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(71) Applicant: **INTEL CORPORATION** [US/US]; 2200 Mission College Boulevard, Santa Clara, CA 95054 (US).

(72) Inventors: **CHATTERJEE, Debdeep**; 1748 Hanchett Ave, San Jose, CA 95128 (US). **XIONG, Gang**; 2402 NW Benson Ln, Portland, OR 97229 (US). **LI, Yingyang**; Room 1114, Buliding 1, Madian Nancun, Xicheng District, Beijing 100032 (CN). **ISLAM, Toufiqul**; 700 Agnew Road, Unit 306, Santa Clara, CA 95054 (US).

(74) Agent: **PARKER, Wesley, E.** et al.; Schwabe, Williamson & Wyatt, P.C., 1211 SW 5th Avenue, Suite 1600, Portland, OR 97204 (US).

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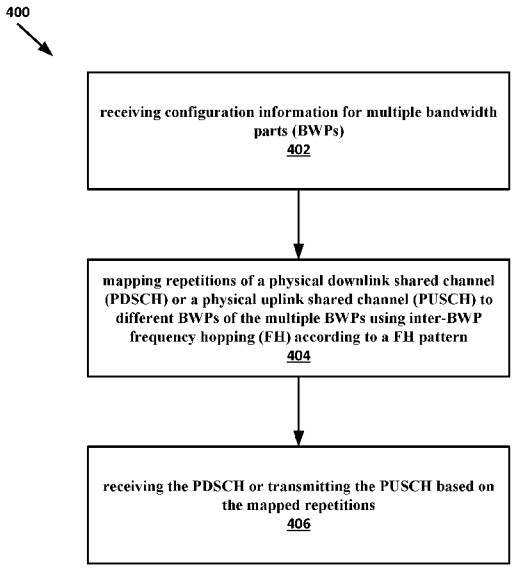


Figure 4

(57) Abstract: Various embodiments herein provide techniques for frequency hopping for reduced capability (RedCap) user equipments (UEs). The technique cause the RedCap UE to : receive configuration information for multiple bandwidth parts (BWPs); map repetitions of a PDSCH or a PUSCH to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH) according to a FH pattern; and receive the PDSCH or transmit the PUSCH based on the mapped repetitions.

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ENHANCED FREQUENCY HOPPING MECHANISMS FOR REDUCED CAPABILITY (REDCAP) DEVICES

CROSS REFERENCE TO RELATED APPLICATION

The present application claims priority to U.S. Provisional Patent Application No. 63/138,286, which was filed January 15, 2021; and U.S. Provisional Patent Application No. 63/138,680, which was filed January 18, 2021.

FIELD

Various embodiments generally may relate to the field of wireless communications. For example, some embodiments may relate to frequency hopping mechanisms for reduced capability (RedCap) user equipments (UEs).

BACKGROUND

The 5G New Radio (NR) specifications cater to support of a diverse set of verticals and use cases, including enhanced mobile broadband (eMBB) as well as the newly introduced ultra-reliable and low latency communication (URLLC) services. Support for Low Power Wide Area (LPWA) networks and use cases for low complexity/cost devices, targeting extreme coverage and ultra-long battery lifetimes, are expected to be served by MTC (Category M user equipments (UEs)) and NB-IoT (Category NB UEs) technologies.

It has been identified as beneficial to support a class of NR UEs with complexity and power consumption levels lower than 3GPP Release (Rel)-15 NR UEs, catering to use cases like industrial wireless sensor networks (IWSN), certain class of wearables, and video surveillance, to fill the gap between current LPWA solutions and eMBB solutions in NR and also to further facilitate a smooth migration from 3.5G and 4G technologies to 5G (NR) technology for currently deployed bands serving relevant use cases requiring relatively low-to-moderate reference (e.g., median) and peak user throughputs, low device complexity, small device form factors, and relatively long battery lifetimes.

Towards the above, a class of Reduced Capability (RedCap) NR UE is expected to be defined that can be served using the currently specified 5G NR framework with necessary adaptations and enhancements to limit device complexity and power consumption while minimizing any adverse impact to network resource utilization, system spectral efficiency, and operation efficiency.

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 schematically illustrates a wireless network in accordance with various embodiments.

Figure 2 schematically illustrates components of a wireless network in accordance with various embodiments.

Figure 3 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein.

Figure 4 is a flowchart of a process in accordance with various embodiments.

Figure 5 is a flowchart of another process in accordance with various embodiments.

DETAILED DESCRIPTION

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

Various embodiments herein provide techniques for frequency hopping in RedCap UEs. For example, the RedCap UE may use frequency hopping across bandwidth parts (BWPs) to receive or transmit a message, such as a physical downlink shared channel (PDSCH), a physical uplink shared channel (PUSCH), and/or another suitable message. The frequency hopping may be performed according to a frequency hopping pattern, which may be predefined or configured. The frequency hopping pattern may be performed across sets of one or more repetitions and/or slots.

For frequency range 1 (FR1), it has been agreed to support RedCap devices with reduced maximum bandwidth (BW) of 20 MHz instead of 100 MHz, while for FR2, RedCap devices are expected to require support of 100 MHz instead of up to 200 MHz. RedCap UEs are also expected to require support of one receiving branch (Rx branch) in frequency bands in which Release 15 NR UEs are required to support 2 Rx branches, while in bands in which Release 15 NR UEs are

required to support 4 Rx branches, RedCap UEs may only need to support up to 1 or 2 Rx branches (yet to be finalized in 3GPP). In addition, considering one of the key use-cases for RedCap UEs is in small form-factor devices, for FR1 bands, a RedCap UE may be allowed to support reduced antenna gains, e.g., that may be up to 3 dB lower than the Rel-15 requirements.

As a consequence of such limited capabilities, link performance for RedCap UEs, e.g., in terms of achievable coverage, reliability, and link spectral efficiency, is expected to degrade compared to Release 15 NR UEs. To compensate for the degradation in reliability and/or coverage, scheduling with repetitions for PDSCH and PUSCH are expected more frequently than Release 15 NR UEs for similar channel conditions. In this disclosure, enhancements to improve the efficiency of repeated transmissions for RedCap UEs are provded.

Various embodiments herein provide mechanisms that may improve the efficiency of repeated transmissions for RedCap UEs. For example, embodiments include systems and methods for:

- Inter-BWP frequency hopping for PDSCH;
- Inter-BWP frequency hopping for PUSCH; and/or
- Considerations on inter-BWP FH in TDD systems.

In order to recover diversity benefits for PDSCH reception or PUSCH transmission, instead of limiting to within 20 MHz BW in FR1, frequency hopping across a larger BW, e.g., 100 MHz can be beneficial. However, due to the maximum BW constraint of 20 MHz for RedCap UEs, this would require support of Frequency Hopping (FH) across bandwidth parts (BWPs), each of which may be limited to within 20 MHz.

Note that, in general, other BWP sizes can also be possible to support the methods of inter-BWP frequency hopping disclosed herein. For example, any BWP size that is supported by RedCap UEs may be used, such as BWPs with maximum BW of 40 MHz in FR1, BWPs with maximum BW of 100 MHz in FR2, and/or BWPs with maximum BW of 20 MHz or less (e.g., 5MHz), etc.

Additionally, although embodiments are described herein with reference to RedCap NR UEs, the embodiments may additionally or alternatively be used for non-RedCap NR UEs.

Furthermore, while repetitions at the slot-level (e.g., "slot aggregation"-based methods) are considered for the presentation of the concepts herein, the techniques disclosed herein may be applied to cases involving other forms of repetitions, e.g., "mini-slot repetitions" similar to PUSCH type B repetitions, etc.

Inter-BWP FH for PDSCH for RedCap NR UEs

In an embodiment, for receiving PDSCH with repetitions, a RedCap UE may be configured to receive the PDSCH such that the reception of the repetitions of the PDSCH are distributed

across multiple downlink (DL) BWPs according to a specified or semi-statically configured (e.g., via Radio Resource Control (RRC) signaling) hopping patterns. Accordingly, in an embodiment, a RedCap UE may be configured with multiple BWPs (e.g.,, *K* BWPs) via dedicated RRC signaling, and when indicated to receive PDSCH using repetitions, the repetitions of the PDSCH are received across multiple DL BWPs.

As an example, for a PDSCH with *R* repetitions, where $R \geq K$, the PDSCH may be received across the K BWPs in a cyclic manner, with at most floor(R/K) consecutive repetitions in each BWP before switching to the next. In an example, the value of R may be specified or configured UE-specifically (e.g., via dedicated RRC signaling) or cell-specifically (e.g., via System Information Block (SIB) signaling).

Cross-slot channel estimation is an important mechanism that can be used to improve the coverage performance of PDSCH and PUSCH. To enable cross-slot channel estimation, in an embodiment, for PDSCH, frequency hopping across BWPs applies every *'r' ($r \geq 1$)* repetitions or slots. In terms of frequency domain resource allocation (FDRA) within a DL BWP, the mechanisms in Rel-15 and Rel-16 may apply for the first 'r' repetitions in the first DL BWP. Further, in an embodiment, the same FDRA applies in the other BWPs.

Note that the embodiments may also apply to the case of PUSCH repetitions with inter-BWP FH. Some possible exceptions for PUSCH are described in the next sub-section.

In an embodiment, once a RedCap UE switches to a DL BWP different from the one in which the scheduling downlink control information (DCI) format was received, it is expected to receive PDCCH in the new DL BWP in the new DL BWP. Further, the existing (e.g., Release 15) timer-based fallback to "default BWP" can be reused to provide robustness against missed scheduling DCI formats. For this option, at the end of reception of the last repetition of the PDSCH, the UE may be expected to continue in the last DL BWP or be expected to retune back to the DL BWP in which the scheduling DCI format was received. Further, in an example, the UE may be configured by higher layers to follow one of the two behaviors.

Alternatively, in some embodiments, once a RedCap UE switches to a DL BWP that is different from the one in which the scheduling DCI format was received, it is not expected to receive PDCCH in the new DL BWP. Thus, the UE may only monitor for and receive PDCCH in a "*scheduling DL BWP*" and skip PDCCH monitoring when switching to other DL BWPs to receive one or more repetitions of the PDSCH. For this alternative, at the end of the last repetition of the PDSCH, the UE may be expected to retune back to the *scheduling DL BWP*.

In order to minimize the resource loss due to BWP switching times necessary to enable BWP hopping, in an embodiment, shorter BWP retuning times may be specified for inter-BWP switching that may primarily account for the radio frequency (RF) retuning and automatic gain

control (AGC) transition times. Further, in an embodiment, the first '*r*' repetitions are scheduled within the DL BWP in which the scheduling PDCCH is received. This allows for avoiding consideration of additional delays due to PDCCH processing time to determine the first BWP in which the first set of PDSCH repetitions are to be received. Additionally, the configured DL and/or uplink (UL) BWPs may be configured such that a common set of values for a set of parameters apply for all or an identified subset of the DL or UL BWPs the UE is configured with. For example, the common set of values may include all parameters configured as part of BWP configurations, except for the center frequency and BW (indicated via *locationAndBandwidth*), bwp-Id, and possibly *subcarrierSpacing* of the BWP. In a further example, a common value of subcarrier spacing (SCS) is used in the configured DL or UL BWPs. That is, other parameters, including one or more of: *subcarrierSpacing, BWP-DownlinkCommon, BWP-DownlinkDedicated, BWP-UplinkCommon, BWP-UplinkDedicated* may be same across all or an identified subset of configured BWPs the UE is configured with for inter-BWP FH. With such constraints, the application time for the new RRC configuration can be reduced significantly (to a few orthogonal frequency division multiplexing (OFDM) symbols (OSs), e.g., 50~200 μs) as the UE may switch from one BWP to another across repetitions. In another example, the BW of the candidate BWPs for inter-BWP FH are restricted to be the same.

Although here and in the rest of the disclosure, the concepts are described for FH between different BWPs, for examples with BWPs sharing common configuration, with exception of center frequency and possibly bandwidth, instead of identifying different BWPs, the physical channels may be mapped to sets of contiguous-in-frequency PRBs (e.g., "PRB sets") that are associated with a same BWP configuration.

Inter-BWP FH for PUSCH for RedCap NR UEs

In various embodiments, transmission of PUSCH with repetitions and inter-BWP frequency hopping may use the techniques described herein for PDSCH. As one possible exception, for the case of PUSCH, there can be benefits from FH within an UL BWP as well, especially when the PUSCH allocation is limited to a small number of PRBs relative to the UL BWP. To enable such methods, in one embodiment, the PUSCH repetitions may be defined to follow a two-stage FH mechanism (of intra- and inter-BWP FH), such that the UE transmits one or more repetitions of the PUSCH in the indicated set of PRBs in the active UL BWP, then transmits a number of repetitions in another one or more frequency resource(s) within the active UL BWP, and then switches to another UL BWP for similar repetitions (with intra-BWP FH) in the new UL BWP. The FH mechanism within an active UL BWP can follow existing specifications, e.g., with inter-slot FH, or following, enhanced FH mechanisms that enable cross-

repetition/slot channel estimation that are expected to be defined for coverage enhancements in Rel-17.

In another variation of the embodiment, the intra-BWP FH is limited to intra-slot FH defined in Release 15 NR specifications, while the inter-BWP FH follows the description for the case of PDSCH described above (that is, r >=1 repetitions or slots within a single UL BWP before switching to another UL BWP.

For both cases, the FDRA and intra-BWP FH offsets can be the same across the different UL BWPs.

Methods for inter-BWP FH in DL and UL in TDD systems for RedCap NR UEs

For unpaired spectrum (e.g., time-division duplexing (TDD) deployments), current specifications restrict that the active DL and active UL BWPs share a common center frequency. This avoids excessive BWP switching whenever transitioning between DL and UL. In an embodiment, when receiving repetitions of PDSCH with inter-BWP hopping, the active UL BWP also changes with the change in the active DL BWP and the candidate DL and UL BWPs share a common center frequency in a pair-wise manner; e.g., for each DL BWP, there is a corresponding UL BWP with the same center frequency. Note that the BW and SCS may be different between the active DL and active UL BWPs. According to this option, the gNB may need to ensure that a DL BWP switch event does not conflict with indicated UL BWP switches. For instance, interleaving between PDSCH reception and PUSCH transmission in respective DL and UL symbols or slots, when both are scheduled with repetitions and with or without frequency hopping, should not cause any conflict in terms of the center frequencies of the respective active DL and UL BWPs.

In another embodiment, when receiving repetitions of PDSCH with inter-BWP hopping in unpaired spectrum, the active UL BWP may not change with the change in the active DL BWP. In this case, additional time for DL-to-UL switching and UL-to-DL switching, beyond the currently specified Tx-Rx switching times (e.g., in 3GPP TS 38.211), need to be specified to accommodate RF retuning time when switching between DL and UL.

In one embodiment, the number of slots ‘Y’ for which the UE stays in one active DL or UL BWP is provided by a common parameter. This constraint may be applicable only to TDD deployments or to both TDD and frequency-division duplexing (FDD) deployments.

Furthermore, in another embodiment, at least for unpaired spectrum (TDD deployments), the FH pattern may defined with respect to an absolute point in time, e.g., by System Frame Number (SFN #0) and/or slot #0, with a common hopping pattern in time domain across DL and UL. Accordingly, once configured, the UE is expected to retune from one active DL/UL BWP pair to another BWP every ‘Y’ slots. Therefore, all DL receptions, including PDCCH reception,

and all UL transmissions are mapped to the corresponding DL/UL BWPs respectively. Note, although not strictly necessary, such a method with a common hopping time-pattern can be applicable for pair spectra (e.g., FDD deployments) as well.

In an example of the embodiment, the inter-BWP FH pattern follows a periodicity and offset defined on the absolute time scale (e.g., SFN #0, slot #0), and the reception and transmission of physical signals and channels follow a common higher layer configuration across the candidate BWPs for inter-BWP FH, and switch from one BWP to another at every FH boundary. In a further example, possible exceptions to this may be the presence of SSB and CORESET #0 as indicated by the synchronization signal block (SSB). The SSB and SSB-defined CORESET #0 may only be identified with the initial DL BWP. Similarly, an additional "CORESET #0" may be assumed in a secondary initial DL BWP if the latter is configured to RedCap UEs.

Further, in an embodiment, the numbers of candidate BWPs configured for inter-BWP FH may be limited to two or four BWPs.

Handling switching transition times for inter-BWP frequency hopping

In an embodiment, the maximum separation between the center frequencies of the DL or UL BWPs configured to a RedCap UE for inter-BWP FH is bounded by specifications. For examples, the maximum separation between the center frequencies of the DL/UL BWPs could be 80 MHz or 100 MHz. Further, the DL BWPs may be assumed to use a single common FFT at the gNodeB transmitter.

Further, in an embodiment, the inter-BWP transition times for DL and UL are reported by the UE from a set of candidate values in absolute time (e.g., in microseconds) or in number of OFDM symbols (OS) that may further be defined as a function of the larger of the SCS between the original and new BWPs. Note that, as mentioned above, for inter-BWP FH, the candidate BWPs may be configured with the same SCS. For instance, such a set of candidate values for inter-BWP transition times for DL/UL may include {0, 1, 2, 3, 4} symbols.

In an embodiment, for inter-BWP FH, the FH across BWPs may only occur at slot boundaries.

In order to accommodate the transition times, in an embodiment, during hopping from a first DL BWP to a second DL BWP at the boundary of slots 'n' and 'n+1', a RedCap UE may skip reception of one or more OFDM symbols at the end of slot 'n' and at the beginning of slot 'n+1'.

This implies that the UE may not be expected to receive PDCCH in PDCCH monitoring occasions (MOs) that may overlap fully or partially with such skipped symbols.

Similarly, in an embodiment, during hopping from a first UL BWP to a second UL BWP at the boundary of slots 'n' and 'n+1', a RedCap UE may skip transmission of one or more OFDM/DFT-S-OFDM symbols at the end of slot 'n' and at the beginning of slot 'n+1'.

In another example, when the BWP transition time amounts to an odd number of symbols, one additional symbol may be skipped from slot 'n' compared to the number of skipped symbols in slot 'n+1'.

In an embodiment, PDSCH and/or PUSCH with repetitions and inter-BWP FH are restricted to PDSCH and PUSCH (respectively) with mapping type A wherein the associated first DMRS symbol occurs not before the 3rd symbol of a slot.

Further, in an embodiment, for PDSCH or PUSCH or PUCCH formats 2, 3, or 4, the skipping of the symbols to accommodate inter-BWP transition time is realized by rate-matching the PDSCH or PUSCH (respectively) to the symbols available for reception or transmission (respectively) in the slot.

Alternatively, for PDSCH or PUSCH or PUCCH formats 2, 3, or 4, the skipping of the symbols to accommodate inter-BWP transition time is realized by assuming the availability of such symbols during rate-matching and resource mapping, but not receiving or transmitting (respectively) the symbols (e.g., via "receiver or transmitter (respectively) side puncturing").

In another embodiment, for physical channels and signals other than one or more of: PDSCH, PUSCH, and PUCCH formats 2, 3, and 4; the skipping of the symbols to accommodate inter-BWP transition time is realized by assuming the availability of such symbols during resource mapping, but not receiving or transmitting (respectively) the symbols (e.g., via "receiver or transmitter (respectively) side puncturing").

SYSTEMS AND IMPLEMENTATIONS

Figures 1-3 illustrate various systems, devices, and components that may implement aspects of disclosed embodiments.

Figure 1 illustrates a network 100 in accordance with various embodiments. The network 100 may operate in a manner consistent with 3GPP technical specifications for LTE or 5G/NR systems. However, the example embodiments are not limited in this regard and the described embodiments may apply to other networks that benefit from the principles described herein, such as future 3GPP systems, or the like.

The network 100 may include a UE 102, which may include any mobile or non-mobile computing device designed to communicate with a RAN 104 via an over-the-air connection. The UE 102 may be communicatively coupled with the RAN 104 by a Uu interface. The UE 102 may be, but is not limited to, a smartphone, tablet computer, wearable computer device, desktop computer, laptop computer, in-vehicle infotainment, in-car entertainment device, instrument cluster, head-up display device, onboard diagnostic device, dashtop mobile equipment, mobile data terminal, electronic engine management system, electronic/engine control unit,

electronic/engine control module, embedded system, sensor, microcontroller, control module, engine management system, networked appliance, machine-type communication device, M2M or D2D device, IoT device, etc.

In some embodiments, the network 100 may include a plurality of UEs coupled directly with one another via a sidelink interface. The UEs may be M2M/D2D devices that communicate using physical sidelink channels such as, but not limited to, PSBCH, PSDCH, PSSCH, PSCCH, PSFCH, etc.

In some embodiments, the UE 102 may additionally communicate with an AP 106 via an over-the-air connection. The AP 106 may manage a WLAN connection, which may serve to offload some/all network traffic from the RAN 104. The connection between the UE 102 and the AP 106 may be consistent with any IEEE 802.11 protocol, wherein the AP 106 could be a wireless fidelity (Wi-Fi®) router. In some embodiments, the UE 102, RAN 104, and AP 106 may utilize cellular-WLAN aggregation (for example, LWA/LWIP). Cellular-WLAN aggregation may involve the UE 102 being configured by the RAN 104 to utilize both cellular radio resources and WLAN resources.

The RAN 104 may include one or more access nodes, for example, AN 108. AN 108 may terminate air-interface protocols for the UE 102 by providing access stratum protocols including RRC, PDCP, RLC, MAC, and L1 protocols. In this manner, the AN 108 may enable data/voice connectivity between CN 120 and the UE 102. In some embodiments, the AN 108 may be implemented in a discrete device or as one or more software entities running on server computers as part of, for example, a virtual network, which may be referred to as a CRAN or virtual baseband unit pool. The AN 108 be referred to as a BS, gNB, RAN node, eNB, ng-eNB, NodeB, RSU, TRxP, TRP, etc. The AN 108 may be a macrocell base station or a low power base station for providing femtocells, picocells or other like cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells.

In embodiments in which the RAN 104 includes a plurality of ANs, they may be coupled with one another via an X2 interface (if the RAN 104 is an LTE RAN) or an Xn interface (if the RAN 104 is a 5G RAN). The X2/Xn interfaces, which may be separated into control/user plane interfaces in some embodiments, may allow the ANs to communicate information related to handovers, data/context transfers, mobility, load management, interference coordination, etc.

The ANs of the RAN 104 may each manage one or more cells, cell groups, component carriers, etc. to provide the UE 102 with an air interface for network access. The UE 102 may be simultaneously connected with a plurality of cells provided by the same or different ANs of the RAN 104. For example, the UE 102 and RAN 104 may use carrier aggregation to allow the UE 102 to connect with a plurality of component carriers, each corresponding to a Pcell or Scell. In

dual connectivity scenarios, a first AN may be a master node that provides an MCG and a second AN may be secondary node that provides an SCG. The first/second ANs may be any combination of eNB, gNB, ng-eNB, etc.

The RAN 104 may provide the air interface over a licensed spectrum or an unlicensed spectrum. To operate in the unlicensed spectrum, the nodes may use LAA, eLAA, and/or feLAA mechanisms based on CA technology with PCells/Scells. Prior to accessing the unlicensed spectrum, the nodes may perform medium/carrier-sensing operations based on, for example, a listen-before-talk (LBT) protocol.

In V2X scenarios the UE 102 or AN 108 may be or act as a RSU, which may refer to any transportation infrastructure entity used for V2X communications. An RSU may be implemented in or by a suitable AN or a stationary (or relatively stationary) UE. An RSU implemented in or by: a UE may be referred to as a "UE-type RSU"; an eNB may be referred to as an "eNB-type RSU"; a gNB may be referred to as a "gNB-type RSU"; and the like. In one example, an RSU is a computing device coupled with radio frequency circuitry located on a roadside that provides connectivity support to passing vehicle UEs. The RSU may also include internal data storage circuitry to store intersection map geometry, traffic statistics, media, as well as applications/software to sense and control ongoing vehicular and pedestrian traffic. The RSU may provide very low latency communications required for high speed events, such as crash avoidance, traffic warnings, and the like. Additionally or alternatively, the RSU may provide other cellular/WLAN communications services. The components of the RSU may be packaged in a weatherproof enclosure suitable for outdoor installation, and may include a network interface controller to provide a wired connection (e.g., Ethernet) to a traffic signal controller or a backhaul network.

In some embodiments, the RAN 104 may be an LTE RAN 110 with eNBs, for example, eNB 112. The LTE RAN 110 may provide an LTE air interface with the following characteristics: SCS of 15 kHz; CP-OFDM waveform for DL and SC-FDMA waveform for UL; turbo codes for data and TBCC for control; etc. The LTE air interface may rely on CSI-RS for CSI acquisition and beam management; PDSCH/PDCCH DMRS for PDSCH/PDCCH demodulation; and CRS for cell search and initial acquisition, channel quality measurements, and channel estimation for coherent demodulation/detection at the UE. The LTE air interface may operating on sub-6 GHz bands.

In some embodiments, the RAN 104 may be an NG-RAN 114 with gNBs, for example, gNB 116, or ng-eNBs, for example, ng-eNB 118. The gNB 116 may connect with 5G-enabled UEs using a 5G NR interface. The gNB 116 may connect with a 5G core through an NG interface, which may include an N2 interface or an N3 interface. The ng-eNB 118 may also connect with

the 5G core through an NG interface, but may connect with a UE via an LTE air interface. The gNB 116 and the ng-eNB 118 may connect with each other over an Xn interface.

In some embodiments, the NG interface may be split into two parts, an NG user plane (NG-U) interface, which carries traffic data between the nodes of the NG-RAN 114 and a UPF 148 (e.g., N3 interface), and an NG control plane (NG-C) interface, which is a signaling interface between the nodes of the NG-RAN114 and an AMF 144 (e.g., N2 interface).

The NG-RAN 114 may provide a 5G-NR air interface with the following characteristics: variable SCS; CP-OFDM for DL, CP-OFDM and DFT-s-OFDM for UL; polar, repetition, simplex, and Reed-Muller codes for control and LDPC for data. The 5G-NR air interface may rely on CSI-RS, PDSCH/PDCCH DMRS similar to the LTE air interface. The 5G-NR air interface may not use a CRS, but may use PBCH DMRS for PBCH demodulation; PTRS for phase tracking for PDSCH; and tracking reference signal for time tracking. The 5G-NR air interface may operating on FR1 bands that include sub-6 GHz bands or FR2 bands that include bands from 24.25 GHz to 52.6 GHz. The 5G-NR air interface may include an SSB that is an area of a downlink resource grid that includes PSS/SSS/PBCH.

In some embodiments, the 5G-NR air interface may utilize BWPs for various purposes. For example, BWP can be used for dynamic adaptation of the SCS. For example, the UE 102 can be configured with multiple BWPs where each BWP configuration has a different SCS. When a BWP change is indicated to the UE 102, the SCS of the transmission is changed as well. Another use case example of BWP is related to power saving. In particular, multiple BWPs can be configured for the UE 102 with different amount of frequency resources (for example, PRBs) to support data transmission under different traffic loading scenarios. A BWP containing a smaller number of PRBs can be used for data transmission with small traffic load while allowing power saving at the UE 102 and in some cases at the gNB 116. A BWP containing a larger number of PRBs can be used for scenarios with higher traffic load.

The RAN 104 is communicatively coupled to CN 120 that includes network elements to provide various functions to support data and telecommunications services to customers/subscribers (for example, users of UE 102). The components of the CN 120 may be implemented in one physical node or separate physical nodes. In some embodiments, NFV may be utilized to virtualize any or all of the functions provided by the network elements of the CN 120 onto physical compute/storage resources in servers, switches, etc. A logical instantiation of the CN 120 may be referred to as a network slice, and a logical instantiation of a portion of the CN 120 may be referred to as a network sub-slice.

In some embodiments, the CN 120 may be an LTE CN 122, which may also be referred to as an EPC. The LTE CN 122 may include MME 124, SGW 126, SGSN 128, HSS 130, PGW

132, and PCRF 134 coupled with one another over interfaces (or "reference points") as shown. Functions of the elements of the LTE CN 122 may be briefly introduced as follows.

The MME 124 may implement mobility management functions to track a current location of the UE 102 to facilitate paging, bearer activation/deactivation, handovers, gateway selection, authentication, etc.

The SGW 126 may terminate an S1 interface toward the RAN and route data packets between the RAN and the LTE CN 122. The SGW 126 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.

The SGSN 128 may track a location of the UE 102 and perform security functions and access control. In addition, the SGSN 128 may perform inter-EPC node signaling for mobility between different RAT networks; PDN and S-GW selection as specified by MME 124; MME selection for handovers; etc. The S3 reference point between the MME 124 and the SGSN 128 may enable user and bearer information exchange for inter-3GPP access network mobility in idle/active states.

The HSS 130 may include a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The HSS 130 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc. An S6a reference point between the HSS 130 and the MME 124 may enable transfer of subscription and authentication data for authenticating/authorizing user access to the LTE CN 120.

The PGW 132 may terminate an SGi interface toward a data network (DN) 136 that may include an application/content server 138. The PGW 132 may route data packets between the LTE CN 122 and the data network 136. The PGW 132 may be coupled with the SGW 126 by an S5 reference point to facilitate user plane tunneling and tunnel management. The PGW 132 may further include a node for policy enforcement and charging data collection (for example, PCEF). Additionally, the SGi reference point between the PGW 132 and the data network 1 36 may be an operator external public, a private PDN, or an intra-operator packet data network, for example, for provision of IMS services. The PGW 132 may be coupled with a PCRF 134 via a Gx reference point.

The PCRF 134 is the policy and charging control element of the LTE CN 122. The PCRF 134 may be communicatively coupled to the app/content server 138 to determine appropriate QoS and charging parameters for service flows. The PCRF 132 may provision associated rules into a PCEF (via Gx reference point) with appropriate TFT and QCI.

In some embodiments, the CN 120 may be a 5GC 140. The 5GC 140 may include an

AUSF 142, AMF 144, SMF 146, UPF 148, NSSF 150, NEF 152, NRF 154, PCF 156, UDM 158, and AF 160 coupled with one another over interfaces (or "reference points") as shown. Functions of the elements of the 5GC 140 may be briefly introduced as follows.

The AUSF 142 may store data for authentication of UE 102 and handle authentication-related functionality. The AUSF 142 may facilitate a common authentication framework for various access types. In addition to communicating with other elements of the 5GC 140 over reference points as shown, the AUSF 142 may exhibit an Nausf service-based interface.

The AMF 144 may allow other functions of the 5GC 140 to communicate with the UE 102 and the RAN 104 and to subscribe to notifications about mobility events with respect to the UE 102. The AMF 144 may be responsible for registration management (for example, for registering UE 102), connection management, reachability management, mobility management, lawful interception of AMF-related events, and access authentication and authorization. The AMF 144 may provide transport for SM messages between the UE 102 and the SMF 146, and act as a transparent proxy for routing SM messages. AMF 144 may also provide transport for SMS messages between UE 102 and an SMSF. AMF 144 may interact with the AUSF 142 and the UE 102 to perform various security anchor and context management functions. Furthermore, AMF 144 may be a termination point of a RAN CP interface, which may include or be an N2 reference point between the RAN 104 and the AMF 144; and the AMF 144 may be a termination point of NAS (N1) signaling, and perform NAS ciphering and integrity protection. AMF 144 may also support NAS signaling with the UE 102 over an N3 IWF interface.

The SMF 146 may be responsible for SM (for example, session establishment, tunnel management between UPF 148 and AN 108); UE IP address allocation and management (including optional authorization); selection and control of UP function; configuring traffic steering at UPF 148 to route traffic to proper destination; termination of interfaces toward policy control functions; controlling part of policy enforcement, charging, and QoS; lawful intercept (for SM events and interface to LI system); termination of SM parts of NAS messages; downlink data notification; initiating AN specific SM information, sent via AMF 144 over N2 to AN 108; and determining SSC mode of a session. SM may refer to management of a PDU session, and a PDU session or "session" may refer to a PDU connectivity service that provides or enables the exchange of PDUs between the UE 102 and the data network 136.

The UPF 148 may act as an anchor point for intra-RAT and inter-RAT mobility, an external PDU session point of interconnect to data network 136, and a branching point to support multi-homed PDU session. The UPF 148 may also perform packet routing and forwarding, perform packet inspection, enforce the user plane part of policy rules, lawfully intercept packets (UP collection), perform traffic usage reporting, perform QoS handling for a user plane (e.g.,

packet filtering, gating, UL/DL rate enforcement), perform uplink traffic verification (e.g., SDF-to-QoS flow mapping), transport level packet marking in the uplink and downlink, and perform downlink packet buffering and downlink data notification triggering. UPF 148 may include an uplink classifier to support routing traffic flows to a data network.

The NSSF 150 may select a set of network slice instances serving the UE 102. The NSSF 150 may also determine allowed NSSAI and the mapping to the subscribed S-NSSAIs, if needed. The NSSF 150 may also determine the AMF set to be used to serve the UE 102, or a list of candidate AMFs based on a suitable configuration and possibly by querying the NRF 154. The selection of a set of network slice instances for the UE 102 may be triggered by the AMF 144 with which the UE 102 is registered by interacting with the NSSF 150, which may lead to a change of AMF. The NSSF 150 may interact with the AMF 144 via an N22 reference point; and may communicate with another NSSF in a visited network via an N31 reference point (not shown). Additionally, the NSSF 150 may exhibit an Nnssf service-based interface.

The NEF 152 may securely expose services and capabilities provided by 3GPP network functions for third party, internal exposure/re-exposure, AFs (e.g., AF 160), edge computing or fog computing systems, etc. In such embodiments, the NEF 152 may authenticate, authorize, or throttle the AFs. NEF 152 may also translate information exchanged with the AF 160 and information exchanged with internal network functions. For example, the NEF 152 may translate between an AF-Service-Identifier and an internal 5GC information. NEF 152 may also receive information from other NFs based on exposed capabilities of other NFs. This information may be stored at the NEF 152 as structured data, or at a data storage NF using standardized interfaces. The stored information can then be re-exposed by the NEF 152 to other NFs and AFs, or used for other purposes such as analytics. Additionally, the NEF 152 may exhibit an Nnef service-based interface.

The NRF 154 may support service discovery functions, receive NF discovery requests from NF instances, and provide the information of the discovered NF instances to the NF instances. NRF 154 also maintains information of available NF instances and their supported services. As used herein, the terms “instantiate,” “instantiation,” and the like may refer to the creation of an instance, and an “instance” may refer to a concrete occurrence of an object, which may occur, for example, during execution of program code. Additionally, the NRF 154 may exhibit the Nnrf service-based interface.

The PCF 156 may provide policy rules to control plane functions to enforce them, and may also support unified policy framework to govern network behavior. The PCF 156 may also implement a front end to access subscription information relevant for policy decisions in a UDR of the UDM 158. In addition to communicating with functions over reference points as shown,

the PCF 156 exhibit an Npcf service-based interface.

The UDM 158 may handle subscription-related information to support the network entities' handling of communication sessions, and may store subscription data of UE 102. For example, subscription data may be communicated via an N8 reference point between the UDM 158 and the AMF 144. The UDM 158 may include two parts, an application front end and a UDR. The UDR may store subscription data and policy data for the UDM 158 and the PCF 156, and/or structured data for exposure and application data (including PFDs for application detection, application request information for multiple UEs 102) for the NEF 152. The Nudr service-based interface may be exhibited by the UDR 221 to allow the UDM 158, PCF 156, and NEF 152 to access a particular set of the stored data, as well as to read, update (e.g., add, modify), delete, and subscribe to notification of relevant data changes in the UDR. The UDM may include a UDM-FE, which is in charge of processing credentials, location management, subscription management and so on. Several different front ends may serve the same user in different transactions. The UDM-FE accesses subscription information stored in the UDR and performs authentication credential processing, user identification handling, access authorization, registration/mobility management, and subscription management. In addition to communicating with other NFs over reference points as shown, the UDM 158 may exhibit the Nudm service-based interface.

The AF 160 may provide application influence on traffic routing, provide access to NEF, and interact with the policy framework for policy control.

In some embodiments, the 5GC 140 may enable edge computing by selecting operator/3rd party services to be geographically close to a point that the UE 102 is attached to the network. This may reduce latency and load on the network. To provide edge-computing implementations, the 5GC 140 may select a UPF 148 close to the UE 102 and execute traffic steering from the UPF 148 to data network 136 via the N6 interface. This may be based on the UE subscription data, UE location, and information provided by the AF 160. In this way, the AF 160 may influence UPF (re)selection and traffic routing. Based on operator deployment, when AF 160 is considered to be a trusted entity, the network operator may permit AF 160 to interact directly with relevant NFs. Additionally, the AF 160 may exhibit an Naf service-based interface.

The data network 136 may represent various network operator services, Internet access, or third party services that may be provided by one or more servers including, for example, application/content server 138.

Figure 2 schematically illustrates a wireless network 200 in accordance with various embodiments. The wireless network 200 may include a UE 202 in wireless communication with an AN 204. The UE 202 and AN 204 may be similar to, and substantially interchangeable with, like-named components described elsewhere herein.

The UE 202 may be communicatively coupled with the AN 204 via connection 206. The connection 206 is illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols such as an LTE protocol or a 5G NR protocol operating at mmWave or sub-6GHz frequencies.

The UE 202 may include a host platform 208 coupled with a modem platform 210. The host platform 208 may include application processing circuitry 212, which may be coupled with protocol processing circuitry 214 of the modem platform 210. The application processing circuitry 212 may run various applications for the UE 202 that source/sink application data. The application processing circuitry 212 may further implement one or more layer operations to transmit/receive application data to/from a data network. These layer operations may include transport (for example UDP) and Internet (for example, IP) operations

The protocol processing circuitry 214 may implement one or more of layer operations to facilitate transmission or reception of data over the connection 206. The layer operations implemented by the protocol processing circuitry 214 may include, for example, MAC, RLC, PDCP, RRC and NAS operations.

The modem platform 210 may further include digital baseband circuitry 216 that may implement one or more layer operations that are "below" layer operations performed by the protocol processing circuitry 214 in a network protocol stack. These operations may include, for example, PHY operations including one or more of HARQ-ACK functions, scrambling/descrambling, encoding/decoding, layer mapping/de-mapping, modulation symbol mapping, received symbol/bit metric determination, multi-antenna port precoding/decoding, which may include one or more of space-time, space-frequency or spatial coding, reference signal generation/detection, preamble sequence generation and/or decoding, synchronization sequence generation/detection, control channel signal blind decoding, and other related functions.

The modem platform 210 may further include transmit circuitry 218, receive circuitry 220, RF circuitry 222, and RF front end (RFFE) 224, which may include or connect to one or more antenna panels 226. Briefly, the transmit circuitry 218 may include a digital-to-analog converter, mixer, intermediate frequency (IF) components, etc.; the receive circuitry 220 may include an analog-to-digital converter, mixer, IF components, etc.; the RF circuitry 222 may include a low-noise amplifier, a power amplifier, power tracking components, etc.; RFFE 224 may include filters (for example, surface/bulk acoustic wave filters), switches, antenna tuners, beamforming components (for example, phase-array antenna components), etc. The selection and arrangement of the components of the transmit circuitry 218, receive circuitry 220, RF circuitry 222, RFFE 224, and antenna panels 226 (referred generically as "transmit/receive

components") may be specific to details of a specific implementation such as, for example, whether communication is TDM or FDM, in mmWave or sub-6 gHz frequencies, etc. In some embodiments, the transmit/receive components may be arranged in multiple parallel transmit/receive chains, may be disposed in the same or different chips/modules, etc.

In some embodiments, the protocol processing circuitry 214 may include one or more instances of control circuitry (not shown) to provide control functions for the transmit/receive components.

A UE reception may be established by and via the antenna panels 226, RFFE 224, RF circuitry 222, receive circuitry 220, digital baseband circuitry 216, and protocol processing circuitry 214. In some embodiments, the antenna panels 226 may receive a transmission from the AN 204 by receive-beamforming signals received by a plurality of antennas/antenna elements of the one or more antenna panels 226.

A UE transmission may be established by and via the protocol processing circuitry 214, digital baseband circuitry 216, transmit circuitry 218, RF circuitry 222, RFFE 224, and antenna panels 226. In some embodiments, the transmit components of the UE 204 may apply a spatial filter to the data to be transmitted to form a transmit beam emitted by the antenna elements of the antenna panels 226.

Similar to the UE 202, the AN 204 may include a host platform 228 coupled with a modem platform 230. The host platform 228 may include application processing circuitry 232 coupled with protocol processing circuitry 234 of the modem platform 230. The modem platform may further include digital baseband circuitry 236, transmit circuitry 238, receive circuitry 240, RF circuitry 242, RFFE circuitry 244, and antenna panels 246. The components of the AN 204 may be similar to and substantially interchangeable with like-named components of the UE 202. In addition to performing data transmission/reception as described above, the components of the AN 208 may perform various logical functions that include, for example, RNC functions such as radio bearer management, uplink and downlink dynamic radio resource management, and data packet scheduling.

Figure 3 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, Figure 3 shows a diagrammatic representation of hardware resources 300 including one or more processors (or processor cores) 310, one or more memory/storage devices 320, and one or more communication resources 330, each of which may be communicatively coupled via a bus 340 or other interface circuitry. For embodiments where node virtualization (e.g., NFV) is utilized, a hypervisor 302 may be executed to provide

an execution environment for one or more network slices/sub-slices to utilize the hardware resources 300.

The processors 310 may include, for example, a processor 312 and a processor 314. The processors 310 may be, for example, a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a DSP such as a baseband processor, an ASIC, an FPGA, a radio-frequency integrated circuit (RFIC), another processor (including those discussed herein), or any suitable combination thereof.

The memory/storage devices 320 may include main memory, disk storage, or any suitable combination thereof. The memory/storage devices 320 may include, but are not limited to, any type of volatile, non-volatile, or semi-volatile memory such as dynamic random access memory (DRAM), static random access memory (SRAM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), Flash memory, solid-state storage, etc.

The communication resources 330 may include interconnection or network interface controllers, components, or other suitable devices to communicate with one or more peripheral devices 304 or one or more databases 306 or other network elements via a network 308. For example, the communication resources 330 may include wired communication components (e.g., for coupling via USB, Ethernet, etc.), cellular communication components, NFC components, Bluetooth® (or Bluetooth® Low Energy) components, Wi-Fi® components, and other communication components.

Instructions 350 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 310 to perform any one or more of the methodologies discussed herein. The instructions 350 may reside, completely or partially, within at least one of the processors 310 (e.g., within the processor's cache memory), the memory/storage devices 320, or any suitable combination thereof. Furthermore, any portion of the instructions 350 may be transferred to the hardware resources 300 from any combination of the peripheral devices 304 or the databases 306. Accordingly, the memory of processors 310, the memory/storage devices 320, the peripheral devices 304, and the databases 306 are examples of computer-readable and machine-readable media.

EXAMPLE PROCEDURES

In some embodiments, the electronic device(s), network(s), system(s), chip(s) or component(s), or portions or implementations thereof, of Figures 1-3, or some other figure herein, may be configured to perform one or more processes, techniques, or methods as described herein,

or portions thereof. One such process 400 is depicted in Figure 4. The process 400 may be performed by a UE (e.g., a RedCap UE) or a portion thereof. At 402, the process 400 may include receiving configuration information for multiple bandwidth parts (BWPs). At 404, the process 400 may further include mapping repetitions of a physical downlink shared channel (PDSCH) or a physical uplink shared channel (PUSCH) to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH) according to a FH pattern. At 406, the process 400 may further include receiving the PDSCH or transmitting the PUSCH based on the mapped repetitions.

Figure 5 illustrates another process 500 in accordance with various embodiments. The process 500 may be performed by a gNB or a portion thereof. At 502, the process 500 may include encoding, for transmission to a reduced capability (RedCap) user equipment (UE), configuration information for multiple bandwidth parts (BWPs). At 504, the process 500 may further include mapping repetitions of a physical downlink shared channel (PDSCH) or a physical uplink shared channel (PUSCH) to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH) according to a FH pattern. At 506, the process 500 may further include transmitting the PDSCH or receiving the PUSCH based on the mapped repetitions.

For one or more embodiments, at least one of the components set forth in one or more of the preceding figures may be configured to perform one or more operations, techniques, processes, and/or methods as set forth in the example section below. For example, the baseband circuitry as described above in connection with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth below. For another example, circuitry associated with a UE, base station, network element, etc. as described above in connection with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth below in the example section.

EXAMPLES

Example A1 may include one or more non-transitory computer-readable media having instructions, stored thereon, that when executed by one or more processors of a reduced capability (RedCap) user equipment (UE), cause the RedCap UE to: receive configuration information for multiple bandwidth parts (BWPs); map repetitions of a physical downlink shared channel (PDSCH) or a physical uplink shared channel (PUSCH) to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH) according to a FH pattern; and receive the PDSCH or transmit the PUSCH based on the mapped repetitions.

Example A2 may include the one or more NTCRM of example A1 or some other example herein, wherein the configuration information is received via dedicated radio resource control (RRC) signaling.

Example A3 may include the one or more NTCRM of example A1 or some other example herein, wherein the FH pattern is predefined.

Example A4 may include the one or more NTCRM of example A1 or some other example herein, wherein the instructions, when executed, are further to cause the RedCap UE to receive FH pattern information to indicate the FH pattern.

Example A5 may include the one or more NTCRM of example A1 or some other example herein, wherein the FH pattern is defined with respect to an absolute point in time.

Example A6 may include the one or more NTCRM of example A5 or some other example herein, wherein the FH pattern is defined based on a system frame number and a slot number, with a common hopping pattern in a time domain across downlink and uplink.

Example A7 may include the one or more NTCRM of example A1 or some other example herein, wherein the configuration information for the BWPs includes a common set of parameters that apply to all or a subset of the BWPs, and wherein the configuration information further includes separate center frequencies and BWP identifiers for the respective BWPs.

Example A8 may include the one or more NTCRM of example A7 or some other example herein, wherein the inter-BWP frequency hopping is performed in accordance with a BWP retuning times that is shorter than a minimum delay for active downlink or uplink BWP change defined in 3GPP Technical Standard (TS) 38.133, V17.4.0.

Example A9 may include the one or more NTCRM of example A1 or some other example herein, wherein a same frequency domain resource allocation (FDRA) is used to map repetitions of a physical channel in each of the BWPs.

Example A10 may include the one or more NTCRM of example A1 or some other example herein, wherein the inter-BWP FH occurs only at slot boundaries.

Example A11 may include the one or more NTCRM of any one of examples A1-A10 or some other example herein, wherein, to receive the PDSCH or transmit the PUSCH, the RedCap UE is to: hop from a first BWP to a second BWP at a boundary of a first slot and a second slot; and skip reception or transmission of one or more symbols at the end of the first slot and at the beginning of the second slot.

Example A12 may include the one or more NTCRM of example A11 or some other example herein, wherein to receive the PDSCH or transmit the PUSCH, the RedCap UE is further to: rate-match the PDSCH or PUSCH to available symbols of the first slot and the second slot; or use receiver-side puncturing for the PDSCH or transmitter-side puncturing for the PUSCH.

Example A13 may include one or more non-transitory computer-readable media having instructions, stored thereon, that when executed by one or more processors of a next generation

Node B (gNB), cause the gNB to: encode, for transmission to a reduced capability (RedCap) user equipment (UE), configuration information for multiple bandwidth parts (BWPs); map repetitions of a physical downlink shared channel (PDSCH) or a physical uplink shared channel (PUSCH) to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH) according to a FH pattern; and transmit the PDSCH or receive the PUSCH based on the mapped repetitions.

Example A14 may include the one or more NTCRM of example A13 or some other example herein, wherein the FH pattern is predefined.

Example A15 may include the one or more NTCRM of example A13 or some other example herein, wherein the instructions, when executed, are further to cause the gNB to encode, for transmission to the RedCap UE, FH pattern information to indicate the FH pattern.

Example A16 may include the one or more NTCRM of example A13 or some other example herein, wherein the FH pattern is defined with respect to a system frame number and a slot number, with a common hopping pattern in a time domain across downlink and uplink.

Example A17 may include the one or more NTCRM of example A13 or some other example herein, wherein the configuration information for the BWPs includes a common set of parameters that apply to all or a subset of the BWPs, and wherein the configuration information further includes separate indications of a center frequency, a bandwidth, and a BWP identifier for the respective BWPs.

Example A18 may include the one or more NTCRM of example A13 or some other example herein, wherein a same frequency domain resource allocation (FDRA) is used to map repetitions of a physical channel in each of the BWPs.

Example A19 may include the one or more NTCRM of example A13 or some other example herein, wherein the inter-BWP FH occurs only at slot boundaries.

Example A20 may include the one or more NTCRM of any one of examples A13-A19 or some other example herein, wherein, to transmit the PDSCH or receive the PUSCH, the gNB is to: hop from a first BWP to a second BWP at a boundary of a first slot and a second slot; and skip reception or transmission of one or more symbols at the end of the first slot and at the beginning of the second slot.

Example A21 may include the one or more NTCRM of example A20 or some other example herein, wherein to receive the PDSCH or transmit the PUSCH, the gNB is further to: rate-match the PDSCH or PUSCH to available symbols of the first slot and the second slot; or use puncturing for the PDSCH or the PUSCH.

Example B1 may include a system or method of wireless communication for a fifth generation (5G) or new radio (NR) system, that includes support of a reduced capability

(RedCap) NR UE, wherein the UE may be configured with multiple BWPs via dedicated RRC signaling and repetitions of PDSCH or PUSCH are mapped to different DL or UL BWPs (respectively) using inter-BWP frequency hopping (FH).

Example B2 may include the system or method of example B1 or some other example herein, wherein the frequency hopping (FH) pattern is either specified or provided to the UE via higher layer signaling.

Example B3 may include the system or method of example B2 or some other example herein, wherein the FH pattern is defined with respect to an absolute point in time, e.g., by System Frame Number (SFN #0), slot #0, with a common hopping pattern in time domain across DL and UL.

Example B4 may include the system or method of example B3 or some other example herein, wherein shorter BWP retuning times are specified for inter-BWP switching that may primarily account for the RF retuning and AGC (automatic gain control) transition times (e.g., shorter BWP retuning time than specified in 3GPP TS 38.133, V17.4.0, for active DL or UL BWP change.

Example B5 may include the system or method of example B4 or some other example herein, wherein a common set of values for all parameters configured as part of BWP configurations, except for the center frequency and BW (indicated via locationAndBandwidth), and bwp-Id, apply for all or an identified subset of the DL or UL BWPs the UE is configured with for inter-BWP FH.

Example B5A may include the system or method of example B1-B5, wherein, instead of identifying different BWPs, the physical channels are mapped to sets of contiguous-in-frequency PRBs (e.g., “PRB sets”) that are associated with a same BWP configuration.

Example B6 may include the system or method of example B5 or some other example herein, wherein for PDSCH or PUSCH, frequency hopping across BWPs applies every ‘r’ ($r \geq 1$) repetitions or slots.

Example B7 may include the system or method of example B5 or some other example herein, wherein the same frequency domain resource allocation (FDRA) applies in all DL/UL (respectively) BWPs.

Example B8 may include the system or method of example B5 or some other example herein, wherein once a RedCap UE switches to a DL BWP different from the one in which the scheduling DCI format was received, it is expected to receive PDCCH in the new DL BWP in the new DL BWP.

Example B9 may include the system or method of example B5 or some other example herein, wherein the PUSCH repetitions follow a two-stage FH mechanism involving intra-BWP and inter-BWP FH.

Example B10 may include the system or method of example B9 or some other example herein, wherein the PUSCH repetitions follow a two-stage FH mechanism, such that the UE transmits one or more repetitions of the PUSCH in the indicated set of PRBs in the active UL BWP, then transmits a number of repetitions in another one or more frequency resource(s) within the active UL BWP, and then switches to another UL BWP for similar repetitions (with intra-BWP FH) in the new UL BWP.

Example B11 may include the system or method of example B9 or some other example herein, wherein the intra-BWP FH is limited to intra-slot FH defined in Release 15 NR specifications.

Example B12 may include the system or method of examples B10 or B11 or some other example herein, wherein the FDRA and intra-BWP FH offsets are the same across the different UL BWPs.

Example B13 may include the system or method of example B4, wherein the maximum separation between the center frequencies of the DL or UL BWPs configured to a RedCap UE for inter-BWP FH is bounded by specifications.

Example B14 may include the system or method of example B4, wherein the inter-BWP transition times for DL and UL are reported by the UE from a set of candidate values in absolute time (e.g., in microseconds) or in number of OFDM symbols (OS) that is defined as a function of the larger of the SCS between the original and new BWPs.

Example B15 may include the system or method of example B4, wherein, for inter-BWP FH, the FH across BWPs may only occur at slot boundaries.

Example B16 may include the system or method of example B4, wherein, during hopping from a first DL BWP to a second DL BWP at the boundary of slots ‘n’ and ‘n+1’, the UE may skip reception of one or more OFDM symbols at the end of slot ‘n’ and at the beginning of slot ‘n+1’.

Example B17 may include the system or method of example B4, wherein, during hopping from a first UL BWP to a second UL BWP at the boundary of slots ‘n’ and ‘n+1’, the UE may skip transmission of one or more OFDM/DFT-S-OFDM symbols at the end of slot ‘n’ and at the beginning of slot ‘n+1’.

Example B18 may include the system or method of examples B16 or B17, wherein, for PDSCH or PUSCH or PUCCH formats 2, 3, or 4, the skipping of the symbols to accommodate

inter-BWP transition time is realized by rate-matching the PDSCH or PUSCH (respectively) to the symbols available for reception or transmission (respectively) in the slot.

Example B19 may include the system or method of examples B16 or B17, wherein, for PDSCH or PUSCH or PUCCH formats 2, 3, or 4, the skipping of the symbols to accommodate inter-BWP transition time is realized by assuming the availability of such symbols during rate-matching and resource mapping, but not receiving or transmitting (respectively) the symbols (e.g., via "receiver or transmitter (respectively) side puncturing").

Example B20 may include the system or method of examples B16 or B17, wherein, for physical channels and signals other than one or more of: PDSCH, PUSCH, and PUCCH formats 2, 3, and 4; the skipping of the symbols to accommodate inter-BWP transition time is realized by assuming the availability of such symbols during resource mapping, but not receiving or transmitting (respectively) the symbols (e.g., via "receiver or transmitter (respectively) side puncturing").

Example B21 may include a method of a reduced capacity (RedCap) user equipment (UE), the method comprising; receiving configuration information for multiple bandwidth parts (BWPs); and mapping repetitions of a PDSCH (e.g., for receipt of the PDSCH) or a PUSCH (e.g., for transmission of the PUSCH) to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH).

Example B22 may include the method of example B21 or some other example herein, wherein the configuration information is received via dedicated RRC signaling.

Example B23 may include the method of example B21-B22 or some other example herein, wherein the repetitions are mapped according to a FH pattern.

Example B24 may include the method of example B23 or some other example herein, wherein the FH pattern is predefined.

Example B25 may include the method of example B23 or some other example herein, further comprising receiving configuration information (e.g., via RRC signaling) to indicate the FH pattern.

Example Z01 may include an apparatus comprising means to perform one or more elements of a method described in or related to any of examples A1-A21, B1-B25, or any other method or process described herein.

Example Z02 may include one or more non-transitory computer-readable media comprising instructions to cause an electronic device, upon execution of the instructions by one or more processors of the electronic device, to perform one or more elements of a method described in or related to any of examples A1-A21, B1-B25, or any other method or process described herein.

Example Z03 may include an apparatus comprising logic, modules, or circuitry to perform one or more elements of a method described in or related to any of examples A1-A21, B1-B25, or any other method or process described herein.

Example Z04 may include a method, technique, or process as described in or related to any of examples A1-A21, B1-B25, or portions or parts thereof.

Example Z05 may include an apparatus comprising: one or more processors and one or more computer-readable media comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the method, techniques, or process as described in or related to any of examples A1-A21, B1-B25, or portions thereof.

Example Z06 may include a signal as described in or related to any of examples A1-A21, B1-B25, or portions or parts thereof.

Example Z07 may include a datagram, packet, frame, segment, protocol data unit (PDU), or message as described in or related to any of examples A1-A21, B1-B25, or portions or parts thereof, or otherwise described in the present disclosure.

Example Z08 may include a signal encoded with data as described in or related to any of examples A1-A21, B1-B25, or portions or parts thereof, or otherwise described in the present disclosure.

Example Z09 may include a signal encoded with a datagram, packet, frame, segment, protocol data unit (PDU), or message as described in or related to any of examples A1-A21, B1-B25, or portions or parts thereof, or otherwise described in the present disclosure.

Example Z10 may include an electromagnetic signal carrying computer-readable instructions, wherein execution of the computer-readable instructions by one or more processors is to cause the one or more processors to perform the method, techniques, or process as described in or related to any of examples A1-A21, B1-B25, or portions thereof.

Example Z11 may include a computer program comprising instructions, wherein execution of the program by a processing element is to cause the processing element to carry out the method, techniques, or process as described in or related to any of examples A1-A21, B1-B25, or portions thereof.

Example Z12 may include a signal in a wireless network as shown and described herein.

Example Z13 may include a method of communicating in a wireless network as shown and described herein.

Example Z14 may include a system for providing wireless communication as shown and described herein.

Example Z15 may include a device for providing wireless communication as shown and described herein.

Any of the above-described examples may be combined with any other example (or combination of examples), unless explicitly stated otherwise. 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.

Abbreviations

Unless used differently herein, terms, definitions, and abbreviations may be consistent with terms, definitions, and abbreviations defined in 3GPP TR 21.905 v16.0.0 (2019-06). For the purposes of the present document, the following abbreviations may apply to the examples and embodiments discussed herein.

3GPP Third Generation Partnership Project
4G Fourth Generation
5G Fifth Generation
5GC 5G Core network
AC Application Client
ACK Acknowledgement
ACID Application Client Identification
AF Application Function
AM Acknowledged Mode
AMBR Aggregate Maximum Bit Rate
AMF Access and Mobility Management Function
AN Access Network
ANR Automatic Neighbour Relation
AP Application Protocol, Antenna Port, Access Point
API Application Programming Interface
APN Access Point Name
ARP Allocation and Retention Priority
ARQ Automatic Repeat Request
AS Access Stratum
ASP Application Service Provider
ASN.1 Abstract Syntax Notation One
AUSF Authentication Server Function
AWGN Additive White Gaussian Noise
BAP Backhaul Adaptation Protocol
BCH Broadcast Channel
BER Bit Error Ratio
BFD Beam Failure Detection
BLER Block Error Rate
BPSK Binary Phase Shift Keying
BRAS Broadband Remote Access Server
BSS Business Support System
BS Base Station
BSR Buffer Status Report
BW Bandwidth
BWP Bandwidth Part
C-RNTI Cell Radio Network Temporary Identity
CA Carrier Aggregation, Certification Authority
CAPEX CAPital EXpenditure
CBRA Contention Based Random Access
CC Component Carrier, Country Code, Cryptographic Checksum
CCA Clear Channel Assessment
CCE Control Channel Element
CCCH Common Control Channel
CE Coverage Enhancement

CDM Content Delivery Network
CDMA Code-Division Multiple Access
CFRA Contention Free Random Access
CG Cell Group
CGF Charging Gateway Function
CHF Charging Function
CI Cell Identity
CID Cell-ID (e.g., positioning method)
CIM Common Information Model
CIR Carrier to Interference Ratio
CK Cipher Key
CM Connection Management, Conditional Mandatory
CMAS Commercial Mobile Alert Service
CMD Command
CMS Cloud Management System
CO Conditional Optional
CoMP Coordinated Multi-Point
CORESET Control Resource Set
COTS Commercial Off-The-Shelf
CP Control Plane, Cyclic Prefix, Connection Point
CPD Connection Point Descriptor
CPE Customer Premise Equipment
CPICH Common Pilot Channel
CQI Channel Quality Indicator
CPU CSI processing unit, Central Processing Unit
C/R Command/Response field bit
CRAN Cloud Radio Access Network, Cloud RAN
CRB Common Resource Block
CRC Cyclic Redundancy Check
CRI Channel-State Information Resource Indicator, CSI-RS Resource Indicator
C-RNTI Cell RNTI
CS Circuit Switched
CSAR Cloud Service Archive
CSI Channel-State Information
CSI-IM CSI Interference Measurement
CSI-RS CSI Reference Signal
CSI-RSRP CSI reference signal received power
CSI-RSRQ CSI reference signal received quality
CSI-SINR CSI signal-to-noise and interference ratio
CSMA Carrier Sense Multiple Access
CSMA/CA CSMA with collision avoidance
CSS Common Search Space, Cell-specific Search Space
CTF Charging Trigger Function
CTS Clear-to-Send

CW Codeword
CWS Contention Window Size
D2D Device-to-Device
DC Dual Connectivity, Direct Current
DCI Downlink Control Information
DF Deployment Flavour
DL Downlink
DMTF Distributed Management Task Force
DPDK Data Plane Development Kit
DM-RS, DMRS Demodulation Reference Signal
DN Data network
DNN Data Network Name
DNAI Data Network Access Identifier
DRB Data Radio Bearer
DRS Discovery Reference Signal
DRX Discontinuous Reception
DSL Domain Specific Language. Digital Subscriber Line
DSLAM DSL Access Multiplexer
DwPTS Downlink Pilot Time Slot
E-LAN Ethernet Local Area Network
E2E End-to-End
ECCA extended clear channel assessment, extended CCA
ECCE Enhanced Control Channel Element, Enhanced CCE
ED Energy Detection
EDGE Enhanced Datarates for GSM Evolution (GSM Evolution)
EAS Edge Application Server
EASID Edge Application Server Identification
ECS Edge Configuration Server
ECSP Edge Computing Service Provider
EDN Edge Data Network
EEC Edge Enabler Client
EECID Edge Enabler Client Identification
EES Edge Enabler Server
EESID Edge Enabler Server Identification
EHE Edge Hosting Environment
EGMF Exposure Governance Management Function
EGPRS Enhanced GPRS
EIR Equipment Identity Register
eLAA enhanced Licensed Assisted Access, enhanced LAA
EM Element Manager
eMBB Enhanced Mobile Broadband

EMS Element Management System
eNB evolved NodeB, E-UTRAN Node B
EN-DC E-UTRA-NR Dual Connectivity
EPC Evolved Packet Core
EPDCCH enhanced PDCCH, enhanced Physical Downlink Control Cannel
EPRE Energy per resource element
EPS Evolved Packet System
EREG enhanced REG, enhanced resource element groups
ETSI European Telecommunications Standards Institute
ETWS Earthquake and Tsunami Warning System
eUICC embedded UICC, embedded Universal Integrated Circuit Card
E-UTRA Evolved UTRA
E-UTRAN Evolved UTRAN
EV2X Enhanced V2X
F1AP F1 Application Protocol
F1-C F1 Control plane interface
F1-U F1 User plane interface
FACCH Fast Associated Control CHannel
FACCH/F Fast Associated Control Channel/Full rate
FACCH/H Fast Associated Control Channel/Half rate
FACH Forward Access Channel
FAUSCH Fast Uplink Signalling Channel
FB Functional Block
FBI Feedback Information
FCC Federal Communications Commission
FCCH Frequency Correction CHannel
FDD Frequency Division Duplex
FDM Frequency Division Multiplex
FDMA Frequency Division Multiple Access
FE Front End
FEC Forward Error Correction
FFS For Further Study
FFT Fast Fourier Transformation
feLAA further enhanced Licensed Assisted Access, further enhanced LAA
FN Frame Number
FPGA Field-Programmable Gate Array
FR Frequency Range
FQDN Fully Qualified Domain Name
G-RNTI GERAN Radio Network Temporary Identity

GERAN GSM EDGE RAN, GSM EDGE Radio Access Network

GGSN Gateway GPRS Support Node

GLONASS GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (Engl.: Global Navigation Satellite System)

gNB Next Generation NodeB

gNB-CU gNB-centralized unit, Next Generation NodeB centralized unit

gNB-DU gNB-distributed unit, Next Generation NodeB distributed unit

GNSS Global Navigation Satellite System

GPRS General Packet Radio Service

GPSI Generic Public Subscription Identifier

GSM Global System for Mobile Communications, Groupe Spécial Mobile

GTP GPRS Tunneling Protocol

GTP-U GPRS Tunnelling Protocol for User Plane

GTS Go To Sleep Signal (related to WUS)

GUMMEI Globally Unique MME Identifier

GUTI Globally Unique Temporary UE Identity

HARQ Hybrid ARQ, Hybrid Automatic Repeat Request

HANDO Handover

HFN HyperFrame Number

HHO Hard Handover

HLR Home Location Register

HN Home Network

HO Handover

HPLMN Home Public Land Mobile Network

HSDPA High Speed Downlink Packet Access

HSN Hopping Sequence Number

HSPA High Speed Packet Access

HSS Home Subscriber Server

HSUPA High Speed Uplink Packet Access

HTTP Hyper Text Transfer Protocol

HTTPS Hyper Text Transfer Protocol Secure (https is http/1.1 over SSL, i.e. port 443)

I-Block Information Block

ICCID Integrated Circuit Card Identification

IAB Integrated Access and Backhaul

ICIC Inter-Cell Interference Coordination

ID Identity, identifier

IDFT Inverse Discrete Fourier Transform
IE Information element
IBE In-Band Emission
IEEE Institute of Electrical and Electronics Engineers
IEI Information Element Identifier
IEIDL Information Element Identifier Data Length
IETF Internet Engineering Task Force
IF Infrastructure
IM Interference Measurement, Intermodulation, IP Multimedia
IMC IMS Credentials
IMEI International Mobile Equipment Identity
IMGI International mobile group identity
IMPI IP Multimedia Private Identity
IMPU IP Multimedia PUblic identity
IMS IP Multimedia Subsystem
IMSI International Mobile Subscriber Identity
IoT Internet of Things
IP Internet Protocol
Ipsec IP Security, Internet Protocol Security
IP-CAN IP-Connectivity Access Network
IP-M IP Multicast
IPv4 Internet Protocol Version 4
IPv6 Internet Protocol Version 6
IR Infrared
IS In Sync
IRP Integration Reference Point
ISDN Integrated Services Digital Network
ISIM IM Services Identity Module
ISO International Organisation for Standardisation
ISP Internet Service Provider
IWF Interworking-Function
I-WLAN Interworking WLAN
Constraint length of the convolutional code, USIM Individual key
kB Kilobyte (1000 bytes)
kbps kilo-bits per second
Kc Ciphering key
Ki Individual subscriber authentication key
KPI Key Performance Indicator
KQI Key Quality Indicator
KSI Key Set Identifier
ksps kilo-symbols per second
KVM Kernel Virtual Machine

L1 Layer 1 (physical layer)
L1-RSRP Layer 1 reference signal received power
L2 Layer 2 (data link layer)
L3 Layer 3 (network layer)
LAA Licensed Assisted Access
LAN Local Area Network
LADN Local Area Data Network
LBT Listen Before Talk
LCM LifeCycle Management
LCR Low Chip Rate
LCS Location Services
LCID Logical Channel ID
LI Layer Indicator
LLC Logical Link Control, Low Layer Compatibility
LPLMN Local PLMN
LPP LTE Positioning Protocol
LSB Least Significant Bit
LTE Long Term Evolution
LWA LTE-WLAN aggregation
LWIP LTE/WLAN Radio Level Integration with IPsec Tunnel
LTE Long Term Evolution
M2M Machine-to-Machine
MAC Medium Access Control (protocol layering context)
MAC Message authentication code (security/encryption context)
MAC-A MAC used for authentication and key agreement (TSG T WG3 context)
MAC-IMAC used for data integrity of signalling messages (TSG T WG3 context)
MANO Management and Orchestration
MBMS Multimedia Broadcast and Multicast Service
MBSFN Multimedia Broadcast multicast service Single Frequency Network
MCC Mobile Country Code
MCG Master Cell Group
MCOT Maximum Channel Occupancy Time
MCS Modulation and coding scheme
MDAF Management Data Analytics Function
MDAS Management Data Analytics Service
MDT Minimization of Drive Tests
ME Mobile Equipment
MeNB master eNB
MER Message Error Ratio
MGL Measurement Gap Length

MGRP Measurement Gap Repetition Period
MIB Master Information Block, Management Information Base
MIMO Multiple Input Multiple Output
MLC Mobile Location Centre
MM Mobility Management
MME Mobility Management Entity
MN Master Node
MNO Mobile Network Operator
MO Measurement Object, Mobile Originated
MPBCH MTC Physical Broadcast CHannel
MPDCCH MTC Physical Downlink Control CHannel
MPDSCH MTC Physical Downlink Shared CHannel
MPRACH MTC Physical Random Access CHannel
MPUSCH MTC Physical Uplink Shared Channel
MPLS MultiProtocol Label Switching
MS Mobile Station
MSB Most Significant Bit
MSC Mobile Switching Centre
MSI Minimum System Information,
MCH Scheduling Information
MSID Mobile Station Identifier
MSIN Mobile Station Identification Number
MSISDN Mobile Subscriber ISDN Number
MT Mobile Terminated, Mobile Termination
MTC Machine-Type Communications
mMTC massive MTC, massive Machine-Type Communications
MU-MIMO Multi User MIMO
MWUS MTC wake-up signal, MTC WUS
NACK Negative Acknowledgement
NAI Network Access Identifier
NAS Non-Access Stratum, Non- Access Stratum layer
NCT Network Connectivity Topology
NC-JT Non-Coherent Joint Transmission
NEC Network Capability Exposure
NE-DC NR-E-UTRA Dual Connectivity
NEF Network Exposure Function
NF Network Function
NFP Network Forwarding Path
NFPD Network Forwarding Path Descriptor

NFV Network Functions Virtualization
NFVI NFV Infrastructure
NFVO NFV Orchestrator
NG Next Generation, Next Gen
NGEN-DC NG-RAN E-UTRA-NR Dual Connectivity
NM Network Manager
NMS Network Management System
N-PoP Network Point of Presence
NMIB, N-MIB Narrowband MIB
NPBCH Narrowband Physical Broadcast CHannel
NPDCCH Narrowband Physical Downlink Control CHannel
NPDSCH Narrowband Physical Downlink Shared CHannel
NPRACH Narrowband Physical Random Access CHannel
NPUSCH Narrowband Physical Uplink Shared CHannel
NPSS Narrowband Primary Synchronization Signal
NSSS Narrowband Secondary Synchronization Signal
NR New Radio, Neighbour Relation
NRF NF Repository Function
NRS Narrowband Reference Signal
NS Network Service
NSA Non-Standalone operation mode
NSD Network Service Descriptor
NSR Network Service Record
NSSAI Network Slice Selection Assistance Information
S-NNSAI Single-NSSAI
NSSF Network Slice Selection Function
NW Network
NWUS Narrowband wake-up signal, Narrowband WUS
NZP Non-Zero Power
O&M Operation and Maintenance
ODU2 Optical channel Data Unit - type 2
OFDM Orthogonal Frequency Division Multiplexing
OFDMA Orthogonal Frequency Division Multiple Access
OOB Out-of-band
OOS Out of Sync
OPEX OPerating EXpense
OSI Other System Information
OSS Operations Support System
OTA over-the-air
PAPR Peak-to-Average Power Ratio

PAR Peak to Average Ratio
PBCH Physical Broadcast Channel
PC Power Control, Personal Computer
PCC Primary Component Carrier, Primary CC
PCell Primary Cell
PCI Physical Cell ID, Physical Cell Identity
PCEF Policy and Charging Enforcement Function
PCF Policy Control Function
PCRF Policy Control and Charging Rules Function
PDCP Packet Data Convergence Protocol, Packet Data Convergence Protocol layer
PDCCH Physical Downlink Control Channel
PDCP Packet Data Convergence Protocol
PDN Packet Data Network, Public Data Network
PDSCH Physical Downlink Shared Channel
PDU Protocol Data Unit
PEI Permanent Equipment Identifiers
PFD Packet Flow Description
P-GW PDN Gateway
PHICH Physical hybrid-ARQ indicator channel
PHY Physical layer
PLMN Public Land Mobile Network
PIN Personal Identification Number
PM Performance Measurement
PMI Precoding Matrix Indicator
PNF Physical Network Function
PNFD Physical Network Function Descriptor
PNFR Physical Network Function Record
POC PTT over Cellular
PP, PTP Point-to-Point
PPP Point-to-Point Protocol
PRACH Physical RACH
PRB Physical resource block
PRG Physical resource block group
ProSe Proximity Services, Proximity-Based Service
PRS Positioning Reference Signal
PRR Packet Reception Radio
PS Packet Services
PSBCH Physical Sidelink Broadcast Channel
PSDCH Physical Sidelink Downlink Channel
PSCCH Physical Sidelink Control Channel
PSSCH Physical Sidelink Shared Channel
PSCell Primary SCell

PSS Primary Synchronization Signal
PSTN Public Switched Telephone Network
PT-RS Phase-tracking reference signal
PTT Push-to-Talk
PUCCH Physical Uplink Control Channel
PUSCH Physical Uplink Shared Channel
QAM Quadrature Amplitude Modulation
QCI QoS class of identifier
QCL Quasi co-location
QFI QoS Flow ID, QoS Flow Identifier
QoS Quality of Service
QPSK Quadrature (Quaternary) Phase Shift Keying
QZSS Quasi-Zenith Satellite System
RA-RNTI Random Access RNTI
RAB Radio Access Bearer, Random Access Burst
RACH Random Access Channel
RADIUS Remote Authentication Dial In User Service
RAN Radio Access Network
RAND RANDom number (used for authentication)
RAR Random Access Response
RAT Radio Access Technology
RAU Routing Area Update
RB Resource block, Radio Bearer
RBG Resource block group
REG Resource Element Group
Rel Release
REQ REQuest
RF Radio Frequency
RI Rank Indicator
RIV Resource indicator value
RL Radio Link
RLC Radio Link Control, Radio Link Control layer
RLC AM RLC Acknowledged Mode
RLC UM RLC Unacknowledged Mode
RLF Radio Link Failure
RLM Radio Link Monitoring
RLM-RS Reference Signal for RLM
RM Registration Management
RMC Reference Measurement Channel
RMSI Remaining MSI, Remaining Minimum System Information
RN Relay Node
RNC Radio Network Controller
RNL Radio Network Layer
RNTI Radio Network Temporary Identifier
ROHC RObust Header Compression
RRC Radio Resource Control, Radio

Resource Control layer
RRM Radio Resource Management
RS Reference Signal
RSRP Reference Signal Received Power
RSRQ Reference Signal Received Quality
RSSI Received Signal Strength Indicator
RSU Road Side Unit
RSTD Reference Signal Time difference
RTP Real Time Protocol
RTS Ready-To-Send
RTT Round Trip Time
Rx Reception, Receiving, Receiver
S1AP S1 Application Protocol
S1-MME S1 for the control plane
S1-U S1 for the user plane
S-GW Serving Gateway
S-RNTI SRNC Radio Network Temporary Identity
S-TMSI SAE Temporary Mobile Station Identifier
SA Standalone operation mode
SAE System Architecture Evolution
SAP Service Access Point
SAPD Service Access Point Descriptor
SAPI Service Access Point Identifier
SCC Secondary Component Carrier, Secondary CC
SCell Secondary Cell
SCEF Service Capability Exposure Function
SC-FDMA Single Carrier Frequency Division Multiple Access
SCG Secondary Cell Group
SCM Security Context Management
SCS Subcarrier Spacing
SCTP Stream Control Transmission Protocol
SDAP Service Data Adaptation Protocol, Service Data Adaptation Protocol layer
SDL Supplementary Downlink
SDNF Structured Data Storage Network Function
SDP Session Description Protocol
SDSF Structured Data Storage Function
SDU Service Data Unit
SEAF Security Anchor Function
SeNB secondary eNB
SEPP Security Edge Protection Proxy
SFI Slot format indication
SFTD Space-Frequency Time Diversity, SFN and frame timing difference

SFN System Frame Number
SgNB Secondary gNB
SGSN Serving GPRS Support Node
S-GW Serving Gateway
SI System Information
SI-RNTI System Information RNTI
SIB System Information Block
SIM Subscriber Identity Module
SIP Session Initiated Protocol
SiP System in Package
SL Sidelink
SLA Service Level Agreement
SM Session Management
SMF Session Management Function
SMS Short Message Service
SMSF SMS Function
SMTC SSB-based Measurement Timing Configuration
SN Secondary Node, Sequence Number
SoC System on Chip
SON Self-Organizing Network
SpCell Special Cell
SP-CSI-RNTISemi-Persistent CSI RNTI
SPS Semi-Persistent Scheduling
SQN Sequence number
SR Scheduling Request
SRB Signalling Radio Bearer
SRS Sounding Reference Signal
SS Synchronization Signal
SSB Synchronization Signal Block
SSID Service Set Identifier
SS/PBCH Block
SSBRI SS/PBCH Block Resource Indicator, Synchronization Signal Block Resource Indicator
SSC Session and Service Continuity
SS-RSRP Synchronization Signal based Reference Signal Received Power
SS-RSRQ Synchronization Signal based Reference Signal Received Quality
SS-SINR Synchronization Signal based Signal to Noise and Interference Ratio
SSS Secondary Synchronization Signal
SSSG Search Space Set Group
SSSIF Search Space Set Indicator
SST Slice/Service Types
SU-MIMO Single User MIMO
SUL Supplementary Uplink
TA Timing Advance, Tracking Area
TAC Tracking Area Code
TAG Timing Advance Group

TAI Tracking Area Identity
TAU Tracking Area Update
TB Transport Block
TBS Transport Block Size
TBD To Be Defined
TCI Transmission Configuration Indicator
TCP Transmission Communication Protocol
TDD Time Division Duplex
TDM Time Division Multiplexing
TDMA Time Division Multiple Access
TE Terminal Equipment
TEID Tunnel End Point Identifier
TFT Traffic Flow Template
TMSI Temporary Mobile Subscriber Identity
TNL Transport Network Layer
TPC Transmit Power Control
TPMI Transmitted Precoding Matrix Indicator
TR Technical Report
TRP, TRxP Transmission Reception Point
TRS Tracking Reference Signal
TRx Transceiver
TS Technical Specifications, Technical Standard
TTI Transmission Time Interval
Tx Transmission, Transmitting, Transmitter
U-RNTI UTRAN Radio Network Temporary Identity
UART Universal Asynchronous Receiver and Transmitter
UCI Uplink Control Information
UE User Equipment
UDM Unified Data Management
UDP User Datagram Protocol
UDSF Unstructured Data Storage Network Function
UICC Universal Integrated Circuit Card
UL Uplink
UM Unacknowledged Mode
UML Unified Modelling Language
UMTS Universal Mobile Telecommunications System
UP User Plane
UPF User Plane Function
URI Uniform Resource Identifier
URL Uniform Resource Locator
URLLC Ultra-Reliable and Low Latency
USB Universal Serial Bus
USIM Universal Subscriber Identity Module
USS UE-specific search space

UTRA UMTS Terrestrial Radio Access

UTRAN Universal Terrestrial Radio Access Network

UwPTS Uplink Pilot Time Slot

V2I Vehicle-to-Infrastruction

V2P Vehicle-to-Pedestrian

V2V Vehicle-to-Vehicle

V2X Vehicle-to-everything

VIM Virtualized Infrastructure Manager

VL Virtual Link, VLAN Virtual LAN, Virtual Local Area Network

VM Virtual Machine

VNF Virtualized Network Function

VNFFG VNF Forwarding Graph

VNFFGD VNF Forwarding Graph Descriptor

VNFM VNF Manager

VoIP Voice-over-IP, Voice-over-Internet Protocol

VPLMN Visited Public Land Mobile Network

VPN Virtual Private Network

VRB Virtual Resource Block

WiMAX Worldwide Interoperability for Microwave Access

WLANWireless Local Area Network

WMAN Wireless Metropolitan Area Network

WPANWireless Personal Area Network

X2-C X2-Control plane

X2-U X2-User plane

XML eXtensible Markup Language

XRES EXpected user RESponse

XOR eXclusive OR

ZC Zadoff-Chu

ZP Zero Power

Terminology

For the purposes of the present document, the following terms and definitions are applicable to the examples and embodiments discussed herein.

The term "circuitry" as used herein refers to, is part of, or includes hardware components such as an electronic circuit, a logic circuit, a processor (shared, dedicated, or group) and/or memory (shared, dedicated, or group), an Application Specific Integrated Circuit (ASIC), a field-programmable device (FPD) (e.g., a field-programmable gate array (FPGA), a programmable logic device (PLD), a complex PLD (CPLD), a high-capacity PLD (HCPLD), a structured ASIC, or a programmable SoC), digital signal processors (DSPs), etc., that are configured to provide the described functionality. In some embodiments, the circuitry may execute one or more software or firmware programs to provide at least some of the described functionality. The term "circuitry" may also refer to a combination of one or more hardware elements (or a combination of circuits used in an electrical or electronic system) with the program code used to carry out the functionality of that program code. In these embodiments, the combination of hardware elements and program code may be referred to as a particular type of circuitry.

The term "processor circuitry" as used herein refers to, is part of, or includes circuitry capable of sequentially and automatically carrying out a sequence of arithmetic or logical operations, or recording, storing, and/or transferring digital data. Processing circuitry may include one or more processing cores to execute instructions and one or more memory structures to store program and data information. The term "processor circuitry" may refer to one or more application processors, one or more baseband processors, a physical central processing unit (CPU), a single-core processor, a dual-core processor, a triple-core processor, a quad-core processor, and/or any other device capable of executing or otherwise operating computer-executable instructions, such as program code, software modules, and/or functional processes. Processing circuitry may include more hardware accelerators, which may be microprocessors, programmable processing devices, or the like. The one or more hardware accelerators may include, for example, computer vision (CV) and/or deep learning (DL) accelerators. The terms "application circuitry" and/or "baseband circuitry" may be considered synonymous to, and may be referred to as, "processor circuitry."

The term "interface circuitry" as used herein refers to, is part of, or includes circuitry that enables the exchange of information between two or more components or devices. The term "interface circuitry" may refer to one or more hardware interfaces, for example, buses, I/O interfaces, peripheral component interfaces, network interface cards, and/or the like.

The term "user equipment" or "UE" as used herein refers to a device with radio communication capabilities and may describe a remote user of network resources in a communications network. The term "user equipment" or "UE" may be considered synonymous to, and may be referred to as, client, mobile, mobile device, mobile terminal, user terminal, mobile unit, mobile station, mobile user, subscriber, user, remote station, access agent, user agent, receiver, radio equipment, reconfigurable radio equipment, reconfigurable mobile device, etc. Furthermore, the term "user equipment" or "UE" may include any type of wireless/wired device or any computing device including a wireless communications interface.

The term "network element" as used herein refers to physical or virtualized equipment and/or infrastructure used to provide wired or wireless communication network services. The term "network element" may be considered synonymous to and/or referred to as a networked computer, networking hardware, network equipment, network node, router, switch, hub, bridge, radio network controller, RAN device, RAN node, gateway, server, virtualized VNF, NFVI, and/or the like.

The term "computer system" as used herein refers to any type interconnected electronic devices, computer devices, or components thereof. Additionally, the term "computer system" and/or "system" may refer to various components of a computer that are communicatively coupled with one another. Furthermore, the term "computer system" and/or "system" may refer to multiple computer devices and/or multiple computing systems that are communicatively coupled with one another and configured to share computing and/or networking resources.

The term "appliance," "computer appliance," or the like, as used herein refers to a computer device or computer system with program code (e.g., software or firmware) that is specifically designed to provide a specific computing resource. A "virtual appliance" is a virtual machine image to be implemented by a hypervisor-equipped device that virtualizes or emulates a computer appliance or otherwise is dedicated to provide a specific computing resource.

The term "resource" as used herein refers to a physical or virtual device, a physical or virtual component within a computing environment, and/or a physical or virtual component within a particular device, such as computer devices, mechanical devices, memory space, processor/CPU time, processor/CPU usage, processor and accelerator loads, hardware time or usage, electrical power, input/output operations, ports or network sockets, channel/link allocation, throughput, memory usage, storage, network, database and applications, workload units, and/or the like. A "hardware resource" may refer to compute, storage, and/or network resources provided by physical hardware element(s). A "virtualized resource" may refer to compute, storage, and/or network resources provided by virtualization infrastructure to an application, device, system, etc. The term "network resource" or "communication resource" may

refer to resources that are accessible by computer devices/systems via a communications network. The term "system resources" may refer to any kind of shared entities to provide services, and may include computing and/or network resources. System resources may be considered as a set of coherent functions, network data objects or services, accessible through a server where such system resources reside on a single host or multiple hosts and are clearly identifiable.

The term "channel" as used herein refers to any transmission medium, either tangible or intangible, which is used to communicate data or a data stream. The term "channel" may be synonymous with and/or equivalent to "communications channel," "data communications channel," "transmission channel," "data transmission channel," "access channel," "data access channel," "link," "data link," "carrier," "radiofrequency carrier," and/or any other like term denoting a pathway or medium through which data is communicated. Additionally, the term "link" as used herein refers to a connection between two devices through a RAT for the purpose of transmitting and receiving information.

The terms "instantiate," "instantiation," and the like as used herein refers to the creation of an instance. An "instance" also refers to a concrete occurrence of an object, which may occur, for example, during execution of program code.

The terms "coupled," "communicatively coupled," along with derivatives thereof are used herein. The term "coupled" may mean two or more elements are in direct physical or electrical contact with one another, may mean that two or more elements indirectly contact each other but still cooperate or interact with each other, and/or may mean that one or more other elements are coupled or connected between the elements that are said to be coupled with each other. The term "directly coupled" may mean that two or more elements are in direct contact with one another. The term "communicatively coupled" may mean that two or more elements may be in contact with one another by a means of communication including through a wire or other interconnect connection, through a wireless communication channel or link, and/or the like.

The term "information element" refers to a structural element containing one or more fields. The term "field" refers to individual contents of an information element, or a data element that contains content.

The term "SMTC" refers to an SSB-based measurement timing configuration configured by *SSB-MeasurementTimingConfiguration*.

The term "SSB" refers to an SS/PBCH block.

The term “a “Primary Cell” refers to the MCG cell, operating on the primary frequency, in which the UE either performs the initial connection establishment procedure or initiates the connection re-establishment procedure.

The term “Primary SCG Cell” refers to the SCG cell in which the UE performs random access when performing the Reconfiguration with Sync procedure for DC operation.

The term “Secondary Cell” refers to a cell providing additional radio resources on top of a Special Cell for a UE configured with CA.

The term “Secondary Cell Group” refers to the subset of serving cells comprising the PSCell and zero or more secondary cells for a UE configured with DC.

The term “Serving Cell” refers to the primary cell for a UE in RRC_CONNECTED not configured with CA/DC there is only one serving cell comprising of the primary cell.

The term “serving cell” or “serving cells” refers to the set of cells comprising the Special Cell(s) and all secondary cells for a UE in RRC_CONNECTED configured with CA/.

The term “Special Cell” refers to the PCell of the MCG or the PSCell of the SCG for DC operation; otherwise, the term “Special Cell” refers to the Pcell.

CLAIMS

1. One or more non-transitory computer-readable media having instructions, stored thereon, that when executed by one or more processors of a reduced capability (RedCap) user equipment (UE), cause the RedCap UE to:

receive configuration information for multiple bandwidth parts (BWPs);

map repetitions of a physical downlink shared channel (PDSCH) or a physical uplink shared channel (PUSCH) to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH) according to a FH pattern; and

receive the PDSCH or transmit the PUSCH based on the mapped repetitions.

2. The one or more NTCRM of claim 1, wherein the configuration information is received via dedicated radio resource control (RRC) signaling.

3. The one or more NTCRM of claim 1, wherein the FH pattern is predefined.

4. The one or more NTCRM of claim 1, wherein the instructions, when executed, are further to cause the RedCap UE to receive FH pattern information to indicate the FH pattern.

5. The one or more NTCRM of claim 1, wherein the FH pattern is defined with respect to an absolute point in time.

6. The one or more NTCRM of claim 5, wherein the FH pattern is defined based on a system frame number and a slot number, with a common hopping pattern in a time domain across downlink and uplink.

7. The one or more NTCRM of claim 1, wherein the configuration information for the BWPs includes a common set of parameters that apply to all or a subset of the BWPs, and wherein the configuration information further includes separate center frequencies and BWP identifiers for the respective BWPs.

8. The one or more NTCRM of claim 7, wherein the inter-BWP frequency hopping is performed in accordance with a BWP retuning times that is shorter than a minimum delay for active downlink or uplink BWP change defined in 3GPP Technical Standard (TS) 38.133, V17.4.0.

9. The one or more NTCRM of claim 1, wherein a same frequency domain resource allocation (FDRA) is used to map repetitions of a physical channel in each of the BWPs.

10. The one or more NTCRM of claim 1, wherein the inter-BWP FH occurs only at slot boundaries.

11. The one or more NTCRM of any one of claims 1-10, wherein, to receive the PDSCH or transmit the PUSCH, the RedCap UE is to:

hop from a first BWP to a second BWP at a boundary of a first slot and a second slot; and

skip reception or transmission of one or more symbols at the end of the first slot and at the beginning of the second slot.

12. The one or more NTCRM of claim 11, wherein to receive the PDSCH or transmit the PUSCH, the RedCap UE is further to:

rate-match the PDSCH or PUSCH to available symbols of the first slot and the second slot; or

use receiver-side puncturing for the PDSCH or transmitter-side puncturing for the PUSCH.

13. One or more non-transitory computer-readable media having instructions, stored thereon, that when executed by one or more processors of a next generation Node B (gNB), cause the gNB to:

encode, for transmission to a reduced capability (RedCap) user equipment (UE), configuration information for multiple bandwidth parts (BWPs);

map repetitions of a physical downlink shared channel (PDSCH) or a physical uplink shared channel (PUSCH) to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH) according to a FH pattern; and

transmit the PDSCH or receive the PUSCH based on the mapped repetitions.

14. The one or more NTCRM of claim 13, wherein the FH pattern is predefined.

15. The one or more NTCRM of claim 13, wherein the instructions, when executed, are further to cause the gNB to encode, for transmission to the RedCap UE, FH pattern information to indicate the FH pattern.

16. The one or more NTCRM of claim 13, wherein the FH pattern is defined with respect to a system frame number and a slot number, with a common hopping pattern in a time domain across downlink and uplink.

17. The one or more NTCRM of claim 13, wherein the configuration information for the BWPs includes a common set of parameters that apply to all of the BWPs, and wherein the configuration information further includes separate indications of a center frequency, a bandwidth, and a BWP identifier for the respective BWPs.

18. The one or more NTCRM of claim 13, wherein a same frequency domain resource allocation (FDRA) is used to map repetitions of a physical channel in each of the BWPs.

19. The one or more NTCRM of claim 13, wherein the inter-BWP FH occurs only at slot boundaries.

20. The one or more NTCRM of any one of claims 13-19, wherein, to transmit the PDSCH or receive the PUSCH, the gNB is to:

hop from a first BWP to a second BWP at a boundary of a first slot and a second slot; and

skip reception or transmission of one or more symbols at the end of the first slot and at the beginning of the second slot.

21. The one or more NTCRM of claim 20, wherein to receive the PDSCH or transmit the PUSCH, the gNB is further to:

rate-match the PDSCH or PUSCH to available symbols of the first slot and the second slot; or

use puncturing for the PDSCH or the PUSCH.

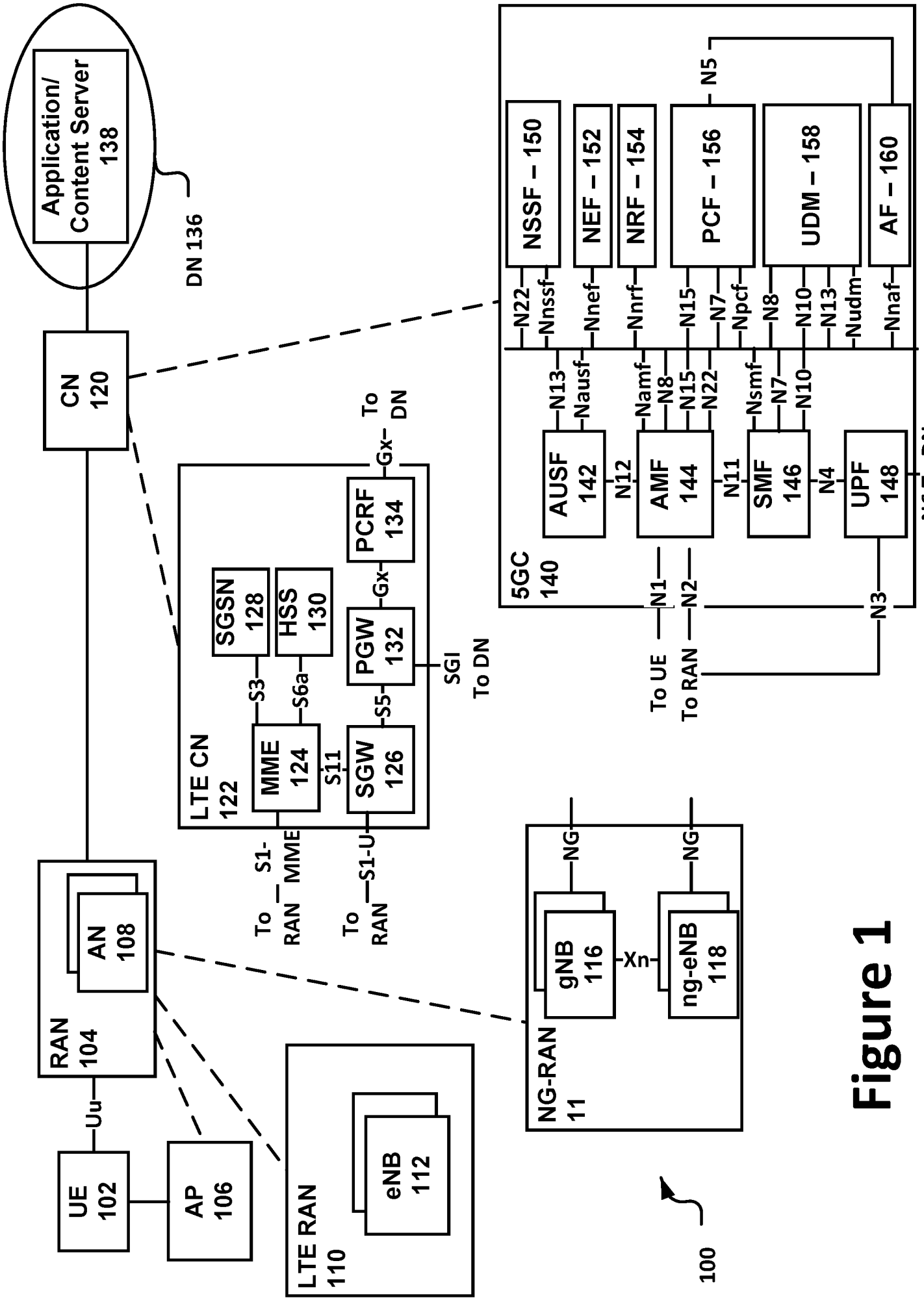

Application/ Content Server 138
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CN 120
5GC 140
NSSF – 150
NEF – 152
NRF – 154
PCF – 156
UDM – 158
AF – 160
AUSF 142
AMF 144
SMF 146
UPF 148
N6 To DN
To UE
To RAN
LTE CN 122
PCRF 134
SGSN 128
HSS 130
PGW 132
MME 124
SGW 126
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SGI
To RAN
RAN 104
AN 108
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NG-RAN 11
gNB 116
ng-eNB 118
Xn
NG
100

Figure 1

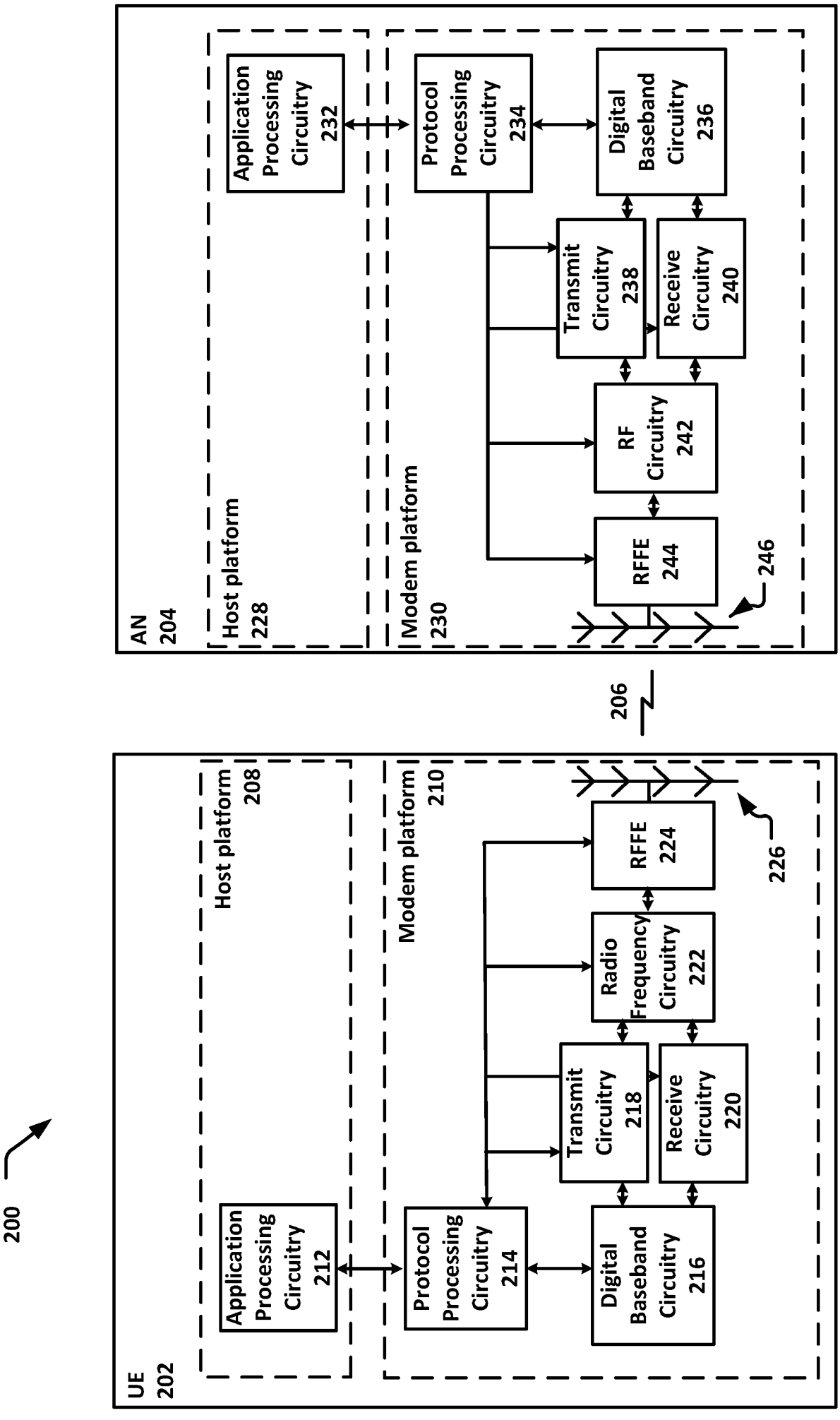

200
UE
202
Host platform
208
Application Processing Circuitry
212
Modem platform
210
Protocol Processing Circuitry
214
Digital Baseband Circuitry
216
Transmit Circuitry
218
Receive Circuitry
220
Radio Frequency Circuitry
222
RFFE
224
226
206
AN
204
Host platform
228
Application Processing Circuitry
232
Modem platform
230
Protocol Processing Circuitry
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Digital Baseband Circuitry
236
Transmit Circuitry
238
Receive Circuitry
240
RF Circuitry
242
RFFE
244
246

Figure 2

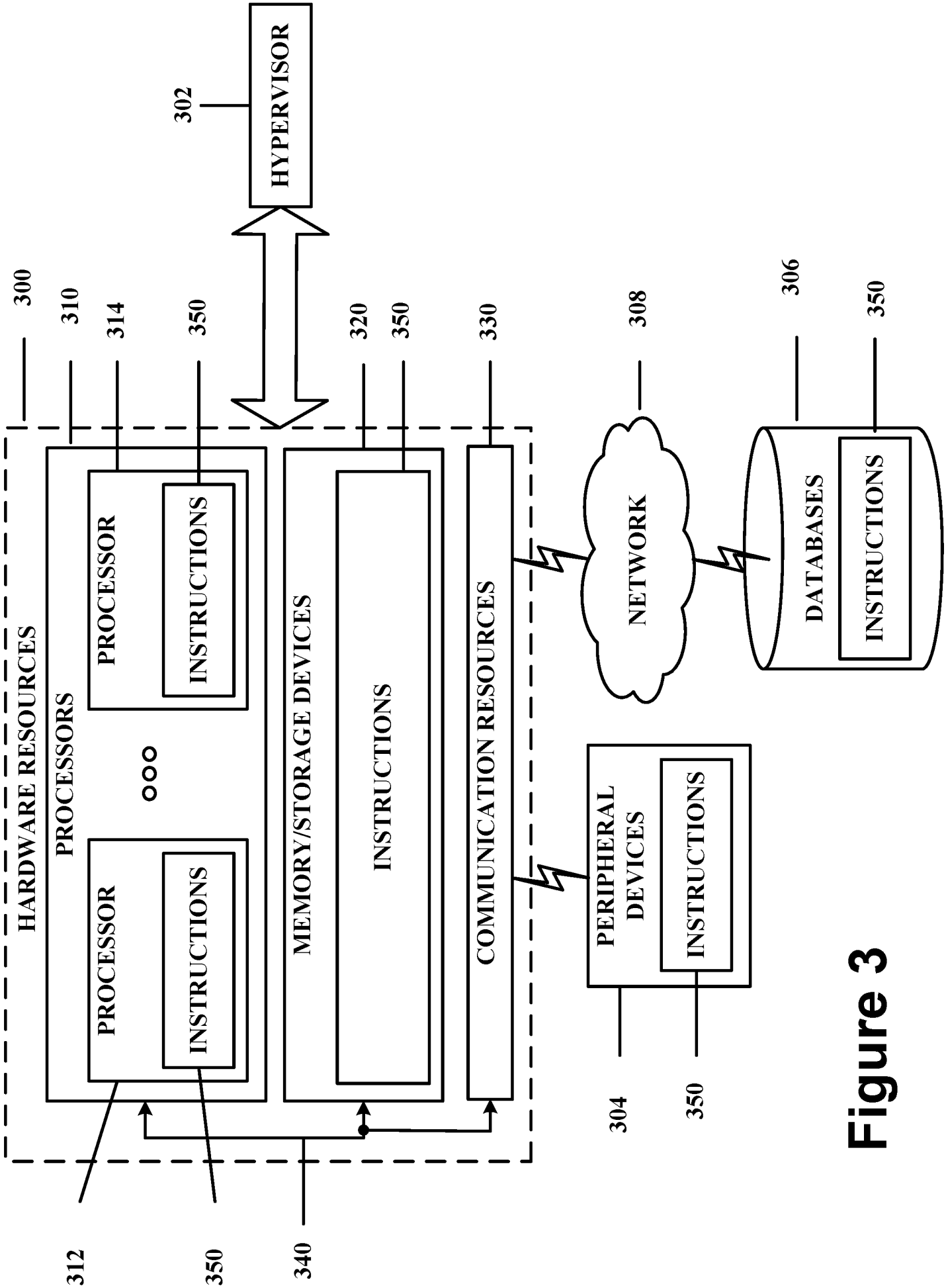

HYPERVISOR
302
300
HARDWARE RESOURCES
310
PROCESSORS
314
PROCESSOR
350
INSTRUCTIONS
PROCESSOR
INSTRUCTIONS
320
MEMORY/STORAGE DEVICES
350
INSTRUCTIONS
330
COMMUNICATION RESOURCES
308
NETWORK
306
DATABASES
350
INSTRUCTIONS
PERIPHERAL DEVICES
304
350
INSTRUCTIONS
312
350
340

Figure 3

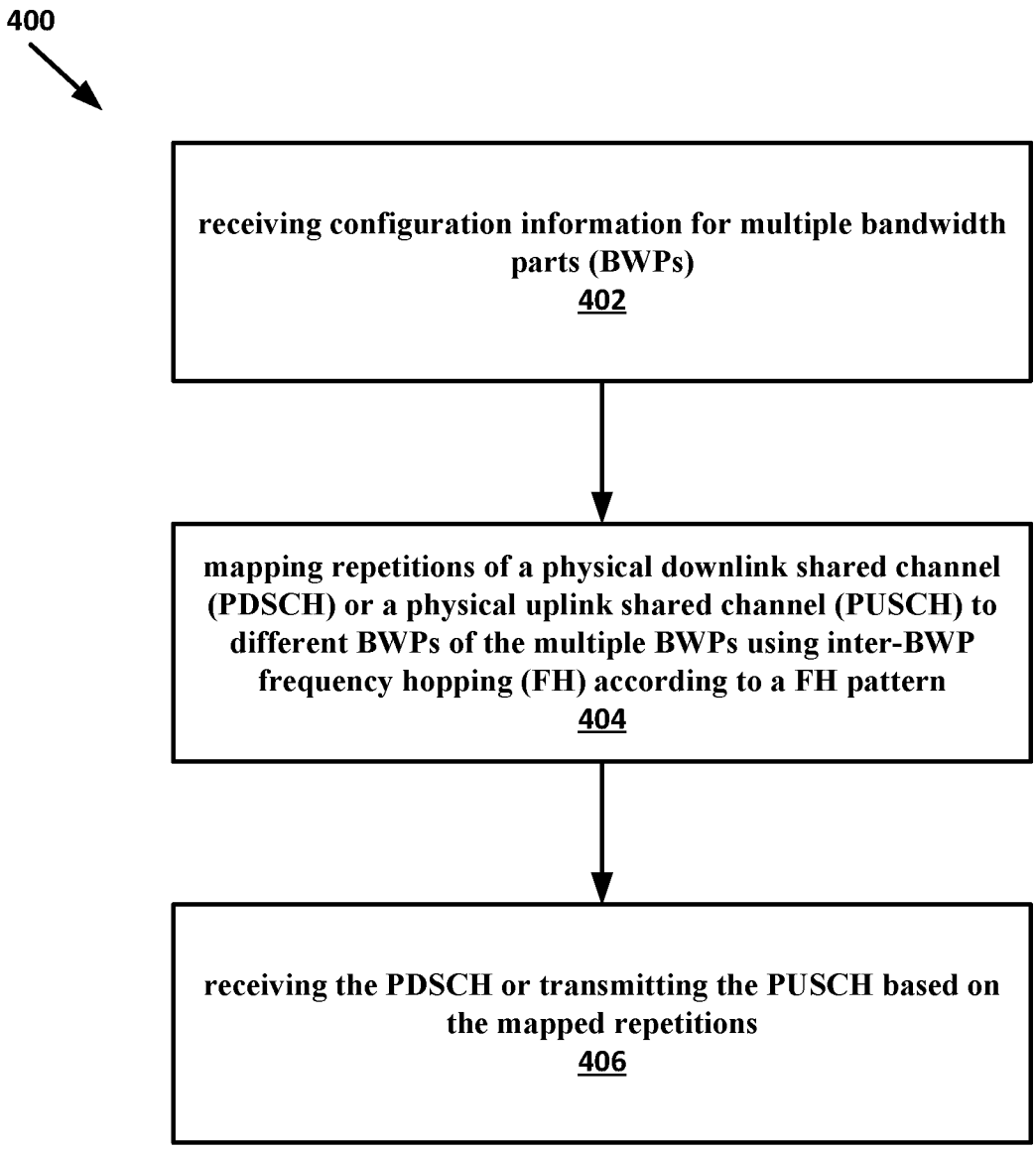

400
receiving configuration information for multiple bandwidth parts (BWPs)
402
mapping repetitions of a physical downlink shared channel (PDSCH) or a physical uplink shared channel (PUSCH) to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH) according to a FH pattern
404
receiving the PDSCH or transmitting the PUSCH based on the mapped repetitions
406

Figure 4

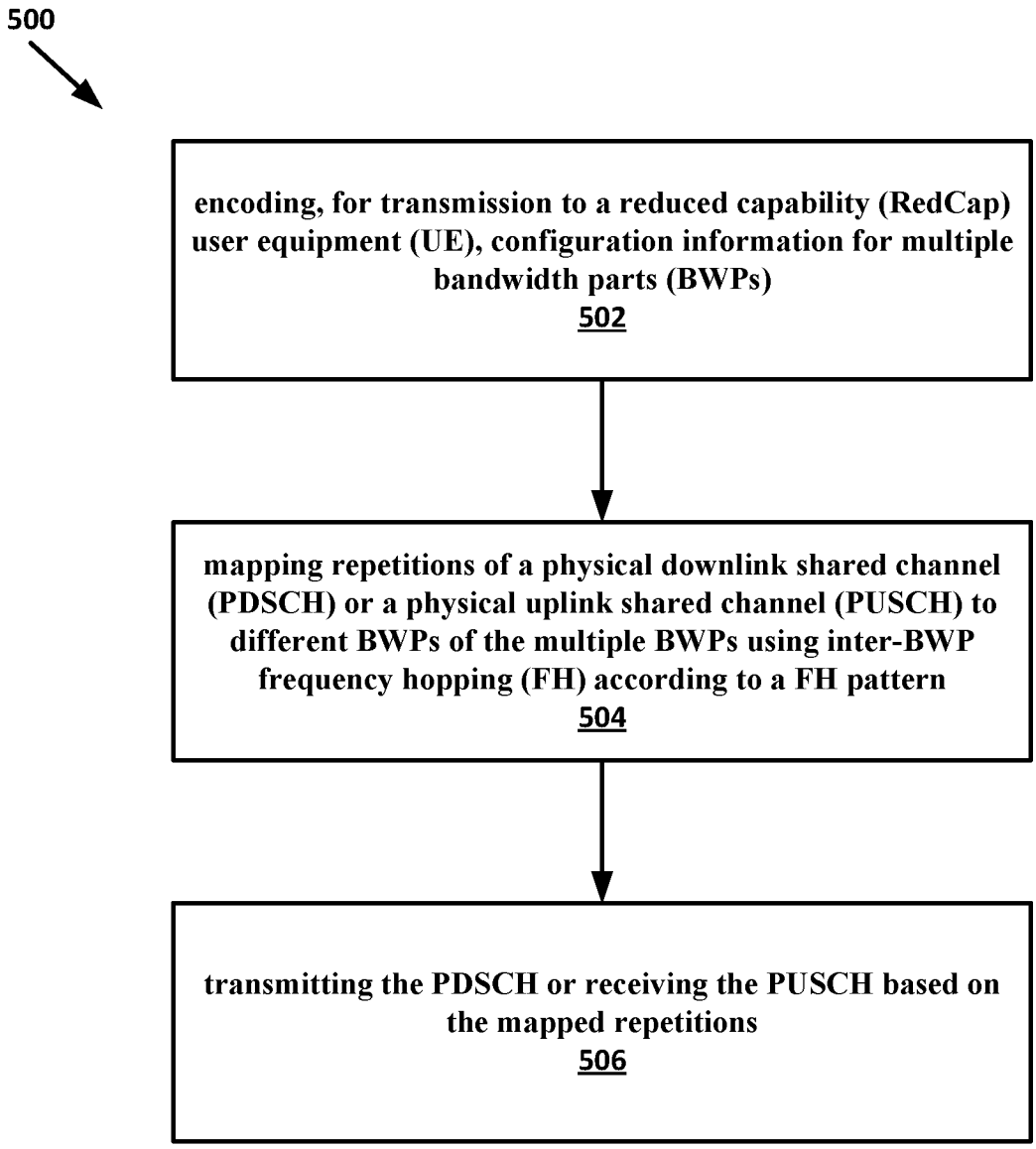

500
encoding, for transmission to a reduced capability (RedCap) user equipment (UE), configuration information for multiple bandwidth parts (BWPs)
502
mapping repetitions of a physical downlink shared channel (PDSCH) or a physical uplink shared channel (PUSCH) to different BWPs of the multiple BWPs using inter-BWP frequency hopping (FH) according to a FH pattern
504
transmitting the PDSCH or receiving the PUSCH based on the mapped repetitions
506

Figure 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2022/012552

A. CLASSIFICATION OF SUBJECT MATTER

H04L 5/00(2006.01)i; **H04W 72/04**(2009.01)i; **H04B 1/713**(2011.01)i

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)

H04L 5/00(2006.01); H04W 72/04(2009.01); H04W 72/12(2009.01)

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

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: RedCap, BWP, frequency hopping, PDSCH/PUSCH

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2020-0077432 A1 (INTEL IP CORPORATION) 05 March 2020 (2020-03-05) paragraphs [0049]-[0051]; and claims 26-31, 38	1-6,13-16
A		7-12,17-21
Y	US 2018-0191474 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 05 July 2018 (2018-07-05) paragraphs [0217]-[0238]; and claims 1-10	1-6,13-16
A	QUALCOMM INCORPORATED, 'UE complexity reduction for NR RedCap devices', R1-2008620, 3 GPP TSG RAN WG1 Meeting #103-e, 01 November 2020 section 3.1.2	1-21
A	MODERATOR (QUALCOMM INC.), 'FL summary #5 on coverage recovery and capacity impact for RedCap', R1-2009660, 3GPP TSG RAN WG1 Meeting #103-e, 11 November 2020 section 5.2	1-21
A	'3GPP; TSG RAN; Study on support of reduced capability NR devices', 3GPP TR 38.875 V1.0.0 (2020-12), 30 November 2020 section 7	1-21

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 April 2022	**28 April 2022**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**KO, Jae Yong**
Facsimile No. **+82-42-481-8578**	Telephone No. **+82-42-481-8212**

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	INTEL CORPORATION, 'On UE complexity reduction for RedCap device', R1-2100660, 3GPP TSG RAN WG1 Meeting #104-e, 19 January 2021 section 2	1,13

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2022/012552

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2020-0077432 A1	05 March 2020	CN 111034320 A	17 April 2020
		EP 3639602 A1	22 April 2020
		EP 3639602 A4	24 February 2021
		WO 2018-231971 A1	20 December 2018
US 2018-0191474 A1	05 July 2018	CN 104067662 A	24 September 2014
		CN 104067662 B	06 November 2018
		CN 109152063 A	04 January 2019
		EP 2922341 A1	23 September 2015
		EP 2922341 A4	02 December 2015
		EP 2922341 B1	28 February 2018
		EP 3373649 A1	12 September 2018
		US 2015-0288490 A1	08 October 2015
		US 9942012 B2	10 April 2018
		WO 2014-094195 A1	26 June 2014