a user equipment (UE), an evolved NodeB (eNB), and/or some other electronic device. In some embodiments, the electronic device 500 may include application circuitry 502, baseband circuitry 504, Radio Frequency (RF) circuitry 506, front-end module (FEM) circuitry 508 45 and one or more antennas 510, coupled together at least as shown. In embodiments where

the electronic device 500 is implemented in or by an eNB 210, the electronic device 500 may also include network interface circuitry (not shown) for communicating over a wired interface (for example, an X2 interface, an S1 interface, and the like).

The application circuitry 502 may include one or more application processors. For example, the application circuitry 502 may include circuitry such as, but not limited to, one or more single-core or multi-core processors 502a. The processor(s) 502a may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors 502a may be coupled with and/or may include computer-readable media 502b (also referred to as “CRM 502b”, “memory 502b”, “storage 502b”, or “memory/storage 502b”) and may be configured to execute instructions stored in the CRM 502b to enable various applications and/or operating systems to run on the system. Application circuitry 502 may, in embodiments, may receive paging configuration messages from the network or the eNB, and may also make the choice as to which carrier to use for monitoring paging. Thus, in some embodiments, application circuitry 502 may include transceiver circuitry to receive paging configuration messages, and paging carrier selection circuitry, coupled to the transceiver circuitry, to process the paging configuration messages and select a paging carrier, based at least in part on the information contained in the paging configuration messages. In embodiments, paging carrier selection circuitry may process paging messages received by transceiver circuitry, and may select a carrier for monitoring paging from a set of available carriers based, at least in part, on information in the paging messages.

The baseband circuitry 504 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 504 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 506 and to generate baseband signals for a transmit signal path of the RF circuitry 506. Baseband circuitry 504 may interface with the application circuitry 502 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 506. For example, in some embodiments, the baseband circuitry 504 may include a second generation (2G) baseband processor 504a, third generation (3G) baseband processor 504b, fourth generation (4G) baseband processor 504c, and/or other baseband processor(s) 504d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 504 (e.g., one or more of baseband processors 504a-d) may handle various radio control functions that enable communication with one or more radio

networks via the RF circuitry 506. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, and the like. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 504 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 504 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

In some embodiments, the baseband circuitry 504 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (E-UTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 504e of the baseband circuitry 504 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 504f. The audio DSP(s) 504f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. The baseband circuitry 504 may further include computer-readable media 504b (also referred to as “CRM 504b”, “memory 504b”, “storage 504b”, or “CRM 5042b”). The CRM 504g may be used to load and store data and/or instructions for operations performed by the processors of the baseband circuitry 504. CRM 504g for one embodiment may include any combination of suitable volatile memory and/or non-volatile memory. The CRM 504g may include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc.). The CRM 504g may be shared among the various processors or dedicated to particular processors. Components of the baseband circuitry 504 may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 504 and the application circuitry 502 may be implemented together, such as, for example, on a system on a chip (SOC).

In some embodiments, the baseband circuitry 504 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 504 may support communication with an E-UTRAN and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 504 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

RF circuitry 506 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 506 may include switches, filters, amplifiers, etc., to facilitate the communication with the wireless network. RF circuitry 506 may include a receive signal path that may include circuitry to down-convert RF signals received from the FEM circuitry 508 and provide baseband signals to the baseband circuitry 504. RF circuitry 506 may also include a transmit signal path that may include circuitry to up-convert baseband signals provided by the baseband circuitry 504 and provide RF output signals to the FEM circuitry 508 for transmission.

In some embodiments, the RF circuitry 506 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 506 may include mixer circuitry 506a, amplifier circuitry 506b and filter circuitry 506c. The transmit signal path of the RF circuitry 506 may include filter circuitry 506c and mixer circuitry 506a. RF circuitry 506 may also include synthesizer circuitry 506d for synthesizing a frequency for use by the mixer circuitry 506a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 506a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 508 based on the synthesized frequency provided by synthesizer circuitry 506d. The amplifier circuitry 506b may be configured to amplify the down-converted signals and the filter circuitry 506c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 504 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 506a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 506a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 506d to generate RF output signals for the FEM circuitry 508. The baseband signals may be provided by the baseband circuitry 504 and
5 may be filtered by filter circuitry 506c. The filter circuitry 506c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 506a of the receive signal path and the mixer circuitry 506a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion, respectively. In some
10 embodiments, the mixer circuitry 506a of the receive signal path and the mixer circuitry 506a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 506a of the receive signal path and the mixer circuitry 506a of the transmit signal path may be arranged for direct downconversion and/or direct upconversion, respectively. In
15 some embodiments, the mixer circuitry 506a of the receive signal path and the mixer circuitry 506a of the transmit signal path may be configured for super-heterodyne operation.

In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in
20 this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 506 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 504 may include a digital baseband interface to communicate with the RF circuitry 506.

25 In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

In some embodiments, the synthesizer circuitry 506d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is
30 not limited in this respect, as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 506d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider. The synthesizer circuitry 506d may be configured to synthesize an output frequency for use by the mixer circuitry 506a of the RF circuitry 506 based on a frequency input and a divider

control input. In some embodiments, the synthesizer circuitry 506d may be a fractional $N/N+1$ synthesizer.

In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 504 or the application circuitry 502 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the application circuitry 502.

Synthesizer circuitry 506d of the RF circuitry 506 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

In some embodiments, synthesizer circuitry 506d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 506 may include an IQ/polar converter.

FEM circuitry 508 may include a receive signal path that may include circuitry configured to operate on RF signals received from one or more antennas 510, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 506 for further processing. FEM circuitry 508 may also include a transmit signal path that may include circuitry configured to amplify signals for transmission provided by the RF circuitry 506 for transmission by one or more of the one or more antennas 510. In some embodiments, the FEM circuitry 508 may include a TX/RX switch to switch

between transmit mode and receive mode operation. The FEM circuitry 508 may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 506). The transmit
5 signal path of the FEM circuitry 508 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 506), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 510).

In some embodiments, the electronic device 500 may include additional elements
10 such as, for example, a display, a camera, one or more sensors, and/or interface circuitry (for example, input/output (I/O) interfaces or buses) (not shown). In embodiments where the electronic device is implemented in or by an eNB, the electronic device 500 may include network interface circuitry. The network interface circuitry may be one or more computer hardware components that connect electronic device 500 to one or more network
15 elements, such as one or more servers within a core network or one or more other eNBs via a wired connection. To this end, the network interface circuitry may include one or more dedicated processors and/or field programmable gate arrays (FPGAs) to communicate using one or more network communications protocols such as X2 application protocol (AP), S1 AP, Stream Control Transmission Protocol (SCTP),
20 Ethernet, Point-to-Point (PPP), Fiber Distributed Data Interface (FDDI), and/or any other suitable network communications protocols.

In some embodiments, the electronic device of Figure 5 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof.

Figure 6 is a block diagram illustrating components, according to some example
25 embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, Figure 6 shows a diagrammatic representation of computer system 600 including one or more processors (or processor
30 cores) 610, one or more computer-readable media 620, and one or more communication resources 630, each of which are communicatively coupled via one or more interconnects 630.

The processors 610 may include one or more central processing unit ("CPUs"), reduced instruction set computing ("RISC") processors, complex instruction set

computing ("CISC") processors, graphics processing units ("GPUs"), digital signal processors ("DSPs") implemented as a baseband processor, for example, application specific integrated circuits ("ASICs"), radio-frequency integrated circuits (RFICs), etc. As shown, the processors 610 may include, a processor 612 and a processor 614.

5 The computer-readable media 620 may be suitable for use to store instructions 650 that cause the computer system 600, in response to execution of the instructions 650 by one or more of the processors 610, to practice selected aspects of the present disclosure described with respect to the UE, an eNB, and/or a location server. In some embodiments, the computer-readable media 620 may be non-transitory. As shown, computer-readable
10 storage medium 620 may include instructions 650. The instructions 650 may be programming instructions or computer program code configured to enable the computer system 600, which may be implemented as the UE 105 or 205, in response to execution of the instructions 650, to implement (aspects of) any of the methods or elements described throughout this disclosure related to RSTD reporting. In some embodiments, programming
15 instructions 650 may be disposed on computer-readable media 650 that is transitory in nature, such as signals.

Any combination of one or more computer-usable or computer-readable media may be utilized as the computer-readable media 620. The computer-readable media 620 may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic,
20 infrared, or semiconductor system, apparatus, device, or propagation medium. More specific examples (a non-exhaustive list) of the computer-readable media would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, RAM, ROM, an erasable programmable read-only memory (for example, EPROM, EEPROM, or Flash memory), an optical fiber, a portable compact disc
25 read-only memory (CD-ROM), an optical storage device, a transmission media such as those supporting the Internet or an intranet, or a magnetic storage device. Note that the computer-usable or computer-readable media could even be paper or another suitable medium upon which the program is printed, as the program can be electronically captured, via, for instance, optical scanning of the paper or other medium, then compiled,
30 interpreted, or otherwise processed in a suitable manner, if necessary, and then stored in a computer memory. In the context of this document, a computer-usable or computer-readable media may be any medium that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The computer-usable media may include a propagated data signal

with the computer-usable program code embodied therewith, either in baseband or as part of a carrier wave. The computer-usable program code may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, radio frequency, etc.

5 Computer program code for carrying out operations of the present disclosure may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on the user's computer, 10 partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the 15 Internet using an Internet Service Provider).

As shown in Figure 6, instructions 650 may reside, completely or partially, within at least one of the processors 610 (e.g., within the processor's cache memory), the computer-readable media 620, or any suitable combination thereof. Furthermore, any portion of the instructions 650 may be transferred to the computer system 600 from any 20 combination of the peripheral devices 604 and/or the databases 606. Accordingly, the memory of processors 610, the peripheral devices 606, and the databases 606 are additional examples of computer-readable media.

The communication resources 630 may include interconnection and/or network interface components or other suitable devices to communicate with one or more 25 peripheral devices 604 and/or one or more databases 606 via a network 608. For example, the communication resources 630 may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components. In some 30 embodiments, the communication resources 630 may include a cellular modem to communicate over a cellular network, an Ethernet controller to communicate over an Ethernet network, etc.

In some embodiments, one or more components of computer system 600 may be included as a part of a UE (for example, UE 105 or 205 of Figures 1 and 2) or an eNB (for

example, eNB 110, 210a, 210b, 210c, and/or 210d). For example, messaging and timer control circuitry 135, messaging circuitry 155, or baseband circuitry 604 may include processors 610, computer-readable media 620, or communication resources 630 to facilitate operations described above with respect to the UE, eNB, or some other element such as the location server.

The present disclosure is described with reference to flowchart illustrations or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the disclosure. It will be understood that each block of the flowchart illustrations or block diagrams, and combinations of blocks in the flowchart illustrations or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create a means for implementing the functions/acts specified in the flowchart or block diagram block or blocks.

These computer program instructions may also be stored in a computer-readable medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable medium produce an article of manufacture including instruction means that implement the function/act specified in the flowchart or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions that execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart or block diagram block or blocks.

Some non-limiting examples are provided below.

EXAMPLES

Example 1 may include a user equipment (UE) that supports non-anchor carriers for monitoring of paging, comprising: transceiver circuitry to receive paging configuration messages in a cellular communications network; and paging carrier selection circuitry coupled to the transceiver circuitry to: process the paging configuration messages, wherein

the message includes information regarding: available carriers for monitoring paging in idle mode, and an anchor carrier indication including an indication as to whether an anchor carrier should be selected; and select a carrier on which to monitor paging in idle mode, based, at least in part, on the information.

5 Example 2 may include the UE of example 1, and/or other examples herein, wherein the paging configuration messages include a list of non-anchor carriers for paging, and a list of paging distribution weights to indicate a percentage of UEs assigned to each carrier.

10 Example 3 may include the UE of example 2, and/or other examples herein, wherein the paging distribution weights are a function of the maximum number of available paging carriers.

 Example 4 may include the UE of example 2, and/or other examples herein, wherein the paging carrier selected for paging monitoring is a function of the UE identification (ID) and the distribution weight of each paging carrier.

15 Example 5 may include the UE of any one of examples 1-4, and/or other examples herein, wherein in the list of paging distribution weights, the first element corresponds to the anchor carrier, and the second element corresponds to the first non-anchor carrier.

 Example 6 may include the UE of example 5, and/or other examples herein, wherein the paging configuration messages are received from an evolved Node B (eNB);

20 Example 7 may include the UE of example 5, and/or other examples herein, wherein the paging configuration messages are received in an extension of an Abstract Syntax Notation One (ASN.1) message sent over System Information Block Type 2 (SIB2) signaling.

 Example 8 may include the UE of any one of examples 1-4, and/or other examples
25 herein, wherein the anchor carrier indication includes an explicit indication to consider a named anchor carrier.

 Example 9 may include the UE of any one of examples 1-4, and/or other examples herein, wherein the paging configuration messages include a list of carriers available for paging, the list to include an anchor carrier and at least one non-anchor carrier.

30 Example 10 may include the UE of any one of examples 1-4, and/or other examples herein, wherein the paging configuration messages include:

 a proportion of the UEs that support non-anchor carriers that are to consider an anchor carrier; and

 a list of non-anchor carriers available for paging.

Example 11 may include the UE of any one of examples 1-4, and/or other examples herein, wherein the paging configuration messages include a list of carriers, wherein individual carriers in the list include a flag to indicate whether or not a
5 corresponding carrier may be used for paging.

Example 12 may include one or more computer-readable media comprising instructions to cause a user equipment (UE), upon execution of the instructions by one or more processors of the UE, to: receive paging configuration messages in a cellular communications network; process the paging configuration messages, wherein the
10 message includes information regarding: available carriers for monitoring paging in idle mode, and an anchor carrier indication including whether an anchor carrier should be selected; and select a carrier on which to monitor paging in idle mode, based, at least in part, on the information.

Example 13 may include the one or more computer-readable media of example 12, and/or other examples herein, wherein the paging configuration messages include a list of
15 non-anchor carriers for paging, and a list of paging distribution weights to indicate a percentage of UEs assigned to each carrier.

Example 14 may include the one or more computer-readable media of example 13, and/or other examples herein, wherein the paging distribution weights are a function of the
20 maximum number of available paging carriers.

Example 15 may include the one or more computer-readable media of example 13, and/or other examples herein, wherein the paging carrier selected for paging monitoring is a function of the UE identification (ID) and the distribution weight of each paging carrier.

Example 16 may include the one or more computer-readable media of any one of
25 examples 12-15, and/or other examples herein, wherein in the list of paging distribution weights, the first element corresponds to the anchor carrier, and the second element corresponds to the first non-anchor carrier.

Example 17 may include the one or more computer-readable media of any one of examples 12-15, and/or other examples herein, wherein the paging configuration messages
30 are received from an evolved Node B (eNB);

Example 18 may include the one or more computer-readable media of any one of examples 12-15, and/or other examples herein, wherein the paging configuration messages are received in an extension of an Abstract Syntax Notation One (ASN.1) message sent over System Information Block Type 2 (SIB2) signaling.

Example 19 may include the one or more computer-readable media of any one of examples 12-15, and/or other examples herein, wherein the anchor carrier indication includes an explicit indication to consider a named anchor carrier.

5 Example 20 may include the one or more computer-readable media of any one of examples 12-15, and/or other examples herein, wherein the paging configuration messages include a list of carriers available for paging, the list to include an anchor carrier and at least one non-anchor carrier.

10 Example 21 may include the one or more computer-readable media of any one of examples 12-15, and/or other examples herein, wherein the paging configuration messages include: a proportion of the UEs that support non-anchor carriers that are to consider an anchor carrier; and a list of non-anchor carriers available for paging.

15 Example 22 may include the one or more computer-readable media of any one of examples 12-15, and/or other examples herein, wherein the paging configuration messages include a list of carriers, wherein individual carriers in the list include a flag to indicate whether or not a corresponding carrier may be used for paging.

20 Example 23 may include a method of selecting a carrier on which to monitor paging messages, comprising: receiving, by a user equipment (UE) that supports non-anchor carriers for monitoring of paging, from an eNB, paging configuration messages; processing the paging configuration messages, wherein the message includes information regarding: available carriers for monitoring paging in idle mode, an anchor carrier indication as to whether an anchor carrier should be selected, and a paging configuration for each carrier; and selecting a carrier on which to monitor paging in idle mode, based, at least in part, on the information.

25 Example 24 may include the method of example 23, and/or other examples herein, wherein the paging configuration comprises a Paging Control Channel (PCCH) configuration for each carrier, including the number of Paging Occasions within a paging cycle (nB) and a Discontinuous Reception (DRX) cycle.

30 Example 25 may include the method of example 24, and/or other examples herein, further comprising if the information only includes a single paging configuration, determining by the UE that the non-anchor carriers have the same paging configuration as the anchor carrier.

Example 26 may include the method of example 24, and/or other examples herein, wherein the paging configuration is different for the anchor carrier and for each of the non-anchor carriers, and each configuration is separately received by the UE.

Example 27 may include the method of example 24, and/or other examples herein, wherein the PCCH configuration is the same for each carrier, but the maximum number of paging repetitions on the narrowband physical downlink control channel (NPDCCH-NumRepetitionPaging) is different.

5 Example 28 may include the method of example 27, and/or other examples herein, wherein the received PCCH configuration includes a common value of n_B and default paging cycle configured by the eNB.

Example 29 may include the method of example 23, and/or other examples herein, wherein the information further includes a weighting for each available carrier.

10 Example 30 may include the method of example 29, and/or other examples herein, wherein the carrier is selected based upon a UE identification number (UE-ID) and the weighting of each available carrier.

Example 31 may include apparatus, comprising control logic, transmit logic and/or receive logic to perform one or more elements of the methods of any one of examples 23-
15 30.

Example 32 may include a method for selecting a paging carrier by a user equipment (UE), comprising: receiving paging configuration messages; processing the paging configuration messages, wherein the message includes information regarding: available carriers for monitoring paging in idle mode, and an anchor carrier indication as
20 to whether an anchor carrier should be selected; and selecting a carrier on which to monitor paging in idle mode, based, at least in part, on the information.

Example 33 may include the method of example 33, and/or other examples herein, wherein the paging configuration messages include a list of non-anchor carriers for paging, and a list of paging distribution weights to indicate a percentage of UEs assigned
25 to each carrier.

Example 34 may include the method of example 33, and/or other examples herein, wherein the paging distribution weights are a function of the maximum number of available paging carriers.

Example 35 may include the method of example 33, and/or other examples herein,
30 wherein the paging carrier selected for paging is a function of the UE identification (ID) and the distribution weight of each paging carrier.

Example 36 may include the method of any one of examples 32-35, and/or other examples herein, wherein in the list of paging distribution weights, the first element

corresponds to the anchor carrier, and the second element corresponds to the first non-anchor carrier.

Example 37 may include the method of any one of examples 32-35, and/or other examples herein, wherein the paging configuration messages are received from an evolved
5 Node B (eNB).

Example 38 may include the method of any one of examples 32-35, and/or other examples herein, wherein the paging configuration messages are received in an extension of an Abstract Syntax Notation One (ASN.1) message sent over System Information Block Type 2 (SIB2) signaling.

10 Example 39 may include the method of any one of examples 32-35, and/or other examples herein, wherein the anchor carrier indication includes an explicit indication to consider a named anchor carrier.

Example 40 may include the method of any one of examples 32-35, and/or other examples herein, wherein the information includes a list of carriers available for paging,
15 the list to include an anchor carrier and at least one non-anchor carrier.

Example 41 may include the method of any one of examples 32-35, and/or other examples herein, wherein the information includes: a proportion of the UEs that support non-anchor carriers that are to consider an anchor carrier; and a list of non-anchor carriers available for paging.

20 Example 42 may include the method of any one of examples 32-35, and/or other examples herein, wherein the information includes a list of carriers, and wherein individual carriers in the list include a flag to indicate whether or not a corresponding carrier may be used for paging.

Example 43 may include apparatus, comprising control logic, transmit logic and/or
25 receive logic to perform one or more elements of the methods of any one of claims 32-42.

Example 44 may include one or more computer-readable media comprising instructions to cause a user equipment (UE) that supports non-anchor carriers for monitoring of paging, upon execution of the instructions by one or more processors of the UE, to: receive by a user equipment (UE), from an eNB, paging configuration messages;
30 process the paging configuration messages, wherein the message includes information regarding: available carriers for monitoring paging in idle mode, the available carriers including an anchor carrier and one or more non-anchor carriers, and a paging configuration for each carrier; and select a carrier on which to monitor paging in idle mode, based, at least in part, on the information.

Example 45 may include the one or more computer-readable media of example 44, and/or other examples herein, wherein the paging configuration comprises a Paging Control Channel (PCCH) configuration for each carrier, including the number of Paging Occasions within a paging cycle (nB) and a Discontinuous Reception (DRX) cycle.

5 Example 46 may include the one or more computer-readable media of example 45, and/or other examples herein, wherein, upon execution, if the information only includes a single paging configuration, the instructions further cause the UE to determine that the non-anchor carriers have the same paging configuration as the anchor carrier.

10 Example 47 may include the one or more computer-readable media of example 45, and/or other examples herein, wherein the paging configuration is different for the anchor carrier and for each of the non-anchor carriers, and each configuration is separately received by the UE.

15 Example 48 may include the one or more computer-readable media of example 45, and/or other examples herein, wherein the PCCH configuration is the same for each carrier, but the maximum number of paging repetitions on the narrowband physical downlink control channel (NPDCCH-NumRepetitionPaging) is different.

 Example 49 may include the one or more computer-readable media of example 48, and/or other examples herein, wherein the received PCCH configuration includes a common value of nB and default paging cycle configured by the eNB.

20 Example 50 may include the one or more computer-readable media of example 44, and/or other examples herein, wherein the information further includes a weighting for each available carrier.

25 Example 51 may include the one or more computer-readable media of example 50, and/or other examples herein, wherein the select the carrier includes select the carrier based upon a UE identification number (UE-ID) and the weighting of each available carrier.

30 The foregoing description of one or more implementations provides illustration and description, but is not intended to be exhaustive or to limit the scope of embodiments to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of various embodiments.

Claims

What is claimed is:

1. A user equipment (UE) that supports non-anchor carriers for monitoring of paging, comprising:

5 transceiver circuitry to receive paging configuration messages in a cellular communications network; and

 paging carrier selection circuitry coupled to the transceiver circuitry to:

 process the paging configuration messages, wherein the message includes information regarding:

10 available carriers for monitoring paging in idle mode, and
 an anchor carrier indication including an indication as to whether an anchor carrier should be selected; and

 select a carrier on which to monitor paging in idle mode, based, at least in part, on the information.

15

2. The UE of claim 1, wherein the paging configuration messages include a list of non-anchor carriers for paging, and a list of paging distribution weights to indicate a percentage of UEs assigned to each carrier.

20 3. The UE of claim 2, wherein the paging distribution weights are a function of the maximum number of available paging carriers.

4. The UE claim 2, wherein the paging carrier selected for paging monitoring is a function of the UE identification (ID) and the distribution weight of each paging carrier.

25

5. The UE of any one of claims 1-4, wherein in the list of paging distribution weights, the first element corresponds to the anchor carrier, and the second element corresponds to the first non-anchor carrier.

30 6. The UE of claim 5, wherein the paging configuration messages are received from an evolved Node B (eNB).

7. The UE of claim 5, wherein the paging configuration messages are received in an extension of an Abstract Syntax Notation One (ASN.1) message sent over System Information Block Type 2 (SIB2) signaling.

5 8. The UE of any one of claims 1-4, wherein the anchor carrier indication includes an explicit indication to consider a named anchor carrier.

 9. The UE of any one of claims 1-4, wherein the paging configuration messages include a list of carriers available for paging, the list to include an anchor carrier and at
10 least one non-anchor carrier.

 10. The UE of any one of claims 1-4, wherein the paging configuration messages include:

 a proportion of the UEs that support non-anchor carriers that are to consider an
15 anchor carrier; and
 a list of non-anchor carriers available for paging.

 11. The UE of any one of claims 1-4, wherein the paging configuration messages include a list of carriers, wherein individual carriers in the list include a flag to indicate
20 whether or not a corresponding carrier may be used for paging.

 12. One or more computer-readable media comprising instructions to cause a user equipment (UE), upon execution of the instructions by one or more processors of the UE, to:

25 receive paging configuration messages in a cellular communications network;
 process the paging configuration messages, wherein the message includes information regarding:

 available carriers for monitoring paging in idle mode, and
 an anchor carrier indication including whether an anchor carrier should be
30 selected; and

 select a carrier on which to monitor paging in idle mode, based, at least in part, on the information.

13. The one or more computer-readable media of claim 12, wherein the paging configuration messages include a list of paging distribution weights to indicate a percentage of UEs assigned to each carrier.

5 14. The one or more computer-readable media of claim 13, wherein the paging distribution weights are a function of the maximum number of available paging carriers.

15 15. The one or more computer-readable media of claim 13, wherein the paging carrier selected for paging monitoring is a function of the UE identification (ID) and the distribution weight of each paging carrier.

16 16. The one or more computer-readable media of any one of claims 12-15, wherein the paging configuration messages are received in an extension of an Abstract Syntax Notation One (ASN.1) message sent over SIB2 signaling by an eNB.

17 17. The one or more computer-readable media of any one of claims 12-15, wherein the configuration message includes an explicit indication to consider an anchor carrier.

20 18. The one or more computer-readable media of any one of claims 12-15, wherein the configuration messages include:
a proportion of the UEs that support non-anchor carriers that are to consider an anchor carrier; and
a list of non-anchor carriers available for paging.

25 19. A method of selecting a carrier on which to monitor paging messages, comprising:

receiving, by a user equipment (UE) that supports non-anchor carriers for monitoring of paging, from an eNB, paging configuration messages;

30 processing the paging configuration messages, wherein the message includes information regarding:

available carriers for monitoring paging in idle mode,

an anchor carrier indication as to whether an anchor carrier should be selected, and a paging configuration for each carrier; and

selecting a carrier on which to monitor paging in idle mode, based, at least in part, on the information.

20. The method of claim 19, wherein the paging configuration comprises a Paging
5 Control Channel (PCCH) configuration for each carrier, including the number of Paging Occasions within a paging cycle (nB) and a Discontinuous Reception (DRX) cycle.

21. The method of claim 20, further comprising:
if the information only includes a single paging configuration, determining by the
10 UE that the non-anchor carriers have the same paging configuration as the anchor carrier.

22. The method of claim 20, wherein the paging configuration is different for the anchor carrier and for each of the non-anchor carriers, and each configuration is separately received by the UE.

15

23. The method of claim 20, wherein the PCCH configuration is the same for each carrier, but the maximum number of paging repetitions on the narrowband physical downlink control channel (NPDCCH-NumRepetitionPaging) is different.

20 24. The method of claim 24, wherein the received PCCH configuration includes a common value of nB and default paging cycle configured by the eNB.

25. Apparatus, comprising control logic, transmit logic and/or receive logic to perform one or more elements of the methods of any one of claims 19-24.

25

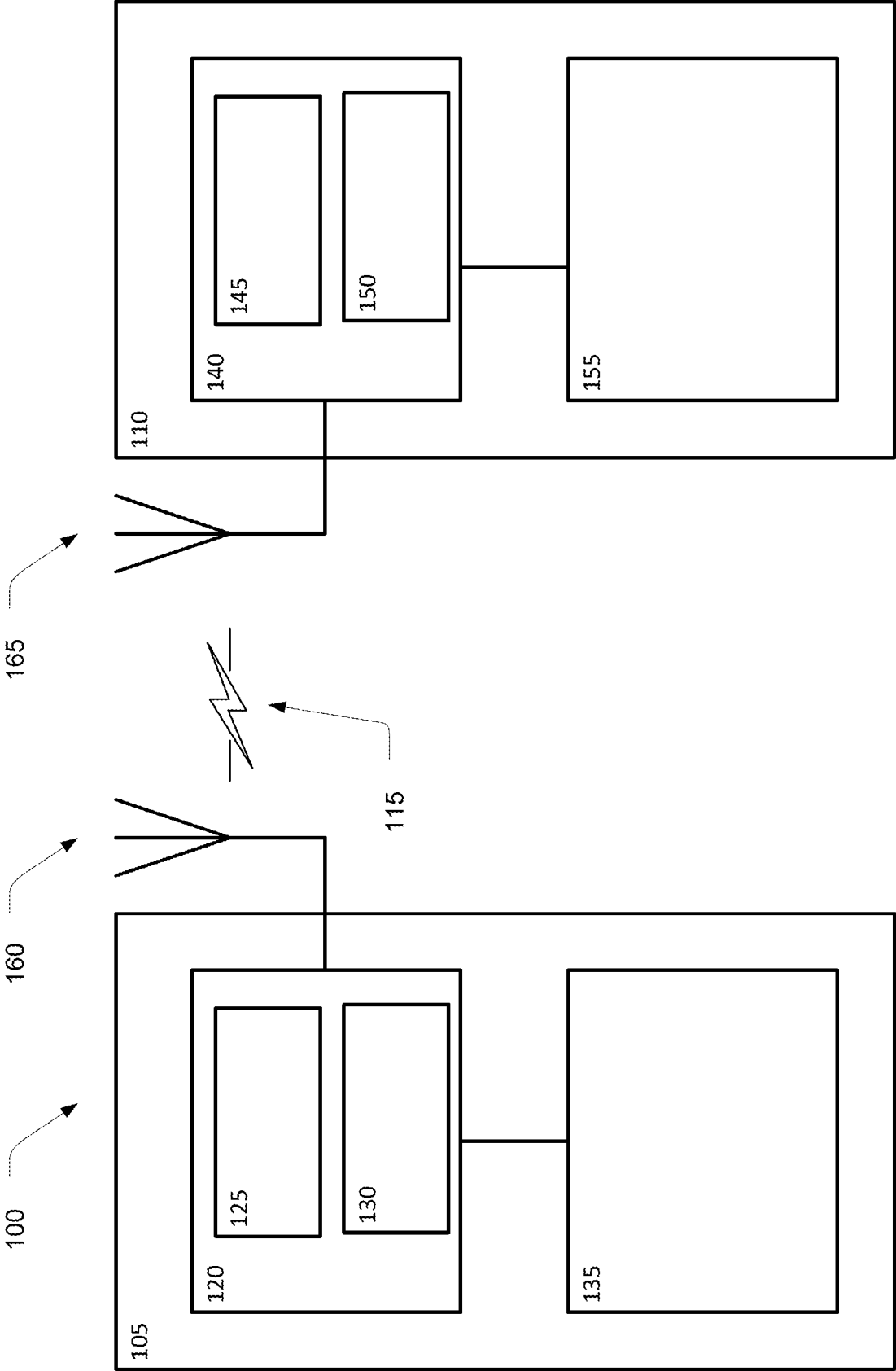


Figure 1

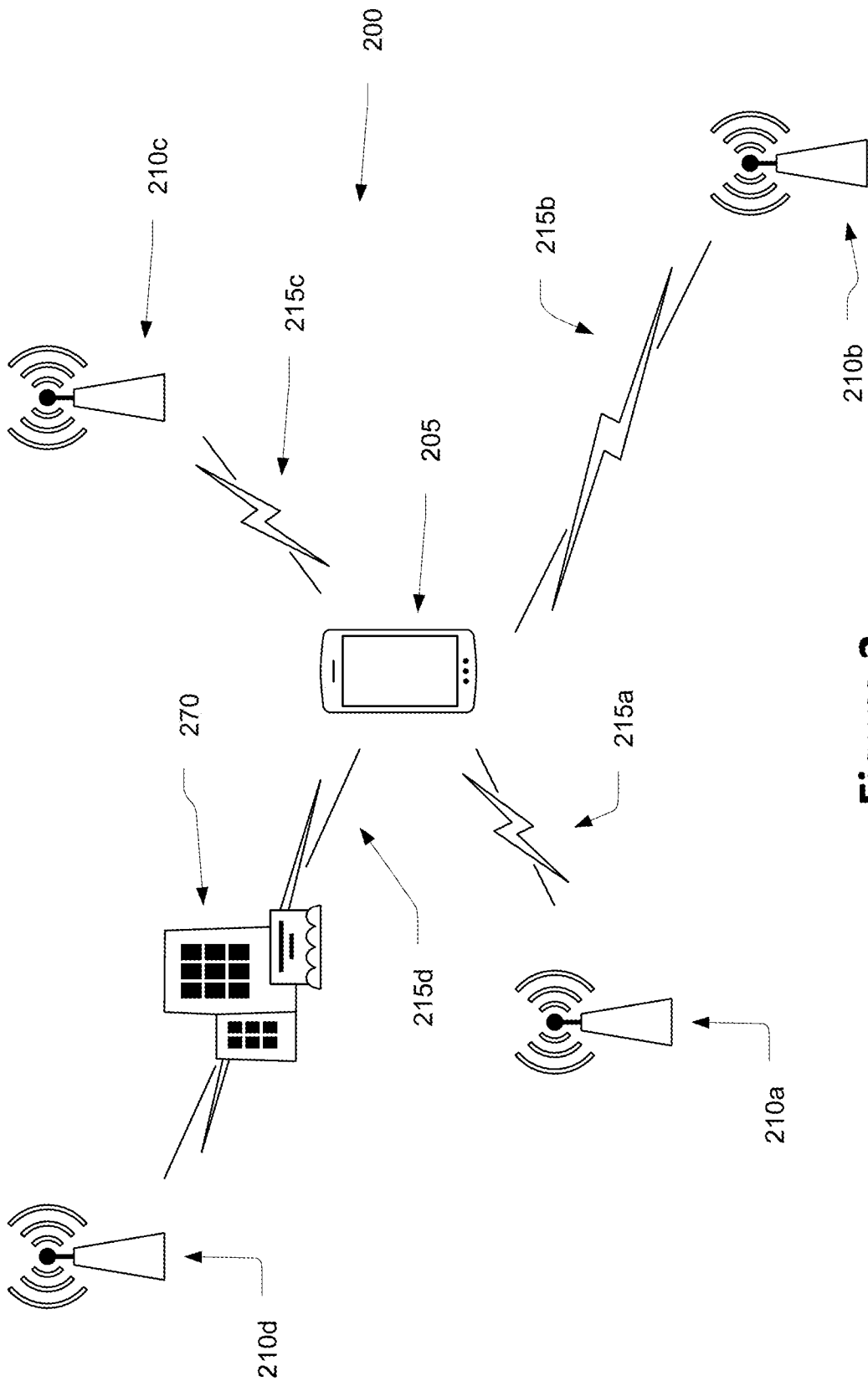
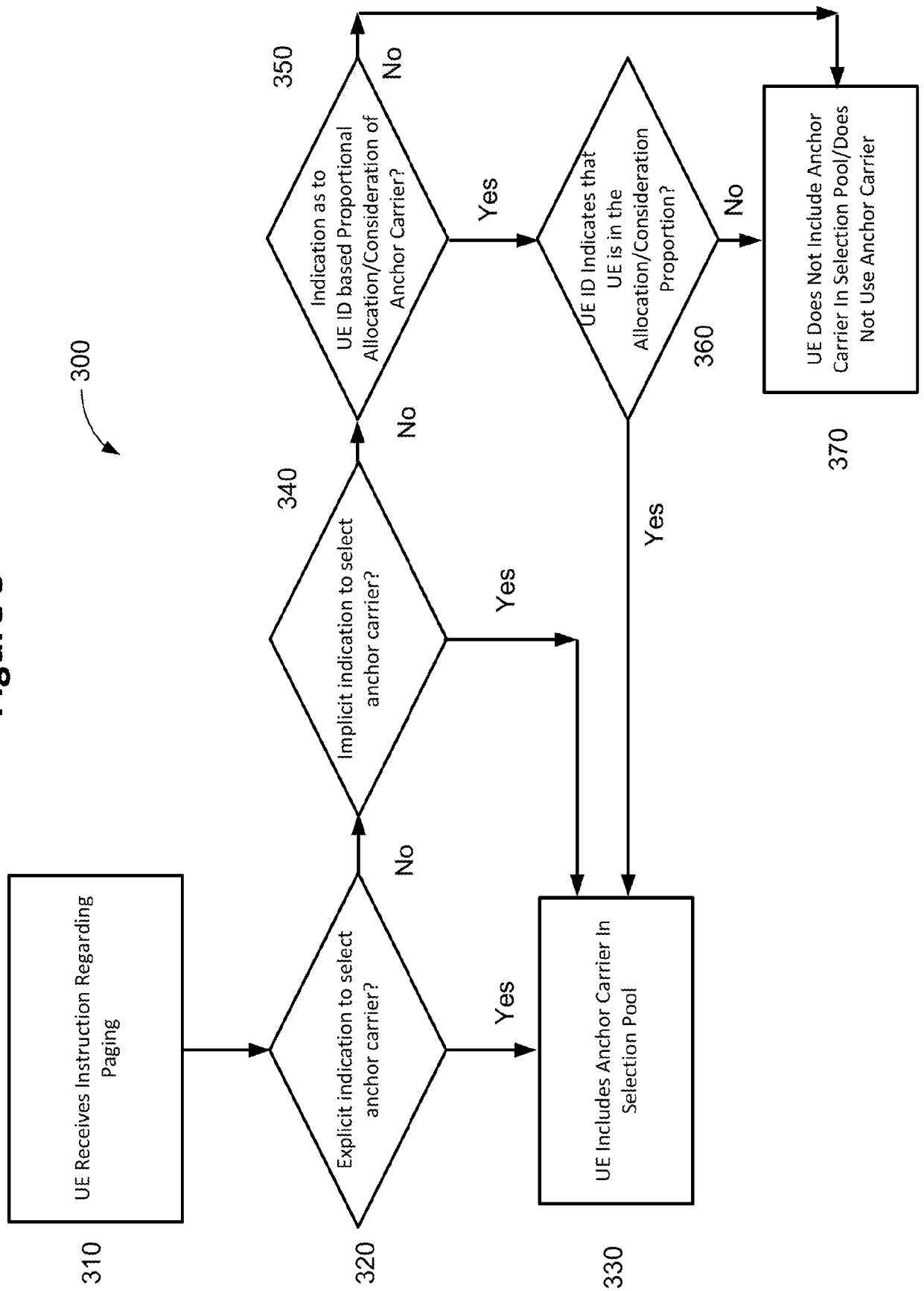
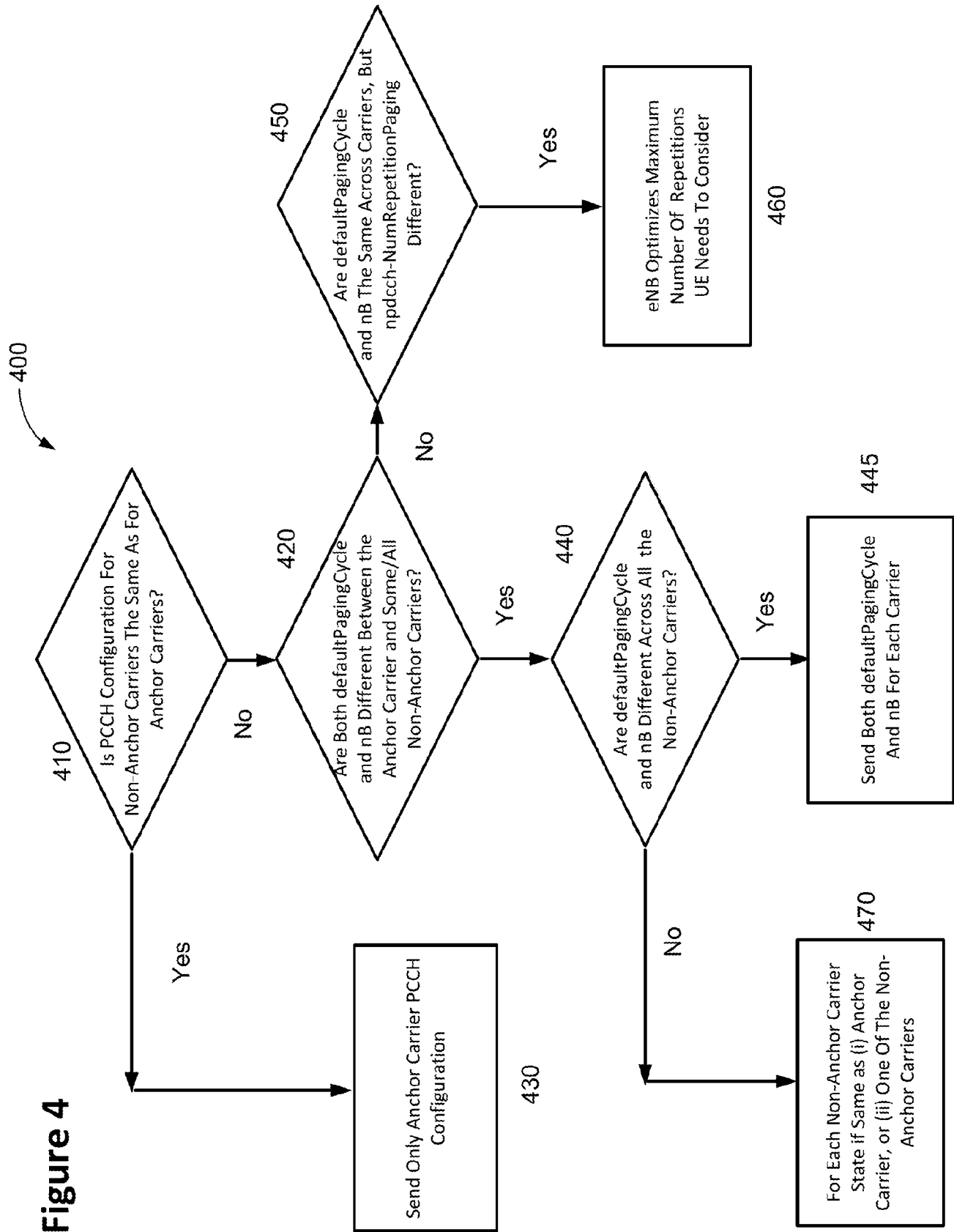


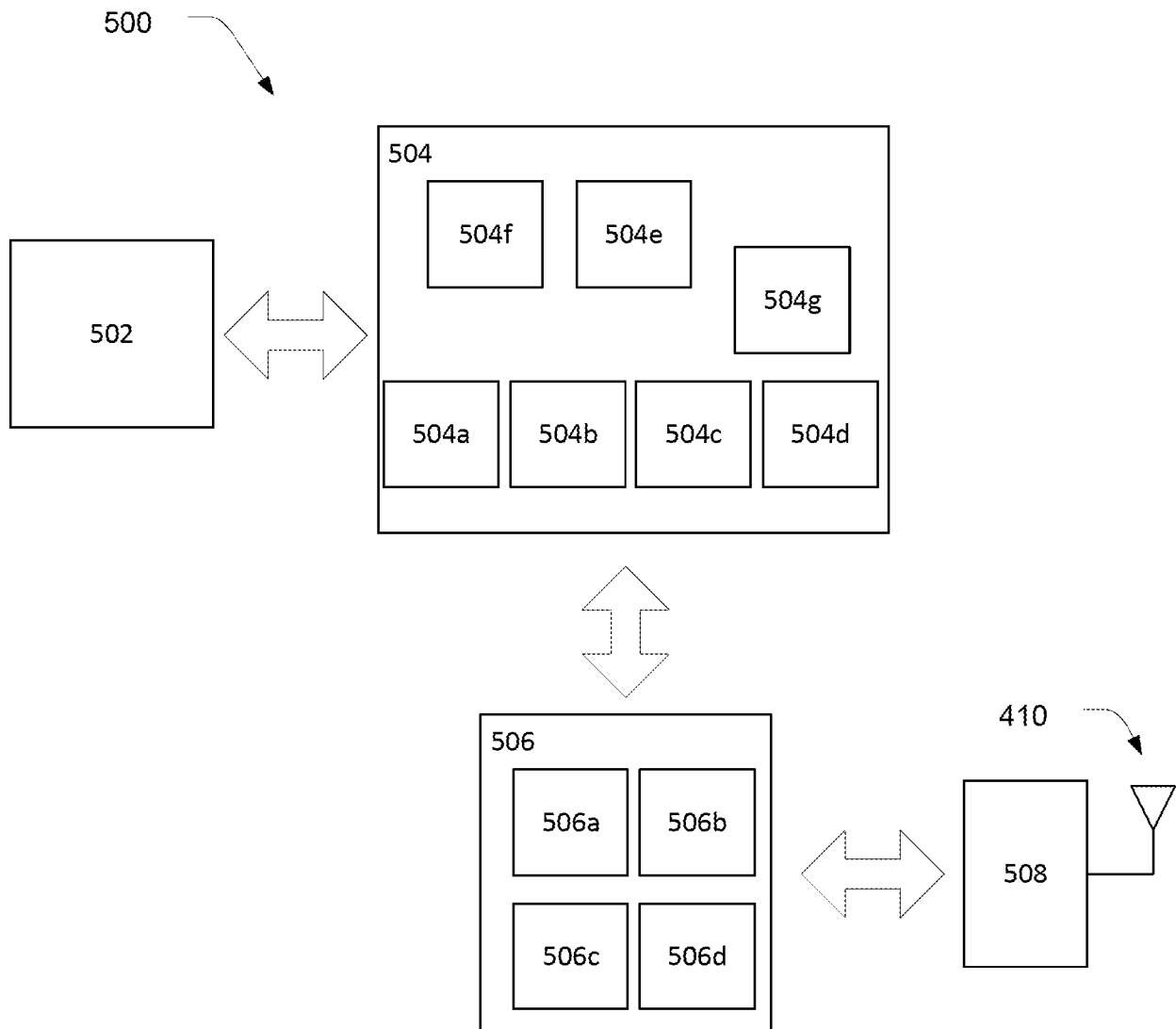
Figure 2

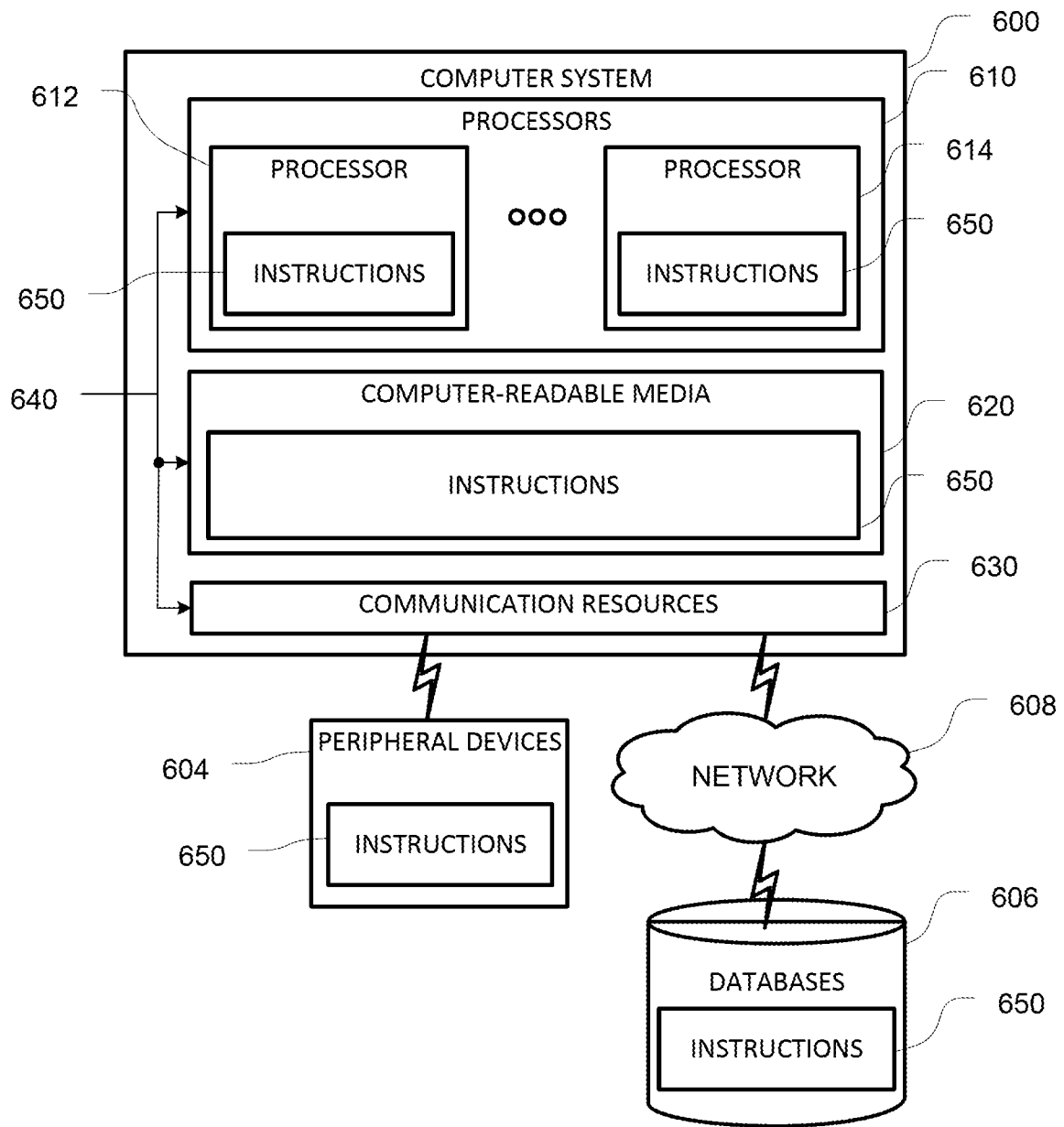
3/6

Figure 3





**Figure 5**

**Figure 6**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/040018

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W68/02
ADD.

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, COMPENDEX, INSPEC, IBM-TDB, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	paragraph [0052] paragraph [0064] paragraph [0070] paragraph [0076]	4,15,21
A	----- US 2003/088695 A1 (KWAK YONG-JUN [KR] ET AL) 8 May 2003 (2003-05-08) paragraph [0036] paragraph [0042] - paragraph [0043] ----- -/-	1,12,19, 25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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Date of the actual completion of the international search

28 September 2017

Date of mailing of the international search report

09/10/2017

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/040018

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