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(54) MAPPING SUBSCRIBERS TO OPERATORS IN SHARED RADIO UNIT ARCHITECTURE USING RAN SLICING

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(57) **ABSTRACT**

Disclosed is a method for mapping a subscriber to a mobile network operator in a fifth-generation New Radio (5G NR) cellular telecommunication radio access network (RAN). The method is performed by a Radio Unit (RU) device operated by a first network operator and includes: transmitting system information including first information indicating network slices and second information indicating Physical Random Access Channel (PRACH) occasions mapped to the network slices, receiving a preamble of a Random Access Channel (RACH) during one of the PRACH occasions indicated by the second information, determining a second network operator based on the one of the PRACH occasions during which the preamble of the RACH is received, and transmitting the preamble of the RACH to a Distributed Unit (DU) device that is operated by the second network operator determined based on the one of the PRACH occasions during which the preamble of the RACH is received.

300

Slice Service Type (SST)	Slice Differentiator (SD)	Mobile Network Operator (MNO)	Physical Resource Blocks (PRBs)	Physical Random Access Channel (PRACH) Occasion
1	000000000000000000000000	Host Operator	PRB-1 to PRB-2 (BW0)	1
2	000000000000000000000001	Host Operator	PRB-1 to PRB-2 (BW0)	1
3	000000000000000000000010	Host Operator	PRB-1 to PRB-2 (BW0)	1
4	000000000000000000000011	Host Operator	PRB-1 to PRB-2 (BW0)	1
128	000000000000000000000100	Host Operator	PRB-1 to PRB-2 (BW0)	1
1	000000000000000000000101	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
1	000000000000000000000110	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
3	000000000000000000000111	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
4	000000000000000000001000	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
129	000000000000000000001001	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
1	000000000000000000001010	Guest Operator 2	PRB-5 to PRB-6 (BW2)	3
2	000000000000000000001011	Guest Operator 2	PRB-5 to PRB-6 (BW2)	3
3	000000000000000000001100	Guest Operator 2	PRB-5 to PRB-6 (BW2)	3
4	000000000000000000001101	Guest Operator 2	PRB-5 to PRB-6 (BW2)	3
130	000000000000000000001110	Guest Operator 2	PRB-5 to PRB-6 (BW2)	4
1	000000000000000000001111	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4
2	000000000000000000010000	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4
3	000000000000000000010001	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4
4	000000000000000000010010	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4
131	000000000000000000010011	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4

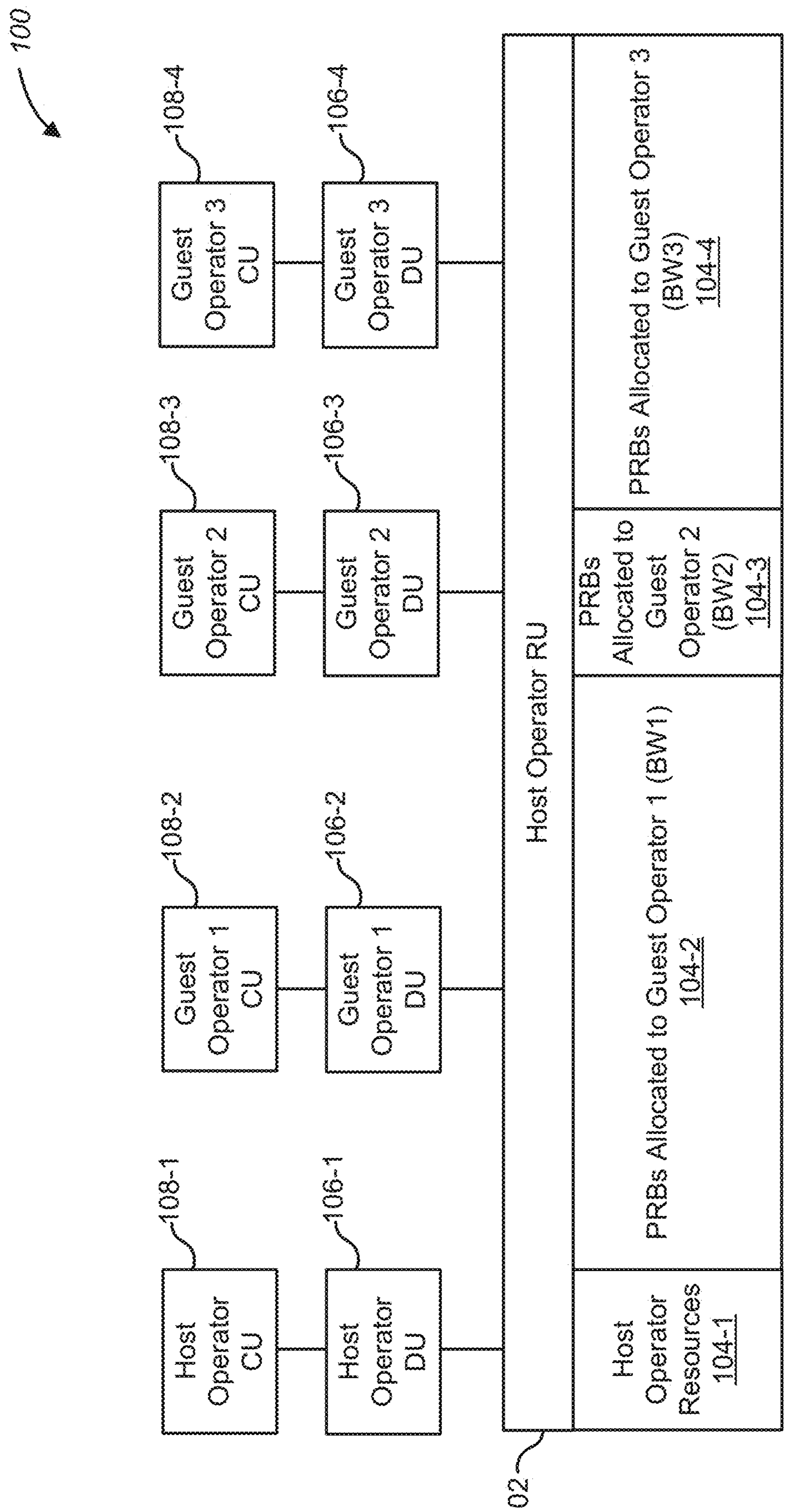
100
Host Operator CU
108-1
Host Operator DU
106-1
Guest Operator 1 CU
108-2
Guest Operator 1 DU
106-2
Guest Operator 2 CU
108-3
Guest Operator 2 DU
106-3
Guest Operator 3 CU
108-4
Guest Operator 3 DU
106-4
Host Operator RU
102
Host Operator Resources 104-1
PRBs Allocated to Guest Operator 1 (BW1) 104-2
PRBs Allocated to Guest Operator 2 (BW2) 104-3
PRBs Allocated to Guest Operator 3 (BW3) 104-4

FIG. 1

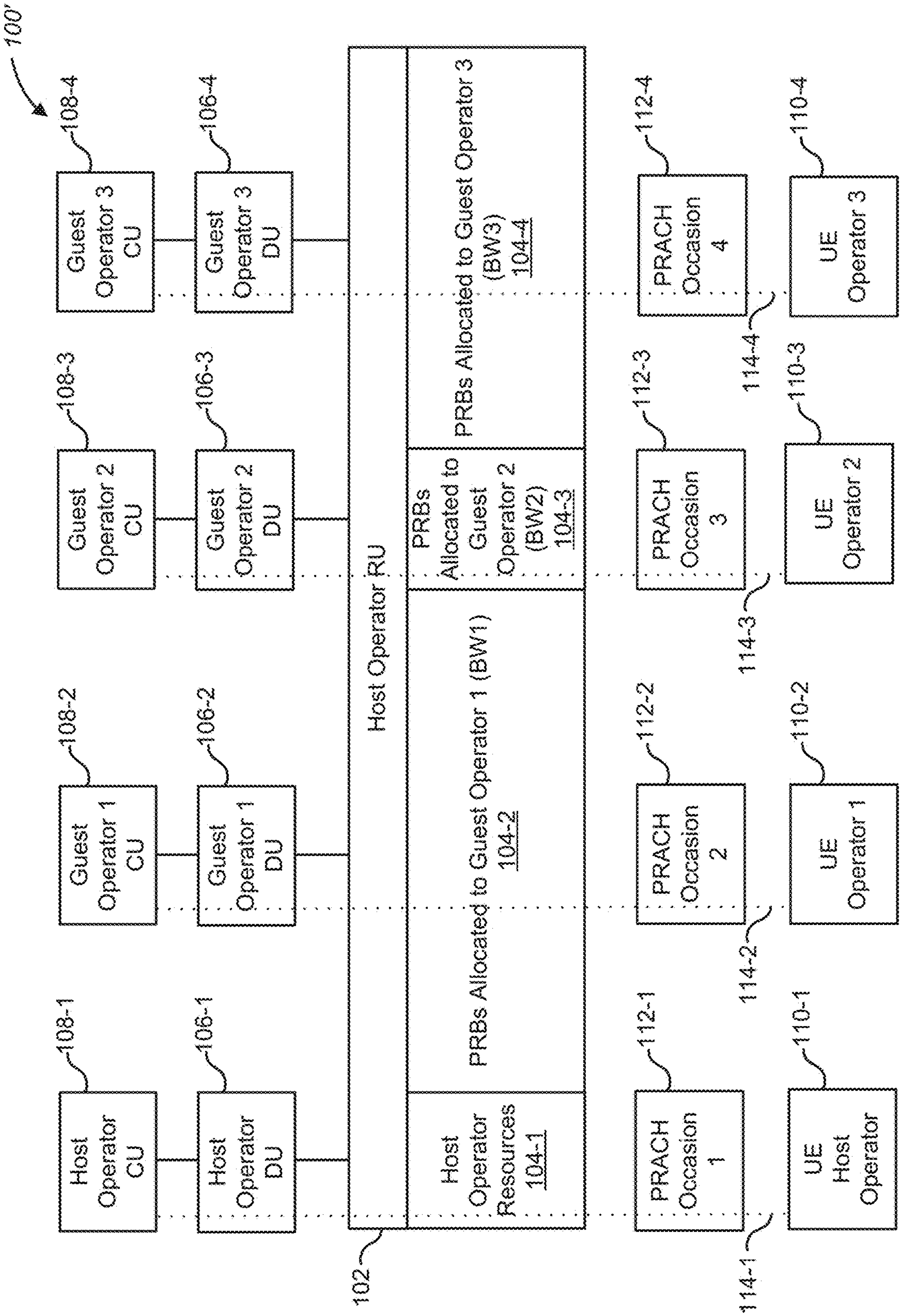
100'
Host Operator CU
108-1
Host Operator DU
106-1
Guest Operator 1 CU
108-2
Guest Operator 1 DU
106-2
Guest Operator 2 CU
108-3
Guest Operator 2 DU
106-3
Guest Operator 3 CU
108-4
Guest Operator 3 DU
106-4
Host Operator RU
102
Host Operator Resources 104-1
PRBs Allocated to Guest Operator 1 (BW1) 104-2
PRBs Allocated to Guest Operator 2 (BW2) 104-3
PRBs Allocated to Guest Operator 3 (BW3) 104-4
PRACH Occasion 1
112-1
PRACH Occasion 2
112-2
PRACH Occasion 3
112-3
PRACH Occasion 4
112-4
UE Host Operator
110-1
UE Operator 1
110-2
UE Operator 2
110-3
UE Operator 3
110-4
114-1
114-2
114-3
114-4

FIG. 2

300

Slice Service Type (SST)	Slice Differentiator (SD)	Mobile Network Operator (MNO)	Physical Resource Blocks (PRBs)	Physical Random Access Channel (PRACH) Occasion
1	000000000000000000000000	Host Operator	PRB-1 to PRB-2 (BW0)	1
2	000000000000000000000001	Host Operator	PRB-1 to PRB-2 (BW0)	1
3	000000000000000000000010	Host Operator	PRB-1 to PRB-2 (BW0)	1
4	000000000000000000000011	Host Operator	PRB-1 to PRB-2 (BW0)	1
128	000000000000000000000100	Host Operator	PRB-1 to PRB-2 (BW0)	1
1	000000000000000000000101	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
1	000000000000000000000110	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
3	000000000000000000000111	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
4	000000000000000000001000	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
129	000000000000000000001001	Guest Operator 1	PRB-3 to PRB-4 (BW1)	2
1	000000000000000000001010	Guest Operator 2	PRB-5 to PRB-6 (BW2)	3
2	000000000000000000001011	Guest Operator 2	PRB-5 to PRB-6 (BW2)	3
3	000000000000000000001100	Guest Operator 2	PRB-5 to PRB-6 (BW2)	3
4	000000000000000000001101	Guest Operator 2	PRB-5 to PRB-6 (BW2)	3
130	000000000000000000001110	Guest Operator 2	PRB-5 to PRB-6 (BW2)	4
1	000000000000000000001111	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4
2	000000000000000000010000	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4
3	000000000000000000010001	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4
4	000000000000000000010010	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4
131	000000000000000000010011	Guest Operator 3	PRB-7 to PRB-8 (BW3)	4

FIG. 3

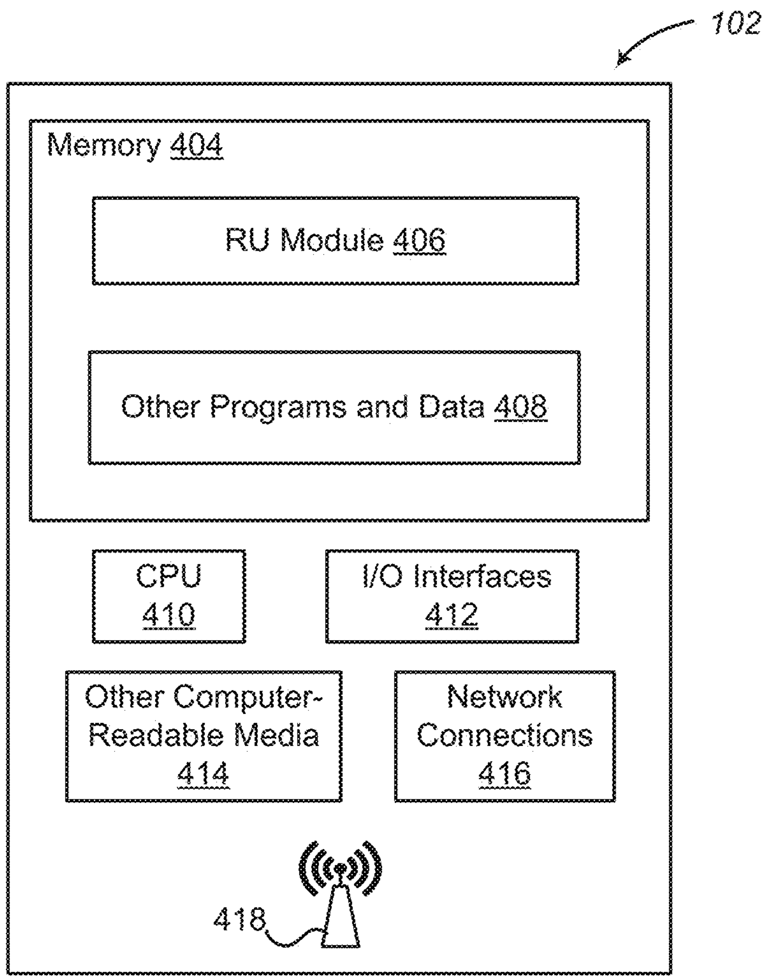
102
Memory 404
RU Module 406
Other Programs and Data 408
CPU 410
I/O Interfaces 412
Other Computer-Readable Media 414
Network Connections 416
418

FIG. 4

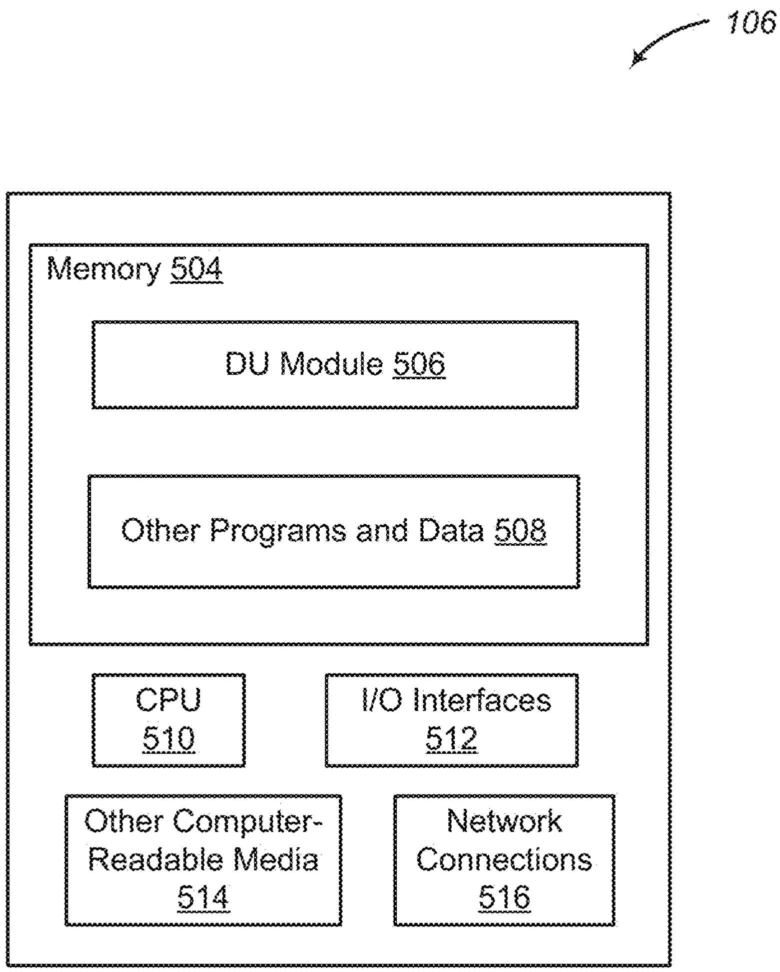
106
Memory 504
DU Module 506
Other Programs and Data 508
CPU 510
I/O Interfaces 512
Other Computer-Readable Media 514
Network Connections 516

FIG. 5

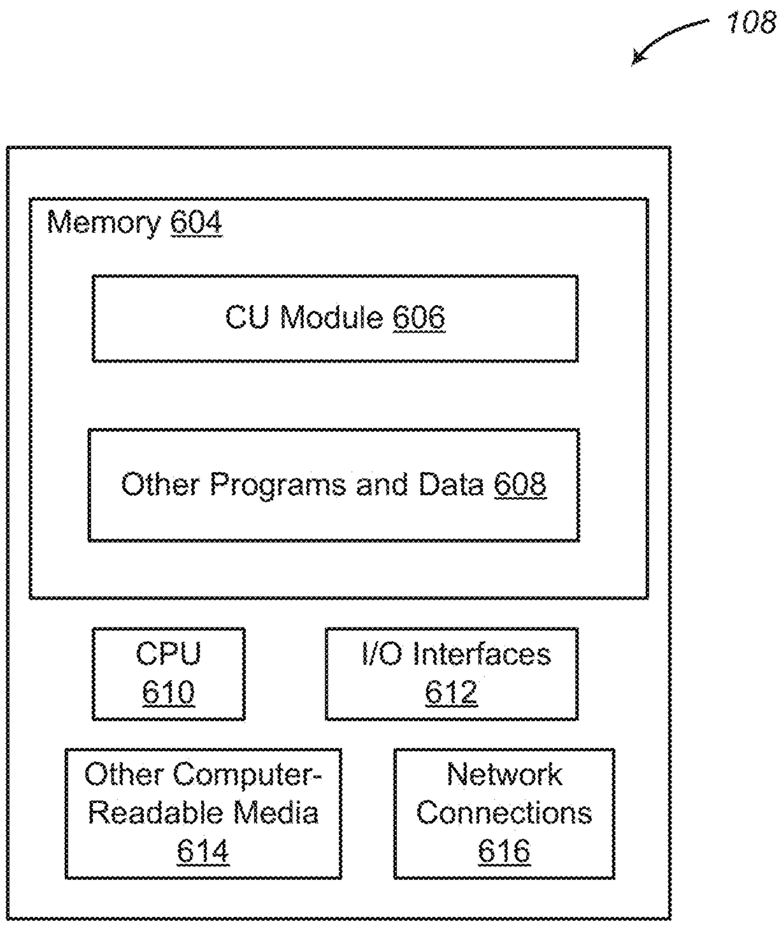
108
Memory 604
CU Module 606
Other Programs and Data 608
CPU
610
I/O Interfaces
612
Other Computer-
Readable Media
614
Network
Connections
616

FIG. 6

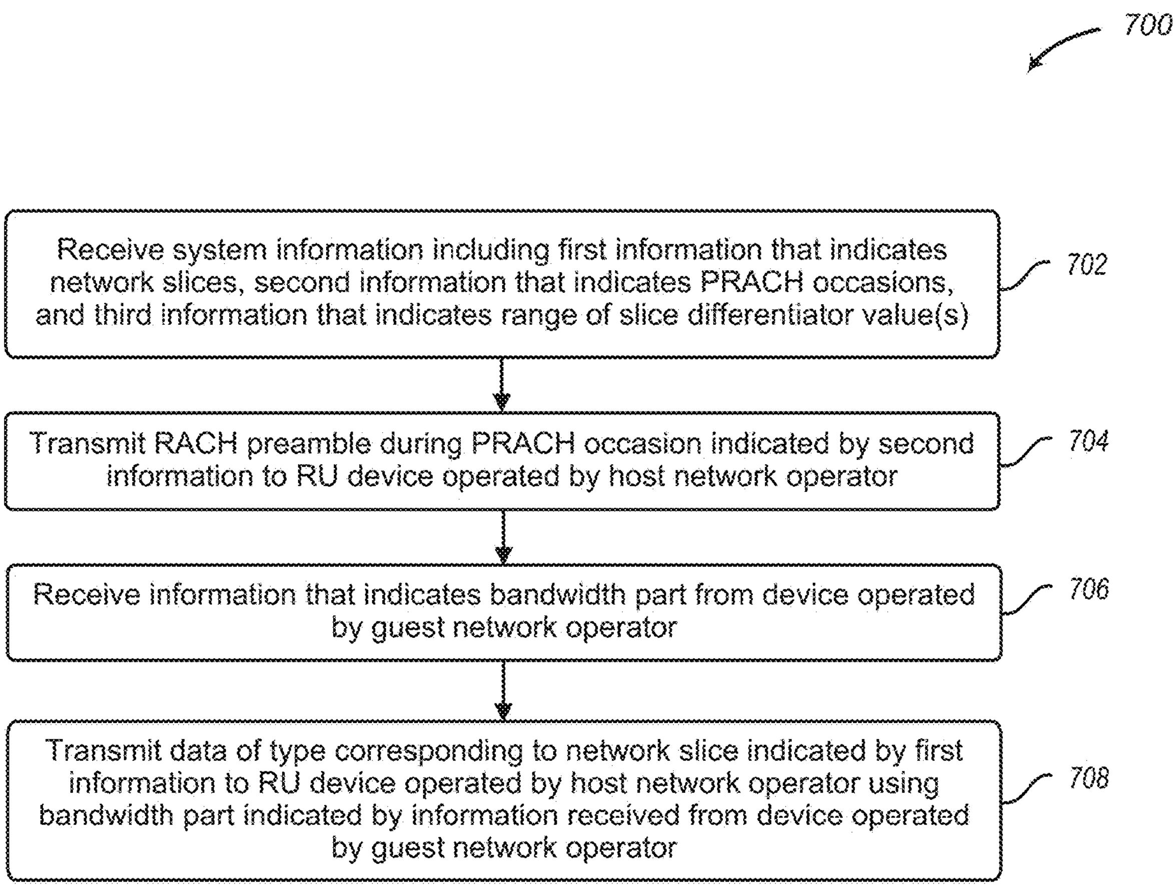
700
Receive system information including first information that indicates network slices, second information that indicates PRACH occasions, and third information that indicates range of slice differentiator value(s)
702
Transmit RACH preamble during PRACH occasion indicated by second information to RU device operated by host network operator
704
Receive information that indicates bandwidth part from device operated by guest network operator
706
Transmit data of type corresponding to network slice indicated by first information to RU device operated by host network operator using bandwidth part indicated by information received from device operated by guest network operator
708

FIG. 7

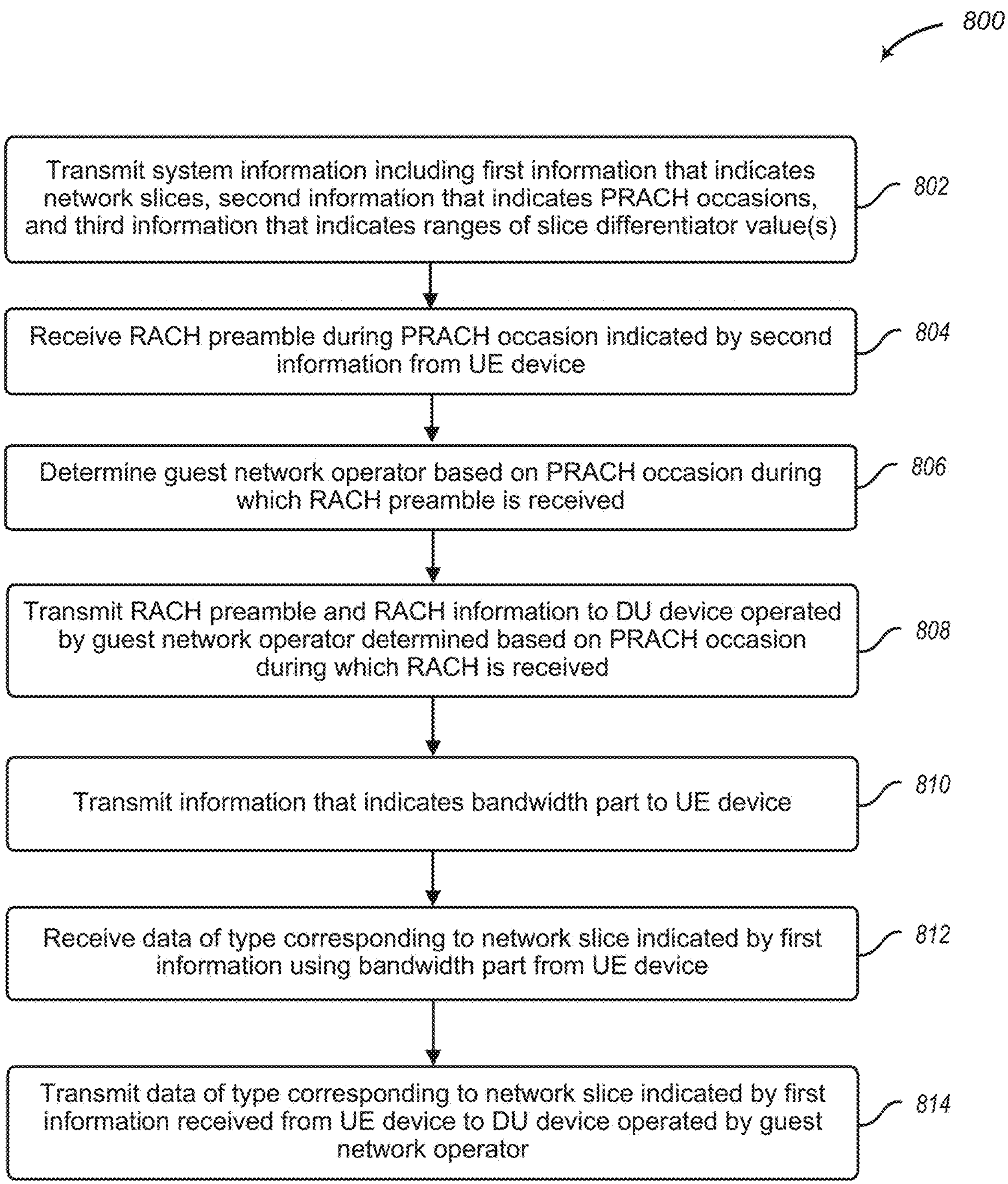
800
Transmit system information including first information that indicates network slices, second information that indicates PRACH occasions, and third information that indicates ranges of slice differentiator value(s)
802
Receive RACH preamble during PRACH occasion indicated by second information from UE device
804
Determine guest network operator based on PRACH occasion during which RACH preamble is received
806
Transmit RACH preamble and RACH information to DU device operated by guest network operator determined based on PRACH occasion during which RACH is received
808
Transmit information that indicates bandwidth part to UE device
810
Receive data of type corresponding to network slice indicated by first information using bandwidth part from UE device
812
Transmit data of type corresponding to network slice indicated by first information received from UE device to DU device operated by guest network operator
814

FIG. 8

MAPPING SUBSCRIBERS TO OPERATORS IN SHARED RADIO UNIT ARCHITECTURE USING RAN SLICING

BACKGROUND

[0001] Radio Access Network (RAN) slicing capabilities are included in Third Generation Partnership Project (3GPP) Release 17. In addition, Radio Unit (RU) sharing can be used in Open RAN (O-RAN) architectures.

BRIEF SUMMARY

[0002] According to the present disclosure, RAN slicing capabilities, for example, as included in 3GPP Release 17 are combined with an O-RAN disaggregated architecture and a novel concept of RU sharing among multiple network operators, in order to map subscribers to their respective network operators in a manner that is more efficient than conventional methods that do use RU sharing.

[0003] A method for mapping a subscriber to a mobile network operator in a fifth-generation New Radio (5G NR) cellular telecommunication radio access network (RAN) according to the present disclosure may be characterized as including: transmitting, by a Radio Unit (RU) device operated by a first network operator, system information including first information indicating a plurality of network slices and second information indicating a plurality of Physical Random Access Channel (PRACH) occasions mapped to the network slices; receiving, by the RU device operated by the first network operator, from a UE device, a preamble of a Random Access Channel (RACH) during one of the PRACH occasions mapped to the network slices that is indicated by the second information; determining, by the RU device operated by the first network operator, a second network operator different from the first network operator based on the one of the PRACH occasions mapped to the network slices that is indicated by the second information during which the preamble of the RACH is received; and transmitting, by the RU device operated by the first network operator, the preamble of the RACH and information included in the RACH to a Distributed Unit (DU) device that is operated by the second network operator determined based on the one of the PRACH occasions mapped to the network slices that is indicated by the second information during which the preamble of the RACH is received.

[0004] The method may further comprise transmitting, by the RU device operated by the first network operator, information included in the RACH to the DU device that is operated by the second network operator determined based on the one of the PRACH occasions mapped to the network slices that is indicated by the second information during which the preamble of the RACH is received.

[0005] The first information may include=a Slice Service Type (SST) value of Single-Network Slice Selection Assistance Information (S-NSSAI) that is stored by the UE device, and the second information indicating the PRACH occasions mapped to the network slices may include a Slice Differentiator (SD) value of the S-NSSAI that is stored by the UE device.

[0006] The system information may include a plurality of items of Single-Network Slice Selection Assistance Information (S-NSSAI), each of the items of S-NSSAI may include a Slice Service Type (SST) value that indicates one of the network slices, and each of the items of S-NSSAI includes a Slice Differentiator (SD) value that may indicate one of the PRACH occasions. The SST value included in a first one of the items of S-NSSAI may be same as the SST value included in a second one of the items of S-NSSAI. The one of the PRACH occasions indicated by the SD value included in a first one of the items of S-NSSAI may be same as the one of the PRACH occasions indicated by the SD value included in a second one of the items of S-NSSAI. The SD value included in each of the items of S-NSSAI may be different.

[0007] The method may further comprise receiving, by the UE device, information that indicates a bandwidth part from the DU device operated by the second network operator; and receiving, by the RU device operated by the first network operator, data corresponding to one of the network slices indicated by the first information that is transmitted by the UE device using the bandwidth part. The method may further comprise transmitting, by the RU device operated by the first network operator, to the DU device operated by the second network operator, the data corresponding to the one of the network slices indicated by the first information that is transmitted by the UE device using the bandwidth part.

[0008] A method for mapping a subscriber to a mobile network operator in a fifth-generation New Radio (5G NR) cellular telecommunication radio access network (RAN) according to the present disclosure may be characterized as including: receiving, by a User Equipment (UE) device, system information including first information indicating a plurality of network slices and second information indicating a plurality of Physical Random Access Channel (PRACH) occasions mapped to the network slices; and transmitting, by the UE device, a preamble of a Random Access Channel (RACH) during one of the PRACH occasions mapped to the network slices indicated by the second information.

[0009] The first information may indicates a service type; and the method may further comprise transmitting, by the UE device, data corresponding to the service type.

[0010] The first information may include a Slice Service Type (SST) value of Single-Network Slice Selection Assistance Information (S-NSSAI) that is stored by the UE device, and the second information indicating the PRACH occasions mapped to the network slices may include a Slice Differentiator (SD) value of the S-NSSAI that is stored by the UE device.

[0011] The system information may include a plurality of items of Single-Network Slice Selection Assistance Information (S-NSSAI), each of the items of S-NSSAI may include a Slice Service Type (SST) value that indicates one of the network slices, and each of the items of S-NSSAI may include a Slice Differentiator (SD) value that indicates one of the PRACH occasions. The SST value included in a first one of the items of S-NSSAI may be same as the SST value included in a second one of the items of S-NSSAI. The one of the PRACH occasions indicated by the SD value included in a first one of the items of S-NSSAI may be same as the one of the PRACH occasions indicated by the SD value included in a second one of the items of S-NSSAI.

[0012] A User Equipment (UE) device that operates in a fifth-generation New Radio (5G NR) cellular telecommunication radio access network (RAN) according to the present disclosure may be characterized as including at least one memory that stores computer executable instructions; and at least one processor that executes the computer executable instructions to cause actions to be performed, the actions including: receive system information including first information indicating a plurality of network slices and second information indicating a plurality of Physical Random Access Channel (PRACH) occasions mapped to the network slices; and transmit a preamble of a Random Access Channel (RACH) during one of the PRACH occasions mapped to the network slices indicated by the second information.

[0013] The first information may include a Slice Service Type (SST) value of Single-Network Slice Selection Assistance Information (S-NSSAI) that is stored by the UE device, and the second information indicating the PRACH occasions includes a Slice Differentiator (SD) value of the S-NSSAI that is stored by the UE device. The system information may include a plurality of items of Single-Network Slice Selection Assistance Information (S-NSSAI), each of the items of S-NSSAI may include a Slice Service Type (SST) value that indicates one of the network slices, and each of the items of S-NSSAI may include a Slice Differentiator (SD) value that indicates one of the PRACH occasions. The SST value included in a first one of the items of S-NSSAI may be same as the SST value included in a second one of the items of S-NSSAI. The one of the PRACH occasions indicated by the SD value included in a first one of the items of S-NSSAI may be same as the one of the PRACH occasions indicated by the SD value included in a second one of the items of S-NSSAI.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0014] Non-limiting and non-exhaustive embodiments are described with reference to the following drawings. In the drawings, like reference numerals refer to like parts throughout the various figures unless otherwise specified.

[0015] For a better understanding of the present disclosure, reference will be made to the following Detailed Description, which is to be read in association with the accompanying drawings.

[0016] FIG. **1** is a block diagram illustrating a communication system in accordance with embodiments described herein.

[0017] FIG. **2** is a block diagram illustrating another communication system in accordance with embodiments described herein.

[0018] FIG. **3** is a diagram illustrating an example of network slice information in accordance with embodiments described herein.

[0019] FIG. **4** is a block diagram illustrating an example of a Radio Unit (RU) device in accordance with embodiments described herein.

[0020] FIG. **5** is a block diagram illustrating an example of a Distributed Unit (DU) device in accordance with embodiments described herein.

[0021] FIG. **6** is a block diagram illustrating an example of a Centralized Unit (CU) device in accordance with embodiments described herein.

[0022] FIG. **7** illustrates a logical flow diagram showing an example of a method of operating a UE device in accordance with embodiments described herein.

[0023] FIG. **8** illustrates a logical flow diagram showing an example of a method of operating a RU device in accordance with embodiments described herein.

DETAILED DESCRIPTION

[0024] 3GPP TR 21.917 V0.5.0 (2022-04) (Release 17) mentions "enhancement of RAN Slicing for NR". Slice-based cell selection or reselection may be achieved by broadcasting System Information (SI) that includes supported slice information of a current cell and neighbor cells, and cell reselection priority per slice for cell reselection assistance. Also, a SI message may be included in an RRCRelease message slice for cell reselection assistance. In addition, supported slice of a serving cell in a SI message may be broadcast for cell selection assistance. For Slice based Random Access Channel (RACH) configuration, separated PRACH occasions (e.g., time-frequency domain and preambles) can be configured for each slice or slice group, and RACH parameters prioritization can be configured for each slice or slice group.

[0025] A Network Slice Selection Assistance Information (NSSAI) format has been defined, which includes a Slice/Service Type (SST) value and a Slice Differentiator (SD) value. For example, an SST value of 1 may indicate an enhanced Mobile Broadband (cMBB) Slice/Service Type, an SST value of 2 may indicate an Ultra Reliable Low Latency Communications (URLLC) Slice/Service Type, an SST value of 3 may indicate a massive Internet of Things (mIoT) Slice/Service Type, SST values from 4 to 127 may indicate a standard Slice/Service Type, and SST values from 128 to 255 may indicate an operator-specific Slice/Service Type.

[0026] A Single NSSAI (S-NSSAI) having an STT value corresponding to a standard STT with an SD value of null may indicate that all Public Land Mobile Networks (PLMNs) are applicable to the S-NSSAI. Also, an S-NSSAI having an STT value corresponding to an operator-specific STT with an SD value of null may indicate that the S-NSSAI is PLMN specific. Any S-NSSAI having an SD value that is not null may indicate that the S-NSSAI is PLMN specific.

[0027] For example, an S-NSSAI having an SST value of 1 and an SD value of null may imply eMBB traffic. Also, an S-NSSAI having an SST value of 3 and an SD value of null may imply IoT traffic. In addition, an S-NSSAI having an SST value of 3 and an SD value that is not null may imply custom IoT traffic.

[0028] According to the present disclosure, S-NSSAIs are mapped to particular services, slices, and operators. A set of SD values are split into different disjoint subsets (e.g., SD ranges) and each of the SD value subsets or ranges are assigned to one network operator. Accordingly, network operators can be differentiated based on the SD values of S-NSSAIs. Thus, different S-NSSAIs can be mapped to different network operators. Each network operator has the flexibility to support multiple slices of the same service type. For example, a network operator with an SD value range between 0000 and 000F, can offer multiple eMBB services for an SST value of 1.

[0029] FIG. **1** is a block diagram illustrating a communication system **100** in accordance with embodiments described herein. The communication system **100** employs a shared Radio Unit (RU) architecture. More particularly, the communication system **100** includes an RU device **102**, which is configured to use resources (e.g., Physical Resource Blocks (PRBs)) **104-1** that are allocated for use by the host network operator, PRBs **104-2** having a bandwidth BW**1** allocated to a first guest network operator, PRBs **104-3** having a bandwidth BW**2** allocated to a second guest network operator, and PRBs **104-4** having a bandwidth BW**3** allocated to a third guest network operator.

[0030] The RU device **102** is coupled to a plurality of Distributed Unit (DU) devices, including a DU device **106-1** that is operated by the host network operator, a DU device **106-2** that is operated by the first guest network operator, a DU device **106-3** that is operated by the second guest network operator, and a DU device **106-4** that is operated by the third guest network operator. The DU device **106-1** that is operated by the host network operator is coupled to a Centralized Unit (CU) device **108-1** that is operated by the host network operator. The DU device **106-2** that is operated by the first guest network operator is coupled to a CU device **108-2** that is operated by the first guest network operator. The DU device **106-3** that is operated by the second guest network operator is coupled to a CU device **108-3** that is operated by the second guest network operator. The DU device **106-4** that is operated by the third guest network operator is coupled to a CU device **108-4** that is operated by the third guest network operator.

[0031] In FIG. **1**, the host network operator owns the RU device **102** that is shared among the host network operator and all the guest network operators. The bandwidth allocation among the host and guest network operators are agreed upon and configured using the 5G BW-Part (BWP) concept. Each network operator owns its own DU device and CU device. The DU devices and CU devices owned by all of the network operators are synchronized to the RU device **102** on both downlink (DL) and uplink (UL). The RU device **102** operated by the host network operator broadcasts Master Information Block (MIB), System Information Block (SIB) Type1 (SIB1) and potentially some other SIBs.

[0032] FIG. **2** is a block diagram illustrating a communication system **100'** in accordance with embodiments described herein. The communication system **100'** shown in FIG. **2** is similar in many relevant respects to the system **100** system in FIG. **1**. The communication system **100'** shown in FIG. **2** includes a plurality of User Equipment (UE) devices, including a UE device **110-1** that is operated by a subscriber of the host network operator, a UE device **110-2** that is operated by a subscriber of the first guest network operator, a UE device **110-3** that is operated by a subscriber of the second guest network operator, and a UE device **110-4** that is operated by a subscriber of the third guest network operator.

[0033] In FIG. **2**, the host network operator broadcasts the System Information (SI) and the PRACH Occasion for each S-NSSAI in an SI message. Each PRACH occasion can be assigned within the BW (BWP) allocated to the appropriate network operator. Because the communication system **100'** allocates separate PRACH occasions to different slices/slice groups (i.e., the slice groups are mapped to different network operators), a UE device will transmit a RACH on the appropriate Physical RACH (PRACH) occasion allocated to its network operator. The communication system **100'** knows which network operator an UE device belongs to, immediately upon receipt of the RACH. The RACH is handled by the DU device of the appropriate network operator, instead of being handled by the DU device **106-1** operated by the host network operator as done in conventional techniques, which increases the speed at which information from the RACH is provided to the DU device of the appropriate network operator.

[0034] For example, when the UE device **110-1** operated by the subscriber of the host network operator uses a first PRACH occasion **112-1** to transmit a first RACH **114-1** to the RU device **102**, the RU device **102** routes or transmits information included in the RACH **114-1** to the DU device **106-1** operated by the host network operator and/or the CU device **108-1** operated by the host network operator. Also, when the UE device **110-2** operated by the subscriber of the first guest network operator uses a second PRACH occasion **112-2** to transmit a second RACH **114-2**, the RU device **102** routes information included in the second RACH **114-2** to the DU device **106-2** operated by the first guest network operator and/or the CU device **108-2** operated by the first guest network operator. Additionally, when the UE device **110-3** operated by the subscriber of the second guest network operator uses a third PRACH occasion **112-3** to transmit a third RACH **114-3**, the RU device **102** routes or transmits information included in the third RACH **114-3** to the DU device **106-3** operated by the second guest network operator and/or the CU device **108-3** operated by the second guest network operator. In addition, when the UE device **110-4** operated by the subscriber of the third guest network operator uses a fourth PRACH occasion **112-4** to transmit a fourth RACH **114-4**, the RU device **102** routes or transmits information included in the fourth RACH **114-4** to the DU device **106-4** operated by the third guest network operator and/or the CU device **108-4** operated by the third guest network operator.

[0035] FIG. **3** is a diagram illustrating an example of network slice information **300** in accordance with embodiments described herein. The network slice information **300** shown in FIG. **3** is simplified for ease of illustration. The network slice information **300** may be used to configure the communication system **100'** shown in FIG. **2**. The network slice information **300** may be stored in a table, wherein each row of the table represent an item of network slice information and each column of the table represent a field of each item of network slice information. More particularly, each item of network slide information includes a Slice Service Type (SST) value, which is associated with a system-unique Slice Differentiator (SD) value, a value indicating a Mobile Network Operator (MNO), a value indicating one or more Physical Resource Blocks (PRBs) corresponding to a bandwidth part, and a value indicating a Physical Random Access Channel (PRACH) occasion.

[0036] FIG. **4** is a block diagram illustrating an example of a Radio Unit (RU) device **102** in accordance with embodiments described herein. In some embodiments, one or more special-purpose computing systems may be used to implement the RU device **102**. Accordingly, various embodiments described herein may be implemented in software, hardware, firmware, or in some combination thereof. The RU device **102** may include one or more memory devices **404**, one or more central processing units (CPUs) **410**, I/O interfaces **412**, other computer-readable media **414**, and network connections **416**.

[0037] The one or more memory devices **404** may include one or more various types of non-volatile and/or volatile storage technologies. Examples of the one or more memory devices **404** may include, but are not limited to, flash memory, hard disk drives, optical drives, solid-state drives, various types of random access memory (RAM), various types of read-only memory (ROM), other computer-readable storage media (also referred to as processor-readable storage media), or the like, or any combination thereof. The one or more memory devices **404** may be utilized to store information, including computer-readable instructions that are utilized by the one or more CPUs **410** to perform actions, including those of embodiments described herein.

[0038] The one or more memory devices **404** may have stored thereon a Radio Unit (RU) module **406**. The Radio Unit (RU) module **406 23** configured to implement and/or perform some or all of the functions of the RU device **102** described herein and interface with radio transceiver **418**. The one or more memory devices **404** may also store other programs and data **408**, which may include PRACH information indicating one or more PRACH occasions that are associated with host and guest network operators (e.g., the network slice information **300** shown in FIG. **3**), RU digital certificates, connection recovery algorithms, connection recovery rules, network protocols, O-RAN operating rules, user interfaces, operating systems, etc.

[0039] Network connections **416** are configured to communicate with other computing devices including a Distributed Unit (DU) device. In various embodiments, the network connections **416** include transmitters and receivers, a layer 2 (L2) switch and physical network ports (not illustrated) to send and receive data as described herein, and to send and receive instructions, commands and data to implement the processes described herein. The L2 switch plays a role as Ethernet forwarding/transparent bridge in order to support Radio Unit (RU) copy and combine function for O-RAN cascade mode. I/O interfaces **412** may include enhanced Common Public Radio Interface (eCPRI) ports, Antenna Interface Standards Group (AISG) interfaces, other data input or output interfaces, or the like. Other computer-readable media **414** may include other types of stationary or removable computer-readable media, such as removable flash drives, external hard drives, or the like.

[0040] FIG. **5** is a block diagram illustrating an example of a Distributed Unit (DU) device **106** in accordance with embodiments described herein. In some embodiments, one or more special-purpose computing systems may be used to implement the Distributed Unit (DU) device **106**. Accordingly, various embodiments described herein may be implemented in software, hardware, firmware, or in some combination thereof. The DU device **106** may include one or more memory devices **504**, one or more central processing units (CPUs) **510**, I/O interfaces **512**, other computer-readable media **514**, and network connections **516**.

[0041] The one or more memory devices **504** may include one or more various types of non-volatile and/or volatile storage technologies. Examples of the one or more memory devices **504** may include, but are not limited to, flash memory, hard disk drives, optical drives, solid-state drives, various types of random access memory (RAM), various types of read-only memory (ROM), other computer-readable storage media (also referred to as processor-readable storage media), or the like, or any combination thereof. The one or more memory devices **504** may be utilized to store information, including computer-readable instructions that are utilized by the one or more CPUs **510** to perform actions, including those of embodiments described herein.

[0042] The one or more memory devices **504** may have stored thereon a Distributed Unit (DU) module **506**. The Distributed Unit (DU) module **506** is configured to implement and/or perform some or all of the functions of the Distributed Unit (DU) **502** described herein. The one or more memory devices **504** may also store other programs and data **508**, which may include a Radio Link Control (RLC) module that implements a RLC sublayer of the 5G NR protocol stack, which interfaces to PDCP sublayer from above and MAC sublayer from below, a Media Access Control (MAC) module that implements a MAC sublayer of the 5G NR protocol stack, which interfaces to the RLC sublayer from above and a Physical (PHY) layer from below, and a PHY module that implements the PHY layer for Enhanced Mobile Broadband (cMBB) communications, Machine-Type-Communications (mMTC), and Ultra-Reliable Low Latency Communications (URLLC).

[0043] Network connections **516** are configured to communicate with other computing devices including one or more Radio Unit (RU) devices, a Centralized Unit (CU) device, and a RAN Intelligent Controller (RIC) device. In various embodiments, the network connections **516** include transmitters and receivers, a layer 3 (L2) switch and physical network ports (not illustrated) to send and receive data as described herein, and to send and receive instructions, commands and data to implement the processes described herein. The L2 switch plays a role as Ethernet forwarding/transparent bridge in order to support Radio Unit (RU) copy and combine function for O-RAN cascade mode. I/O interfaces **512** may include PCI interfaces, PCI-Express interfaces, other data input or output interfaces, or the like. Other computer-readable media **514** may include other types of stationary or removable computer-readable media, such as removable flash drives, external hard drives, or the like.

[0044] FIG. **6** is a block diagram illustrating an example of a Centralized Unit (CU) device **108** in accordance with embodiments described herein. In some embodiments, one or more special-purpose computing systems may be used to implement the Centralized Unit (CU) device **108**. Accordingly, various embodiments described herein may be implemented in software, hardware, firmware, or in some combination thereof. The DU device **106** may include one or more memory devices **604**, one or more central processing units (CPUs) **610**, I/O interfaces **612**, other computer-readable media **614**, and network connections **616**.

[0045] The one or more memory devices **604** may include one or more various types of non-volatile and/or volatile storage technologies. Examples of the one or more memory devices **604** may include, but are not limited to, flash memory, hard disk drives, optical drives, solid-state drives, various types of random access memory (RAM), various types of read-only memory (ROM), other computer-readable storage media (also referred to as processor-readable storage media), or the like, or any combination thereof. The one or more memory devices **604** may be utilized to store information, including computer-readable instructions that are utilized by the one or more CPUs **610** to perform actions, including those of embodiments described herein.

[0046] The one or more memory devices **604** may have stored thereon a Centralized Unit (CU) module **606**. The Centralized Unit (CU) module **606** is configured to implement and/or perform some or all of the functions of the Centralized Unit (CU) **602** described herein. The one or more memory devices **604** may also store other programs and data **608**, which may include Radio Resource Control (RRC) module that implements an RRC a layer within the 5G NR protocol stack in a control plane of a gNB, a Service Data Adaptation Protocol (SDAP) module that implements a sublayer in a plane in the gNB, and a Packet Data

Convergence Protocol (PDCP) module that implements a PDCP layer within the 5G NR protocol stack.

[0047] Network connections **616** are configured to communicate with other computing devices including one or more Radio Unit (RU) devices, one or more Distributed Unit (CU) devices, one or more devices that implement Access and Mobility Management Function (AMF) operations, and one or more devices that implement User Plane Function (UPF) operations. In one or more implementations, the network connections **616** includes connections made via N2, N3, F1-C, and F1-U interfaces, for example.

[0048] FIG. **7** illustrates a logical flow diagram showing an example of a method **700** of operating a UE device in accordance with embodiments described herein. The method **700** begins at **702**.

[0049] At **702**, the UE device receives system information including first information that indicates a plurality of network slices, second information that indicates a plurality of Physical Random Access Channel (PRACH) occasions mapped to the network slices, and third information that indicates a range of one or more Slice Differentiator (SD) values (i.e., an SD range) associated with the network slices.

[0050] For example, the UE device **110-2** operated by the subscriber of the first guest network operator receives first information that indicates a plurality of SST values (e.g., 1, 2, 3) corresponding to a plurality of slice service types (e.g., eMBB, URLLC, MIoT), second information that indicates a plurality of PRACH occasions (e.g., information that indicates the PRACH occasions 2, 3, 4), and third information that indicates a plurality of SD ranges (e.g., 000000000000000000000101-000000000000000000001001, 000000000000000000001010-000000000000000000001110, 000000000000000000001111-000000000000000000010011) associated with the network slices. Up to eight items of Single-Network Slice Selection Assistance Information (S-NSSAI) may be stored by and configured in the UE device **110-2**. The UE device **110-2** maps the items of S-NSSAI that have an SD value included in the SD range indicated by the third information received at **702** to the PRACH occasions indicated by the second information received at **702**. The method **700** then proceeds to **704**.

[0051] At **704**, the UE device transmits a preamble of a RACH during the PRACH occasion indicated by the second information received at **702**. For example, the UE device **110-2** operated by the subscriber of the first guest network operator transmits a preamble of the RACH **114-2** during the second PRACH occasion **112-2** shown in FIG. **2**. The method **700** then proceeds to **706**.

[0052] At **706**, the UE device receives information that indicates a bandwidth part from a device operated by a guest network operator. For example, after the UE device **110-2** operated by the subscriber of the first guest network operator has been successfully authenticated, and Radio Resource Control (RRC) and Non-Access-Stratum (NAS) have been established between the UE device **110-2** and the CU device **108-2** operated by the first guest network operator and a device operated by the first guest network operator that performs an Access and Mobility Management Function (AMF), respectively, the UE device **110-2** receives information that indicates a contiguous set of Physical Resource Blocks (PRBs) on a particular carrier frequency (e.g., bandwidth part BW**1** shown in FIG. **2**) from the CU device **108-2** or the DU device **106-2** by RRC signaling. The method **700** then proceeds to **708**.

[0053] At **708**, the UE device transmits data corresponding to the service type indicated by the first information received at **702** to an RU device operated by the host network operator using the bandwidth part indicated by the information received from the device operated by the guest network operator at **706**. For example, the system information received at **702** includes first information that indicates an SST value of 1, which corresponds to an eMBB slice/service type, and the UE device **110-2** operated by the subscriber of the first guest network operator transmits eMBB data to the RU device **102** operated by the host network operator using the bandwidth part indicated by the information indicating the bandwidth part received from the CU device **108-2** operated by the first guest network operator (e.g., bandwidth part BW**1** shown in FIG. **2**). The method **700** then ends.

[0054] FIG. **8** illustrates a logical flow diagram showing an example of a method **800** of operating a RU device in accordance with embodiments described herein. The method **800** begins at **802**.

[0055] At **802**, the RU device transmits system information including first information that indicates a plurality of network slices, second information that indicates a plurality of Physical Random Access Channel (PRACH) occasions mapped to the network slices, and third information that indicates ranges of one or more Slice Differentiator (SD) values (i.e., SD ranges) associated with the network slice. For example, the RU device **102** operated by the host network operator transmits system information including first information that indicates a plurality of SST values (e.g., 1, 2, 3) corresponding to a plurality of slice service types (e.g., eMBB, URLLC, MIoT) for the network slices, second information that indicates a plurality of PRACH occasions (e.g., information that indicates PRACH occasions 2, 3, 4), and third information that indicates a plurality of SD ranges (e.g., 000000000000000000000101-000000000000000000001001, 000000000000000000001010-000000000000000000001110, 000000000000000000001111-000000000000000000010011). The method **800** then proceeds to **804**.

[0056] At **804**, the RU device receives a RACH preamble during one of the PRACH occasions indicated by the second information transmitted at **802**. For example, the RU device **102** operated by the host network operator receives a preamble of the RACH **114-2** shown in FIG. **2** during the second PRACH occasion **112-2** shown in FIG. **2** from the UE device **110-2** operated by the subscriber of the first guest network operator. The method **800** then proceeds to **806**.

[0057] At **806**, the RU device determines a network operator based on the PRACH occasion during which the RACH preamble is received at **804**. For example, the RU device **102** uses the network slice information **300** shown in FIG. **3** to determine that the network operator corresponding to the RACH **114-2** is the first guest network operator (e.g., Guest Operator 1) based on the preamble of the RACH **114-2** being received during PRACH occasion 2 (e.g., the second PRACH occasion **112-2** shown in FIG. **2**). The method **800** then proceeds to **808**.

[0058] At **808**, the RU device transmits the preamble of the RACH received at **804** and information included in the RACH received at **804** to a DU device operated by the network operator determined at **806**. For example, the RU device **102** stores an Internet Protocol (IP) address in association with an identifier of the first guest network operator (e.g., Guest Operator 1) and uses that IP address to route the preamble of the RACH **114-2** and information included in the RACH **114-2** to the DU device **106-2** operated by the first guest network operator and/or the CU device **108-2** operated by the first guest network operator. The method **800** then proceeds to **810**.

[0059] At **810**, a device operated by the guest network operator transmits information that indicates a bandwidth part to the UE device. For example, after the UE device **110-2** operated by the subscriber of the first guest network operator has been successfully authenticated, and Radio Resource Control (RRC) and Non-Access-Stratum (NAS) have been established between the UE device **110-2** and the CU device **108-2** operated by the first guest network operator and a device operated by the first guest network operator that performs an Access and Mobility Management Function (AMF), respectively, the CU device **108-2** transmits information that indicates a contiguous set of Physical Resource Blocks (PRBs) on a particular carrier frequency (e.g., bandwidth part BW**1** shown in FIG. **2**) to the UE device **110-2**. The method **800** then proceeds to **812**.

[0060] At **812**, the RU device receives data of a type corresponding to the one of the network slices indicated by first information transmitted by the UE device using the bandwidth part. For example, the RU device **102** receives eMBB data that is transmitted by the UE device **110-2** using the bandwidth part BW**1** shown in FIG. **2**. The method **800** then proceeds to **814**.

[0061] At **814**, the RU device transmits the data received at **812** to the DU device operated by guest network operator. For example, the RU device **102** transmits the eMBB data received at **812** to the DU device **106-2** operated by the first guest network operator operated by the first guest network operator. In one or more implantations, the RU device **102** determines that the eMBB data is to be transmitted to the based on the bandwidth part (e.g., bandwidth part BW**1** shown in FIG. **2**), using the network slice information **300** shown in FIG. **3**. The method **800** then ends.

[0062] The various embodiments described above can be combined to provide further embodiments. Aspects of the embodiments can be modified, if necessary to employ concepts of the various patents, applications and publications to provide yet further embodiments.

[0063] These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

1. A method, comprising:

transmitting, by a radio unit of a first network operator that is allocated a first bandwidth part, a message that indicates a second bandwidth part allocated to a second network operator, wherein the second network operator is separate from the first network operator, and the second bandwidth part is different from the first bandwidth part;

receiving, by the radio unit, data from a user device using the second bandwidth part, wherein the user device is a subscriber of the second network operator; and

routing, by the radio unit, the data to a distributed unit operated by the second network operator.

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

receiving, by the radio unit, second data from a second user device using the first bandwidth part, wherein the second user device is a subscriber of the first network operator; and

routing, by the radio unit, the second data to a second distributed unit operated by the first network operator.

3. The method of claim **1**, wherein transmitting the message comprises:

broadcasting, by the radio unit, the message indicating the first bandwidth part allocated to the first network operator and the second bandwidth part allocated to the second network operator.

4. The method of claim **1**, wherein transmitting the message comprises:

broadcasting, by the radio unit, the message indicating the first bandwidth part allocated to the first network operator, the second bandwidth part allocated to the second network operator, and a third bandwidth part allocated to a third network operator, wherein the first network operator is separate from the first network operator and the second network operator.

5. The method of claim **4**, further comprising:

receiving, by the radio unit, second data from a second user device using the third bandwidth part, wherein the second user device is a subscriber of the third network operator; and

routing, by the radio unit, the second data to a second distributed unit operated by the third network operator.

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

allocating, by the radio unit, the first bandwidth part to the first network operator; and

allocating, by the radio unit, the second bandwidth part to the second network operator.

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

allocating, by the radio unit, a third bandwidth part to a third network operator that is separate from the first network operator and the second network operator.

8. The method of claim **1**, wherein transmitting the message comprises:

receiving, by the radio unit, an indication of the second bandwidth part from a central unit operated by the second network operator; and

transmitting, by the radio unit to the user device, the message with the indication of the second bandwidth part to be used by the user device when transmitting data to the radio unit.

9. The method of claim **1**, wherein transmitting the message comprises:

receiving, by the radio unit, an indication of the second bandwidth part from the distributed unit operated by the second network operator; and

transmitting, by the radio unit to the user device, the message with the indication of the second bandwidth part to be used by the user device when transmitting data to the radio unit.

10. The method of claim **1**, wherein the first network operator is a host network operator.

11. The method of claim **1**, wherein the second network operator is a guest network operator.

12. The method of claim **1**, wherein the radio unit is a shared radio unit among a plurality of network operators, wherein the plurality of network operators includes the first network operator and the second network operator.

13. A method, comprising:

connecting, by a user device, to a radio unit of a first network operator, wherein the first network operator is allocated a first bandwidth part, and wherein the user device is a subscriber to a second network operator that is separate from the first network operator;

receiving, by the user device from the radio unit, an indication of a second bandwidth part allocated to the second network operator, wherein the second bandwidth part is different from the first bandwidth part; and

transmitting, by the user device to the radio unit of the first network operator, data using the second bandwidth part allocated to the second network operator.

14. The method of claim **13**, wherein receiving the indication of the second bandwidth part allocated to the second network operator comprises:

receiving, by the user device, a message that is broadcast from the radio unit and that includes the indication of the second bandwidth part allocated to the second network operator.

15. The method of claim **13**, wherein receiving the indication of the second bandwidth part allocated to the second network operator comprises:

receiving, by the user device and in response to authentication of the user device with the second network operator, the indication of the second bandwidth part allocated to the second network operator from a distributed unit operated by the second network operator.

16. The method of claim **13**, wherein receiving the indication of the second bandwidth part allocated to the second network operator comprises:

receiving, by the user device and in response to authentication of the user device with the second network operator, the indication of the second bandwidth part allocated to the second network operator from a central unit operated by the second network operator.

17. A wireless network system, comprising:

a radio unit of a first network operator that is allocated a first bandwidth part, the radio unit configured to:

transmit an indication of a second bandwidth part allocated to a second network operator, wherein the second network operator is separate from the first network operator, and the second bandwidth part is different from the first bandwidth part;

a user device that is a subscriber of the second network operator, the user device configured to:

receive the indication of the second bandwidth part allocated to the second network operator from the radio unit; and

transmit data to the radio unit using the second bandwidth part allocated to the second network operator; and

wherein the radio unit is further configured to:

receive the data from the user device using the second bandwidth part; and

route the data to a distributed unit operated by the second network operator.

18. The wireless network system of claim **17**, further comprising:

the distributed unit operated by the second network operator, wherein the distributed unit is configured to handle communications with the user device using the second bandwidth part; and

a second distributed unit operated by the first network operator, wherein the second distributed unit is configured to handle communications with other user devices using the first bandwidth part.

19. The wireless network system of claim **17**, further comprising:

a second user device that is a subscriber of the first network operator, the second user device configured to:

transmit second data to the radio unit using the first bandwidth part allocated to the first network operator; and

wherein the radio unit is further configured to:

receive the second data from the second user device using the first bandwidth part; and

route the second data to a second distributed unit operated by the first network operator.

20. The wireless network system of claim **17**, wherein the radio unit is a shared radio unit among a plurality of network operators, wherein the plurality of network operators includes the first network operator and the second network operator.

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