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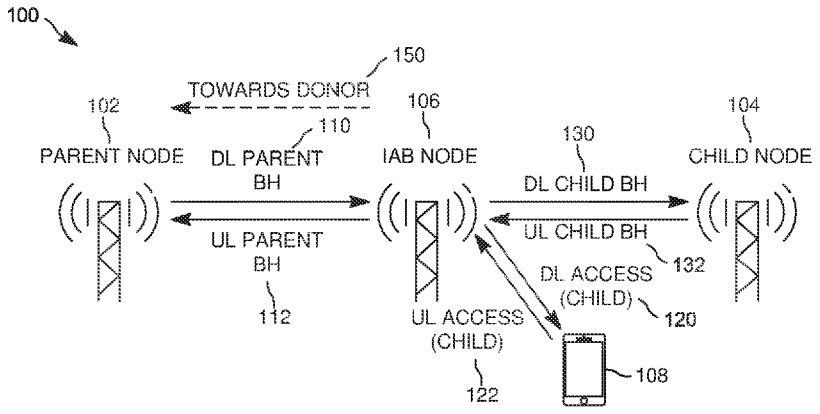


FIG. 1

(57) Abstract: The disclosure is directed to apparatuses, systems, and methods tor managing resources for a wireless network for an integrated access and backhaul (IAB) distributed unit (DU) through a semi-static configuration provided over an application protocol (AP) back haul signal to indicate resource availability and assigning resource availability types for the IAB distributed unit in a frequency domain through the semi-static configuration with an indication of availability of simultaneous frequency operations of the resources, including always available (hard), sometimes available (soft), and not available, (H/S/NA) indication.

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NEW RADIO PHYSICAL LAYER HARD, SOFT, NOT AVAILABLE (H/S/NA) IN DISTRIBUTED UNIT (DU) FREQUENCY-DOMAIN

CROSS-REFERENCE TO RELATED PATENT APPLICATION(S)

This application claims the benefit of U.S. Provisional Application No. 63/137,500, filed January 14, 2021, the disclosure of which is incorporated by reference as set forth in full.

TECHNICAL FIELD

Various embodiments generally may relate to the field of wireless communications and, more particularly, to new radio physical layer hard, soft, not available (H/S/NA) in distributed unit (DU) frequency-domain.

BACKGROUND

The next generation mobile networks, in particular Third Generation Partnership Project (3GPP) systems such as Fifth Generation (5G) and Long-Term Evolution (LTE) and the evolutions thereof, are among the latest cellular wireless technologies developed to deliver ten times faster data rates than LTE and are being deployed with multiple carriers in the same area and across multiple spectrum bands.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed description is set forth below with reference to the accompanying drawings. The use of the same reference numerals may indicate similar or identical items. Various embodiments may utilize elements and/or components other than those illustrated in the drawings, and some elements and/or components may not be present in various embodiments. Elements and/or components in the figures are not necessarily drawn to scale. Throughout this disclosure, depending on the context, singular and plural terminology may be used interchangeably.

FIG. 1 illustrates an IAB node network in accordance with and embodiment of the disclosure.

FIG. 2 illustrates simultaneous transmissions of a mobile termination and distributed unit in accordance with an embodiment of the disclosure.

FIG. 3 illustrates different schemes for providing hard, soft, not available resource availability information in resource blocks that do not support bandwidth parts (BWP) in accordance with an embodiment of the disclosure.

FIG. 4 illustrates different schemes for providing hard, soft, not available resource availability information in resource blocks that support bandwidth parts (BWP) in accordance with an embodiment of the disclosure.

FIG. 5 illustrates a flow diagram of a method in accordance with an embodiment of the disclosure.

FIG. 6 illustrates an exemplary network in accordance with various embodiments of the disclosure.

FIG. 7 illustrates an exemplary wireless network in accordance with various embodiments of the disclosure.

FIG. 8 illustrates an exemplary system diagram of hardware resources in accordance with various embodiments of the disclosure.

DETAILED DESCRIPTION

In terms of a general overview, this disclosure is generally directed to systems and methods for managing resources for a wireless network for an integrated access and backhaul (IAB) distributed unit (DU) through a semi-static configuration provided over an application protocol (AP) back haul signal to indicate resource availability; and assigning resource availability types for the IAB distributed unit in a frequency domain through the semi-static configuration with an indication of availability of simultaneous frequency operations of the resources, including always available (hard), sometimes available (soft), and not available, (H/S/NA) indication.

In one or more embodiments, an always available hard resource type is a resource that will transmit or receive at a second frequency, and a soft resource will transmit or receive only when the second frequency is available, and a not available resource will not transmit or receive at the second frequency.

In one or more embodiments the systems and methods further provide the H/S/NA indication when a distributed unit (DU) does not support bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks, and provide the H/S/NA indication through one of grouped resource blocks, grouped according to a resource indication value (RIV) grouping of resource blocks, or providing the H/S/NA indication according to a mobile terminal bandwidth part.

In one or more embodiments, the systems and methods further provide the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency

domain through a component carrier (CC) in resource blocks; and provide the H/S/NA indication through one of grouping the H/S/NA indication according to resource blocks, a resource indication value (RIV) grouping of resource blocks, a mobile termination (MT) bandwidth part, or bandwidth parts (BWP) for the distributed unit.

In one or more embodiments, the systems and method are directed to enhancing an F1 application protocol (AP) signal by providing the H/S/NA indication according to frequency BWP availability and resource block grouping.

In one or more embodiments, the enhanced F1AP signal is an existing GNB-DU RESOURCE CONFIGURATION, gNB-DU Cell Resource Configuration IE message, or introducing a new dedicated F1AP message.

In one or more embodiments the systems and methods provide for dynamically indicating a soft availability of resources in frequency domain bandwidth part configurations for the IAB DU by extending a downlink control information (DCI) format 2_5 soft resource message carried in a packet data control channel (PDCCH) transmitted from a parent DU to a co-located mobile termination (MT).

The disclosure will be described more fully hereinafter with reference to the accompanying drawings, in which example embodiments of the disclosure are shown. This disclosure may, however, be embodied in many different forms and should not be construed as limited to the example embodiments set forth herein. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made to various embodiments without departing from the spirit and scope of the present disclosure. Thus, the breadth and scope of the present disclosure should not be limited by any of the above-described example embodiments but should be defined only in accordance with the following claims and their equivalents. The description below has been presented for the purposes of illustration and is not intended to be exhaustive or to be limited to the precise form disclosed. It should be understood that alternative implementations may be used in any combination desired to form additional hybrid implementations of the present disclosure. For example, any of the functionality described with respect to a particular device or component may be performed by another device or component. Furthermore, while specific device characteristics have been described, embodiments of the disclosure may relate to numerous other device characteristics. Further, although embodiments have been described in language specific to structural features and/or methodological acts, it is to be understood that the disclosure is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as illustrative forms of implementing the embodiments.

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).

Embodiments herein address a Fifth Generation (5G) wireless communication system. Specifically, 5G supports simultaneous operations at an IAB node for mobile termination/distributed unit (MT/DU) which may be fulfilled wither with frequency division multiplexing (FDM) for spatial division multiplexing (SDM). For 5G, MT/DU simultaneous operations at an IAB node may be fulfilled either with SDM or with FDM. In spatial domain multiplexing (SDM), the parent link and child link are separated. In FDM, parent link and child link must be separated in the frequency domain. Thus, to facilitate an IAB-MT and a co-located IAB-DU to operate at the same component carrier (CC), resource capabilities are identified as being Hard, Soft, Not available (H/S/NA) resource types. Hard is defined as hard resource wherein simultaneous operations may be performed regardless of a DU/MTs ability to transmit or receive at a second frequency simultaneously. Soft is defined as a soft resource when simultaneous operations may be performed only if the DU/MT is not always able to transmit or receive at a second frequency simultaneously. Not available (NA) refers to DU/MTs that are unable to perform simultaneous operations.

In one or more embodiments, the hard, soft, not available indication can be assigned to IAB DU frequency-domain resources through semi-static configuration. After that, availability indication of IAB-DU's soft frequency-domain resources can be dynamically transmitted.

There is no frequency-domain resource allocation defined for an IAB DU in Rel-16 IAB. In accordance with one or more embodiments, IAB DU frequency domain resource allocation may operate in conjunction with semi-static configuration of bandwidth parts (BWPs) for an IAB DU, which are part of the discussion in 3GPP RAN1 meetings. Regarding H/S/NA resource types in DU frequency-domain, one or more embodiments present schemes without DU BWP configuration and schemes with DU BWP configuration, as well as signaling

for H/S/NA indication in DU frequency-domain.

A BWP refers to a 5G UE/MT to communicate on a bandwidth smaller than a cell's channel bandwidth. The smaller bandwidth is introduced in 5G as a Bandwidth Part (BWP). In radio resource control (RRC) signaling, a UE is configured with multiple BWPs, in downlink and uplink. In the physical layer (PHY) layer, the network dynamically activates a BWP for transmission or reception. Through such dynamic adaptation, BWPs allow a 5G system to use radio resources optimally to suit current needs.

In one or more embodiments, the frequency-domain resource allocation schemes (semi-static and dynamic) are defined for a UE or an IAB MT. Some embodiments may operate in conjunction with semi-static configuration of BWPs for an IAB DU, which are part of 3GPP RAN1 meetings.

Solutions are needed for IAB-MT and IAB-DU operating at the same CC with overlapping frequency domain resources, and, therefore, require an H/S/NA indication. One or more embodiments are directed to H/S/NA indication schemes for IAB-DU frequency-domain, with or without IAB-DU BWP configuration. Additionally, one or more embodiments are directed to an F1 application protocol (AP) signaling to provide H/S/NA indication schemes. In general, an F1 setup procedure is to exchange application level data needed for the gNB-DU and the gNB-CU (centralized unit) to correctly interoperate on the F1 interface.

Referring to FIG. 1, an Integrated Access and Backhaul (IAB) Network 100 illustrates different IAB link types, including a parent node 102, a child node 104 and an IAB node 106 that may connect to its parent node 102 as either an IAB donor or another IAB node through parent backhaul (BH) link shown as downlink Parent BH 110 and uplink parent BH 112. The IAB node 106 can also connect to a child user equipment (UE) 108 through child access link shown as downlink access 120 and uplink access 122. IAB node 106 can further connect to its child IAB node 104 through download Child BH 130 and uplink Child BH 132. FIG. 1 also indicates data direction 150 towards donor.

In some IAB network architectures, a central unit (CU)/distributed unit (DU) split has been leveraged wherein each IAB node holds a DU and a Mobile-Termination (MT) function. Specifically, in an MT function, an IAB node connects to a parent IAB node or an IAB-donor like node via UE. In a DU function, an IAB node communicates with its child UEs and child MTs like a base station. RRC signaling is used between the CU in the IAB donor and the UE/MT and F1AP signaling is used between the CU and the DU in an IAB node.

In NR Rel-16, Physical Layer section 214 includes an IAB section that focuses on supporting time division multiplexing (TDM)-based DU functions and MT functions within an

IAB node. Extended IAB may include duplexing enhancements to increase spectral efficiency and reduce latency through the support of SDM/FDM-based resource management, through simultaneous transmissions and/or reception on IAB-nodes.

Referring now to FIG. 2, block diagrams 200 illustrate simultaneous transmission possibilities of an MT/DU. Specifically, simultaneous operation (transmission and/or reception) of IAB-node's child and parent links includes four cases, 202, MT TX/DU TX, 204, MT RX/DU RX, 206, MT TX/DU RX, and 204, MT RX/DU TX.

MT/DU Simultaneous operations at an IAB node can be fulfilled either with SDM or with FDM. In SDM, parent link and child link are separated in spatial domain and we don't have to separate them in frequency domain. However, in FDM, parent links and child links must be separated in the frequency domain. In order to facilitate an IAB-MT and co-located IAB-DU to operate at the same component carrier (CC), Hard, Soft, Not available (H/S/NA) resource types can be assigned to IAB DU frequency-domain resources through semi-static configuration. After that, availability indication of IAB-DU's soft frequency-domain resources can be dynamically transmitted.

The 3GPP 5G New Radio Release 16 discussion of IAB does not define frequency-domain resource allocation for an IAB DU. One or more embodiments provide simultaneous operations in conjunction with semi-static configuration of BWPs for an IAB DU. Regarding H/S/NA resource types in DU frequency-domain, embodiments relate to schemes without DU BWP configuration and schemes with DU BWP configuration.

Referring now to FIG. 3, exemplary schemes for resource blocks (RB) appropriate for embodiments are shown. Specifically, FIG. 3 includes simultaneous transmission indicators MT RB in MT BWP 302, DU RB that are "hard" "H" 304, DU RB that are "soft" "S" 306, and DU RB that are not available "NA" 308. The RB-based H/S/NA 310 is shown compared to the transmission with Resource Indication Value (RIV) based H/S/NA 320, and MT BWP-based H/S/NA 330. One of ordinary skill in the art will appreciate that a resource indicator value (RIV)-based H/S/NA indication is the same concept as the RB-group based H/S/NA indication, and that RIV is one specific way to indicate the RB-group.

As shown RB-based H/S/NA 310 with CC bandwidth 312, MT RB in MT BWP resource blocks 314 and resource blocks 318 showing different hard, soft and not available resources. RIV-based H/S/NA 320 also illustrates CC bandwidth 322, MT RB in MT BWP 324 and grouped resource blocks 328 that show RIV4-soft 340, RIV3 not available blocks 342, RIV2 hard resource blocks 344 and RIV1 soft blocks 346.

MT BWP-based HS/NA 330 also shows CC bandwidth 332, MT RB in MT BWP 334,

and BWP based resource blocks grouped including MT BWP2 soft 350, MT BWP1 not available blocks 352 and MT BWP0 soft blocks 356.

The three BWPs BWP0, BWP1 and BWP2 are three BWPs semi-statically configured. For the collocated IAB-DU operating under the same CC, there can be several schemes to semi-statically assign H/S/NA resource types in DU frequency-domain without DU BWP configuration.

Scheme 1-1 is shown as 310, an RB-based H/S/NA indication for DU frequency-domain resource. A resource block (RB)-based H/S/NA indication for DU frequency-domain resource is shown, i.e., H/S/NA is indicated per DU RB over the whole CC 312. Each DU RB will have a resource type from H/S/NA.

320 illustrates scheme 1-2 and represents RIV-based H/S/NA indications for DU frequency-domain resources. The resource indicator value (RIV)-based H/S/NA indication for DU frequency-domain resource is shown, i.e., H/S/NA is indicated per DU RIV. Thus, each RIV has its starting point and number of RBs. Each DU RIV has a resource type from H/S/NA. In this example, there are four RIVs indicated for IAB DU with RIV1 indicated as Soft, 346, RIV2 indicated as Hard, 344, RIV3 indicated as NA, 342, and RIV4 indicated as Soft, 340.

330 illustrates scheme 1-3 and represents MT BWP-based H/S/NA indication for DU frequency-domain resources. Specifically, 330 is an MT BWP-based H/S/NA indication for DU frequency-domain resources assuming all RBs not overlapping with MT BWPs are indicated as Hard and capable of simultaneous transmissions, and H/S/NA is indicated per MT BWP. In this example, since there are three IAB MT BWPs, three H/S/NA indications are given as Soft for MT BWP0 356, NA for MT BWP1 352 and Soft for MT BWP2 350.

Referring now to FIG. 4, other embodiments of IAB resources as hard, soft, not available are shown. Resource blocks MT RB in MT BWP are shown as 402, DU RB-H blocks are shown as 404, RU RB-S blocks are shown as 406, and DU REB-NA blocks are shown as 408. RB-Based H/S/NA 410 includes CC bandwidth 412 with MT RB in MT BWP 414 and RB based blocks 416 showing individual blocks as hard, soft or not available. RIV-based HS/NA blocks 420 show separated soft blocks identified as RIV5 426, not available blocks as RIV4 427, hard blocks RIV3 428, hard blocks RIV2 429 and soft blocks RIV1 425.

FIG. 4 also shows CC bandwidths with frequency BWP-based H/S/NA a mobile terminal BWP based H/S/NA 430 and a distributed unit BWP-based H/S/NA 440. MT BWP based H/S/NA shows resource blocks 434, and DU BWP based H/S/NA shows resource blocks 444 with three BWPs semi-statically configured. In addition, the collocated IAB DU operating under the same CC is configured with four BWPs. There can be several schemes to semi-

statically assign H/S/NA resource types in DU frequency-domain with DU BWP configuration.

410 illustrates scheme 2-1: RB-based H/S/NA indication for DU BWPs. A resource block (RB)-based H/S/NA indication for DU BWPs is shown, i.e., H/S/NA is indicated per DU RB over DU BWPs 416 over CC bandwidth 412 and RBs 414. Each DU RB 416 will have a resource type from H/S/NA.

420 illustrates scheme 2-2: RIV-based H/S/NA indication for DU BWPs. A resource indicator value (RIV)-based H/S/NA indication for DU BWPs is shown, i.e., H/S/NA is indicated per DU RIV (each RIV has its starting point and number of RBs). Each DU RIV will have a resource type from H/S/NA. In this example, there are five RIVs indicated within DU BWPs, with RIV1 indicated as Soft 425, RIV2 indicated as Hard 429, RIV3 indicated as Hard 428, RIV4 indicated as NA 427and RIV4 indicated as Soft 426. And blocks 424 indicated as MT RBs.

430 illustrates scheme 2-3: MT BWP-based H/S/NA indication for DU BWPs. As shown an MT BWP-based H/S/NA 439 indication for DU BWPs over MTs 434, i.e., assuming all RBs in DU BWPs not overlapping with MT BWPs as Hard as shown be slanted line blocks 404, and H/S/NA is indicated per MT BWP. In this example, since there are three IAB MT BWPs, three H/S/NA indications are given as Soft for MT BWP0 439, NA for MT BWP1 438 and Soft for MT BWP2 436. DU RBs overlapping with those MT BWPs will be indicated accordingly.

440 illustrates scheme 2-4, DU BWP-based H/S/NA indication for DU BWPs. Specifically, scheme 440 DU BWP-based H/S/NA indication for DU BWPs is shown, i.e., H/S/NA is indicated per DU BWP. Each DU BWP will have a resource type from H/S/NA. In this example, since there are four IAB DU BWPs, four H/S/NA indications are given as Soft for DU BWP0 425, Hard for DU BWP1 429, NA for DU BWP2 428 and Soft for DU BWP3 446.

In another embodiment, semi-static H/S/NA configuration in IAB-DU frequency-domain can be fulfilled by F1AP signaling. There can be several options to enhance the F1AP signaling to include BWP configuration for DU.

Specifically, in one or more embodiments, the schemes shown in FIGs. 3 and 4 may be enhanced by three options for F1 application protocol signaling.

The three options to enhance the schemes include option 1: Enhancement of the existing GNB-DU RESOURCE CONFIGURATION message; option 2: Enhancement of the existing gNB-DU Cell Resource Configuration IE; and option 3: Introduction of a new dedicated F1AP message/IE.

For scheme 310, 1-1 (RB-based H/S/NA indication without DU BWP configuration), one embodiment is shown as below in Table 1, which can be included in F1AP signaling.

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
>RB-based H/S/NA freq-domain indication		1..<maxnoofRBsPerCC>				
>>RBresourcetype	O		ENUMERATED (hard, soft, not available)	DU freq-domain resource type per RB		

TABLE 1

For 320, scheme 1-2 (RIV-based H/S/NA indication without DU BWP configuration), Table 2, below illustrates another embodiment is shown as below.

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
>RIV-based H/S/NA freq-domain indication		1..<maxnoofRIVsPerCC>				
>>RIVlocationandBandwidth	O		INTEGER (0…37949)	Frequency domain location and bandwidth of this resource type. The value of this field shall be interpreted as Resource indicator value (RIV).		
>>RIVresourcetype	O		ENUMERATED (hard, soft, not available)	DU freq-domain resource type per RIV		

TABLE 2

For 330, scheme 1-3 (MT BWP-based H/S/NA indication without DU BWP configuration), one embodiment is shown in Table 3, below.

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
>MT BWP-based H/S/NA freq-domain indication		1..<maxnoofMTBWPs>				
>>MTBWP-ID	O		BWP-Id	Index to MT's BWPs.		
>>MTBWPresourcetype	O		ENUMERATED (hard, soft, not available)	DU freq-domain resource type per MT BWP		

TABLE 3

In one or more embodiments, similar F1AP enhancements apply to schemes, 2-1, 410, 2-2, 420, 2-3 430, and 2-4 440.

One or more embodiments are directed to a dynamic-soft availability indication in DU frequency-domain. After semi-static H/S/NA resource type configuration in DU frequency-domain, dynamic indication about soft availability in DU frequency-domain can be further fulfilled, either by extend DCI format 2_5 or a new DCI format carried in PDCCH transmitted from its parent DU to its co-located MT. Specifically, the main purpose of DCI (Downlink Control Information) is to provide data that schedules downlink data channel (e.g, PDSCH) or uplink data channel (e.g, PUSCH). Format 2_5 relates to soft resources. Therefore, one embodiment is directed to providing H/S/NA dynamic indications for simultaneous transmissions.

Referring to FIG. 5, a flow diagram illustrates a method 500 in accordance with one or more embodiments. As shown, block 510 provides for managing resources for a wireless network for an integrated access and backhaul (IAB) distributed unit (DU) through a semi-static configuration provided over an application protocol (AP) back haul signal to indicate resource availability. For example, the IAB nodes shown in FIG. 1 that are capable of semi-static configuration.

Block 520 provides for assigning resource availability types for the IAB distributed unit over in a frequency domain through the semi-static configuration with an indication of availability of simultaneous frequency operations of the resources, including always available (hard), sometimes available (soft), and not available, (H/S/NA) indication. For example, as

shown in FIGs. 3 and 4, semi static configurations for H/S/NA are illustrated in resource blocks in different schemes. In one or more embodiments, an always available hard resource type is a resource that will transmit or receive at a second frequency, and a soft resource will transmit or receive only when the second frequency is available, and a not available resource will not transmit or receive at the second frequency.

Block 530 illustrates providing the H/S/NA indication when a distributed unit (DU) does not support bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks, and provide the H/S/NA indication through one of grouped resource blocks, grouped according to a resource indication value (RIV) grouping of resource blocks, or providing the H/S/NA indication according to a mobile terminal bandwidth part. For example, as shown in FIG. 3, when a DU does not support BWP, three schemes may support H/S/NA indications.

Block 540 illustrates providing the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks, and provide the H/S/NA indication through one of grouping the H/S/NA indication according to resource blocks, a resource indication value (RIV) grouping of resource blocks, a mobile termination (MT) bandwidth part, or bandwidth parts (BWP) for the distributed unit. For example, as shown in FIG. 4, when a DU does support BWP, four schemes may support H/S/NA indications.

Block 550 provides for enhancing an F1 application protocol (AP) signal to provide availability of resources in frequency domain bandwidth part configurations for the IAB DU by enhancing an existing GNB-DU RESOURCE CONFIGURATION, gNB-DU Cell Resource Configuration IE message, or introducing a new dedicated F1AP message. For example, as shown in Tables 1, 2 and 3, an F1AP signal message is altered to accommodate H/S/NA signaling.

Block 560 provides for dynamically indicating a soft availability of resources in frequency domain bandwidth part configurations for the IAB DU by extending a downlink control information (DCI) format 2_5 soft resource message carried in a packet data control channel (PDCCH) transmitted from a parent DU to a co-located mobile termination (MT).

FIGs. 6, 7 and 8 illustrate various systems, devices, and components that may implement aspects of disclosed embodiments.

FIG. 6 illustrates a network 600 in accordance with various embodiments. The network 600 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 600 may include a UE 602, which may include any mobile or non-mobile computing device designed to communicate with a RAN 604 via an over-the-air connection. The UE 602 may be communicatively coupled with the RAN 604 by a Uu interface. The UE 602 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 600 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 602 may additionally communicate with an AP 606 via an over-the-air connection. The AP 606 may manage a WLAN connection, which may serve to offload some/all network traffic from the RAN 604. The connection between the UE 602 and the AP 606 may be consistent with any IEEE 802.11 protocol, wherein the AP 606 could be a wireless fidelity (Wi-Fi®) router. In some embodiments, the UE 602, RAN 604, and AP 606 may utilize cellular-WLAN aggregation (for example, LWA/LWIP). Cellular-WLAN aggregation may involve the UE 602 being configured by the RAN 604 to utilize both cellular radio resources and WLAN resources.

The RAN 604 may include one or more access nodes, for example, AN 608. AN 608 may terminate air-interface protocols for the UE 602 by providing access stratum protocols including RRC, PDCP, RLC, MAC, and L1 protocols. In this manner, the AN 608 may enable data/voice connectivity between CN 620 and the UE 602. In some embodiments, the AN 608 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 608 be referred to as a BS, gNB, RAN node, eNB, ng-eNB, NodeB, RSU, TRxP, TRP, etc. The AN 608 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 604 includes a plurality of ANs, they may be coupled with one another via an X2 interface (if the RAN 604 is an LTE RAN) or an Xn interface (if the RAN 604 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 604 may each manage one or more cells, cell groups, component carriers, etc. to provide the UE 602 with an air interface for network access. The UE 602 may be simultaneously connected with a plurality of cells provided by the same or different ANs of the RAN 604. For example, the UE 602 and RAN 604 may use carrier aggregation to allow the UE 602 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 604 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 602 or AN 608 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 604 may be an LTE RAN 610 with eNBs, for example, eNB 612. The LTE RAN 610 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 604 may be an NG-RAN 614 with gNBs, for example, gNB 616, or ng-eNBs, for example, ng-eNB 618. The gNB 616 may connect with 5G-enabled UEs using a 5G NR interface. The gNB 616 may connect with a 5G core through an NG interface, which may include an N2 interface or an N3 interface. The ng-eNB 618 may also connect with the 5G core through an NG interface, but may connect with a UE via an LTE air interface. The gNB 616 and the ng-eNB 618 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 614 and a UPF 648 (e.g., N3 interface), and an NG control plane (NG-C) interface, which is a signaling interface between the nodes of the NG-RAN614 and an AMF 644 (e.g., N2 interface).

The NG-RAN 614 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 602 can be configured with multiple BWPs where each BWP configuration has a different SCS. When a BWP change is indicated to the UE 602, 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 602 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 602 and in some cases at the gNB 616. A BWP containing a larger number of PRBs can be used for scenarios with higher traffic load.

The RAN 604 is communicatively coupled to CN 620 that includes network elements to provide various functions to support data and telecommunications services to customers/subscribers (for example, users of UE 602). The components of the CN 620 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 620 onto physical compute/storage resources in servers, switches, etc. A logical instantiation of the CN 620 may be referred to as a network slice, and a logical instantiation of a portion of the CN 620 may be referred to as a network sub-slice.

In some embodiments, the CN 620 may be an LTE CN 622, which may also be referred to as an EPC. The LTE CN 622 may include MME 624, SGW 626, SGSN 628, HSS 630, PGW 632, and PCRF 634 coupled with one another over interfaces (or "reference points") as shown. Functions of the elements of the LTE CN 622 may be briefly introduced as follows.

The MME 624 may implement mobility management functions to track a current location of the UE 602 to facilitate paging, bearer activation/deactivation, handovers, gateway selection, authentication, etc.

The SGW 626 may terminate an S1 interface toward the RAN and route data packets between the RAN and the LTE CN 622. The SGW 626 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 628 may track a location of the UE 602 and perform security functions and access control. In addition, the SGSN 628 may perform inter-EPC node signaling for mobility between different RAT networks; PDN and S-GW selection as specified by MME 624; MME selection for handovers; etc. The S3 reference point between the MME 624 and the SGSN 628 may enable user and bearer information exchange for inter-3GPP access network mobility in idle/active states.

The HSS 630 may include a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The HSS 630 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc. An S6a reference point between the HSS 630 and the MME 624 may enable transfer of subscription and authentication data for authenticating/authorizing user access to the LTE CN 620.

The PGW 632 may terminate an SGi interface toward a data network (DN) 636 that may include an application/content server 638. The PGW 632 may route data packets between the LTE CN 622 and the data network 636. The PGW 632 may be coupled with the SGW 626 by an S5 reference point to facilitate user plane tunneling and tunnel management. The PGW 632 may further include a node for policy enforcement and charging data collection (for example, PCEF). Additionally, the SGi reference point between the PGW 632 and the data network 6 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 632 may be coupled with a PCRF 634 via a Gx reference point.

The PCRF 634 is the policy and charging control element of the LTE CN 622. The PCRF 634 may be communicatively coupled to the app/content server 638 to determine appropriate QoS and charging parameters for service flows. The PCRF 632 may provision associated rules into a PCEF (via Gx reference point) with appropriate TFT and QCI.

In some embodiments, the CN 620 may be a 5GC 640. The 5GC 640 may include an AUSF 642, AMF 644, SMF 646, UPF 648, NSSF 650, NEF 652, NRF 654, PCF 656, UDM 658, and AF 660 coupled with one another over interfaces (or "reference points") as shown. Functions of the elements of the 5GC 640 may be briefly introduced as follows.

The AUSF 642 may store data for authentication of UE 602 and handle authentication-related functionality. The AUSF 642 may facilitate a common authentication framework for various access types. In addition to communicating with other elements of the 5GC 640 over reference points as shown, the AUSF 642 may exhibit an Nausf service-based interface.

The AMF 644 may allow other functions of the 5GC 640 to communicate with the UE 602 and the RAN 604 and to subscribe to notifications about mobility events with respect to the UE 602. The AMF 644 may be responsible for registration management (for example, for registering UE 602), connection management, reachability management, mobility management, lawful interception of AMF-related events, and access authentication and authorization. The AMF 644 may provide transport for SM messages between the UE 602 and the SMF 646, and act as a transparent proxy for routing SM messages. AMF 644 may also provide transport for SMS messages between UE 602 and an SMSF. AMF 644 may interact with the AUSF 642 and the UE 602 to perform various security anchor and context management functions. Furthermore, AMF 644 may be a termination point of a RAN CP interface, which may include or be an N2 reference point between the RAN 604 and the AMF 644; and the AMF 644 may be a termination point of NAS (N1) signaling, and perform NAS ciphering and integrity protection. AMF 644 may also support NAS signaling with the UE 602

over an N3 IWF interface.

The SMF 646 may be responsible for SM (for example, session establishment, tunnel management between UPF 648 and AN 608); UE IP address allocation and management (including optional authorization); selection and control of UP function; configuring traffic steering at UPF 648 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 644 over N2 to AN 608; 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 602 and the data network 636.

The UPF 648 may act as an anchor point for intra-RAT and inter-RAT mobility, an external PDU session point of interconnect to data network 636, and a branching point to support multi-homed PDU session. The UPF 648 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 648 may include an uplink classifier to support routing traffic flows to a data network.

The NSSF 650 may select a set of network slice instances serving the UE 602. The NSSF 650 may also determine allowed NSSAI and the mapping to the subscribed S-NSSAIs, if needed. The NSSF 650 may also determine the AMF set to be used to serve the UE 602, or a list of candidate AMFs based on a suitable configuration and possibly by querying the NRF 654. The selection of a set of network slice instances for the UE 602 may be triggered by the AMF 644 with which the UE 602 is registered by interacting with the NSSF 650, which may lead to a change of AMF. The NSSF 650 may interact with the AMF 644 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 650 may exhibit an Nnssf service-based interface.

The NEF 652 may securely expose services and capabilities provided by 3GPP network functions for third party, internal exposure/re-exposure, AFs (e.g., AF 660), edge computing or fog computing systems, etc. In such embodiments, the NEF 652 may authenticate, authorize, or throttle the AFs. NEF 652 may also translate information exchanged with the AF 660 and information exchanged with internal network functions. For example, the NEF 652 may

translate between an AF-Service-Identifier and an internal 5GC information. NEF 652 may also receive information from other NFs based on exposed capabilities of other NFs. This information may be stored at the NEF 652 as structured data, or at a data storage NF using standardized interfaces. The stored information can then be re-exposed by the NEF 652 to other NFs and AFs, or used for other purposes such as analytics. Additionally, the NEF 652 may exhibit an Nnef service-based interface.

The NRF 654 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 654 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 654 may exhibit the Nnrf service-based interface.

The PCF 656 may provide policy rules to control plane functions to enforce them, and may also support unified policy framework to govern network behavior. The PCF 656 may also implement a front end to access subscription information relevant for policy decisions in a UDR of the UDM 658. In addition to communicating with functions over reference points as shown, the PCF 656 exhibit an Npcf service-based interface.

The UDM 658 may handle subscription-related information to support the network entities' handling of communication sessions, and may store subscription data of UE 602. For example, subscription data may be communicated via an N8 reference point between the UDM 658 and the AMF 644. The UDM 658 may include two parts, an application front end and a UDR. The UDR may store subscription data and policy data for the UDM 658 and the PCF 656, and/or structured data for exposure and application data (including PFDs for application detection, application request information for multiple UEs 602) for the NEF 652. The Nudr service-based interface may be exhibited by the UDR 221 to allow the UDM 658, PCF 656, and NEF 652 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 658 may exhibit the

Nudm service-based interface.

The AF 660 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 640 may enable edge computing by selecting operator/3rd party services to be geographically close to a point that the UE 602 is attached to the network. This may reduce latency and load on the network. To provide edge-computing implementations, the 5GC 640 may select a UPF 648 close to the UE 602 and execute traffic steering from the UPF 648 to data network 636 via the N6 interface. This may be based on the UE subscription data, UE location, and information provided by the AF 660. In this way, the AF 660 may influence UPF (re)selection and traffic routing. Based on operator deployment, when AF 660 is considered to be a trusted entity, the network operator may permit AF 660 to interact directly with relevant NFs. Additionally, the AF 660 may exhibit an Naf service-based interface.

The data network 636 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 638.

FIG. 7 schematically illustrates a wireless network 700 in accordance with various embodiments. The wireless network 700 may include a UE 702 in wireless communication with an AN 704. The UE 702 and AN 704 may be similar to, and substantially interchangeable with, like-named components described elsewhere herein.

The UE 702 may be communicatively coupled with the AN 704 via connection 706. The connection 706 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 702 may include a host platform 708 coupled with a modem platform 710. The host platform 708 may include application processing circuitry 712, which may be coupled with protocol processing circuitry 714 of the modem platform 710. The application processing circuitry 712 may run various applications for the UE 702 that source/sink application data. The application processing circuitry 712 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 714 may implement one or more of layer operations to facilitate transmission or reception of data over the connection 706. The layer operations implemented by the protocol processing circuitry 714 may include, for example, MAC, RLC,

PDCP, RRC and NAS operations.

The modem platform 710 may further include digital baseband circuitry 716 that may implement one or more layer operations that are "below" layer operations performed by the protocol processing circuitry 714 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 710 may further include transmit circuitry 718, receive circuitry 720, RF circuitry 722, and RF front end (RFFE) 724, which may include or connect to one or more antenna panels 726. Briefly, the transmit circuitry 718 may include a digital-to-analog converter, mixer, intermediate frequency (IF) components, etc.; the receive circuitry 720 may include an analog-to-digital converter, mixer, IF components, etc.; the RF circuitry 722 may include a low-noise amplifier, a power amplifier, power tracking components, etc.; RFFE 724 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 718, receive circuitry 720, RF circuitry 722, RFFE 724, and antenna panels 726 (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 714 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 726, RFFE 724, RF circuitry 722, receive circuitry 720, digital baseband circuitry 716, and protocol processing circuitry 714. In some embodiments, the antenna panels 726 may receive a transmission from the AN 704 by receive-beamforming signals received by a plurality of antennas/antenna elements of the one or more antenna panels 726.

A UE transmission may be established by and via the protocol processing circuitry 714,

digital baseband circuitry 716, transmit circuitry 718, RF circuitry 722, RFFE 724, and antenna panels 726. In some embodiments, the transmit components of the UE 704 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 726.

Similar to the UE 702, the AN 704 may include a host platform 728 coupled with a modem platform 730. The host platform 728 may include application processing circuitry 732 coupled with protocol processing circuitry 734 of the modem platform 730. The modem platform may further include digital baseband circuitry 736, transmit circuitry 738, receive circuitry 740, RF circuitry 742, RFFE circuitry 744, and antenna panels 746. The components of the AN 704 may be similar to and substantially interchangeable with like-named components of the UE 702. In addition to performing data transmission/reception as described above, the components of the AN 708 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.

FIG. 8 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, FIG. 8 shows a diagrammatic representation of hardware resources 800 including one or more processors (or processor cores) 810, one or more memory/storage devices 820, and one or more communication resources 830, each of which may be communicatively coupled via a bus 840 or other interface circuitry. For embodiments where node virtualization (e.g., NFV) is utilized, a hypervisor 802 may be executed to provide an execution environment for one or more network slices/sub-slices to utilize the hardware resources 800.

The processors 810 may include, for example, a processor 812 and a processor 814. The processors 810 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 820 may include main memory, disk storage, or any suitable combination thereof. The memory/storage devices 820 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 830 may include interconnection or network interface controllers, components, or other suitable devices to communicate with one or more peripheral devices 804 or one or more databases 806 or other network elements via a network 808. For example, the communication resources 830 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 850 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 810 to perform any one or more of the methodologies discussed herein. The instructions 850 may reside, completely or partially, within at least one of the processors 810 (e.g., within the processor's cache memory), the memory/storage devices 820, or any suitable combination thereof. Furthermore, any portion of the instructions 850 may be transferred to the hardware resources 800 from any combination of the peripheral devices 804 or the databases 806. Accordingly, the memory of processors 810, the memory/storage devices 820, the peripheral devices 804, and the databases 806 are examples of computer-readable and machine-readable media.

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.

The following examples pertain to further embodiments.

Example 1 may include an apparatus comprising: at least one processor configured to: manage resources for the wireless network for an integrated access and backhaul (IAB) distributed unit (DU) through a semi-static configuration provided over an application protocol (AP) back haul signal to indicate resource availability; and assign resource availability types for the IAB distributed unit in a frequency domain through the semi-static configuration with an indication of availability of simultaneous frequency operations of the resources, including always available (hard), sometimes available (soft), and not available, (H/S/NA) indication;

and a memory to store the indication of availability of simultaneous frequency operations of the resources.

Example 2 may include the apparatus of example 1 and/or some other example herein, wherein an always available hard resource type may be a resource that will transmit or receive at a second frequency, and a soft resource will transmit or receive only when the second frequency may be available, and a not available resource will not transmit or receive at the second frequency.

Example 3 may include the apparatus of example 1 and/or some other example herein, wherein the at least one processor may be further configured to: provide the H/S/NA indication when a distributed unit (DU) does not support bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks; and provide the H/S/NA indication through one of grouped resource blocks, grouped according to a resource indication value (RIV) grouping of resource blocks, or providing the H/S/NA indication according to a mobile terminal bandwidth part.

Example 4 may include the apparatus of example 1 and/or some other example herein, wherein the at least one processor may be further configured to: provide the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks; and provide the H/S/NA indication through one of grouping the H/S/NA indication according to resource blocks, a resource indication value (RIV) grouping of resource blocks, a mobile termination (MT) bandwidth part, or bandwidth parts (BWP) for the distributed unit.

Example 5 may include the apparatus of example 1 and/or some other example herein, wherein the at least one processor may be further configured to: provide the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks; and provide the H/S/NA indication through one of grouping the H/S/NA indication according to resource blocks, a resource indication value (RIV) grouping of resource blocks, a mobile termination (MT) bandwidth part, or bandwidth parts (BWP) for the distributed unit.

Example 6 may include the apparatus of example 1 and/or some other example herein, wherein the at least one processor may be further configured to: enhance an F1 application protocol (F1AP) signal by providing the H/S/NA indication according to frequency BWP availability and resource block grouping.

Example 7 may include the apparatus of example 6 and/or some other example herein, wherein the enhanced F1AP signal may be an existing GNB-DU RESOURCE

CONFIGURATION, gNB-DU Cell Resource Configuration IE message, or introducing a new dedicated F1AP message.

Example 8 may include the apparatus of example 1 and/or some other example herein, wherein the at least one processor may be further configured to: dynamically indicate a soft availability of resources in frequency domain bandwidth part configurations for the IAB DU by extending a downlink control information (DCI) format 2_5 soft resource message carried in a packet data control channel (PDCCH) transmitted from a parent DU to a co-located mobile termination (MT).

Example 9 may include a computer-readable storage medium comprising instructions to cause processing circuitry, upon execution of the instructions by the processing circuitry, to: manage resources for a wireless network for an integrated access and backhaul (IAB) distributed unit (DU) through a semi-static configuration provided over an application protocol (AP) back haul signal to indicate resource availability; and assign resource availability types for the IAB distributed unit in a frequency domain through the semi-static configuration with an indication of availability of simultaneous frequency operations of the resources, including always available (hard), sometimes available (soft), and not available, (H/S/NA) indication.

Example 10 may include the computer-readable storage medium of example 9 and/or some other example herein, wherein an always available hard resource type may be a resource that will transmit or receive at a second frequency, and a soft resource will transmit or receive only when the second frequency may be available, and a not available resource will not transmit or receive at the second frequency.

Example 11 may include the computer-readable storage medium of example 9 and/or some other example herein, wherein the processing circuitry may be further configured to provide the H/S/NA indication when a distributed unit (DU) does not support bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks.

Example 12 may include the computer-readable storage medium of example 9 and/or some other example herein, wherein the processing circuitry may be further configured to provide the H/S/NA indication through one of: grouped resource blocks; grouped according to a resource indication value (RIV) grouping of resource blocks; or provide the H/S/NA indication according to a mobile terminal bandwidth part.

Example 13 may include the computer-readable storage medium of example 9 and/or some other example herein, wherein the processing circuitry may be further configured to provide the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks.

Example 14 may include the computer-readable storage medium of example 9 and/or some other example herein, wherein the processing circuitry may be further configured to: provide the H/S/NA indication through one of: group the H/S/NA indication according to resource blocks; a resource indication value (RIV) grouping of resource blocks; a mobile termination (MT) bandwidth part; or bandwidth parts (BWP) for the distributed unit.

Example 15 may include the computer-readable storage medium of example 9 and/or some other example herein, wherein the processing circuitry may be further configured to enhance an F1 application protocol (F1AP) signal to include an existing GNB-DU RESOURCE CONFIGURATION, gNB-DU Cell Resource Configuration IE message, introducing a new dedicated F1AP message, or a new DCI format carried in PDCCH.

Example 16 may include the computer-readable storage medium of example 15 and/or some other example herein, wherein the processing circuitry may be further configured to provide a dynamic indication as to a soft availability of resources in frequency domain bandwidth part configurations for the IAB DU, wherein the F1AP signal provides dynamic indication by extending a downlink control information (DCI) format 2_5 soft resource message.

Example 17 may include the computer-readable storage medium of example 16 and/or some other example herein, wherein the dynamic indication of a soft resource may be carried in a packet data control channel (PDCCH) transmitted from a parent DUto a co-located mobile termination (MT).

Example 18 may include the computer-readable storage medium of example 9 and/or some other example herein, wherein the processing circuitry may be further configured to dynamically indicate a soft availability of resources in frequency domain bandwidth part configurations for the IAB DU by extending a downlink control information (DCI) format 2_5 soft resource message carried in a packet data control channel (PDCCH) transmitted from a parent DU to a co-located mobile termination (MT).

Example 19 may include a method comprising: managing resources for a wireless network for an integrated access and backhaul (IAB) distributed unit (DU) through a semi-static configuration provided over an application protocol (AP) back haul signal to indicate resource availability; and assigning resource availability types for the IAB distributed unit in a frequency domain through the semi-static configuration with an indication of availability of simultaneous frequency operations of the resources, including always available (hard), sometimes available (soft), and not available, (H/S/NA) indication.

Example 20 may include the method of example 19 and/or some other example herein,

wherein an always available hard resource type may be a resource that will transmit or receive at a second frequency, and a soft resource will transmit or receive only when the second frequency may be available, and a not available resource will not transmit or receive at the second frequency.

Example 21 may include the method of example 19 and/or some other example herein, further comprising: providing the H/S/NA indication when a distributed unit (DU) does not support bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks.

Example 22 may include the method of example 21 and/or some other example herein, further comprising: providing the H/S/NA indication through one of: grouped resource blocks; grouped according to a resource indication value (RIV) grouping of resource blocks; or providing the H/S/NA indication according to a mobile terminal bandwidth part.

Example 23 may include the method of example 19 and/or some other example herein, further comprising: providing the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks.

Example 24 may include an apparatus comprising means for performing any of the methods of examples 17-23.

Example 25 may include a network node comprising a communication interface and processing circuitry connected thereto and configured to perform the methods of examples 17-23.

Example 26 may include an apparatus comprising means to perform one or more elements of a method described in or related to any of examples 1-23, or any other method or process described herein.

Example 27 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 1-23, or any other method or process described herein.

Example 28 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 1-23, or any other method or process described herein.

Example 29 may include a method, technique, or process as described in or related to any of examples 1-23, or portions or parts thereof.

Example 30 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 1-23, or portions thereof.

Example 31 may include a signal as described in or related to any of examples 1-23, or portions or parts thereof.

Example 32 may include a datagram, packet, frame, segment, protocol data unit (PDU), or message as described in or related to any of examples 1-23, or portions or parts thereof, or otherwise described in the present disclosure.

Example 33 may include a signal encoded with data as described in or related to any of examples 1-23, or portions or parts thereof, or otherwise described in the present disclosure.

Example 34 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 1-23, or portions or parts thereof, or otherwise described in the present disclosure.

Example 35 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 1-23, or portions thereof.

Example 36 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 1-23, or portions thereof.

Example 37 may include a signal in a wireless network as shown and described herein.

Example 38 may include a method of communicating in a wireless network as shown and described herein.

Example 39 may include a system for providing wireless communication as shown and described herein.

Example 40 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.

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.

Table 4 - Abbreviations:

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
CDN	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 Reference	Demodulation 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 EDGE	GSM EDGE RAN, GSM 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 (security/encryption	Message authentication code context)
MAC-A	MAC used for authentication and key agreement (TSG T WG3 context)
MAC-I	MAC 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	Preceding 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-RNTI	Semi-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 Module	Universal Subscriber Identity
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
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network
WPAN	Wireless 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 Po

In the above disclosure, reference has been made to the accompanying drawings, which form a part hereof, which illustrate specific implementations in which the present disclosure may be practiced. It is understood that other implementations may be utilized, and structural changes may be made without departing from the scope of the present disclosure. References in the specification to "one embodiment," "an embodiment," "an example embodiment," "an example embodiment," "example implementation," etc., indicate that the embodiment or implementation described may include a particular feature, structure, or characteristic, but every embodiment or implementation may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment or implementation. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment or implementation, one skilled in the art will recognize such feature, structure, or characteristic in connection with other embodiments or implementations whether or not explicitly described. For example, various features, aspects, and actions described above with respect to an autonomous parking maneuver are applicable to various other autonomous maneuvers and must be interpreted accordingly.

Implementations of the systems, apparatuses, devices, and methods disclosed herein may comprise or utilize one or more devices that include hardware, such as, for example, one or more processors and system memory, as discussed herein. An implementation of the devices, systems, and methods disclosed herein may communicate over a computer network. A "network" is defined as one or more data links that enable the transport of electronic data between computer systems and/or modules and/or other electronic devices. When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or any combination of hardwired or wireless) to a computer, the computer properly views the connection as a transmission medium. Transmission media can include a network and/or data links, which can be used to carry desired program code means in the form of computer-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer. Combinations of the above should also be included within the scope of non-transitory computer-readable media.

Computer-executable instructions comprise, for example, instructions and data which, when executed at a processor, cause the processor to perform a certain function or group of functions. The computer-executable instructions may be, for example, binaries, intermediate format instructions such as assembly language, or even source code. Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not

necessarily limited to the described features or acts described above. Rather, the described features and acts are disclosed as example forms of implementing the claims.

A memory device can include any one memory element or a combination of volatile memory elements (e.g., random access memory (RAM, such as DRAM, SRAM, SDRAM, etc.)) and non-volatile memory elements (e.g., ROM, hard drive, tape, CDROM, etc.). Moreover, the memory device may incorporate electronic, magnetic, optical, and/or other types of storage media. In the context of this document, a "non-transitory computer-readable medium" can be, for example but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device. More specific examples (a non-exhaustive list) of the computer-readable medium would include the following: a portable computer diskette (magnetic), a random-access memory (RAM) (electronic), a read-only memory (ROM) (electronic), an erasable programmable read-only memory (EPROM, EEPROM, or Flash memory) (electronic), and a portable compact disc read-only memory (CD ROM) (optical). Note that the computer-readable medium could even be paper or another suitable medium upon which the program is printed, since the program can be electronically captured, for instance, via optical scanning of the paper or other medium, then compiled, interpreted or otherwise processed in a suitable manner if necessary, and then stored in a computer memory.

Those skilled in the art will appreciate that the present disclosure may be practiced in network computing environments with many types of computer system configurations, including in-dash vehicle computers, personal computers, desktop computers, laptop computers, message processors, nomadic devices, multi-processor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, mobile telephones, PDAs, tablets, pagers, routers, switches, various storage devices, and the like. The disclosure may also be practiced in distributed system environments where local and remote computer systems, which are linked (either by hardwired data links, wireless data links, or by any combination of hardwired and wireless data links) through a network, both perform tasks. In a distributed system environment, program modules may be located in both the local and remote memory storage devices.

Further, where appropriate, the functions described herein can be performed in one or more of hardware, software, firmware, digital components, or analog components. For example, one or more application specific integrated circuits (ASICs) can be programmed to carry out one or more of the systems and procedures described herein. Certain terms are used throughout the description, and claims refer to particular system components. As one skilled

in the art will appreciate, components may be referred to by different names. This document does not intend to distinguish between components that differ in name, but not function.

At least some embodiments of the present disclosure have been directed to computer program products comprising such logic (e.g., in the form of software) stored on any computer-usable medium. Such software, when executed in one or more data processing devices, causes a device to operate as described herein.

While various embodiments of the present disclosure have been described above, it should be understood that they have been presented by way of example only, and not limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the present disclosure. Thus, the breadth and scope of the present disclosure should not be limited by any of the above-described example embodiments but should be defined only in accordance with the following claims and their equivalents. The foregoing description has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the present disclosure to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. Further, it should be noted that any or all of the aforementioned alternate implementations may be used in any combination desired to form additional hybrid implementations of the present disclosure. For example, any of the functionality described with respect to a particular device or component may be performed by another device or component. Further, while specific device characteristics have been described, embodiments of the disclosure may relate to numerous other device characteristics. Further, although embodiments have been described in language specific to structural features and/or methodological acts, it is to be understood that the disclosure is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as illustrative forms of implementing the embodiments. Conditional language, such as, among others, "can," "could," "might," or "may," unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments could include, while other embodiments may not include, certain features, elements, and/or steps. Thus, such conditional language is not generally intended to imply that features, elements, and/or steps are in any way required for one or more embodiments.

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

That which is claimed is:

1. An apparatus for a network node in a wireless network comprising:

at least one processor configured to:

manage resources for the wireless network for an integrated access and backhaul (IAB) distributed unit (DU) through a semi-static configuration provided over an application protocol (AP) back haul signal to indicate resource availability; and

assign resource availability types for the IAB distributed unit in a frequency domain through the semi-static configuration with an indication of availability of simultaneous frequency operations of the resources, including always available (hard), sometimes available (soft), and not available, (H/S/NA) indication; and

a memory to store the indication of availability of simultaneous frequency operations of the resources.

2. The apparatus of claim 1, wherein an always available hard resource type is a resource that will transmit or receive at a second frequency, and a soft resource will transmit or receive only when the second frequency is available, and a not available resource will not transmit or receive at the second frequency.

3. The apparatus of claim 1, wherein the at least one processor is further configured to:

provide the H/S/NA indication when a distributed unit (DU) does not support bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks; and

provide the H/S/NA indication through one of grouped resource blocks, grouped according to a resource indication value (RIV) grouping of resource blocks, or providing the H/S/NA indication according to a mobile terminal bandwidth part.

4. The apparatus of claim 1, wherein the at least one processor is further configured to:

provide the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks; and

provide the H/S/NA indication through one of grouping the H/S/NA indication according to resource blocks, a resource indication value (RIV) grouping of resource blocks, a mobile termination (MT) bandwidth part, or bandwidth parts (BWP) for the distributed unit.

5. The apparatus of claim 1, wherein the at least one processor is further configured to:

provide the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks; and

provide the H/S/NA indication through one of grouping the H/S/NA indication according to resource blocks, a resource indication value (RIV) grouping of resource blocks, a mobile termination (MT) bandwidth part, or bandwidth parts (BWP) for the distributed unit.

6. The apparatus of claim 1, wherein the at least one processor is further configured to:

enhance an F1 application protocol (F1AP) signal by providing the H/S/NA indication according to frequency BWP availability and resource block grouping.

7. The apparatus of claim 6, wherein the enhanced F1AP signal is an existing GNB-DU RESOURCE CONFIGURATION, gNB-DU Cell Resource Configuration IE message, or introducing a new dedicated F1AP message.

8. The apparatus of any one of claims 1-7, wherein the at least one processor is further configured to:

dynamically indicate a soft availability of resources in frequency domain bandwidth part configurations for the IAB DU by extending a downlink control information (DCI) format 2_5 soft resource message carried in a packet data control channel (PDCCH) transmitted from a parent DU to a co-located mobile termination (MT).

9. A computer-readable storage medium comprising instructions to cause processing circuitry, upon execution of the instructions by the processing circuitry, to:

manage resources for a wireless network for an integrated access and backhaul (IAB) distributed unit (DU) through a semi-static configuration provided over an application protocol (AP) back haul signal to indicate resource availability; and

assign resource availability types for the IAB distributed unit in a frequency domain through the semi-static configuration with an indication of availability of simultaneous frequency operations of the resources, including always available (hard), sometimes available (soft), and not available, (H/S/NA) indication.

10. The computer-readable storage medium of claim 9, wherein an always available hard resource type is a resource that will transmit or receive at a second frequency, and a soft resource will transmit or receive only when the second frequency is available, and a not available resource will not transmit or receive at the second frequency.

11. The computer-readable storage medium of claim 9, wherein the processing circuitry is further configured to provide the H/S/NA indication when a distributed unit (DU) does not support bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks.

12. The computer-readable storage medium of claim 9, wherein the processing circuitry is further configured to provide the H/S/NA indication through one of:

grouped resource blocks;

grouped according to a resource indication value (RIV) grouping of resource blocks; or

provide the H/S/NA indication according to a mobile terminal bandwidth part.

13. The computer-readable storage medium of claim 9, wherein the processing circuitry is further configured to provide the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks.

14. The computer-readable storage medium of claim 9, wherein the processing circuitry is further configured to:

provide the H/S/NA indication through one of:

group the H/S/NA indication according to resource blocks;

a resource indication value (RIV) grouping of resource blocks;
a mobile termination (MT) bandwidth part; or
bandwidth parts (BWP) for the distributed unit.

15. The computer-readable storage medium of claim 9, wherein the processing circuitry is further configured to enhance an F1 application protocol (F1AP) signal to include an existing GNB-DU RESOURCE CONFIGURATION, gNB-DU Cell Resource Configuration IE message, introducing a new dedicated F1AP message, or a new DCI format carried in PDCCH.

16. The computer-readable storage medium of claim 15, wherein the processing circuitry is further configured to provide a dynamic indication as to a soft availability of resources in frequency domain bandwidth part configurations for the IAB DU, wherein the F1AP signal provides dynamic indication by extending a downlink control information (DCI) format 2_5 soft resource message.

17. The computer-readable storage medium of claim 16, wherein the dynamic indication of a soft resource is carried in a packet data control channel (PDCCH) transmitted from a parent DUto a co-located mobile termination (MT).

18. The computer-readable storage medium of any one of claims 9-17, wherein the processing circuitry is further configured to dynamically indicate a soft availability of resources in frequency domain bandwidth part configurations for the IAB DU by extending a downlink control information (DCI) format 2_5 soft resource message carried in a packet data control channel (PDCCH) transmitted from a parent DU to a co-located mobile termination (MT).

19. A method comprising:

managing resources for a wireless network for an integrated access and backhaul (IAB) distributed unit (DU) through a semi-static configuration provided over an application protocol (AP) back haul signal to indicate resource availability; and

assigning resource availability types for the IAB distributed unit in a frequency domain through the semi-static configuration with an indication of availability of

simultaneous frequency operations of the resources, including always available (hard), sometimes available (soft), and not available, (H/S/NA) indication.

20. The method of claim 19, wherein an always available hard resource type is a resource that will transmit or receive at a second frequency, and a soft resource will transmit or receive only when the second frequency is available, and a not available resource will not transmit or receive at the second frequency.

21. The method of claim 19, further comprising:

providing the H/S/NA indication when a distributed unit (DU) does not support bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks.

22. The method of any one of claims 19-21, further comprising:

providing the H/S/NA indication through one of:

grouped resource blocks;

grouped according to a resource indication value (RIV) grouping of resource blocks; or

providing the H/S/NA indication according to a mobile terminal bandwidth part.

23. The method of claim 19, further comprising:

providing the H/S/NA indication when a distributed unit (DU) supports bandwidth parts (BWP) in the frequency domain through a component carrier (CC) in resource blocks.

24. An apparatus comprising means for performing any of the methods of claims 17-23.

25. A network node comprising a communication interface and processing circuitry connected thereto and configured to perform the method of claims 17-23.

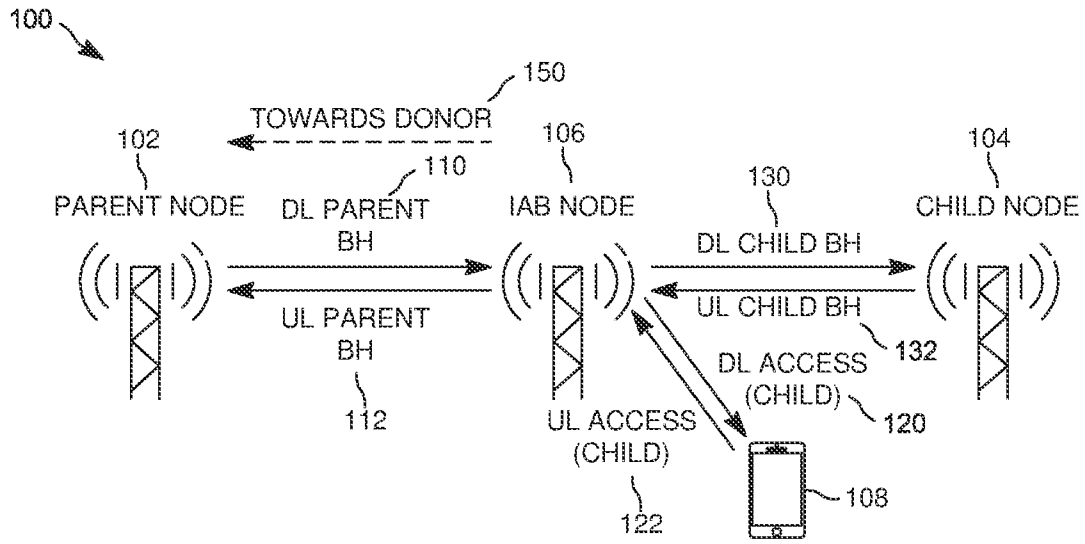

100
150
TOWARDS DONOR
102
PARENT NODE
110
DL PARENT BH
106
IAB NODE
130
DL CHILD BH
104
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UL CHILD BH
132
UL PARENT BH
112
DL ACCESS (CHILD)
120
UL ACCESS (CHILD)
122
108

FIG. 1

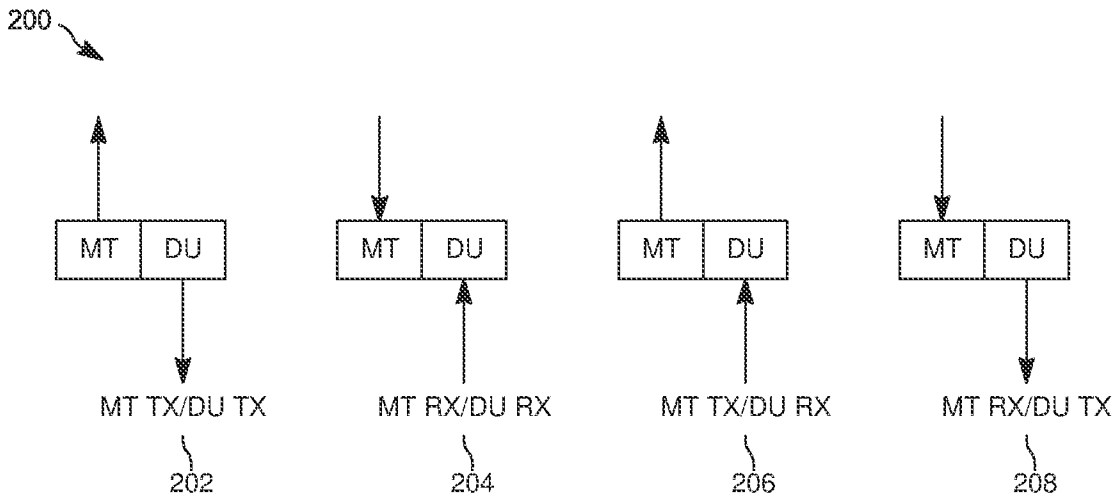

200
MT
DU
MT TX/DU TX
202
MT RX/DU RX
204
MT TX/DU RX
206
MT RX/DU TX
208

FIG. 2

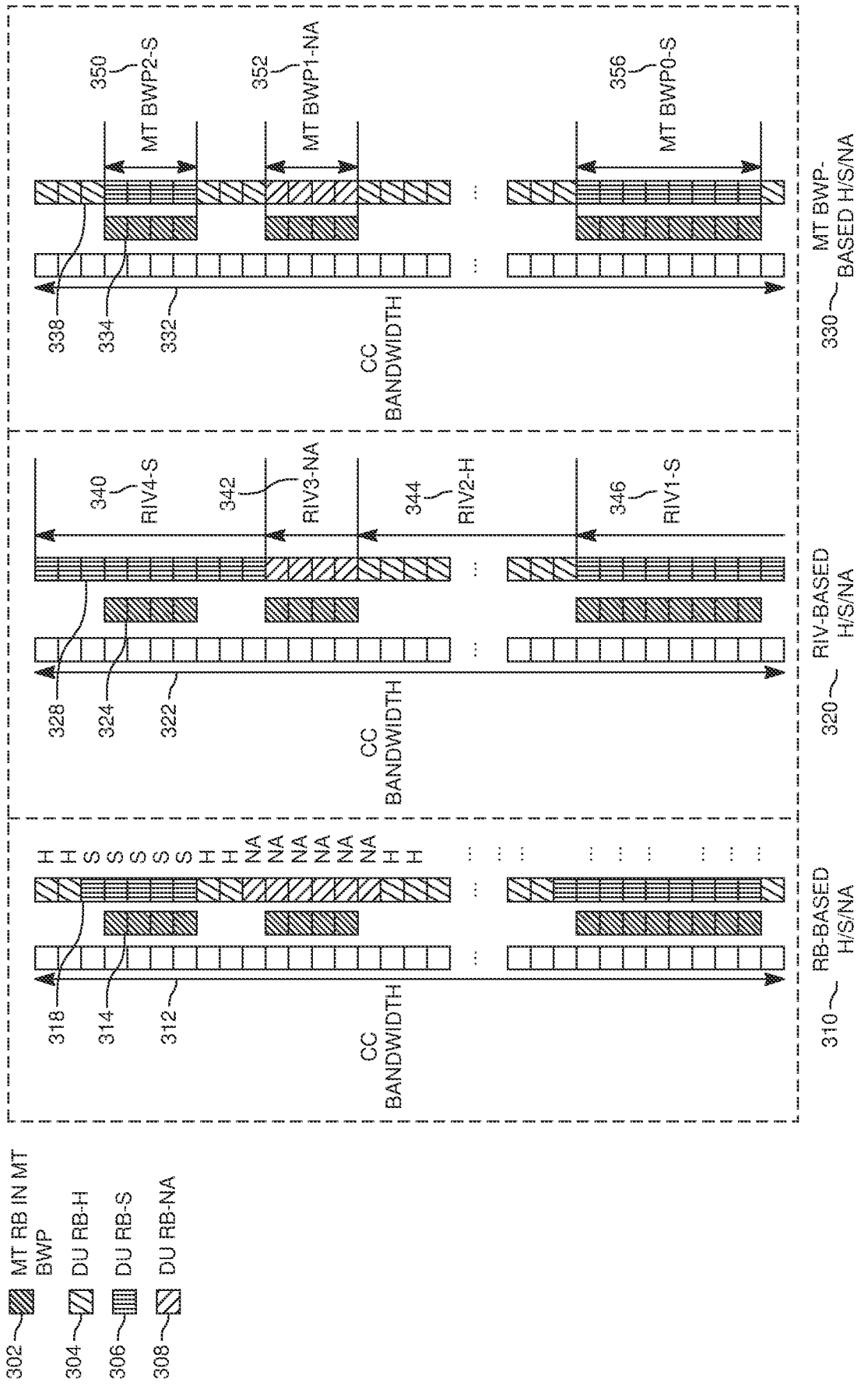

302 MT RB IN MT BWP
304 DU RB-H
306 DU RB-S
308 DU RB-NA
310 RB-BASED H/S/NA
320 RIV-BASED H/S/NA
330 MT BWP-BASED H/S/NA
312
314
318
322
324
328
332
334
338
340 RIV4-S
342 RIV3-NA
344 RIV2-H
346 RIV1-S
350 MT BWP2-S
352 MT BWP1-NA
356 MT BWP0-S
CC BANDWIDTH
H
S
NA

FIG. 3

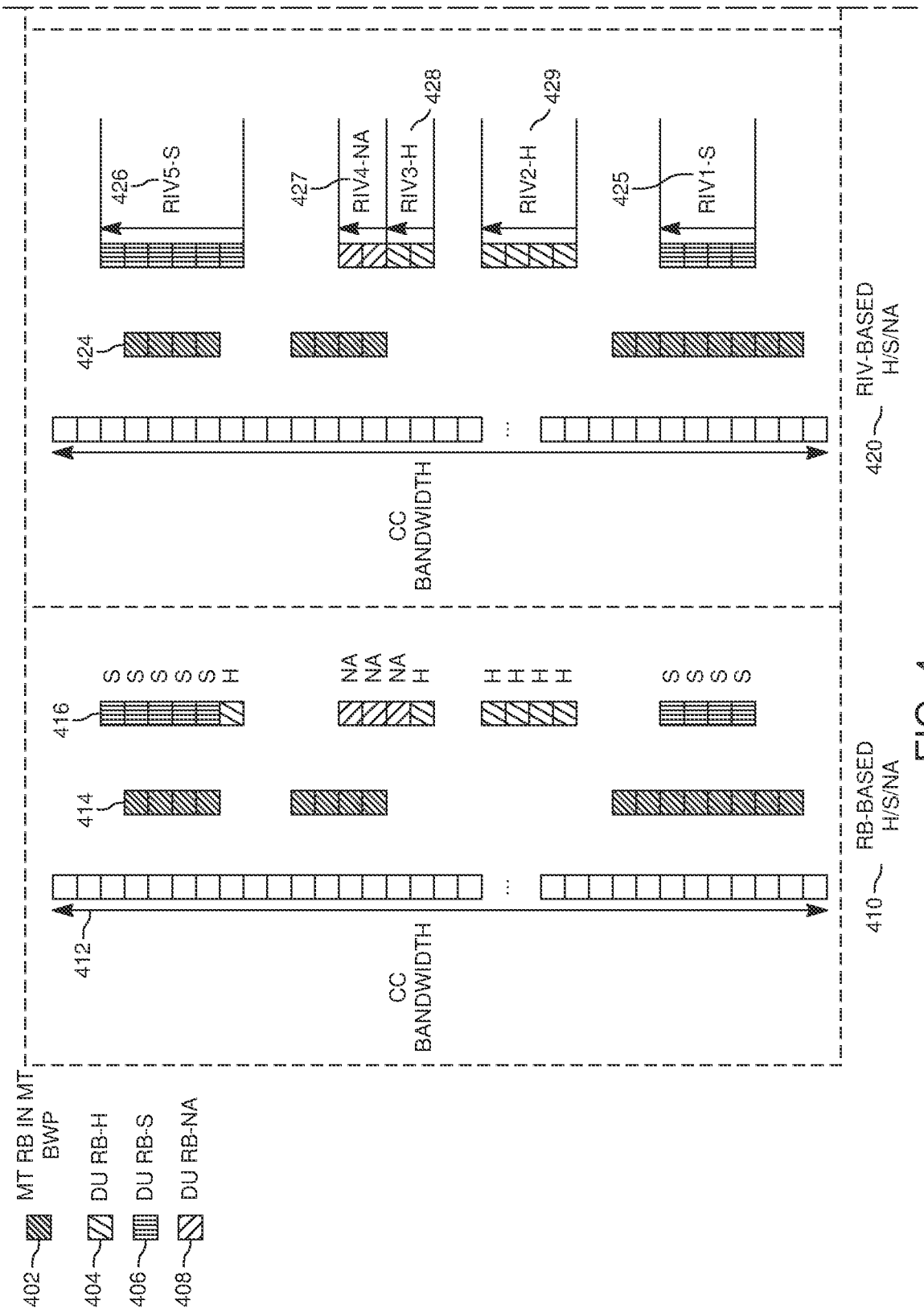

MT RB IN MT BWP
DU RB-H
DU RB-S
DU RB-NA
402
404
406
408
RB-BASED H/S/NA
410
412
414
416
S S S S S H
NA NA NA H
H H H H
S S S S
CC BANDWIDTH
RIV-BASED H/S/NA
420
424
425
RIV1-S
427
RIV4-NA
RIV3-H
428
RIV2-H
429
426
RIV5-S
CC BANDWIDTH

FIG. 4

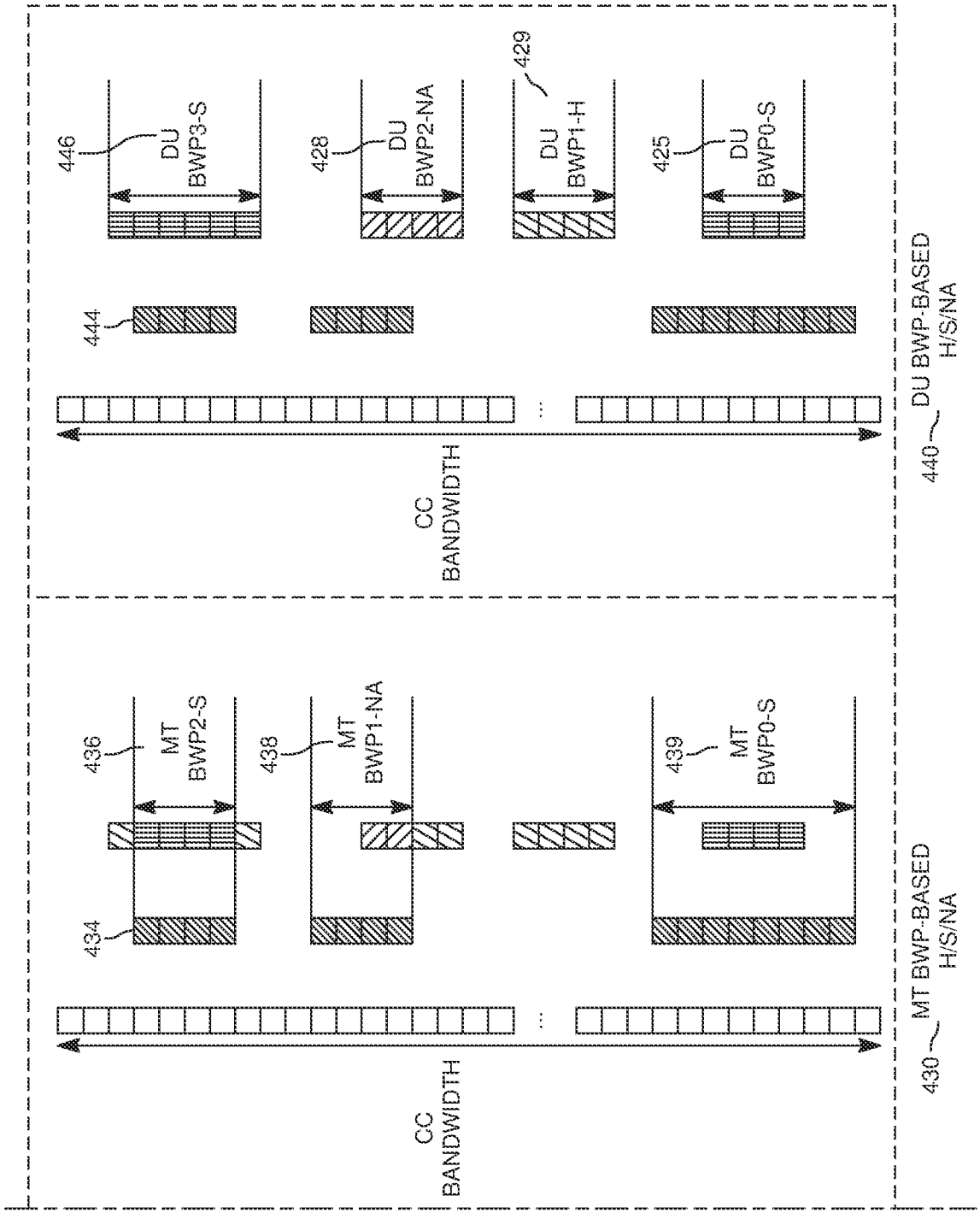


FIG. 4 (CONTINUED)

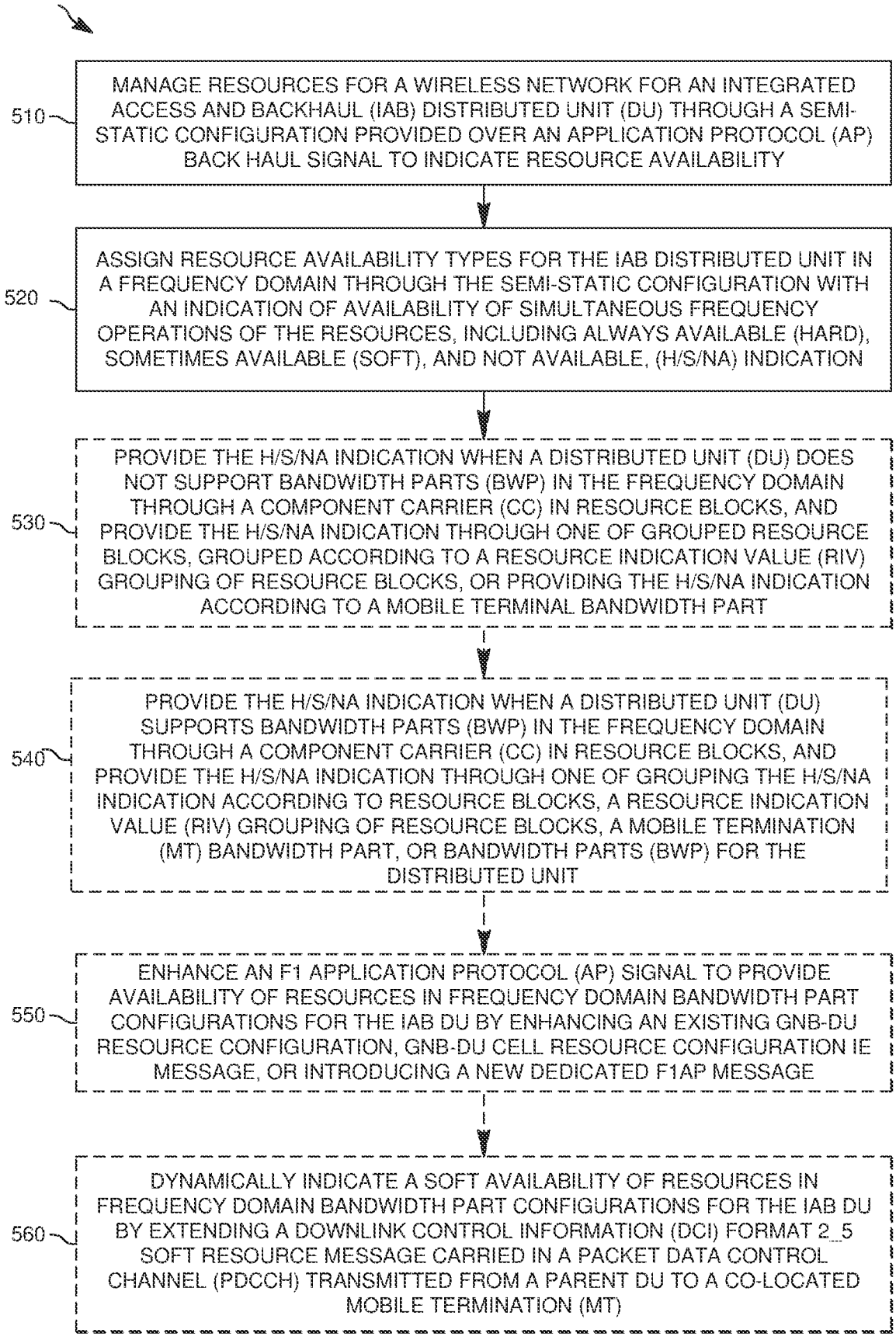

510
MANAGE RESOURCES FOR A WIRELESS NETWORK FOR AN INTEGRATED ACCESS AND BACKHAUL (IAB) DISTRIBUTED UNIT (DU) THROUGH A SEMI-STATIC CONFIGURATION PROVIDED OVER AN APPLICATION PROTOCOL (AP) BACK HAUL SIGNAL TO INDICATE RESOURCE AVAILABILITY
520
ASSIGN RESOURCE AVAILABILITY TYPES FOR THE IAB DISTRIBUTED UNIT IN A FREQUENCY DOMAIN THROUGH THE SEMI-STATIC CONFIGURATION WITH AN INDICATION OF AVAILABILITY OF SIMULTANEOUS FREQUENCY OPERATIONS OF THE RESOURCES, INCLUDING ALWAYS AVAILABLE (HARD), SOMETIMES AVAILABLE (SOFT), AND NOT AVAILABLE, (H/S/NA) INDICATION
530
PROVIDE THE H/S/NA INDICATION WHEN A DISTRIBUTED UNIT (DU) DOES NOT SUPPORT BANDWIDTH PARTS (BWP) IN THE FREQUENCY DOMAIN THROUGH A COMPONENT CARRIER (CC) IN RESOURCE BLOCKS, AND PROVIDE THE H/S/NA INDICATION THROUGH ONE OF GROUPED RESOURCE BLOCKS, GROUPED ACCORDING TO A RESOURCE INDICATION VALUE (RIV) GROUPING OF RESOURCE BLOCKS, OR PROVIDING THE H/S/NA INDICATION ACCORDING TO A MOBILE TERMINAL BANDWIDTH PART
540
PROVIDE THE H/S/NA INDICATION WHEN A DISTRIBUTED UNIT (DU) SUPPORTS BANDWIDTH PARTS (BWP) IN THE FREQUENCY DOMAIN THROUGH A COMPONENT CARRIER (CC) IN RESOURCE BLOCKS, AND PROVIDE THE H/S/NA INDICATION THROUGH ONE OF GROUPING THE H/S/NA INDICATION ACCORDING TO RESOURCE BLOCKS, A RESOURCE INDICATION VALUE (RIV) GROUPING OF RESOURCE BLOCKS, A MOBILE TERMINATION (MT) BANDWIDTH PART, OR BANDWIDTH PARTS (BWP) FOR THE DISTRIBUTED UNIT
550
ENHANCE AN F1 APPLICATION PROTOCOL (AP) SIGNAL TO PROVIDE AVAILABILITY OF RESOURCES IN FREQUENCY DOMAIN BANDWIDTH PART CONFIGURATIONS FOR THE IAB DU BY ENHANCING AN EXISTING GNB-DU RESOURCE CONFIGURATION, GNB-DU CELL RESOURCE CONFIGURATION IE MESSAGE, OR INTRODUCING A NEW DEDICATED F1AP MESSAGE
560
DYNAMICALLY INDICATE A SOFT AVAILABILITY OF RESOURCES IN FREQUENCY DOMAIN BANDWIDTH PART CONFIGURATIONS FOR THE IAB DU BY EXTENDING A DOWNLINK CONTROL INFORMATION (DCI) FORMAT 2_5 SOFT RESOURCE MESSAGE CARRIED IN A PACKET DATA CONTROL CHANNEL (PDCCH) TRANSMITTED FROM A PARENT DU TO A CO-LOCATED MOBILE TERMINATION (MT)

FIG. 5

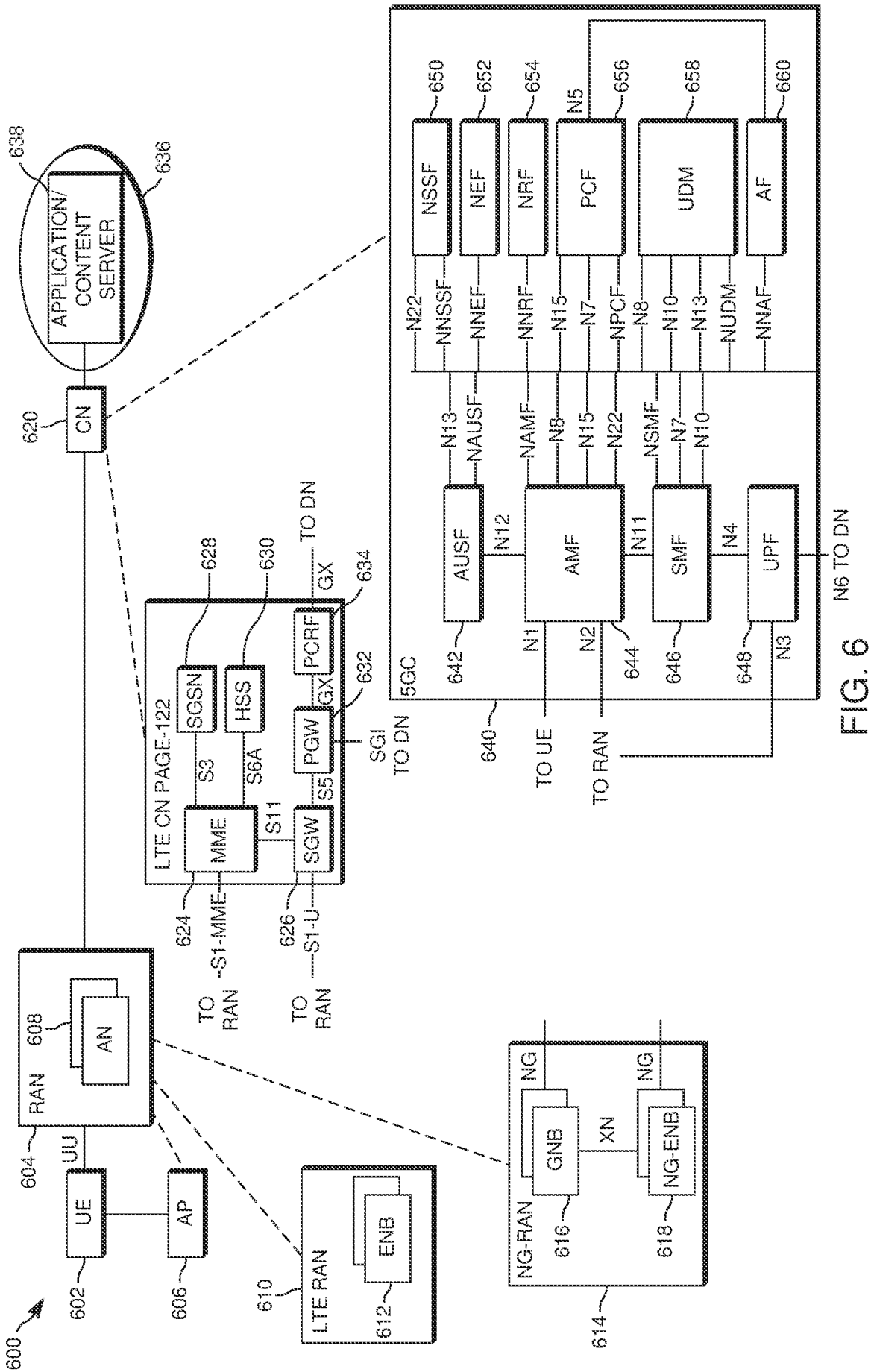

600
602
UE
604
UU
606
AP
608
RAN
AN
610
LTE RAN
612
ENB
614
NG-RAN
616
GNB
618
NG-ENB
XN
NG
620
CN
624
-S1-MME
TO RAN
626
S1-U
TO RAN
628
630
632
634
LTE CN PAGE-122
SGSN
HSS
MME
SGW
PGW
PCRF
S3
S6A
S11
S5
GX
GX
TO DN
SGi
TO DN
636
638
APPLICATION/ CONTENT SERVER
640
TO UE
TO RAN
5GC
642
644
646
648
N1
N2
N3
AUSF
AMF
SMF
UPF
N12
N11
N4
N13
NAUSF
NAMF
N8
N15
N22
NSMF
N7
N10
650
652
654
656
658
660
NSSF
NEF
NRF
PCF
UDM
AF
N5
N22
NNSSF
NNEF
NNRF
N15
N7
NPCF
N8
N10
N13
NUDM
NNAF
N6 TO DN

FIG. 6

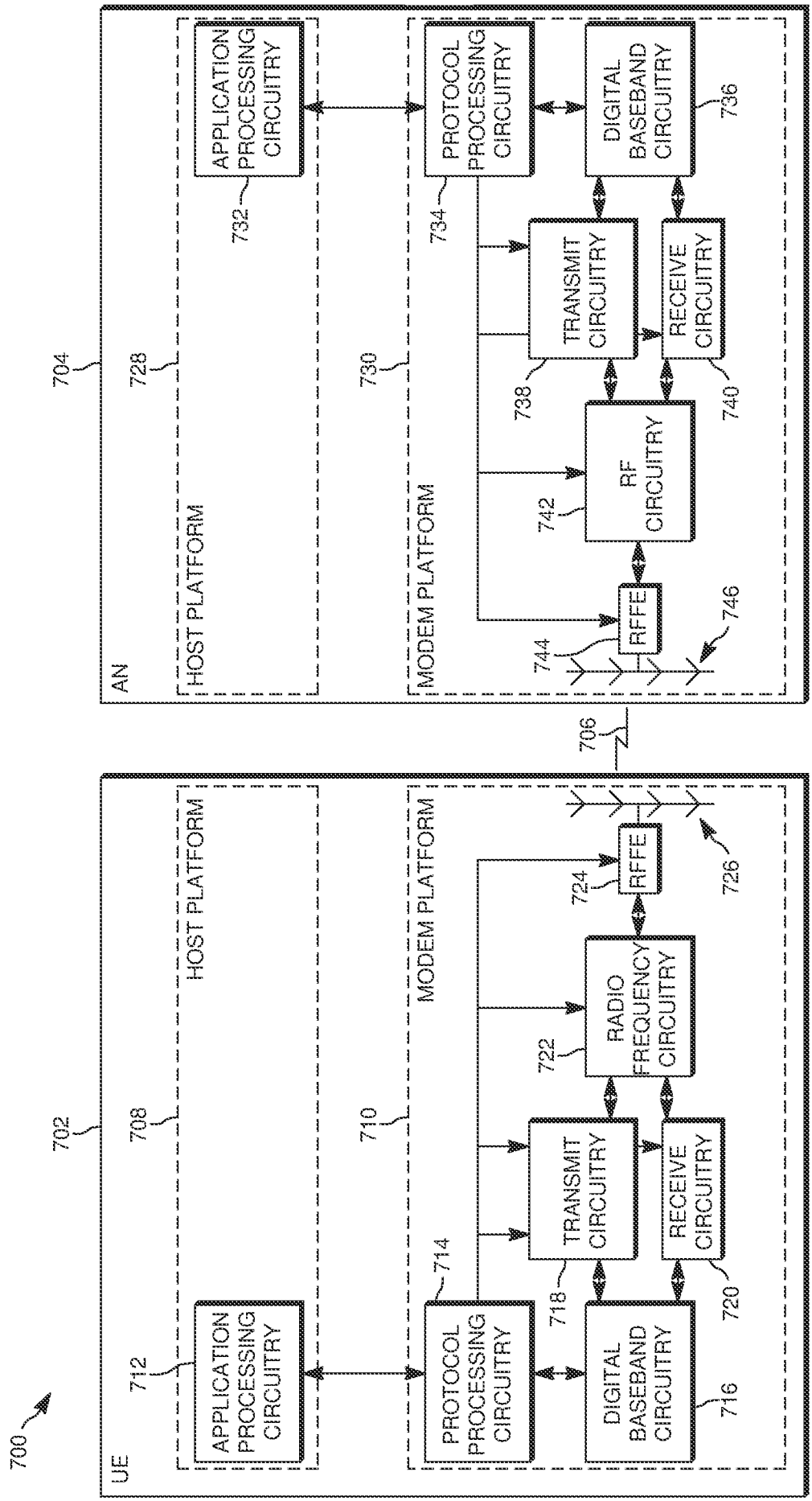

700
UE
702
HOST PLATFORM
708
APPLICATION PROCESSING CIRCUITRY
712
MODEM PLATFORM
710
PROTOCOL PROCESSING CIRCUITRY
714
DIGITAL BASEBAND CIRCUITRY
716
TRANSMIT CIRCUITRY
718
RECEIVE CIRCUITRY
720
RADIO FREQUENCY CIRCUITRY
722
RFFE
724
726
706
AN
704
HOST PLATFORM
728
APPLICATION PROCESSING CIRCUITRY
732
MODEM PLATFORM
730
PROTOCOL PROCESSING CIRCUITRY
734
DIGITAL BASEBAND CIRCUITRY
736
TRANSMIT CIRCUITRY
738
RECEIVE CIRCUITRY
740
RF CIRCUITRY
742
RFFE
744
746

FIG. 7

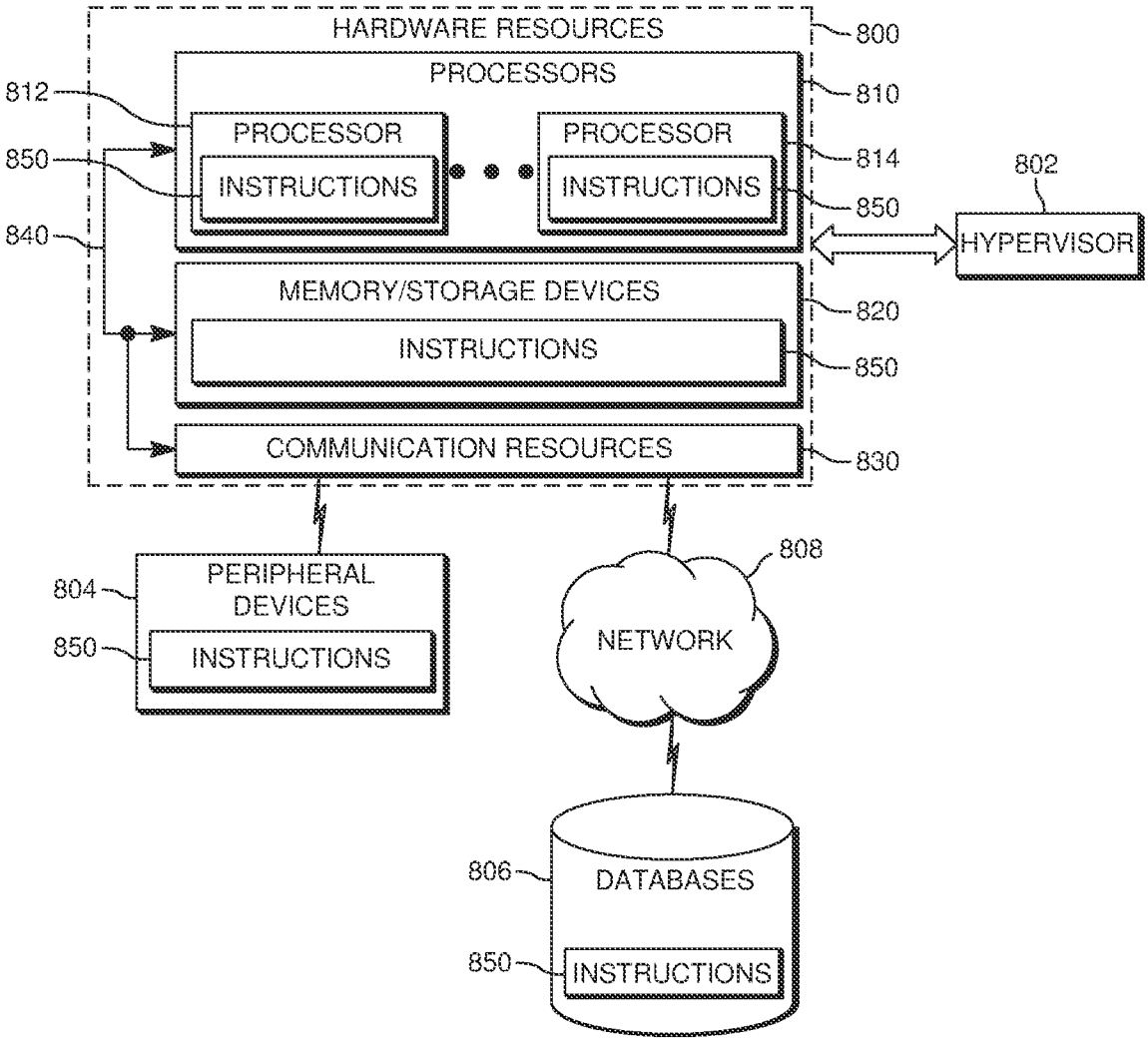

HARDWARE RESOURCES
800
PROCESSORS
810
812
PROCESSOR
INSTRUCTIONS
PROCESSOR
INSTRUCTIONS
814
850
802
HYPERVISOR
840
MEMORY/STORAGE DEVICES
820
INSTRUCTIONS
850
COMMUNICATION RESOURCES
830
808
804
PERIPHERAL DEVICES
850
INSTRUCTIONS
NETWORK
806
DATABASES
850
INSTRUCTIONS

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2022/012354

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04(2009.01)i; **H04W 84/04**(2009.01)i; **H04W 88/04**(2009.01)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)

H04W 72/04(2009.01); H04W 88/08(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: IAB(integrated access and backhaul), DU(distributed unit), semi-static, resource availability, simultaneous, H/S/NA(hard/soft/not available)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	LENOVO et al., 'Enhancements to resource multiplexing for IAB', R1-2009108, 3GPP TSG RAN WG1 Meeting #103-e, 01 November 2020 sections 1-2.1	1-25
Y	INTEL CORPORATION, 'Enhancements to Resource Multiplexing between Child and Parent Links of an IAB Node', R1-2008995, 3GPP TSG RAN WG1 Meeting #103-e, 01 November 2020 sections 2.1-2.2	1-25
A	NOKIA et al., `Enhancements for resource multiplexing among IAB backhaul and access links', R1-2008863, 3GPP TSG RAN WG1 Meeting #103-e, 01 November 2020 sections 1-3	1-25
A	ZTE et al., `Enhancements to the IAB resource multiplexing', R1-2008858, 3GPP TSG RAN WG1 Meeting #103-e, 01 November 2020 sections 1-2.3	1-25
A	WO 2020-167987 A1 (APPLE INC.) 20 August 2020 (2020-08-20) paragraphs [0037]-[0232]; and figures 1A-22	1-25

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
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"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
26 April 2022	**26 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**	**YANG, Jeong Rok**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2022/012354

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2020-167987 A1	20 August 2020	None	