(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 May 2017 (04.05.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/074486 Al

(51) International Patent Classification:
H04L 12/801 (2013.01) *H04L 12/851* (2013.01)
H04L 12/803 (2013.01)

(21) International Application Number:
PCT/US2016/020027

(22) International Filing Date:
29 February 2016 (29.02.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/247,664 28 October 2015 (28.10.2015) US

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

(54) Title: SLICE-BASED OPERATION IN WIRELESS NETWORKS WITH END-TO-END NETWORK SLICING

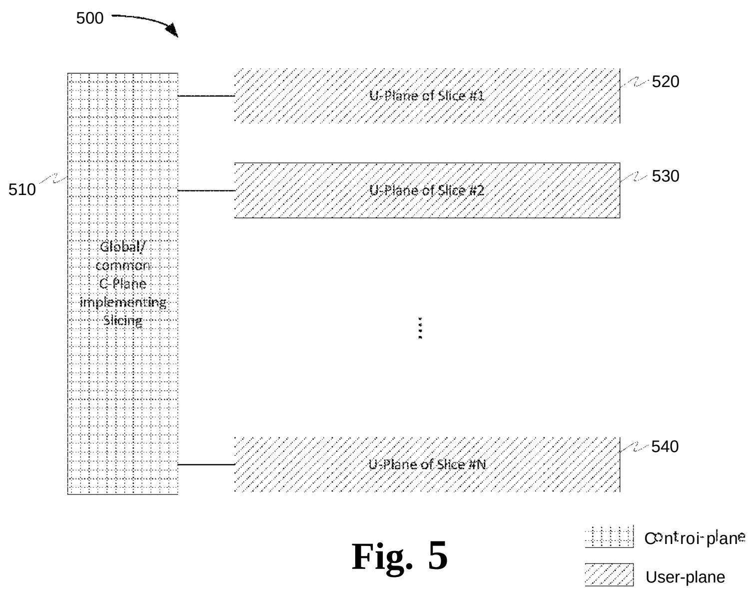

Fig. 5

(57) Abstract: Embodiments provide a BS apparatus operable in a wireless communication for a 5G system, the apparatus comprising RF circuitry to receive at least one communication originating from a network virtualization component and/or software defined network, and baseband circuitry to identify based on information from the communication a first association of a first local component of a RAN and a second remote component of the RAN, the first association corresponding to a network slice, and identify based on information of the same or a different communication of the at least one communication a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice, wherein the second association is based on at least one of traffic type, traffic load, or a QoS requirement.

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SLICE-BASED OPERATION IN WIRELESS NETWORKS WITH END-TO-END NETWORK SLICING

RELATED APPLICATIONS

The present application claims priority to U.S. Provisional Patent Application No. 62/247,664, filed October 28, 2015, the entire specification of which is hereby incorporated by reference in its entirety for all purposes.

TECHNICAL FIELD

Embodiments described herein generally relate to the field of wireless communications systems, and in particular to the management of the Radio Access Network of a wireless communications system.

BACKGROUND

Implementations of the disclosure generally may relate to the field of wireless communications.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects, features and advantages of embodiments of the present disclosure will become apparent from the following description of embodiments in reference to the appended drawings in which like numerals denote like elements and in which:

Figure 1 shows a first view of the broad concept of vertical and horizontal network slicing;

Figure 2 shows a second view of a portion of the wireless network of Figure 1;

Figure 3 shows how a Radio Access Network (RAN) can be sliced into horizontal and vertical slices according to an embodiment that is alternative (or additional) to that shown in Figure 1;

Figure 4 shows a more detailed example of horizontal slicing in a sliceable wireless network architecture according to examples;

Figure 5 shows a first example C/U-plane implementation with a decoupled configuration for the network slices;

Figure 6 shows a second example C/U-plane implementation with a coupled configuration for the network slices;

Figure 7 shows a third example C/U-plane implementation with a partially decoupled, partially coupled, configuration for the network slices;

Figure 8 shows a first example slice-on procedure by a UE based on thresholds;

Figure 9 shows a second example slice-on procedure by a UE based on Quality of Service class;

Figure 10 shows a first example slice-on procedure by a base station;

Figure 11 shows a first example slice-off procedure by a base station;

Figure 12 shows a first example random access procedure;

Figure 13 shows an example implementation of an electronic device (e.g. UE or base station) according to an embodiment;

Figure 14 shows a first example method of wireless communication for a fifth generation (5G) system according to an embodiment;

Figure 15 shows a second example method of wireless communication for a fifth generation (5G) system according to an embodiment;

Figure 16 shows a diagrammatic representation of hardware resources according to an embodiment.

DETAILED DESCRIPTION

The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the various aspects of the present disclosure. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the claims 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 present disclosure with unnecessary detail.

In fourth generation Long Term Evolution (4G-LTE) and LTE-Advanced/Pro wireless communications networks, there has been a trend for heterogeneity in the network architecture and applications. Examples of these trends are the development of small cells and relay networks, device-to-device (D2D) communication networks (also known as proximity services), and machine type communications (MTC). Small cells may be considered any form of cell that is smaller than the traditional macro eNB/base station, e.g. micro/pico/femto cells. Moving into fifth generation (5G) wireless communications networks, the trend of heterogeneity may be more prominent, and suitably improved methods and apparatus for control of the wireless resources is desirable. For example, because the 5G wireless communication networks may be expected to serve diverse range of applications (with various traffic types and requirements), network and user equipment (with various communication and computation capabilities), and commercial markets (i.e. use-cases) other than the more traditional voice services (e.g. Voice over LTE, VoLTE) and mobile broadband (MBB), there is a desire to provide control over each of these use-cases, so that an optimized, or at least improved, use of the wireless resources is possible.

Embodiments of the present disclosure generally relate to the slicing of a radio access network (RAN) architecture of a wireless communications network. The RAN may be the portion of the wireless communications network that implements one or more radio access technologies (RATs), and may be considered to reside at a position located between a user device (UE) such as a mobile phone, smartphone, connected laptop, or any remotely controlled (or simply accessible) machine and provides connection with the core network (CN) servicing the wireless communications network. The RAN may be implemented using silicon chip(s) residing in the UEs and/or base stations, such as enhanced Node B (eNBs), base stations, or the like that form the cellular based wireless communications network/system. Examples of RANs include, but are not limited to: GRAN (a GSM radio access network); GERAN (essentially an EDGE enabled GRAN); UTRAN (a UMTS radio access network); and E-UTRAN (an LTE, or LTE-Advance/Pro, high speed and low latency radio access network).

The herein described embodiments discuss the general architecture of network slicing in a radio access network of a wireless communication network, such as but not limited to a 5G wireless communication network. In particular, embodiments may include the concept of horizontal and vertical network slicing. Vertical slicing may comprise slicing the radio access network according to vertical markets, where a vertical market may comprise a single/particular type of communication (i.e. that may be defined as a single or particular use-case for the communications involved), out of the many existing and new types of communication that may be carried out over future wireless communication networks, particularly including the radio access network. A commercial market that may be provisioned over a wireless communications network may also be called a vertical market. The existing types include Mobile Broad Band (MBB) and Voice (VoLTE), while the new types of communication may include new types of connectivity services and use-cases, such machine type communications (MTC), personal area networks, dedicated health networks, machine to machine (M2M), enhanced MBB (eMBB), time critical communications, vehicle communications (V2X) (including vehicle to vehicle (V2V) and vehicle to infrastructure (V2I)), and the like. The definition of a vertical market is not limited, and will cover any existing or future logical separation (i.e. segregation, partition or the like) of a physical radio access network for exclusive use by wireless communications for particular use, or type of communication. In some examples, there may be multiple physical radio access networks in use, each separated into logically separated radio access networks.

The proposed network slices may be programmable and highly scalable and flexible, taking into consideration the availability, latency and power requirements and impact on battery life, reliability, capacity, security and speed of the wireless communications network required by each particular use-case.

Network slicing is considered as one of the key technologies to fulfill the diverse requirements and the diverse services and applications expected to be supported in 5G communication networks. This is because, in wireless communication technologies, further improving the spectral efficiency at the radio link level is becoming increasingly challenging, so new ways have been found to build future wireless networks and devices served by those wireless networks to meet the ever increasing capacity demand. To achieve these goals, 5G and future generations of wireless networks, and in particular the wireless devices serving those, or served by those wireless networks, are evolving, to be about the combination of computing and communications, and the provision of end-to-end solutions. This is a paradigm shift from previous generations where technology development focused primarily on single level communications alone.

To provide the increased capacity in wireless networks, they may be sliced. This may involve slicing (i.e. logically partitioning/separating) the traditional large, single, mobile broadband network into multiple virtual networks to serve vertical industries and applications in a more cost and resource efficient manner. Each network slice may have a different network architecture, and different application, control, packet and signal processing capabilities and capacity, in order to achieve optimum return on investment. New vertical slices (i.e. industry or type of service) can be added to an existing sliceable wireless network at any time, instead of deploying a new dedicated wireless network for that vertical market. Thus, vertical network slicing provides a practical means to segregate the traffic from a vertical application standpoint from the rest of general mobile broadband services, thereby practically avoiding or dramatically simplifying the traditional QoS engineering problem. Wireless network slicing may include slicing in both the core network and the radio access networks (i.e. is an end-to-end solution).

In 5G wireless networks and beyond, the capacity scaling of a network may no longer be as uniform as it has been in previous generations. For example, the scaling factor may be higher when the wireless network is closer to a user, and lower as we move deeper into the infrastructure of the wireless network. This non-uniform scaling may be a result of an augmented user experience enabled by the significantly increased sensing capabilities (and/or processing resources) available at the wireless devices making use of wireless networks. Unlike previous generations of wireless networks where a network serves primarily as a data pipe, scaling uniformly (but singularly) from end-to-end as the air interface improves, 5G and future generations of wireless networks may at least partly rely on information networks comprising diverse (heterogeneous and/or homogeneous) computing, networking and storage capabilities of the wireless networks and the wireless devices they serve/are served by.

For example, the overall wireless network may continue to scale up rapidly, but the computing and networking at the network edge may grow even faster, therefore enabling user data traffic to be processed at the edge of the wireless network (so-called edge cloud applications). User devices may no longer be simply "terminals" that terminate a communication link. Instead, they may become a new generation of moving or fixed networking nodes for a new generation of consumer devices, machines, and things. For example, a laptop, a tablet, a smart phone, a home gateway or any other wireless network device (or component device forming the , or part of the, wireless network device as sold to the consumer), can become a computing and networking center of a network cluster with many devices or things deployed around it. For example, it may form a Personal Area Network (PAN). Many such mobile or fixed wireless network clusters may form what may be called an underlay network, a new type of network in 5G and beyond, with devices capable of communicating with each other or directly with the fixed networks, and with computing able to be offloaded to larger form-factor platforms or edge cloud base stations (i.e. entities in the wireless network with greater processing resources, either outright, or simply available at the that time). This may be done to achieve optimum mobile computing and communication over a virtualized platform across many devices, including the edge cloud.

This new kind of wireless network scaling may be driven by a number of factors. For example, as device sensing is typically local, the processing of sensed data may be local, and the decisions and actions upon sensed data become local. This trend may be further amplified by the proliferation of wearable devices and the internet of things. For example, as machines start playing a greater role in communication than human users, the whole communication link speed may be increased.

The definition of end-to-end is to be revisited, as an increasing number of communication links are in the proximity of users and user devices. It is therefore proposed to provide a cloud architecture framework that may incorporate data centers as well as edge clouds providing local intelligence and services closer to the end users or devices. This may be because, for example, as wireless networks and systems get deployed in enterprise, home, office, factory and automobile, edge cloud servers become more important for both performance and information privacy and security. These latter factors may be driven by user's (and governments) growing concern on privacy and security. Moreover, data centers deep into the fixed networks may continue to grow rapidly since many existing services may be better served with centralized architecture, with the new generation of portable and wearable devices, drones, industrial machines, self-driving cars, and the like fueling even more rapid growth in communication and computing capabilities at the edge of the network and locally around users.

The newly introduced concept of network slicing, particularly of the sort that provides a wireless network system architecture that has End-to-End (E2E) vertical and horizontal network slicing may introduce changes to the air interface, the radio access network (RAN) and the core network (CN) to enable a wireless network system with E2E network slicing.

In simple terms horizontal slicing enhances device capability by allowing computing resources to be shared across devices serving or being served (i.e. in or on) the wireless network, according to the processing needs of those devices over time and space/location.

Horizontal network slicing is designed to accommodate the new trend of traffic scaling and enable edge cloud computing and computing offloading: The computing resources in the base station and the portable device may be horizontally sliced, and these slices, together with the wearable devices may be integrated to form a virtual computing platform though a new wireless air interface design as described herein, in order to significantly augment the computing capability of future portable and wearable devices. Horizontal slicing augments device capability and enhances user experience.

Network slicing, in the most general of terms, may be thought of as a way to use virtualization technology to architect, partition and organize computing and communication resources of a physical wireless network infrastructure, into one or more logically separated radio access networks, to enable flexible support of diverse use-case realizations. For example, with network slicing in operation, one physical wireless network may be sliced into multiple logical radio access networks, each architected and optimized for a specific requirement and/or specific application/service (i.e. use-case). Thus, a network slice may be defined as a self-contained, in terms of operation and traffic flow, and may have its own network architecture, engineering mechanisms and network provision. Network slicing as proposed herein is able to simplify the creation and operation of network slices and allows function reuse and resource sharing of the physical wireless network infrastructure (i.e. provides efficiencies), whilst still providing sufficient wireless network resources (communications and processing resources) for the wireless devices served by the wireless network.

Vertical slicing is targeted at supporting diverse services and applications (i.e. use-case/types of communication). Examples include but are not limited to: Wireless/Mobile Broadband (MBB) communications; Extreme Mobile Broadband (E-MBB) communications; Real-time use-case such as Industrial Control communications, Machine-to-Machine communications (MTC/MTC1); non-real-time use-case, such as Internet-of-Things (IoT) sensors communications, or massive-scale Machine-to-Machine communications (M-MTC/MTC2); Ultra Reliable Machine-to-Machine communications (U-MTC); Mobile Edge Cloud, e.g. caching, communications; Vehicle-to-Vehicle (V2V) communications; Vehicle-to-Infrastructure (V2I) communications; Vehicle-to-anything communications (V2X). This is to say, the present disclosure relates to providing network slicing according to any readily definable/distinguishable type of communication that can be carried out over a wireless network. Vertical network slicing enables resource sharing among services and applications, and may avoid or simplify a traditional QoS engineering problem.

Horizontal network slicing, meanwhile, is targeted at extending the capabilities of devices in the wireless network, particularly mobile devices that may have limitations on the local resources available to them, and enhancing user experiences. Horizontal network slicing goes across and beyond the hardware platforms' physical boundaries. Horizontal network slicing enables resource sharing among network nodes and devices, i.e., highly capable network nodes/devices may then share their resources (e.g., computation, communication, storage) to enhance the capabilities of less capable network nodes/devices. A simple example may be to use a network base station and/or a smartphone mobile device, to supplement the processing and communication capabilities of a wearable device. An end result of horizontal network slicing may be to provide a new generation of mobile (e.g. moving) underlay network clusters, where mobile terminals become moving networking nodes. Horizontal slicing may provide over-the-air resource sharing across wireless network nodes. The wireless network air interface in use may be an integrated part and an enabler of horizontal slicing.

Vertical network slicing and horizontal network slicing may form independent slices. The end-to-end traffic flow in a vertical slice may transit between the core network and the terminal devices. The end-to-end traffic flow in a horizontal slice may be local and transit between the client and host of a mobile edge computation service.

In vertical slicing, each of the network nodes may implement similar functions among the separate slices. A dynamic aspect of vertical slicing may lie predominantly in the resource partitioning. In horizontal slicing, however, new functions could be created at a network node when supporting a slice. For example, a portable device may use different functions to support different types of wearable devices. The dynamic aspect of horizontal slicing may therefore lie in the network functions as well as the resource partitioning.

Figure 1 shows a first view of the broad concept of vertical and horizontal network slicing. There is shown a complete wireless network 100, including multiple vertical slices 110 - 140, each serving a different (or at least separate) vertical market, i.e. use-case. In the example shown vertical slice #1 110 serves mobile broadband communications, vertical slice *#2* 120 serves vehicle-to-vehicle communications, vertical slice #3 130 serves security communications, and vertical slice *#4* 140 serves industrial control communications. These are only exemplary use-cases, and the use-cases that may be served by sliceable wireless network according to the present disclosure is practically unlimited.

The wireless network 100 includes a core network layer portion 150 (e.g. having multiple servers/control entitles/control portions of eNode-Bs, etc.), a radio access network layer portion 160 (e.g. including multiple base stations, e-Node Bs, etc.), a device layer portion 170 (including e.g. portable devices such as UEs, vehicles, surveillance devices, industrial devices, etc.), and a personal/wearable layer portion 180 (including, e.g. wearable devices such as smart watches, health monitors, Google™ glasses/Microsoft™ Hololens type devices, and the like). The wearable portion may only be involved in some use-cases, as shown by its inclusion in only vertical slices #1 and *#2* in the example of Figure 1.

In the vertical domain, the physical computation/storage/radio processing resources in the network infrastructure (as denoted by the servers and base stations 150/160) and the physical radio resources (in terms of time, frequency, and space) are sliced, by use-case (i.e. type of communication) to form end-to-end vertical slices. In the horizontal domain, the physical resources (in terms of computation, storage, radio) in adjacent layers of the network hierarchy are sliced to form horizontal slices. In the example shown, there is a first horizontal network slice 190 operating between the RAN 160 and Device 170 layers, and a second horizontal network slice 195 operating between the Device 170 and wearable 180 layers. Any given device served or to be served by the wireless network 100 as a whole, and the RAN 160 (and below layers) in particular, could operate on multiple network slices, of either (or both) types. For instance, a smart phone can operation in a vertical slice on mobile broad band (MBB) service, a vertical slice on health care service and a horizontal slice supporting wearable devices.

When enabling network slicing in the RAN (including the air interfaces employed in the RAN), besides meeting the 5G requirements (e.g., data rate, latency, number of connections, etc.), further desirable features of the RAN/air interfaces used to enable network slicing and in general 5G may include Flexibility (i.e. support flexible radio resource allocation among slices); Scalability (i.e. easily scale up with the addition of new slices; and Efficiency (e.g. efficiently use the radio and energy resources).

Horizontal slicing may comprise slicing the network hierarchy, e.g. the layers of network connectivity and compute (i.e. processing resource) capability. This may be done across any number of the vertical slices served by the network 100, for example anything from all the vertical markets down to within a one or more vertical slice(s). This is shown as the different widths of the two exemplary horizontal slices in Figure 1 - horizontal slice #1 190 is limited to a single vertical slice, whereas horizontal slice *#2* is covers two vertical slices. Examples of network hierarchy/layers may include, but is not limited to, a macro network layer, a micro/small cell network layer, a device to device communications layer, and the like. Other network layers may also be involved.

Figure 2 shows a second view 200 of a portion of the wireless network 100 of Figure 1. In particular, Figure 2 shows an example of a slice-specific RAN architecture, where slices may be across multiple levels of the traditional wireless network architecture. For example, depending on factors such as traffic type, traffic load, QoS requirement, the RAN architecture of each of the slices may be dynamically configured. In a first example, slice #1 210 may only operate on the macro cell level. Whereas slice #2 220 only operates on the small cells level. Finally, slice #3 230 may operate on both macro and small cells levels. In another example, a slice (e.g. slice #1 210) may open up operation on small cells while another slice (e.g. slice #3 230) may close operation on some of the small cells. Opening up operation/activating a slice may be referenced as a network slice turn-on, and closing operation/deactivating a slice may be referenced as a network slice turn-off. The slice-specific RAN architecture may require slice-specific control-plane/user-plane operation, slice on/off operation and slice-based treatment on access control and load balancing, as will be discussed in more detail below.

Horizontal slicing comprising slicing the network/device computation and communication resources may achieve computation offloading. Examples include the base station using a slice of its computation resource to help a user device's computation, or a user device (e.g. smartphone) using a slice of its computation resource to help computation of an associated wearable device(s).

Embodiments of the present disclosure are not limited to any particular form of slicing in the vertical (markets) or horizontal (network hierarchy/layers) directions. Embodiments of the present disclosure may provide a management entity operable across the Control-plane (C-plane) and/or User-plane (U-plane), that may provide a management-plane entity that may be used to coordinate the operation of the different slices, either horizontal or vertical (or multiple/combined, or partial, ones thereof). The management entity may use a flat management architecture or a hierarchal management architecture.

Slicing of the radio access network may be considered as compartmentalization of the radio access network according to predetermined vertical markets, or horizontal network layers (or multiple/partial layers) of the network. This may be considered a form of logical separation between the wireless resources provided by, or in use by, the radio access network. Logical separation of the wireless resources may allow that they may be separately defined, managed, and/or (generally or specifically) resourced. This separation may provide the ability for the different slices to not be able to, or allowed to, affect one another. Equally, in some embodiments, one or more slices may be specifically provided with the ability to manage another one or more slices, for operational reasons.

In some embodiments network functions may be fully offloaded to a network slice, and the slice may operate in a standalone mode, for example a standalone millimeter-wave (mmWave) small cell network, and an out-of-coverage D2D network. A mmWave small cell is one that uses milli-meter size radio waves (i.e. high frequency - e.g. 60GHz).

In some embodiments network function(s) may be partially offloaded to a slice, and the slice may operate in a non-standalone mode, for example in an anchor-booster architecture, where an anchor-booster architecture may comprise an anchor cell, providing a control-plane and a mobility anchor for maintaining connectivity. In an embodiment, the anchor cell may be a cell with wide coverage, for example a macro cell. The anchor-booster architecture may further comprise a booster cell, providing user-plane data offloading. In an embodiment, the booster cell may be a small cell, and may be deployed under the coverage of an anchor cell. From a device perspective, the control-plane and user-plane may be decoupled, i.e., the control-plane may be maintained at the anchor cell while the data-plane may be maintained at the booster cell.

In some example embodiments, the horizontal slices and vertical slices may be viewed as intertwined (i.e. where the radio access network functions/resources are shared among some of the vertical and horizontal slices), as illustrated in the graph 300 of Figure 3. Thus, Figure 3 shows how a Radio Access Network (RAN) can be sliced into horizontal and vertical slices according to an embodiment that is alternative (or additional) to that shown in Figure 1, where the slices are totally independent in terms of traffic flow and operation. The graph 300 of Figure 1 has Network Hierarchy 302 (i.e. the network layers involved/in use) along the y-axis, and Radio Resource 304 (i.e. indicative of using separate radio resources, such as frequencies, time slots, etc.) along the x-axis. In the example of Figure 1, vertical slicing is shown as comprising four vertical slices 306. However, any number of different markets/use-cases may be involved. The four vertical markets/use-cases shown chosen for the vertical slices are mobile broadband (MBB) 110, a vehicle type communication (V2X) 120, a first machine type communication (MTC-1) 130, a second machine type communication (MTC-2) 140, being slices Slice#l-Slice#4, respectively. These are only exemplary choices of the use-cases that could be served.

Also shown in Figure 3 is horizontal slicing, in this example again comprising four horizontal slices 308. The four horizontal slices shown are macro network layer 210, micro network layer 220, device to device network layer 230, and Personal Area Network (PAN) (e.g. wearable) network layer 240. According to an example, each horizontal slice contains a portion of multiple vertical slices. Equally, each vertical slice contains a portion of each horizontal slice. The separate portions, as separated in both the horizontal and vertical directions may be referred to as a slice portion. Thus, in the example of Figure 1, the MBB vertical slice 110 comprises four slice portions: Macro Network layer portion 112; Micro Network layer portion 114; D2D Network layer portion 116; and PAN Network layer portion 118. Similarly, V2X vertical slice 120 comprises four slice portions: Macro Network layer portion 122; Micro Network layer portion 124; D2D Network layer portion 126; and PAN Network layer portion 128. Meanwhile, the MTC-1 vertical slice 130 comprises four slice portions: Macro Network layer portion 132; Micro Network layer portion 134; D2D Network layer portion 136; and PAN Network layer portion 138, and MTC-2 vertical slice 140 comprises four slice portions: Macro Network layer portion 142; Micro Network layer portion 144; D2D Network layer portion 146; and PAN Network layer portion 148.

An example of such an architecture is, in a personal area network, a wearable health sensor may belong to a dedicated health network. The personal area network layer may then represent a horizontal network slice. The health sensor running under the coverage of the personal area network may belong to a vertical network slice. In the same token, each horizontal network slice could comprise multiple vertical network slices. Each vertical network slice may have multiple horizontal network slices. Another example is a macro cell (i.e. macro eNB) that serves a number of different use-case communications. Likewise, each vertical slice may contain portions of multiple horizontal slices, for example, in a V2X network, there may be V2I and V2V layers. In another example, the mobile broad band (MBB) vertical slice includes portions in each of the macro, micro and device to device layers, as shown. Thus, embodiments provide a way to logically carve up the wireless resources provided by, and/or in use by, the radio access network, according to both use-case (vertically) and network layer (horizontally).

Communication and computation have been helping each other in pushing the boundaries of information and computing technologies. At the network side, computation has been used to help communication by moving computation and storage to the edge.

With edge cloud and edge computation, the communication link between the source and the destination is getting shorter, thereby improving the communication efficiency and reducing the amount of information propagation in the network. The optimal deployment of edge cloud and computation scheme varies. As a general rule, the less capable the end device is and/or the higher the device density, the closer the cloud and computation to the network edge.

Moving forward at the device side, with the devices further shrinking in size from portable devices to wearable devices and the user expectation on computation keeping increasing, we expect future communications will help to deliver the user experience, e.g., the network nodes slice out part of their computation resources to help computation at the portable device, while the portable devices slice out part of their computation resources to help the computation at the wearable devices. In this way, the network is horizontally sliced. The sliced out computation resources and the air interface connecting the two ends form an integrated part that delivers the required service.

Figure 4 shows a more detailed example of horizontal slicing in a sliceable wireless network architecture according to embodiments. The left hand side shows the traditional 3G/4G architecture (but only from the RAN down). This comprises a base station portion 410, comprising an up-stream/core network side communication function 412, a base station compute function 414 (i.e. the processing resources available in the base station, or closely coupled entity thereof), and a down-stream/wireless/device side communication function 416 (to communicate with the devices being served by that base station, or other, peer base station, e.g. in the case of fronthaul, etc.). There is also shown a portable portion 420 (e.g. a User Equipment, or a like device) comprising a similar combination of up-stream and down-stream communication resources and local processing resources. In this case, the up-stream communication link is the typical cellular wireless communication link 422 (e.g. OFDM/CDMA/LTE type link) and a down-stream communication link 426 such as a 5G radio access technology (RAT) (e.g. OFDM/CDMA/LTE type link), a next generation communication link(s) such as a 5G PAN RAT (yet to be created), or a current or next generation other PAN wireless communication technology, e.g. Bluetooth, zigbee or the like. In between is the local compute function 424, i.e. processing resources local to the portable device. Lastly, in the example, there is the wearable portion 430, which typically has only a single up-stream communications link 432 and limited local processing resources function 434.

The right hand side of figure 4 shows the one of the new proposed horizontal network slicing concepts, in particular, how the processing resources of higher and lower entities in the network can be "combined", i.e. shared between themselves, using the communications and processing resource abilities of the entities taking part. The basic functions are similar, therefore are denoted as items 410' to 434' respectively, and act in similar ways. However, there is now the concept of horizontal slices, in this case, showing the horizontal slices #1 190 and *#2* 195 of Figure 1 in more detail. In this basic example, the wearable device 430' is able to make use of the processing resources 424' of portable device 420', by using the communications functions to share processing data (e.g. data to process and the resultant processed data). Similarly, the portable device 420' is able to use the base station 410' processing resources 414'.

There will now follow more detailed description of a portion of the network slicing concept, according to the present disclosure. In some example, these functions may be provided as new network function (NFs), which may be virtualized in some cases, e.g. by using network function virtualization (NFV). These NFs and NFVs may be slice specific, or operate over multiple/all slices. The proposed wireless network, both as a whole (e.g. including the core network), but particularly the RAN will now be slice aware, by making use of a newly implemented slice identification.

According to the present disclosure, network slicing is designed to build slice-specific end-to-end communication solution and enables a scalable 5G radio access network (RAN) and core network (CN) with heterogeneous deployment, heterogeneous traffics and services, and heterogeneous requirements. Network slicing is considered as one of the key technologies for 5G.

The criterion and the granularity of doing network slicing may be implementation specific. However, as discussed above, in general, network slicing may include two dimensions: vertical slicing and horizontal slicing and may be carried out to achieve a user-centric service.

Each slice may be self-contained, operating on the assigned logical resource, e.g. logically separated radio access network (RAN) and corresponding (i.e. serving) core network (CN). In an example, this may involve slice-specific treatment in the CN and RAN. In the CN, network function virtualization (NFV) and software defined network (SDN) may be the technical enablers for network slicing. For example, NFV and SDN may be used to virtualize the network elements and functions, which in turn may enable easily configured/reused network elements and functions in (or for) each slice, in order to meet each slice's own operational requirement(s). In the RAN, slicing may be built on the logical resources abstracted from physical radio resource(s) (e.g. transmission point, spectrum, time, etc.). Each slice may have its own air-interface and RAN architecture.

In the RAN, each cell site may have multiple slices operating on them, each slice may have its own RAN architecture and each mobile device, such as user equipment (UE), may subscribe to one or multiple slices. The mobile device (e.g. UE) association, access control and load balancing schemes may be slice-specific instead of cell-specific as in current mobile networks. Slice on/off operation may be enabled at each access point (AP) or base station (BS). The control-plane and user-plane configuration may be tailored considering the slice-based operation. In a sense, the slice-specific operation may blur the concept of the physical cell site (e.g. base station) and makes the network operation more service/traffic/user oriented instead of physical cell oriented.

Examples of the present disclosure provide slice-based operation in the RAN. Specifically, the following aspects are discussed: 1) Slice-specific RAN architecture; 2) Control-plane and user-plane configuration with network slicing; 3) Slice on/off operation; 4) Slice-based access control; and/or 5) Slice-based load balancing.

1. <u>Slice-specific RAN architecture</u>

Figure 2 showed an example of a slice-specific RAN architecture that depends on factors such as traffic type, traffic load, QoS requirement, and the like, and the RAN architecture of each of the slices may be dynamically configured. The proposed sliceable RAN architecture may include control-plane and user-plane functions, which may provide functionality for slice on/off operation and slice-based treatment on access control and load balancing, amongst other functions. The proposed sliceable RAN architecture may utilize control-plane and user-plane operation, where the c-plane portion may be either common or slice-specific, or a combination thereof, as will be illustrated in the following sections.

2. <u>Control-plane and user-plane configuration in the RAN</u>

Depending on how the control-plane (C-plane) and the user-plane (U-plane) are (de) coupled in the RAN, there are various options on how the C/U-planes may be configured for use in a sliceable RAN architecture. In the following, the reference to 'decoupled' may mean the respective portions are not co-located, or are not on the same logical or physical signal path for the signaling messages (i.e. if decoupled, the messages for the C-plane do not travel the same path as the messages for the u-plane). The term coupled may mean the opposite, i.e. the respective portions are co-located, or are on the same logical or physical signal path for the signaling messages.

Option 1: Control-plane as an independent slice, decouple control-plane slice and user-plane slices

In this option, the C-plane and the U-plane of each network slice are decoupled. There may be one C-plane slice supporting all the U-planes. The C-plane slice and the U-plane slice may operate on different network nodes. For example, the C-plane slice may be maintained at the macro BSs while the U-plane slices may operate on macro BS, small cell BS, and/or via device-to-device links. The advantage of this option is that the C-plane functions may be always-on, providing full coverage for the devices being served by the network slice(s). The drawbacks may be the signaling exchange between the C-plane slice and the U-plane slice when they are not physically co-located. Figure 5 shows an example C/U-plane implementation 500 with a decoupled configuration for the network slices. In particular, Figure 5 shows a global common c-plane 510 (i.e. for use on all the network slices), connected to the respective u-planes, e.g. u-plane of slice #1 520, u-plane of slice *#2* 530, all the way down to the u-plane of slice #N 540. This is to say, the specific number of u-planes (of) slices/number of slices in use is arbitrary for any given example implementation and the current circumstances of that implementation.

Option 2: Control-plane coupled with user-plane in each slice

In this option, the C-plane and the U-plane of each slice may be coupled and physically co-located. The advantage of this configuration may include less control signaling delay and signaling exchange overhead among transmission points. In some examples, in order to ensure C-plane coverage, the slices may be kept on at the transmission points that only have small traffic on that slice. Figure 6 shows a C/U-plane coupled slice configuration 600, in which a slice-specific c-plane of slice #1 610 is coupled to the u-plane of slice #1 620, a slice-specific c-plane of slice *#2* 630 is coupled to the u-plane of slice *#2* 640, and may continue all the way down (i.e. up to) to a slice-specific c-plane of slice #N 650 being coupled to the u-plane of slice #N 660. Again, the number of slices in use is arbitrary to the implementation and the current circumstances of that implementation.

Option 3: Control-plane splitting into a common control-plane slice and slice-specific control-plane

In this option, some of the common control-plane functions such as the functions in 'radio resource control-idle' (RRC-idle) mode (e.g., paging, cell reselection, tracking area update) may be categorized into a common C-plane portion, while the functions in 'radio resource control-connected' (RRC-connected) mode (e.g., handover, dedicated bearer setup) may be categorized into slice-specific control plane function. In an example, the advantage is to provide coverage and at the same time reduce control signaling exchange among network nodes. Figure 7 shows a partially decoupled C/U-plane configuration 700 in which a common c-plane function 710 is connected to: a slice-specific portion for Slice #1 720 and the slice-specific u-plane function for slice #1 730; a slice-specific portion for Slice *#2* 740 and the slice-specific u-plane function for slice *#2* 750, and may continue all the way down (i.e. up to) to a slice-specific portion for Slice #N 760 and the slice-specific u-plane function for slice #N 770. Again, the number of slices in use is arbitrary to the implementation and the current circumstances of that implementation.

3. Slice on/off procedure

Regardless of the c-plane/u-plane topology in use, the proposed slice-specific RAN architecture inherently suggests the use of a slice on/off procedure. Some scenarios of slice on/off include: opening up a slice in a small cell underlying macro cell coverage; opening up a slice in a cell operating on a different frequency band (e.g. high frequency band, unlicensed band). The triggers for turning on a slice at an access point may include:

a) Traffic load of a slice goes beyond a certain threshold - e.g. such information may be obtained from the UEs trying to access the AP on the slice and/or indicated by the neighboring APs and/or by the network central controller and/or by the APs in the parent hierarchy, e.g., a macro cell.

b) The number of active UEs operating on a slice goes beyond a certain threshold - e.g. such information may be obtained from the UEs trying to access the AP on the slice and/or by the neighboring APs, and/or by the APs in the parent hierarchy, e.g., a macro cell

c) In order to keep service continuality of a moving UE, where the US is moving across base-stations (e.g. Macro BSs), and is connected to a particular slice (or slices) on one base station, but the base station to which they are about to move (and handover) does not yet have any or all of the respective slices in operation thereon.

d) In order to meet certain QoS requirement, such as low latency, ultra-reliability, etc., i.e. a QoS requirement is instigated that may be best/better served by a new slice for that QoS class.

Slice-on at one AP may be triggered by UE or by network. Figure 6 - Figure 8 show the slice-on procedure by different types of triggers. When triggered by the UE, the UE may send an indication on the intended slice during random access. Depending on the types of UE triggering, i.e., due to traffic load or due to QoS requirement, the slice-on procedures may be different. In the traffic-load motivated slice-on, the BS may only turn on the slice when it sees enough traffic coming. The UE access request may not always be accepted if the BS decide not to turn on the slice. In the QoS-motivated slice on, the BS may turn on the slice when have the QoS demand. The UE access request may be accepted given the requested QoS meet certain criterion. When triggered by the peer BS/AP, the peer BS/AP may send a triggering message to request slice on at the targeted BS.

Figure 8 shows a first example 800 UE triggered slice on (i.e. slice turn-on). In the example of Figure 8, the instigating parameter is that the number of UEs requesting the slice (be turned on) goes beyond a certain threshold. In Figure 8, the example turn-on process starts by respective UEs carrying out a Random Access that includes an indication (i.e. data element) of an intended slice the UEs wish to use. This comprises a message 810 sent from the UE(s) to the base station. When enough UEs have requested the use of the same network slice (i.e. a threshold number has been exceeded), the receiving base station may then turn-on the requested network slice 820. As a result of the slice turn-on, messages implementing the slice turn-on may be sent from (and received by) the base station to (and from) the Mobility Management Entity (MME) or other network control entity that implements the slice management process(es), the messages being an exchange of configuration information on the slice. This is shown in figure 8 as the bidirectional messages arrow 830. A result of the configuration messages exchange may be the assignment of wireless resources for the slice to be turned-on (e.g. frequencies, numerologies, etc.). The slice information may then be included 850 in the system information messages (i.e. system broadcasting information), for ready access by all devices being served by the respective base station (and/or network control entity). This allows all the devices wishing to access the newly turned-on slice with the information to do so, e.g. by providing the slice-specific control information such as, but not limited to: the downlink control information (DCI), physical random access channel (PRACH) resource, slice random access (RA) configuration, and the like. Using this newly acquired information, the respective UE(s) may then random access the newly created network slice 870.

Figure 9 shows a second example 900 UE triggered slice on, in which the instigating parameter is that the type of UE request falls into certain QoS class. The process is very similar to process 800 of Figure 8 (like items are referenced by the same numbers). However in this case the slice is turned-on 920 after a device sends a request (e.g. by a random access, with the respective request information therein) that falls into a given QoS class. Other classes may be provided, in some implementations. In this example, the base station provides a random access response 930 early, which means the device requesting the slice based on QoS requirement is able to access the slice earlier, and in a simplified fashion at 940 as at least a portion of the information is already provided to the Device in message 930.

Figure 10 shows a first example 1000 network triggered slice turn-on. In the example of this Figure, there is a triggering base station (i.e. the base station that is requesting the turning-on of a slice, e.g. it may already have the respective slice in operation, and is about to hand over a UE to the target base station), and a target base station (i.e. a base station that is receiving the request to turn-on a respective slice, e.g. because it is about to be handed over a device making use of that respective slice). The request is sent from the triggering base station to the target base station 1010. The target base station then starts the turn-on of the respective slice 1020, which instigates the exchange of configuration information 1030 for the slice with the MME/network control entity managing the respective slice. The MME/network control entity provides the slice configuration information to the target base station 1040 (and so set up the slice accordingly), and the respective slice information can then be included in the system information broadcasted to all deices, so that devices wishing to access the newly turned-on slice are able to use that broadcasted information do so.

Meanwhile, the triggers for turning-off a slice at an access point (or base station) may include:

a) Traffic load of a slice goes below a certain threshold;
b) The number of active UEs operating on a slice goes below a certain threshold.

Figure 11 shows an example slice turning off procedure 1100 in one base station (e.g. source base station). This example is based on the UE reporting on the neighboring cell condition and the traffic load/number of connection condition on the slice, the BS (the source BS) may decide to turn off the slice. To prepare for slice turn-off, the BS may handover the active UEs camped on the BS operating on the slice to the neighbor BS (i.e. target base station) with the slice operating thereon. The process of figure 11 starts with a message 1110 being sent from a UE currently connected to the source Base station, to said source base station, that includes a report measurement of the target base station. On the basis of the report in message 1110, the source base station may decide to turn-off (i.e. close) the slice because the slice turn-off conditions have now been satisfied, e.g. low traffic load. The active devices (e.g. UEs) on the slice may be handed over to a neighbor base station to maintain continuality of their service. In which case, a source base station led (i.e. instigated) handover procedure 1130 may be carried out to hand over devise to the corresponding slice on the target base station. An exchange of information 1140 on the SI interface (or any other suitable base station to core network interface) may then be carried out, to exchange the information used to reconfigure the slice statuses on the target and source base stations, respectively, such that the slice on the source base station may then be closed at 1150.

As can be seen from the above-described examples, the turn-on and turn-off of a particular network slice may be instigated by any entity making use of or providing a function within the slice, and for a variety of reasons. The examples shown are merely exemplary of some of the types of slice management procedures, and what sub-processes may be employed in those management procedures, according to the present disclosure.

4. Slice-based access control

As the RAN architecture of each slice may be different, the access control may be slice-specific as well. The access control applies when a UE tries to become radio resource control (RRC) connected and/or during handover. For UEs in an idle mode, the UE may camp on any base station and be kept in an idle mode. In this situation, the C/U-plane configurations option 1 and 2 (of Figures 5 and 6) discussed may be applied.

Figure 12 shows an example of the slice-specific random access procedure 1200. The base station system information (i.e. broadcasted system information) may carry information on the active slices in the BS 1210. Based on the BS system information, the UE may decide 1220 whether to do a random access with the BS. If the intended slice is active in the BS and given good channel condition, the UE may access that active slice by carrying out an RA request including information on the slice the UE would like to access

1230. Even if the intended slice is not supported by the BS, the UE may still decide to request access. In this case, factors affecting the decision may be: link condition, QoS requirement, traffic load of the neighboring cells, etc. If the UE make the access request but the slice is not currently active in the BS, the BS may have to decide whether to accept the request, and turn-on the respective slice. Signaling exchange among the BSs or between the BS and the central controller may be used to facilitate the BS decision (as shown in Figures 8 to 11, for example). Once the BS decides to accept the access request, the BS may turn-on the slice using the procedure discussed in the previous section. IN either case, a base station response may be made by the base station to the UE RA request (i.e. in the affirmative, or negative) 1240.

For UEs that may be simultaneously operated on multiple slices, and where the multiple slices are activate in different APs or BSs, in an example, the UE may have to keep multiple connections simultaneously. In this case, the C/U-plane configuration options as discussed in the previous section become relevant here. For example, the UE may be anchored in one C-plane and keep multiple connections on the U-planes of the different slices (as in C/U-plane configuration option 1 - Figure 5), or the UE may have one common C-plane for maintaining basic C-plane operation while having slice-specific/dedicated C-plane portions for each slice (as in C/U-plane configuration option 2- Figure 6), or the UE may have multiple connections and multiple C-planes, each serving one slice (as in C/U-plane configuration option 3- Figure 7).

In an example, slice-based load-balancing may be provided. Slice-base load balancing may achieve traffic shaping gain, reduce control signaling overhead and/or improve overall spectrum efficiency. The operation on slice-based load-balancing may involve coordination across slice and across APs/BSs. Signaling exchange regarding the load conditions on each of the slices among the APs/BSs may be used. Slice-based load-balancing may require joint application of the slice on/off procedure and the slice-specific access control procedure.

In an example, a slice-specific RAN architecture is provided. Depending on factors such as traffic type, traffic load, QoS requirement, the RAN architecture of each of the slices may be dynamically configured.

In an example, control-plane and user-plane configuration options may be provided in support of RAN slicing. In an example, C/U-plane may be decoupled from slice configuration (e.g., control-plane as an independent slice, decouple control-plane slice and user-plane slices). In another example, C/U-plane may not be decoupled from slice configuration (e.g., control-plane coupled with user-plane in each slice). In another example, C/U-plane may be partially decoupled from slice configuration (e.g., control-plane splitting into a common control-plane slice and slice-specific control-plane). In some examples decoupling may be provided by ensuring the decoupled portions are not co-located, or do not comprise the same logical or physical signal path. For example, when the C-plane is decoupled from the U-plane, the C-plane function is not co-located with the U-plane function, and/or, the C-plane messaging does not follow the same logical or physical signal path as the corresponding U-plane messaging. In some examples, coupling may be provided by ensuring the coupled portions are co-located, or comprise the same logical or physical signal path. For example, when the C-plane is coupled to the U-plane, the C-plane function is co-located with the U-plane function, and/or, the C-plane messaging follows the same logical or physical signal path as the corresponding U-plane messaging.

In an example, triggering factors for slice on/off at an AP or BS may include at least one of traffic load of a slice goes beyond a certain threshold at the AP/BS, the number of active UEs operating on that slice goes beyond a certain threshold, to maintain service continuality of a moving UE, or to Meet certain QoS requirement, such as low latency, ultra-reliability, etc.

In an example, slice-on at one AP may be triggered by UE or by network. When triggered by the UE, the UE may send an indication on the intended slice during random access. When triggered by the peer BS/AP, the peer BS/AP may send an triggering message to request slice on at the targeted BS. The AP/BS and the MME/network control entity may exchange signaling when turning on a slice.

In an example, depending on the types of UE triggering, (e.g., due to traffic load or due to QoS requirement) the slice-on procedures may be different. In an example, in the traffic-load motivated slice-on, the BS may only turn on the slice when it sees enough traffic coming. In an example, the UE access request may not be accepted if the BS decides not to turn on the slice. In another example, in the QoS-motivated slice on, the BS may turn on the slice responsive to QoS demand (e.g., the UE access request may be accepted given the requested QoS meet certain criterion).

In an example, the triggers for turning off a slice at an access point may include at least one of traffic load of that slice goes below a certain threshold or a number of active UEs operating on that slice goes below a certain threshold.

In an example, a BS may determine to turn off the slice based on at least one of UE report on the neighboring cell condition or the traffic load/number of connection condition on the slice.

In an example, the BS handover the active UEs on the slice to the neighboring BS when turning a slice off.

In an example, the BS system may carry information on the active slices in the BS.

In an example, the UE may decide whether to access a BS based on at least one of whether the intended slice is on at the BS, the link condition, QoS requirement, or traffic load of the neighboring cells.

In an example, signaling exchange may be among the BSs or between the BS and the central controller may be used to assist BS's decision on whether to turn on a slice or not.

In an example, for UEs that may be simultaneously operated on multiple slices and the multiple slices are activated in different APs or BSs, the UE may keep multiple connections simultaneously.

In an example, slice-based load-balancing may require coordination across slice and across APs/BSs. Signaling exchange regarding the load conditions on each of the slices among the APs/BSs may be used.

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

Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Figure 13 shows, for one embodiment, example components of an electronic device 1300. In embodiments, the electronic device

1300 may be, implement, be incorporated into, or otherwise be a part of a user equipment (UE), an evolved NodeB (eNB), or another network component (e.g. a network component corresponding to a network virtualization device and/or a software defined network device). In some embodiments, the electronic device 1300 may include application circuitry 1310, baseband circuitry 1320, Radio Frequency (RF) circuitry 1330, front-end module (FEM) circuitry 1340 and one or more antennas 1350, coupled together at least as shown.

The application circuitry 1310 may include one or more application processors. For example, the application circuitry 1310 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

The baseband circuitry 1320 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1320 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 1330 and to generate baseband signals for a transmit signal path of the RF circuitry 1330. Baseband processing circuitry 1320 may interface with the application circuitry 13 10 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1330. For example, in some embodiments, the baseband circuitry 1320 may include a second generation (2G) baseband processor 1321, third generation (3G) baseband processor 1322, fourth generation (4G) baseband processor 1323, and/or other baseband processor(s) 1324 for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 1320 (e.g., one or more of baseband processors 1321-1324) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1330. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 1320 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1320 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

In some embodiments, the baseband circuitry 1320 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 1325 of the baseband circuitry 1320 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC Layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 1326. The audio DSP(s) 1326 may be include elements for compression/decompression and echo maycellation and may include other suitable processing elements in other embodiments.

The baseband circuitry 1320 may further include memory/storage 1327. The memory/storage 1327 may be used to load and store data and/or instructions for operations performed by the processors of the baseband circuitry 1320. Memory/storage for one embodiment may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 1327 may include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. The memory/storage 1327 may be shared among the various processors or dedicated to particular processors.

Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 1320 and the application circuitry 1310 may be implemented together such as, for example, on a system on a chip (SOC).

In some embodiments, the baseband circuitry 1320 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1320 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 1320 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

RF circuitry 1330 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1330 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1330 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 1340 and provide baseband signals to the baseband circuitry 1320. RF circuitry 1330 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1320 and provide RF output signals to the FEM circuitry 1340 for transmission.

In some embodiments, the RF circuitry 1330 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 1330 may include mixer circuitry 1331, amplifier circuitry 1332 and filter circuitry 1333. The transmit signal path of the RF circuitry 1330 may include filter circuitry 1333 and mixer circuitry 1331. RF circuitry 1330 may also include synthesizer circuitry 1334 for synthesizing a frequency for use by the mixer circuitry 1331 of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1331 of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 1340 based on the synthesized frequency provided by synthesizer circuitry 1334. The amplifier circuitry 1332 may be configured to amplify the down-converted signals and the filter circuitry 1333 may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 1320 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 1331 of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 1331 of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1332 to generate RF output signals for the FEM circuitry 1340. The baseband signals may be provided by the baseband circuitry 1320 and may be filtered by filter circuitry 1333. The filter circuitry 1333 may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 1331 of the receive signal path and the mixer circuitry 1331 of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 1331 of the receive signal path and the mixer circuitry 1331 of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 1331 of the receive signal path and the mixer circuitry 1331 may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 1331 of the receive signal path and the mixer circuitry 1331 of the transmit signal path may be configured for super-heterodyne operation.

In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 1330 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1320 may include a digital baseband interface to communicate with the RF circuitry 1330.

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

In some embodiments, the synthesizer circuitry 1334 may be a fractional-N synthesizer or a fractional N/N+l synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 1334 may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

The synthesizer circuitry 1334 may be configured to synthesize an output frequency for use by the mixer circuitry 1331 of the RF circuitry 1330 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1334 may be a fractional N/N+l synthesizer.

In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 1320 or the applications processor 1310 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 1310.

Synthesizer circuitry 1334 of the RF circuitry 1330 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+l (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

In some embodiments, synthesizer circuitry 1334 may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 1330 may include an IQ/polar converter.

FEM circuitry 1340 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 1350, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1330 for further processing. FEM circuitry 1340 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 1330 for transmission by one or more of the one or more antennas 1350.

In some embodiments, the FEM circuitry 1340 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1330). The transmit signal path of the FEM circuitry 1340 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1330), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1350).

In some embodiments, the electronic device 1300 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

In some embodiments where the electronic device 1300 is, implements, is incorporated into, or otherwise implements a base station, such as an eNB, the baseband circuitry 1320 may be to identify based on information from the communication a first association of a first local component of a Radio Access Network and a second remote component of the RAN. The first association may correspond to a network slice. The baseband circuitry 1320 may be to identify based on information of the same or a different communication of the at least one communication a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice. The second association may be based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement. The RF circuitry 1330 may be to receive from at least one communication originating from a network virtualization component and/or software defined network.

In some embodiments where the electronic device 1300 is, implements, is incorporated into, or otherwise implements a UE, the RF circuitry 1330 may be to receive at least one communication originating from a network virtualization component and/or software defined network. The baseband circuitry 1320 may be to identify based on information from the communication a first association of a first local component of a Radio Access Network and a second remote component of the RAN. The first association may correspond to a network slice. The baseband circuitry 1320 may be to identify based on information from the communication a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN. The second association may correspond to the network slice. The second association may be based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement.

As herein described, the terms mobile network, wireless network and wireless communication network discuss and describe the same sort of network.

In some embodiments, the electronic device of Figure 13 may be to perform one or more processes, techniques, and/or methods as described herein, or portions thereof. One such process is depicted in Figure 14, for example an aspect on slice-based operation in 5G networks with end-to-end network slicing. For example, the process may include identifying a first association of a first local component of a Radio Access Network and a second remote component of the RAN, the first association corresponding to a network slice. The process may further include identifying a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice. In an example, the second association may be based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement. Another such process is depicted in Figure 15, for example a method of operating a UE for aspects on slice-based operation in 5G networks with end-to-end network slicing.

For example, the process may include identifying at a UE a first association of a first local component of a Radio Access Network and a second remote component of the RAN, the first association corresponding to a network slice. The process may further include identifying at a UE a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice. In an example, the second association may be based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement.

Figure 15 shows a second example method 1500 of wireless communication for a fifth generation (5G) system, such as a wireless network. The method comprises identifying at a UE a first association of a first local component of a Radio Access Network and a second remote component of the RAN, the first association corresponding to a network slice 1510, and identifying at a UE a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice 1520. The second association may be based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement.

Figure 16 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 machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, Figure 16 shows a diagrammatic representation of hardware resources 1600 including one or more processors (or processor cores) 1610, one or more memory/storage devices 1620, and one or more communication resources 1630, each of which are communicatively coupled via a bus 1640.

The processors 1610 (e.g., 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 digital signal processor (DSP) such as a baseband processor, an application specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor 1612 and a processor 1614. The memory/storage devices 1620 may include main memory, disk storage, or any suitable combination thereof.

The communication resources 1630 may include interconnection and/or network interface components or other suitable devices to communicate with one or more peripheral devices 1604 and/or one or more databases 1606 via a network 1608. For example, the communication resources 1630 may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components.

Instructions 1650 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 1610 to perform any one or more of the methodologies discussed herein. The instructions 1650 may reside, completely or partially, within at least one of the processors 1610 (e.g., within the processor's cache memory), the memory/storage devices 1620, or any suitable combination thereof. Furthermore, any portion of the instructions 1650 may be transferred to the hardware resources 1600 from any combination of the peripheral devices 1604 and/or the databases 1606. Accordingly, the memory of processors 1610, the memory/storage devices 1620, the peripheral devices 1604, and the databases 1606 are examples of computer-readable and machine-readable media.

Other methods of wireless communication are also disclosed, as discussed above with reference to Figure 8 to 12, for example.

Embodiments can be realized according to any of the following examples taken jointly and severally in any and all permutations:

Figure 14 shows a first example method 1400 of wireless communication for a fifth generation (5G) system, such as a wireless network. Example 1 may include a method of wireless communication for a fifth generation (5G) system, such as a wireless network, comprising: identifying a first association of a first local component of a Radio Access Network (RAN) and a second remote component of the RAN, the first association corresponding to a network slice 1420; and identifying a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice; wherein the second association is based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement.

Example 2 may include the example of example 1 or some other example herein, further comprising: identifying an association of a control-plane slice of the network slice; and identifying an association of a user-plane slice of a plurality of user-plane slices and the control-plane slice.

Example 3 may include the example of example 1 or some other example herein, further comprising: identifying an association of a control-plane slice of the network slice; and identifying an association of a single user-plane slice and the control-plane slice.

Example 4 may include the example of example 1 or some other example herein, further comprising: identifying an association of a common control-plane slice of the network slice; and identifying an association of a user-plane slice of a plurality of user-plane slices and the common control-plane slice; and identifying an association of a splice-specific control-plane of a plurality of slice-specific control-planes and the common control-plane slice.

Example 5 may include the example of example 1 or some other example herein, further comprising: determining whether to change a power state of the first component or the second component based on at least one of a traffic load associated with the network slice exceeding or dropping below a threshold, a number of active UEs operating on the network slice exceeding or dropping below a threshold, to maintain service continuality of a moving UE, or to meet a particular QoS requirement (e.g., low latency, ultra-reliability, or the like, or combinations thereof).

Example 6 may include the example of example 5 or some other example herein, further comprising: determining whether to change a power state of the first component or the second component based on a received control signal; wherein the control signal originates from at least one of a UE (and includes an indication on an intended slice during a random access) or a peer base station / access point (BS/AP) (and includes a triggering message to request slice power state change at the targeted BS).

Example 7 may include the example of example 5 or some other example herein, further comprising: transmitting a signal to at least one of a remote AP/BS or the Mobility Management Entity (MME)/network control entity to exchange signaling responsive to determining to change the power state of the first component or the second component.

Example 8 may include the example of example 6 or some other example herein, wherein the control signal is received over an UE interface (e.g. the control signal originates from the UE), and the method further comprises: determining whether to maintain a power state of the first component or the second component based on traffic monitoring responsive to receiving the control signal.

Example 9 may include the example of example 6 or some other example herein, wherein the control signal is received over an UE interface, and the method further comprises: determining whether to maintain a power state of the first component or the second component based on a QoS criterion responsive to receiving the control signal.

Example 10 may include the example of example 1 or some other example herein, further comprising: determining whether to change a power state of the first component or the second component based on at least one of a UE report on the neighboring cell condition or the traffic load/number of connection condition on the network slice.

Example 11 may include the example of example 5 or 10 or some other example herein, further comprising: handing over an active UE on the slice to a neighboring BS in response to determining to change the power state of the first component or the second component.

Example 12 may include the example of example 5 or 10 or some other example herein, further comprising: transmitting or receiving system information carrying information on active slices in a BS.

Example 13 may include the example of example 1 or some other example herein, further comprising: determining whether to change a power state of the first component or the second component based a signal exchange among a plurality of BS or between a BS of the plurality of a central controller of the plurality of BSs.

Example 14 may include the example of example 13 or some other example herein, further comprising, transmitting or receiving signaling indicating load conditions on each of a plurality of network slices including the network slice to or from an AP or BS.

Figure 15 shows example 15 of a method 1500 of wireless communication for a fifth generation (5G) system, such as a wireless network. Example 15 may include a method of wireless communication for a fifth generation (5G) system, comprising: identifying at a UE a first association of a first local component of a Radio Access Network and a second remote component of the RAN, the first association corresponding to a network slice 1510; and identifying at a UE a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice; wherein the second association is based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement 1520.

Example 16 may include the example of example 15 or some other example herein, further comprising: determining whether to access a BS based on at least one of a power state of a BS of an intended slice, the link condition, QoS requirement, or traffic load of neighboring cells.

Example 17 may include the example of example 15 or some other example herein, further comprising: maintaining a connection to the network slice and another network slice of a different AP or BS than the network slice at a same time.

Example 18 may include an apparatus, (e.g. an electronic device of any network device including but not limited to an eNB) operable in a wireless communication for a fifth generation (5G) system, such as a wireless network, the apparatus comprising: radio frequency (RF) circuitry to receive at least one communication originating from a network virtualization component and/or software defined network; and baseband circuitry to: identify based on information from the communication a first association of a first local component of a Radio Access Network (RAN) and a second remote component of the RAN, the first association corresponding to a network slice; and identify based on information of the same or a different communication of the at least one communication a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice; wherein the second association is based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement.

Example 19 may include the example of example 18 or some other example herein, wherein the baseband circuitry is to: identify an association of a control-plane slice of the network slice; and identify an association of a user-plane slice of a plurality of user-plane slices and the control-plane slice.

Example 20 may include the example of example 18 or some other example herein, wherein the baseband circuitry is to: identify an association of a control-plane slice of the network slice; and identify an association of a single user-plane slice and the control-plane slice.

Example 21 may include the example of example 18 or some other example herein, wherein the baseband circuitry is to: identify an association of a common control-plane slice of the network slice; and identify an association of a user-plane slice of a plurality of user-plane slices and the common control-plane slice; and identify an association of a splice-specific control-plane of a plurality of slice-specific control-planes and the common control-plane slice.

Example 22 may include the example of example 18 or some other example herein, wherein the baseband circuitry is to: determine whether to change a power state of the first component or the second component based on at least one of a traffic load associated with the network slice exceeding or dropping below a threshold, a number of active UEs operating on the network slice exceeding or dropping below a threshold, to maintain service continuality of a moving UE, or to meet a particular QoS requirement (e.g., low latency, ultra-reliability, or the like, or combinations thereof).

Example 23 may include the example of example 22 or some other example herein, wherein the baseband circuitry is to: determine whether to change a power state of the first component or the second component based on control signal received by the RF circuitry; wherein the control signal originates from at least one of a UE (and includes an indication on an intended slice during a random access) or a peer BS/AP (and includes a triggering message to request slice power state change at the targeted BS).

Example 24 may include the example of example 22 or some other example herein, wherein the baseband circuitry is to: transmit a signal to at least one of a remote AP/BS or the MME/network control entity to exchange signaling responsive to determining to change the power state of the first component or the second component.

Example 25 may include the example of example 23 or some other example herein, wherein the control signal is received over an UE interface, and wherein the baseband circuitry is to: determine whether to maintain a power state of the first component or the second component based on traffic monitoring responsive to receiving the control signal.

Example 26 may include the example of example 23 or some other example herein, wherein the control signal is received over an UE interface, and wherein the baseband circuitry is to: determine whether to maintain a power state of the first component or the second component based on a QoS criterion responsive to receiving the control signal.

Example 27 may include the example of example 18 or some other example herein, wherein the baseband circuitry is to: determine whether to change a power state of the first component or the second component based on at least one of a UE report on the neighboring cell condition or the traffic load/number of connection condition on the network slice.

Example 28 may include the example of example 22 or 27 or some other example herein, wherein the baseband circuitry is to: handover an active UE on the slice to a neighboring BS in response to determining to change the power state of the first component or the second component.

Example 29 may include the example of example 22 or 27 or some other example herein, wherein the baseband circuitry is to cause the RF circuitry to transmit system information carrying information on active slices in a BS or the RF circuitry is to receive system information carrying information on active slices in a BS.

Example 30 may include the example of example 18 or some other example herein, wherein the baseband circuitry is to: determine whether to change a power state of the first component or the second component based a signal exchange among a plurality of BS or between a BS of the plurality of a central controller of the plurality of BSs.

Example 31 may include the example of example 30 or some other example herein, wherein the baseband circuitry is to cause the RF circuitry to, transmit signaling indicating load conditions on each of a plurality of network slices including the network slice to or from an AP or BS, or the RF circuitry is to receive signaling indicating load conditions on each of a plurality of network slices including the network slice to or from an AP or BS.

Example 32 may include an apparatus (e.g. an electronic device of user equipment operable in a wireless communication for a fifth generation (5G) system), the apparatus comprising: radio frequency (RF) circuitry to receive from at least one communication originating from a network virtualization component and/or software defined network; and baseband circuitry to: identify based on information from the communication a first association of a first local component of a radio access network (RAN) and a second remote component of the RAN, the first association corresponding to a network slice; and identify based on information from the communication a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice; wherein the second association is based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement.

Example 33 may include the example of example 32 or some other example herein, wherein the baseband circuitry is to: determine whether to access a BS based on at least one of a power state of a BS of an intended slice, the link condition, QoS requirement, or traffic load of neighboring cells.

Example 34 may include the example of example 32 or some other example herein, wherein the baseband circuitry is to: maintain a connection to the network slice and another network slice of a different AP or BS than the network slice at a same time.

Example 35 may include the example of any of examples 1 to 34, or some other example herein, wherein a network slice comprises any one or more of: a logical partition of a physical radio access network infrastructure for or in exclusive use of a single type of communication; a logical partition of a physical radio access network infrastructure for or in exclusive use by communications of a specific use-case of communication; a logical partition of a physical radio access network infrastructure having self-contained operation and traffic flow independent of operation and traffic flow on any other logical partition of the physical radio access network infrastructure. An advantage of this example, and other examples described herein, is a more efficient wireless network, for example because, it allows a given amount of (e.g. a single) physical radio access network infrastructure to be used by multiple use-cases, thereby resulting in less hardware/infrastructure than would otherwise be used (e.g. double, or more, hardware, for example to provide separate physical radio access network infrastructure for each use case).

Example 36 may include the example of any of examples 1 to 35, or some other example herein, wherein a network slice is an end-to-end network slice, wherein end-to-end comprises logical separation of both a physical radio access network infrastructure and a physical core network infrastructure in use to provide the network slice.

Example 37 may include the example of any of examples 1 to 36, or some other example herein, wherein a specific use-case of communication includes any readily definable/distinguishable type of communication that can be carried out over a wireless network.

Example 38 may include the example of any of examples 1 to 37, or some other example herein, wherein a network slice comprises a logically separate radio access network carried over a shared physical radio access network (RAN).

Example 39 may include the example of any of examples 1 to 38, or some other example herein, wherein the network slices comprises a vertical slice per use-case and/or a horizontal slice per shared resource, wherein a shared resource is a shared layer of the radio access network or a resources shared between select ones of entities in different layers of the wireless network.

Example 40 may include a radio access network (RAN) control entity comprising circuitry to: logically separate a physical infrastructure of the radio access network into two or more logically separated virtual radio access networks, wherein a logically separated virtual radio access network comprises a radio access network optimized for a predefined type of communication and wherein the logically separated virtual access network comprises self-contained operation and traffic flow independent of operation and traffic flow on any other logically separated virtual access network; wherein each of the two or more logically separated virtual access networks are dynamically configured, according to at least one parameter associated with the predefined type of communication to be used for each of the two or more logically separated virtual access networks; wherein the at least one parameter associated with the predefined type of communication is at least one of: a traffic type of the predefined type of communication, a traffic load of the predefined type of communication, a quality of service requirement of the predefined type of communication.

Example 41 may include the example of example 40, or some other example herein, wherein to logically separate a physical infrastructure of the radio access network into two or more logically separated virtual radio access networks comprises to turn-on or activate a logically separated virtual access network.

Example 42 may include the example of examples 40 or 41, or some other example herein, wherein a turn-on or activation of a logically separated virtual access network comprises any one or more of: when triggered by a device served by the wireless network, the device transmits an indication of an intended logically separated virtual access network to use in an initial random access (RA); when triggered by a peer access point (AP) or base station (BS), the peer access point (AP) or base station (BS) transmits a triggering message to a target access point (AP) or base station (BS), said triggering message including a request for turn-on or activation of a specified logically separated virtual access network; a signaling exchange between an access point (AP) or base station (BS), and a Mobility Management Entity (MME) or network control entity associated with the physical radio access network, to determine configuration parameters of a logically separated virtual access network to use, turn-on or activate.

Example 43 may include the example of examples 40-42, or some other example herein, wherein the traffic load of the predefined type of communication comprises any one or more of: exceeding a predefined threshold level of traffic at an access point (AP) or base station (BS); exceeding a predefined number of active devices operating on an already existing logically separated virtual access network

Example 44 may include the example of examples 40-43, or some other example herein, wherein the quality of service requirement of the predefined type of communication comprises or is based upon any one or more of: maintaining a service continuity of a moving device served by a radio access network and wherein the device is active in using the predefined type of communication; providing a predetermined maximum latency of the predefined type of communication; providing a predetermined minimum reliability of communication of the predefined type of communication; providing a predetermined minimum data rate for the predefined type of communication.

Example 45 may include the example of examples 40-44, or some other example herein, wherein the circuitry is further to: turn off, or logically de-separate, a logically separated virtual access network based upon at least one further parameter associated with the predefined type of communication, wherein the at least one further parameter is based on at least one of: a level of traffic at an access point (AP) or base station (BS) falling below a predefined threshold; a number of active devices operating on an already existing logically separated virtual access network falling below a predefined threshold; a data report on a or the logically separated virtual access network, or a condition of a neighboring cell, base station or access point.

Example 46 may include the example of example 45, or some other example herein, wherein a data report comprises a system information block or portions thereof.

Example 47 may include the example of examples 45-46, or some other example herein, wherein a data report comprises a system information block, or portions thereof, carrying information on active logically separated virtual access network(s).

Example 48 may include the example of examples 40-47, or some other example herein, wherein, when a logically separated virtual access network is de-separated or turned off, the circuitry is further to: handover any devices remaining on the logically separated virtual access network to another different logically separated virtual access network operating on a same base station or access point; or handover any devices remaining on the logically separated virtual access network to another base station or access point maintaining operation of a same logically separated virtual access network to be turned-off

Example 49 may include the example of examples 40-48, or some other example herein, wherein a device to be served by a radio access network comprises a user equipment (UE).

Example 50 may include the example of examples 40-49, or some other example herein, wherein the device to be served or UE is to determine whether and how to access a logically separated virtual access network based on any one or more of: an indication that a selected logically separated virtual access network is currently active on a serving access point (AP) or base station (BS) currently serving the UE; a link condition of a wireless link between the UE and the serving access point (AP) or base station (BS) currently serving the UE; a QoS requirement of a wireless communication provided to the UE; or a traffic load between neighboring access points (APs) or base stations (BSs) to the access points (APs) or base stations (BSs) currently serving the UE.

Example 51 may include the example of examples 40-50, or some other example herein, wherein signaling between devices being served by, or the serving access points (APs) or base stations (BSs) serving the device is operable to assist a one of the access points (APs) or base stations (BSs) to determine whether to instigate a logically separated virtual access network turn-on procedure or a logically separated virtual access network turn-off procedure.

Example 52 may include the example of examples 40-51, or some other examples herein, wherein the signaling comprises signaling of load conditions on each active logically separated virtual access network between the access points (APs) or base stations (BSs) serving the devices, to provide the respective logically separated virtual access network(s).

Example 53 may include the example of examples 40-52, or some other examples herein, wherein a device served by the radio access network is operable to maintain active connections to multiple logically separated virtual access networks and/or to multiple access points (APs) or base stations (BSs) serving the devices to provide the logically separated virtual access network(s).

Example 54 may include the example of examples 40-53, or some other examples herein, wherein to logically separate the physical infrastructure of the radio access network into two or more logically separated virtual access networks comprises providing two or more network slices, and wherein the control entity provides control plane and user plane configurations for the two or more network slices, wherein the control plane and user plane configurations comprise any one of: a network-slice-specific user plane for each operational network slice and a single common control plane for use by all operational network slices, wherein the control plane and user plane functions of a particular network slice are decoupled from one another; or a network-slice-specific user plane for each operational network slice and a network-slice-specific control plane, wherein the control plane and user plane functions of a particular network slice are coupled to one another; or a network-slice-specific control plane for each operational network slice, and a control plane for each operational network slice comprising: a first, common, control plane portion; and a second, network-slice-specific, control plane portion; wherein the control plane and user plane functions of a particular network slice are partially decoupled from one another and partially coupled to one another.

Example 55 may include machine executable instructions arranged, when executed by one or more than one processor, to implement a method in a wireless communications network comprising: logically separating a physical infrastructure of the radio access network into two or more logically separated virtual radio access networks, wherein a logically separated virtual radio access network comprises a radio access network optimized for a predefined type of communication and wherein the logically separated virtual access network comprises self-contained operation and traffic flow independent of operation and traffic flow on any other logically separated virtual access network; dynamically configuring each of the two or more logically separated virtual access networks according to at least one parameter associated with the predefined type of communication to be used for each of the two or more logically separated virtual access networks; wherein the at least one parameter associated with the predefined type of communication is at least one of: a traffic type of the predefined type of communication, a traffic load of the predefined type of communication, a quality of service requirement of the predefined type of communication.

Example 56 may include the example of example 55, or some other example herein, wherein logically separating a physical infrastructure of the radio access network into two or more logically separated virtual radio access networks comprises turning-on a logically separated virtual access network.

Example 57 may include the example of examples 55 or 56, or some other example herein, wherein turning-on of a logically separated virtual access network comprises any one or more of: transmitting an indication of an intended logically separated virtual access network to use in an initial random access (RA), when triggered by a device served by the wireless network; transmitting a triggering message to a target access point (AP) or base station (BS) from a peer access point (AP) or base station (BS), when triggered by a peer access point (AP) or base station (BS), said triggering message including a request for turning-on of a specified logically separated virtual access network; exchanging signaling between an access point (AP) or base station (BS), and a Mobility Management Entity (MME) or network control entity associated with the physical radio access network, to determine configuration parameters of a logically separated virtual access network to use, turn-on or activate.

Example 58 may include the example of examples 55-57, or some other example herein, wherein the traffic load of the predefined type of communication comprises any one or more of: exceeding a predefined threshold level of traffic at an access point (AP) or base station (BS); exceeding a predefined number of active devices operating on an already existing logically separated virtual access network.

Example 59 may include the example of examples 55-58, or some other example herein, wherein the quality of service requirement of the predefined type of communication comprises or is based upon any one or more of: maintaining a service continuity of a moving device served by a radio access network and wherein the device is active in using the predefined type of communication; providing a predetermined maximum latency of the predefined type of communication; providing a predetermined minimum reliability of communication of the predefined type of communication; providing a predetermined minimum data rate for the predefined type of communication.

Example 60 may include the example of examples 55-59, or some other example herein, further comprising: turning off, or logically de-separating a logically separated virtual access network based upon at least one further parameter associated with the predefined type of communication, wherein the at least one further parameter is based on at least one of: a level of traffic at an access point (AP) or base station (BS) falling below a predefined threshold; a number of active devices operating on an already existing logically separated virtual access network falling below a predefined threshold; a data report on a or the logically separated virtual access network, or a condition of a neighboring cell, base station or access point.

Example 61 may include the example of example 60, or some other example herein, wherein a data report comprises a system information block or portions thereof.

Example 62 may include the example of examples 60 or 61, or some other example herein, wherein a data report comprises a system information block, or portions thereof, carrying information on active logically separated virtual access network(s).

Example 63 may include the example of examples 55-62, or some other example herein, wherein, when a logically separated virtual access network is de-separated or turned off, the method further comprises: handing over any devices remaining on the logically separated virtual access network to another different logically separated virtual access network operating on a same or different base station or access point; or handing over any devices remaining on the logically separated virtual access network to another base station or access point maintaining operation of a same logically separated virtual access network to be turned-off at current base station.

Example 64 may include the example of examples 55-63, or some other example herein, wherein a device to be served by a radio access network comprises a user equipment (UE).

Example 65 may include the example of examples 55-64, or some other example herein, further comprising the device to be served or UE determining whether and how to access a logically separated virtual access network based on any one or more of: an indication that a selected logically separated virtual access network is currently active on a serving access point (AP) or base station (BS) currently serving the UE; a link condition of a wireless link between the UE and the serving access point (AP) or base station (BS) currently serving the UE; a QoS requirement of a wireless communication provided to the UE; or a traffic load between neighboring access points (APs) or base stations (BSs) to the access points (APs) or base stations (BSs) currently serving the UE.

Example 66 may include the example of examples 55-65, or some other example herein, wherein signaling between devices being served by, or the serving access points (APs) or base stations (BSs) serving the device is operable to assist a one of the access points (APs) or base stations (BSs) to determine whether to instigate a logically separated virtual access network turn-on procedure or a logically separated virtual access network turn-off procedure.

Example 67 may include the example of examples 55-66, or some other example herein, wherein the signaling comprises signaling of load conditions on each active logically separated virtual access network between the access points (APs) or base stations (BSs) serving the devices, to provide the respective logically separated virtual access network(s).

Example 68 may include the example of examples 55-67, or some other example herein, further comprising the device served by the radio access network(s) maintaining active connections to multiple logically separated virtual access networks and/or to multiple access points (APs) or base stations (BSs) serving the devices to provide the logically separated virtual access network(s).

Example 69 may include the example of examples 55-68, or some other example herein, wherein logically separating the physical infrastructure of the radio access network into two or more logically separated virtual access networks comprises providing two or more network slices, and the method further comprises providing control plane and user plane configurations for the two or more network slices, wherein the control plane and user plane configurations comprise any one of: a network-slice-specific user plane for each operational network slice and a single common control plane for use by all operational network slices, wherein the control plane and user plane functions of a particular network slice are decoupled from one another; or a network-slice-specific user plane for each operational network slice and a network-slice-specific control plane, wherein the control plane and user plane functions of a particular network slice are coupled to one another; or a network-slice-specific control plane for each operational network slice, and a control plane for each operational network slice comprising: a first, common, control plane portion; and a second, network-slice-specific, control plane portion; wherein the control plane and user plane functions of a particular network slice are partially decoupled from one another and partially coupled to one another.

Example 70 may include a device to trigger network slicing in a radio access network comprising: circuitry to trigger turn on or turn off of a network slice in accordance with any one or more of: traffic load of a radio access network or a traffic load of a network slice of the radio access network crossing a threshold traffic load, optionally wherein the threshold traffic load is the traffic load at an access point (AP) or base station (BS) in the radio access network (RAN); and/or a number of active user equipments (UEs) operating on a radio access network or a network slice of the radio access network crossing a threshold number of active UEs; in accordance with maintaining a service continuality requirement of a moving UE in use on the radio access network or in use on a network slice of the radio access network; in accordance with meeting or maintaining a quality of service (QoS) requirement of a device in use on the radio access network or in use on a network slice of the radio access network, optionally wherein the QoS requirement includes but is not limited to an amount of latency of a wireless connection of the radio access network or network slice or a level of reliability of a wireless connection of the radio access network or network slice.

Advantages of example 70, or the other examples described herein, may include improved radio access network performance, efficiency, reliability, maintaining of service and quality of service, for all devices operating across the RAN, and within each slice of the RAN.

Example 71 may include the example of examples 70, or some other example herein, wherein a network slice is turned on at the access point (AP) or base station (BS), and wherein a trigger for turn-on of the network slice comprises: receiving a UE trigger signal from a UE, said UE trigger signal including an indication of an intended network slice for use by the UE, optionally wherein the UE trigger signal is included in a random access of the UE; or receiving, by a target access point (AP) or target base station (BS), a trigger signal from a peer access point (AP) or peer base station (BS), said trigger signal including a request for a network slice turn on at the target access point (AP) or base station (BS).

Example 72 may include the example of examples 70 or 71, or some other example herein, wherein turn-on of a network slice comprises an exchange of signaling between the access point (AP) or base station (BS) and a mobility management entity (MME) or network control entity, in order to turn-on the network slice.

Example 73 may include the example of examples 70-72, or some other example herein, wherein, in a traffic-load motivated network slice turn-on, an access point (AP) or base station (BS) only turns on a network slice when the access point (AP) or base station (BS) receives a sufficient amount of traffic to make the network slice turn-on worthwhile, wherein a sufficient amount of traffic is a predetermined value.

Example 74 may include the example of examples 70-73, or some other example herein, wherein if the amount of traffic is insufficient, the access point (AP) or base station (BS) refuses a random access (RA) request from a requesting entity.

Example 75 may include the example of examples 70-74, or some other example herein, wherein, in a QoS motivated network slice turn-on, an access point (AP) or base station (BS) only turns on a network slice when the access point (AP) or base station (BS) receives a QoS service request meeting a predefined criterion.

Example 76 may include a base station (BS) apparatus operable in a wireless communication network, the apparatus comprising: radio frequency (RF) circuitry to receive at least one communication originating from a wireless network device or transmit at least one communication to a wireless network device; and a radio access network control entity according to any of examples 40 to 54; or a device comprising means for, or modules to carry out, any of examples 55 to 69; or the device of any of examples 70 to 75; or some other example herein.

Example 77 may include a user equipment (UE) apparatus operable in a wireless communication network, the apparatus comprising: radio frequency (RF) circuitry to receive or transmit at least one communication to another device in the wireless communication network; and a radio access network control entity according to any of examples 40 to 54; or a device comprising means for, or modules to carry out, any of examples 55 to 69; or the device of any of examples 70 to 75; or some other example herein.

Example 78 may include an apparatus comprising means to perform one or more elements of a method described in or related to any of examples 1-17, 35-39, 55-69, or any other method or process described herein.

Example 79 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 1-17, 35-39, 55-69, or any other method or process described herein, or to provide the functionality of the apparatus or device according to any of claims 18-54 or 70-75.

Example 80 may include an apparatus comprising logic, modules, means for and/or circuitry to perform one or more elements of a method described in or related to any of examples 1-17, 35-39, 55-69, or any other method or process described herein.

Example 81 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 1-17, 35-39, 55-69, or any other method or process described herein.

Example 82 may include a method of communicating in a wireless network as shown and described herein.

Example 83 may include a system for providing wireless communication as shown and described herein.

Example 84 may include a device for providing wireless communication as shown and described herein.

Example 85 may include a device to enable network slicing in a radio access network comprising any combination of the devices, entities or methods described herein, or portions of the devices, entities or methods described herein.

Example 86 may include a radio access network comprising any combination of the devices, entities or methods described herein, or portions of the devices, entities or methods described herein.

Example 87 may include a device for use in a radio access network comprising any combination of the devices, entities or methods described herein, or portions of the devices, entities or methods described herein.

Examples use-cases/types of communications may include: Wireless/Mobile Broadband (MBB) communications; Extreme Mobile Broadband (E-MBB) communications; Real-time use-case such as Industrial Control communications, Machine-to-Machine communications (MTC/MTC1); non-real-time use-case, such as Internet-of-Things (IoT) sensors communications, or massive-scale Machine-to-Machine communications (M-MTC/MTC2); Ultra Reliable Machine-to-Machine communications (U-MTC); Mobile Edge Cloud, e.g. caching, communications; Vehicle-to-Vehicle (V2V) communications; Vehicle-to-Infrastructure (V2I) communications; Vehicle-to-any thing communications (V2X). This is to say, the present disclosure relates to providing network slicing according to any readily definable/distinguishable type of communication that can be carried out over a wireless network.

In some examples, the RAN control entity is distributed across portions of the RAN. In some examples, the portions of RAN are the base stations (e.g. eNBs) of the RAN, in others, the portion(s) of the RAN may be a UE, or any other device being or to be served by the wireless network/RAN, or forming part of (or serving) the same, e.g. mobility management engine (MME), baseband unit (BBU), remote radio head (RRH) or, etc. In some examples, if the RAN control entity is physically distributed, the RAN control entity can be collocated with the macro BS, and only manage the slice portions that under the coverage of the macro BS. In some examples, if the RAN control entity is in a central location, the RAN control entity can manage a slice portion across multiple BSs which are under the coverage of the RAN control entity. The RAN control entity may comprise at least a portion controlling allocation of RAN, or device, resources according to a need of the one or more horizontal or vertical slices, for example computational resources at/in, or available to, a device in the wireless network.

As herein described, where an example or claim recites RF circuitry, for example, to form a greater entity within the wireless network, e.g. a base station, this is also intended to cover the or an alternative embodiment which does not include the RF circuitry, for example for use in (or to provide) a distributed form of entity according to the disclosure. This may be applicable, for example, when the entity forms part of a Cloud RAN, where the radio portions (e.g. RRH) are not co-located/within the same entity as at least a significant portion of the control function (entity, module, etc.) , e.g. BBU. Thus, no embodiments are intended to be restricted to only those having an RF portion that sends or receives messages to or form the wireless network. For example, some implementations may be part of front-haul capabilities, which may be the connections to radio front ends (e.g. RRHs) from a centralized, or more centralized baseband function (e.g. BBU).

As used herein, any reference to computer program product or computer readable medium, may include reference to both transitory (e.g. physical media) and non-transitory forms (e.g. signals or data structures thereof).

Various examples disclosed herein may provide many advantages, for example, but not limited to: providing full(er) coverage for the devices being served, for any given amount of core network and/or RAN resources (e.g. computing, radio, etc); less control signaling delay and signaling exchange overhead among transmission points; providing improved coverage and at the same time reducing control signaling exchange among network nodes (inc. transmission points); a more efficient (overall, or substantial portion of a) wireless network, for example because, it allows a given amount of (e.g. a single) physical radio access network infrastructure to be used by multiple use-cases, thereby resulting in less hardware/infrastructure than would otherwise be used (e.g. double, or more, hardware, for example to provide separate physical radio access network infrastructure for each use case); generally improved radio access network performance, efficiency, reliability, maintaining/maintenance of service and quality of service, for all devices operating across the RAN, and within each slice of the RAN.

As herein described, turn-on, activation or logical separation, or the like, of the, or a, network slice may be equivalent to one another, and the terms used inter-changeably. Similarly, the turn-off, deactivation or logical desperation, or the like, of a network slice may all be equivalent to one another, and the terms used inter-changeably. A network slice may also be referenced as a logically separate (separated, partitioned, etc.) radio network access, or as a logically separate (separated, partitioned, etc.) radio network access portion. A device being, or to be served by the physical radio access network infrastructure, or a network slice may include a UE, however any and all other forms of devices that may be served are also interchangeable with a reference to a UE herein. A device may be referenced as a wireless network device. However, a wireless network device as used herein may also reference a serving entity, such as base station, MME, BBU, RRH, etc., dependent on context of use. Operationally, in terms of the disclosed network slicing, an access point and base station may be considered similar in use or deployment.

As herein described, specific examples have been used to explain the disclosed methods and functions (and function units that carry out those functions), however, the disclosure is not so limited. For example, embodiments of the disclosure is/are not limited to any specific example, such as: where a specific vertical market is disclosed in relation to a Figure, this is only an example, and any vertical market may be used instead; where a specific portion of a slice is disclosed in relation to a Figure, any portion of a slice may be used instead; where a RAN has been disclosed as having a certain size, type or number of slices (horizontal or vertical) in relation to a Figure, any size, type or number of slices may be used instead; where a slice or slice portion has been disclosed as having a certain size, type or number (in the horizontal or the vertical) in relation to a Figure, any size, type or number of slice or slice portion may be used instead. Also, in the foregoing, whilst a numbering scheme for the slices has been applied starting from 1, other numbering schemes may also be implemented, e.g. the numbers may start from 0 instead, such that Slice#l may be Slice#0, and the like. Thus, the specific numbers are not limiting, other than by showing an exemplary distinction between slices (by being differently numbered) or an exemplary relation between numbered slice portions (by being consecutively numbered sub-parts of the same numbered slice).

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

As used herein, any reference to a (RAN) architecture may include anything that may be defined as or thought of as any form of specific process(es), technique(s), technology(ies), implementation detail, improvement in or type of operation of a wireless network (or similar networking system entity), particularly in the RAN. Architectures may be typically introduced, maintained and updated in the standards documents for the respective wireless network technologies in use, for example the third generation partnership project (3GPP) standards, and the like.

It will be appreciated that any of the disclosed methods (or corresponding apparatuses, programs, data carriers, etc.) may be carried out by either a host or client, depending on the specific implementation (i.e. the disclosed methods/apparatuses are a form of communication(s), and as such, may be carried out from either 'point of view', i.e. in corresponding to each other fashion). Furthermore, it will be understood that the terms "receiving" and "transmitting" encompass "inputting" and "outputting" and are not limited to an RF context of transmitting and receiving radio waves. Therefore, for example, a chip or other device or component for realizing embodiments could generate data for output to another chip, device or component, or have as an input data from another chip, device or component, and such an output or input could be referred to as "transmit" and "receive" including gerund forms, that is, "transmitting" and "receiving", as well as such "transmitting" and "receiving" within an RF context.

As used in this specification, any formulation used of the style "at least one of A, B or C", and the formulation "at least one of A, B and C" use a disjunctive "or" and a disjunctive "and" such that those formulations comprise any and all joint and several permutations of A, B, C, that is, A alone, B alone, C alone, A and B in any order, A and C in any order, B and C in any order and A, B, C in any order. There may be more or less than three features used in such formulations.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word 'comprising' does not exclude the presence of other elements or steps then those listed in a claim. Furthermore, the terms "a" or "an," as used herein, are defined as one or more than one. Also, the use of introductory phrases such as "at least one" and "one or more" in the claims should not be construed to imply that the introduction of another claim element by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim element to inventions containing only one such element, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an." The same holds true for the use of definite articles. Unless stated otherwise, terms such as "first" and "second" are used to arbitrarily distinguish between the elements such terms describe. Thus, these terms are not necessarily intended to indicate temporal or other prioritization of such elements. The mere fact that certain measures are recited in mutually different claims does not indicate that a combination of these measures cannot be used to advantage.

Unless otherwise explicitly stated as incompatible, or the physics or otherwise of the embodiments, example or claims prevent such a combination, the features of the foregoing embodiments and examples, and of the following claims may be integrated together in any suitable arrangement, especially ones where there is a beneficial effect in doing so. This is not limited to only any specified benefit, and instead may arise from an "ex post facto" benefit. This is to say that the combination of features is not limited by the described forms, particularly the form (e.g. numbering) of the example(s), embodiment s), or dependency of the claim(s). Moreover, this also applies to the phrase "in one embodiment", "according to an embodiment" and the like, which are merely a stylistic form of wording and are not to be construed as limiting the following features to a separate embodiment to all other instances of the same or similar wording. This is to say, a reference to 'an', 'one' or 'some' embodiment(s) may be a reference to any one or more, and/or all embodiments, or combination(s) thereof, disclosed. Also, similarly, the reference to "the" embodiment may not be limited to the immediately preceding embodiment.

In the foregoing, reference to 'layer' may be a reference to a predefined (or definable) portion of the infrastructure, whereas reference to 'Layer' may be a reference to a network protocol Layer in operation on/in the network infrastructure, or portion thereof. As used herein, a vertical slice may be referenced as or related to a vertical market segment. As used herein, any machine executable instructions may carry out a disclosed method, and may therefore be used synonymously with the term method.

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 the claims to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of various implementations of the disclosure.

CLAIMS:

1. Machine executable instructions arranged, when executed by one or more than one processor, to implement a method of wireless communication for a fifth generation (5G) system, comprising:

identifying a first association of a first local component of a Radio Access Network (RAN) and a second remote component of the RAN, the first association corresponding to a network slice; and

identifying a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice;

wherein the second association is based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement.

2. The machine executable instructions of claim 1, further comprising:

identifying an association of a control-plane slice of the network slice; and

identifying an association of a user-plane slice of a plurality of user-plane slices and the control-plane slice.

3. The machine executable instructions of claim 1, further comprising:

identifying an association of a control-plane slice of the network slice; and

identifying an association of a single user-plane slice and the control-plane slice.

4. The machine executable instructions of claim 1, further comprising:

identifying an association of a common control-plane slice of the network slice;

identifying an association of a user-plane slice of a plurality of user-plane slices and the common control-plane slice; and

identifying an association of a slice-specific control-plane of a plurality of slice-specific control-planes and the common control-plane slice.

5. The machine executable instructions of claim 1, further comprising:

determining whether to change a power state of the first component or the second component based on at least one of a traffic load associated with the network slice exceeding or dropping below a threshold, a number of active user equipments (UEs) operating on the network slice exceeding or dropping below a threshold, to maintain service continuality of a moving user equipment (UE), or to meet a particular QoS requirement (e.g., low latency, ultra-reliability, or the like, or combinations thereof).

6. The machine executable instructions of claim 5, further comprising:

determining whether to change a power state of the first component or the second component based on a received control signal;

wherein the control signal originates from at least one of a UE (and includes an indication on an intended slice during a random access) or a peer base station / access point (BS/AP) (and includes a triggering message to request slice power state change at the targeted BS).

7. The machine executable instructions of claim 5, further comprising:

transmitting a signal to at least one of a remote AP/BS or the mobility management entity (MME)/network control entity to exchange signaling responsive to determining to change the power state of the first component or the second component.

8. The machine executable instructions of claim 6, wherein the control signal is received over an UE interface (e.g. the control signal originates from the UE), and the method further comprises:

determining whether to maintain a power state of the first component or the second component based on traffic monitoring responsive to receiving the control signal.

9. The machine executable instructions of claim 6, wherein the control signal is received over an UE interface, and the method further comprises:

determining whether to maintain a power state of the first component or the second component based on a QoS criterion responsive to receiving the control signal.

10. The machine executable instructions of claim 1, further comprising:

determining whether to change a power state of the first component or the second component based on at least one of a UE report on the neighboring cell condition or the traffic load/number of connection condition on the network slice.

11. The machine executable instructions of claim 5, further comprising:

handing over an active UE on the slice to a neighboring BS in response to determining to change the power state of the first component or the second component.

12. The machine executable instructions of claim 5, further comprising:

transmitting or receiving system information carrying information on active slices in a base station (BS).

13. The machine executable instructions of claim 1, further comprising:

determining whether to change a power state of the first component or the second component based a signal exchange among a plurality of base stations (BSs) or between a base station (BS) of the plurality of a central controller of the plurality of BSs.

14. The machine executable instructions of claim 13, further comprising, transmitting or receiving signaling indicating load conditions on each of a plurality of network slices including the network slice to or from an access point (AP) or a base station (BS).

15. Machine executable instructions arranged, when executed by one or more than one processor, to implement a method of wireless communication for a fifth generation (5G) system, comprising:

identifying at a user equipment (UE) a first association of a first local component of a radio access network (RAN) and a second remote component of the RAN, the first association corresponding to a network slice; and

identifying at a UE a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice;

wherein the second association is based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement.

16. The machine executable instructions of claim 15, further comprising:

determining whether to access a base station (BS) based on at least one of a power state of a BS of an intended slice, the link condition, QoS requirement, or traffic load of neighboring cells.

17. The machine executable instructions of claim 15, further comprising:

maintaining a connection to the network slice and another network slice of a different access point (AP) or base station (BS) than the network slice at a same time.

18. An apparatus for a base station (BS) operable in a wireless communication for a fifth generation (5G) system, the apparatus comprising:

radio frequency (RF) circuitry to receive at least one communication originating from a network virtualization component and/or software defined network; and

baseband circuitry to:

identify based on information from the communication a first association of a first local component of a Radio Access Network (RAN) and a second remote component of the RAN, the first association corresponding to a network slice; and

identify based on information of the same or a different communication of the at least one communication a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice;

wherein the second association is based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement.

19. The apparatus of claim 18, wherein the baseband circuitry is to:

identify an association of a control-plane slice of the network slice; and

identify an association of a user-plane slice of a plurality of user-plane slices and the control-plane slice.

20. The apparatus of claim 18, wherein the baseband circuitry is to:

identify an association of a control-plane slice of the network slice; and

identify an association of a single user-plane slice and the control-plane slice.

21. The apparatus of claim 18, wherein the baseband circuitry is to:

identify an association of a common control-plane slice of the network slice;

identify an association of a user-plane slice of a plurality of user-plane slices and the common control-plane slice; and

identify an association of a slice-specific control-plane of a plurality of slice-specific control-planes and the common control-plane slice.

22. The apparatus of claim 18, wherein the baseband circuitry is to:

determine whether to change a power state of the first component or the second component based on at least one of a traffic load associated with the network slice exceeding or dropping below a threshold, a number of active user equipments (UEs) operating on the network slice exceeding or dropping below a threshold, to maintain service continuality of a moving user equipment (UE), or to meet a particular QoS requirement (e.g., low latency, ultra-reliability, or the like, or combinations thereof).

23. The apparatus of claim 22, wherein the baseband circuitry is to:

determine whether to change a power state of the first component or the second component based on control signal received by the RF circuitry;

wherein the control signal originates from at least one of a UE (and includes an indication on an intended slice during a random access) or a peer base station / access point (BS/AP) (and includes a triggering message to request slice power state change at the targeted BS).

24. The apparatus of claim 22, wherein the baseband circuitry is to:

transmit a signal to at least one of a remote AP/BS or the mobility management entity (MME)/network control entity to exchange signaling responsive to determining to change the power state of the first component or the second component.

25. The apparatus of claim 23, wherein the control signal is received over an UE interface, and wherein the baseband circuitry is to:

determine whether to maintain a power state of the first component or the second component based on traffic monitoring responsive to receiving the control signal.

26. The apparatus of claim 23, wherein the control signal is received over an UE interface, and wherein the baseband circuitry is to:

determine whether to maintain a power state of the first component or the second component based on a QoS criterion responsive to receiving the control signal.

27. The apparatus of claim 18, wherein the baseband circuitry is to:

determine whether to change a power state of the first component or the second component based on:

at least one of a UE report on the neighboring cell condition or the traffic load/number of connection condition on the network slice; or

a signal exchange among a plurality of BS or between a BS of the plurality of a central controller of the plurality of BSs.

28. The apparatus of claim 22, wherein the baseband circuitry is to:

handover an active UE on the slice to a neighboring BS in response to determining to change the power state of the first component or the second component.

29. The apparatus of claim 22, wherein the baseband circuitry is to cause the RF circuitry to transmit system information carrying information on active slices in a BS or the RF circuitry is to receive system information carrying information on active slices in a BS.

30. The apparatus of claim 27, wherein the baseband circuitry is to cause the RF circuitry to:

transmit signaling indicating load conditions on each of a plurality of network slices including the network slice to or from an AP or BS; or

receive signaling indicating load conditions on each of a plurality of network slices including the network slice to or from an AP or BS.

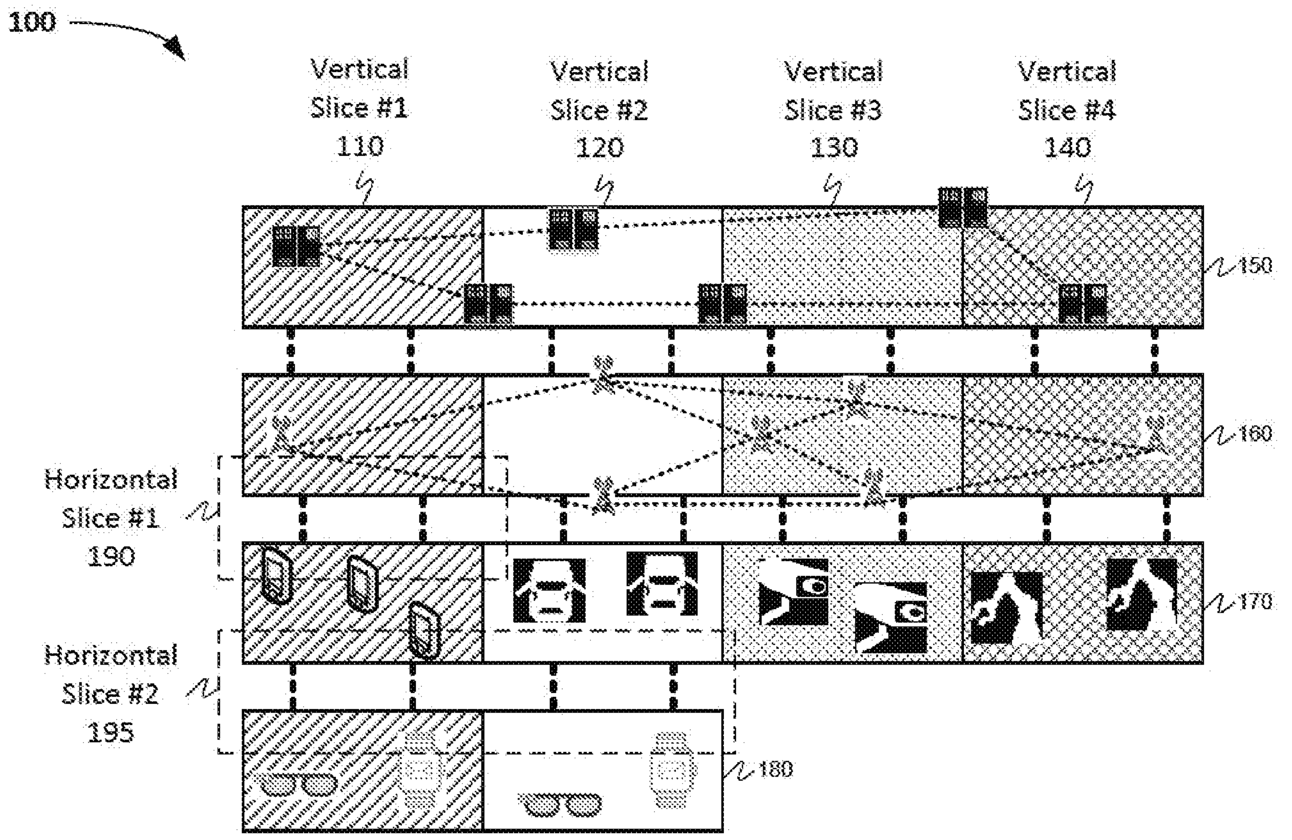
100
Vertical Slice #1 110
Vertical Slice #2 120
Vertical Slice #3 130
Vertical Slice #4 140
150
160
170
180
Horizontal Slice #1 190
Horizontal Slice #2 195

Fig. 1

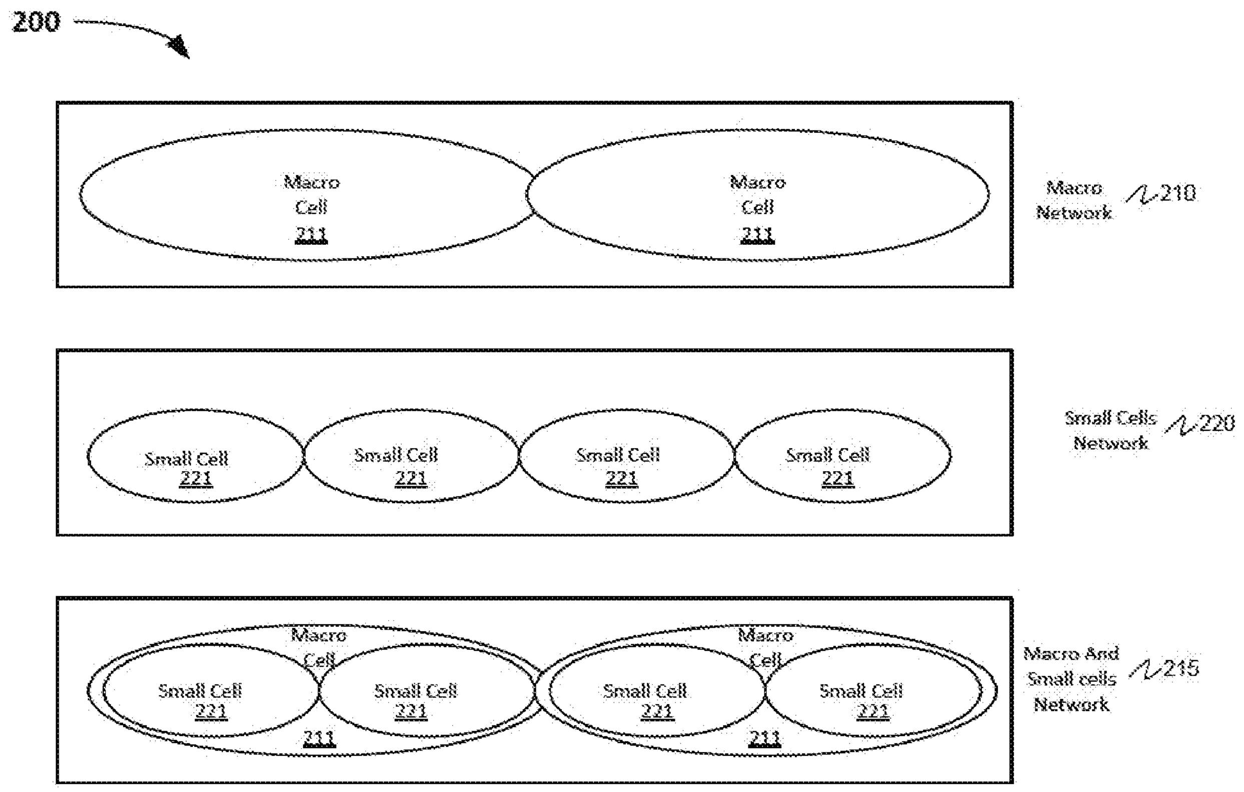
200
Macro Cell 211
Macro Cell 211
Macro Network 210
Small Cell 221
Small Cell 221
Small Cell 221
Small Cell 221
Small Cells Network 220
Macro Cell 211
Small Cell 221
Small Cell 221
Macro Cell 211
Small Cell 221
Small Cell 221
Macro And Small cells Network 215

Fig. 2

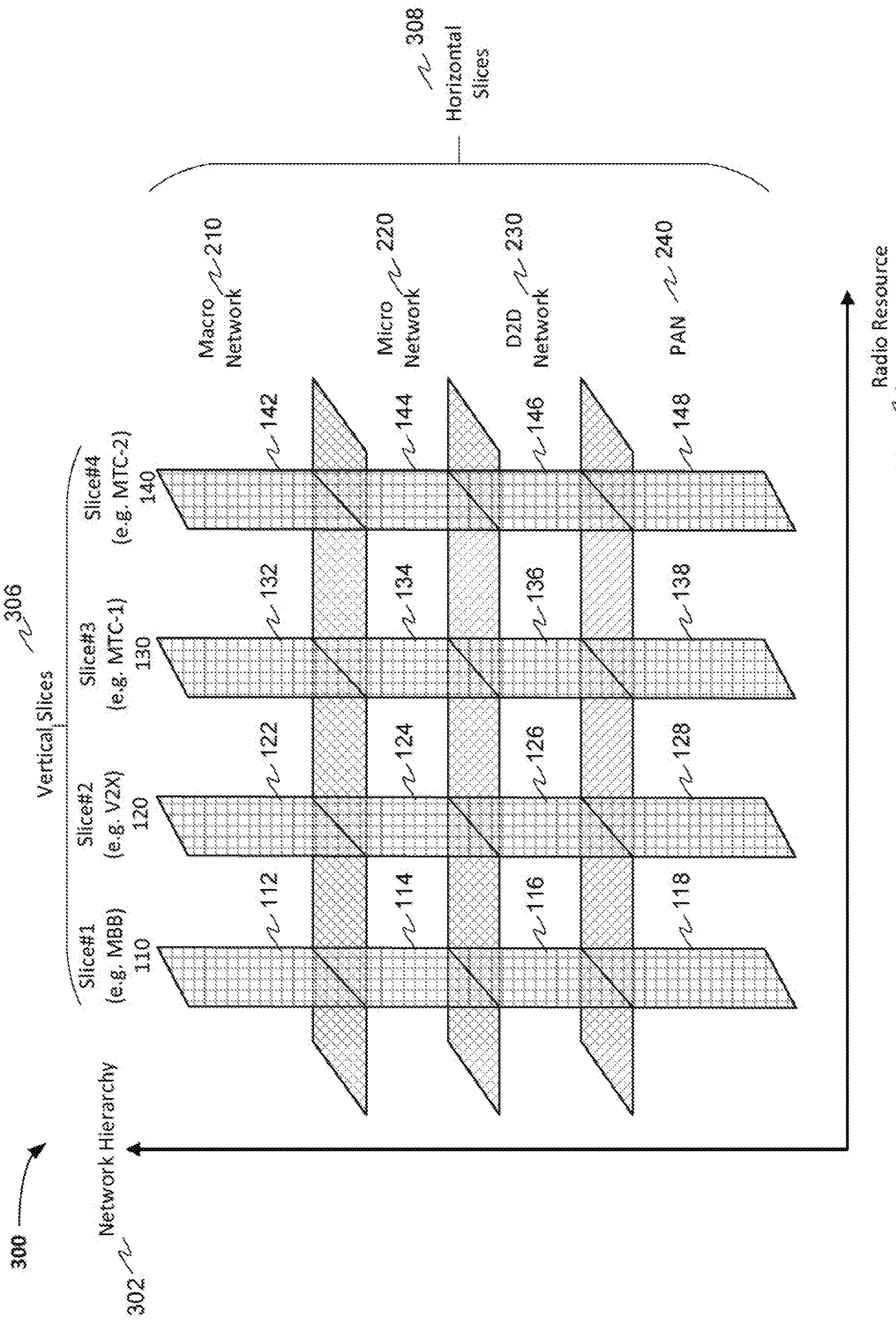
300
302
Network Hierarchy
304
Radio Resource
306
Vertical Slices
308
Horizontal Slices
Slice#1 (e.g. MBB) 110
Slice#2 (e.g. V2X) 120
Slice#3 (e.g. MTC-1) 130
Slice#4 (e.g. MTC-2) 140
Macro Network 210
Micro Network 220
D2D Network 230
PAN 240
112
114
116
118
122
124
126
128
132
134
136
138
142
144
146
148

Fig. 3

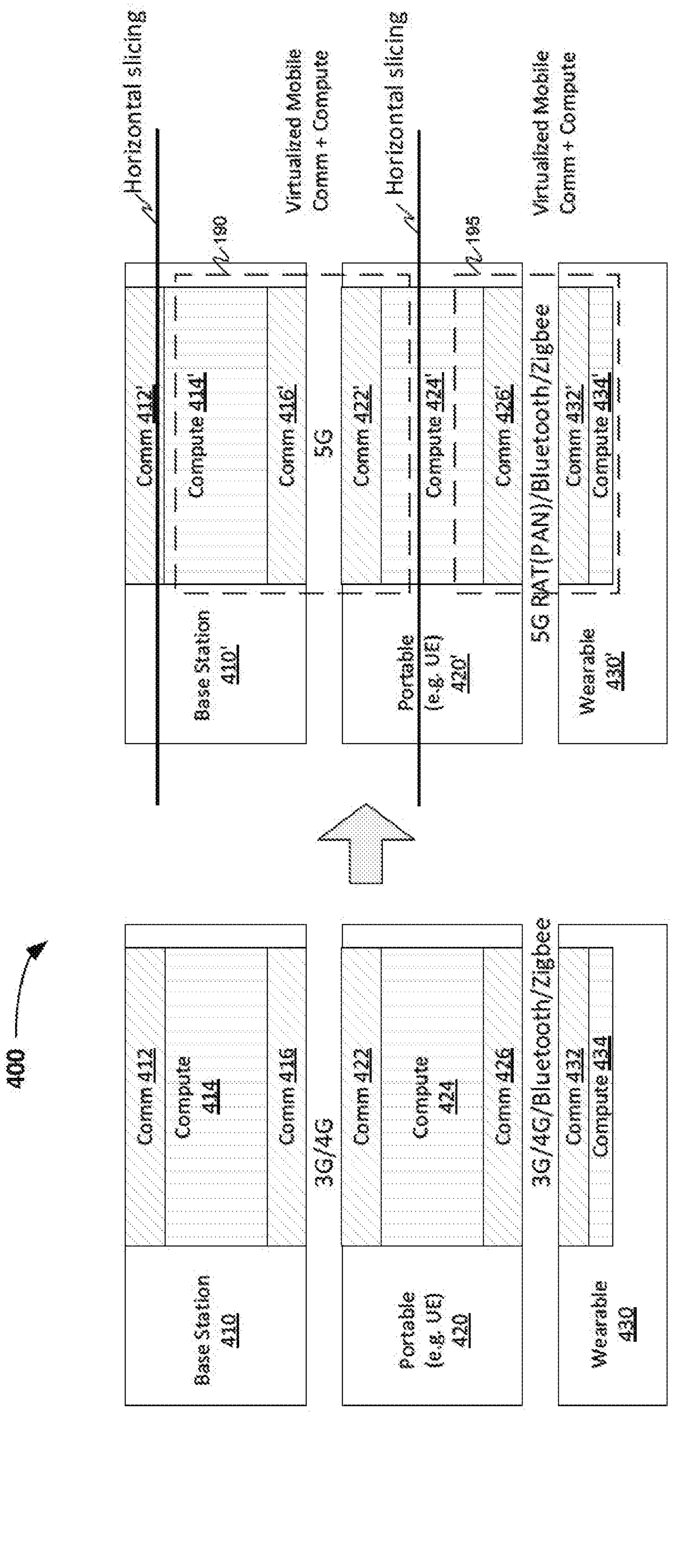
400
Base Station 410
Comm 412
Compute 414
Comm 416
3G/4G
Portable (e.g. UE) 420
Comm 422
Compute 424
Comm 426
3G/4G/Bluetooth/Zigbee
Wearable 430
Comm 432
Compute 434
Horizontal slicing
Virtualized Mobile Comm + Compute
190
Base Station 410'
Comm 412'
Compute 414'
Comm 416'
5G
Horizontal slicing
Virtualized Mobile Comm + Compute
195
Portable (e.g. UE) 420'
Comm 422'
Compute 424'
Comm 426'
5G RAT(PAN)/Bluetooth/Zigbee
Wearable 430'
Comm 432'
Compute 434'

Fig. 4

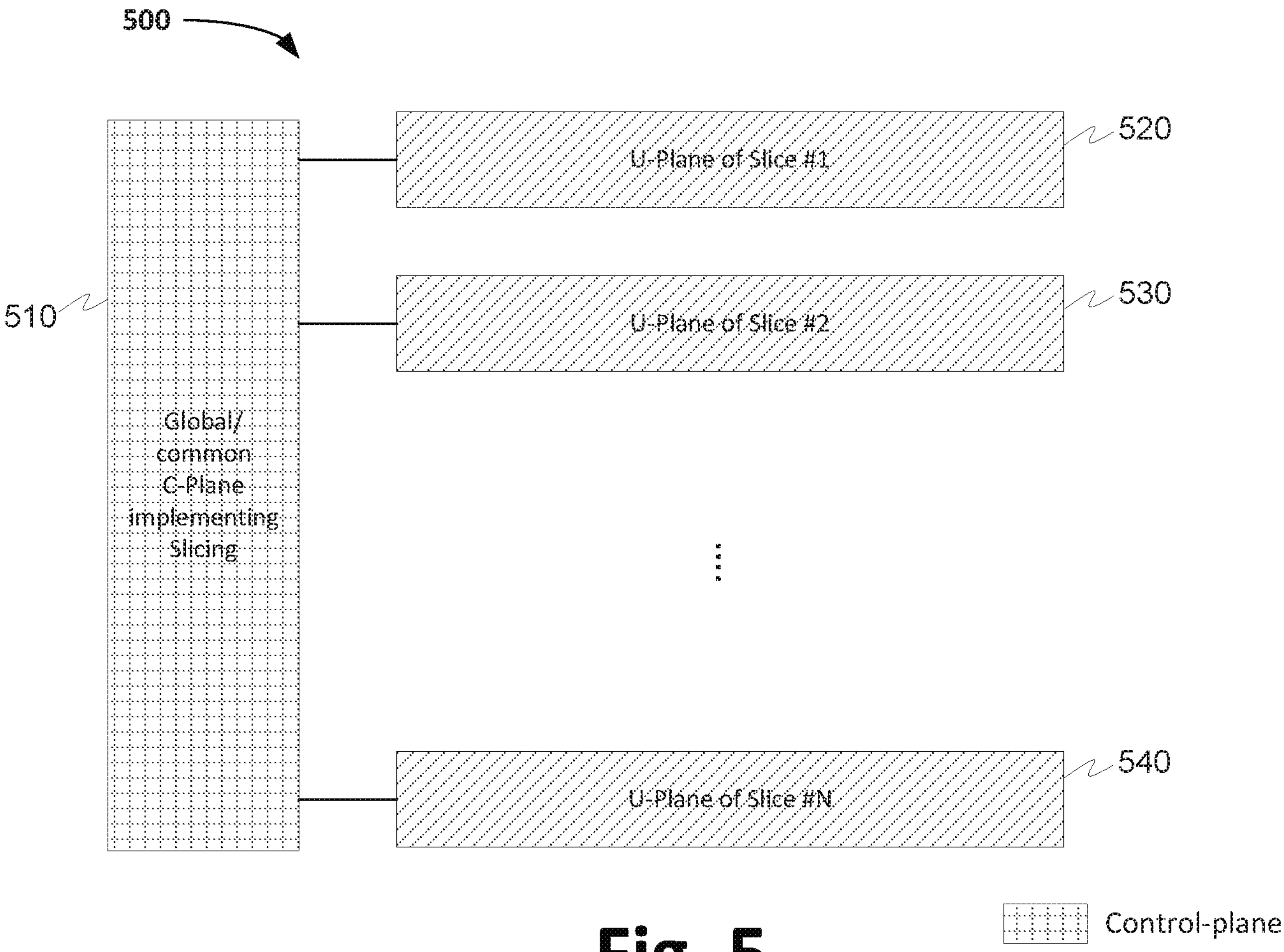
500
510
Global/
common
C-Plane
implementing
Slicing
U-Plane of Slice #1
520
U-Plane of Slice #2
530
U-Plane of Slice #N
540
Control-plane
User-plane

Fig. 5

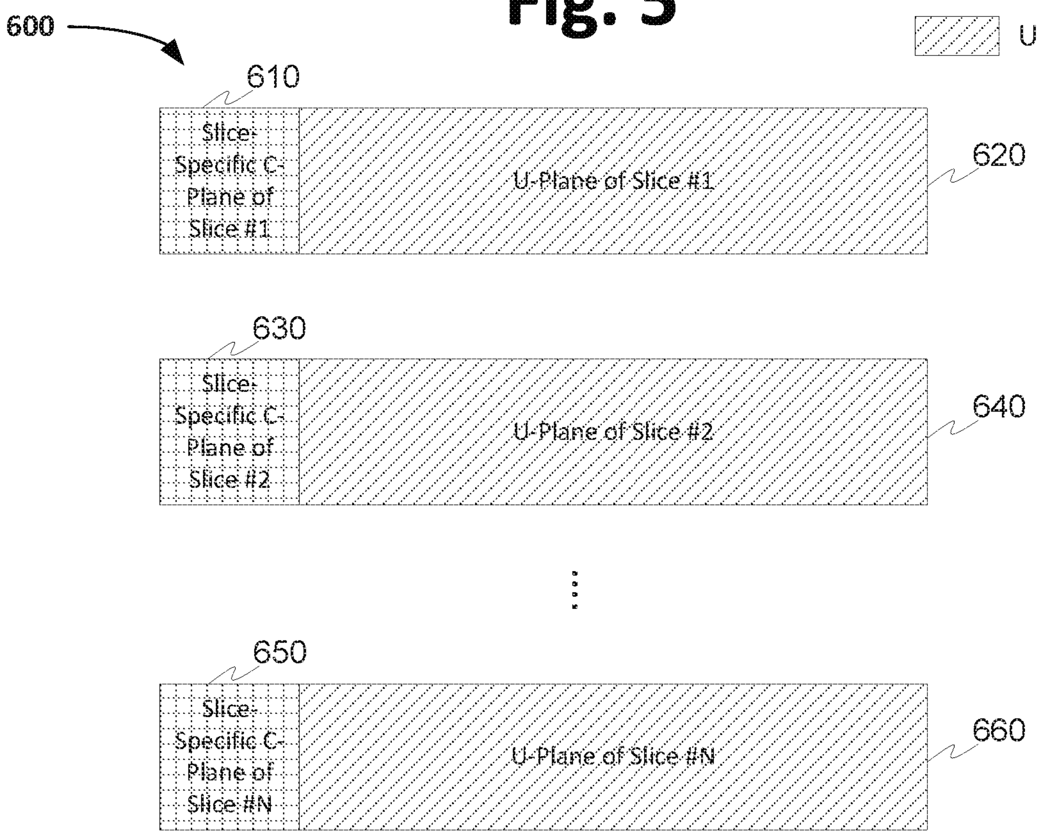
600
610
Slice-Specific C-Plane of Slice #1
U-Plane of Slice #1
620
630
Slice-Specific C-Plane of Slice #2
U-Plane of Slice #2
640
650
Slice-Specific C-Plane of Slice #N
U-Plane of Slice #N
660

Fig. 6

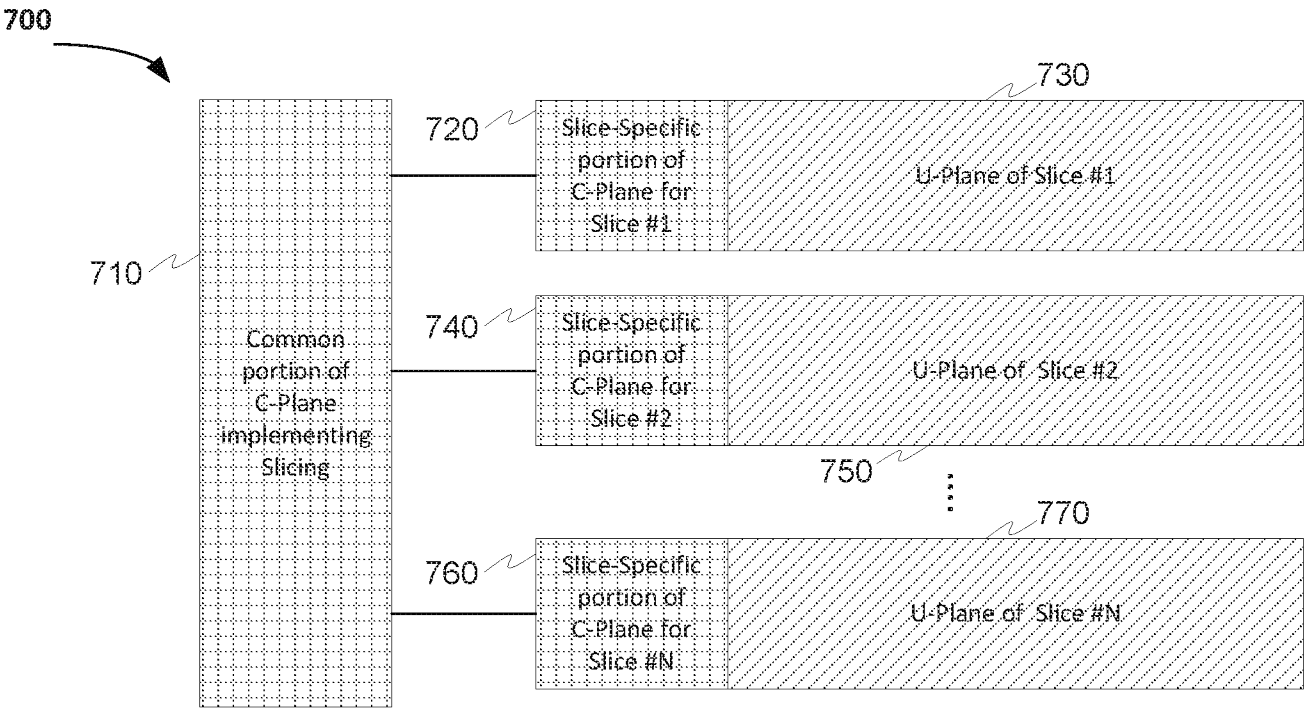
700
730
720
Slice-Specific portion of C-Plane for Slice #1
U-Plane of Slice #1
710
740
Common portion of C-Plane implementing Slicing
Slice-Specific portion of C-Plane for Slice #2
U-Plane of Slice #2
750
770
760
Slice-Specific portion of C-Plane for Slice #N
U-Plane of Slice #N

Fig. 7

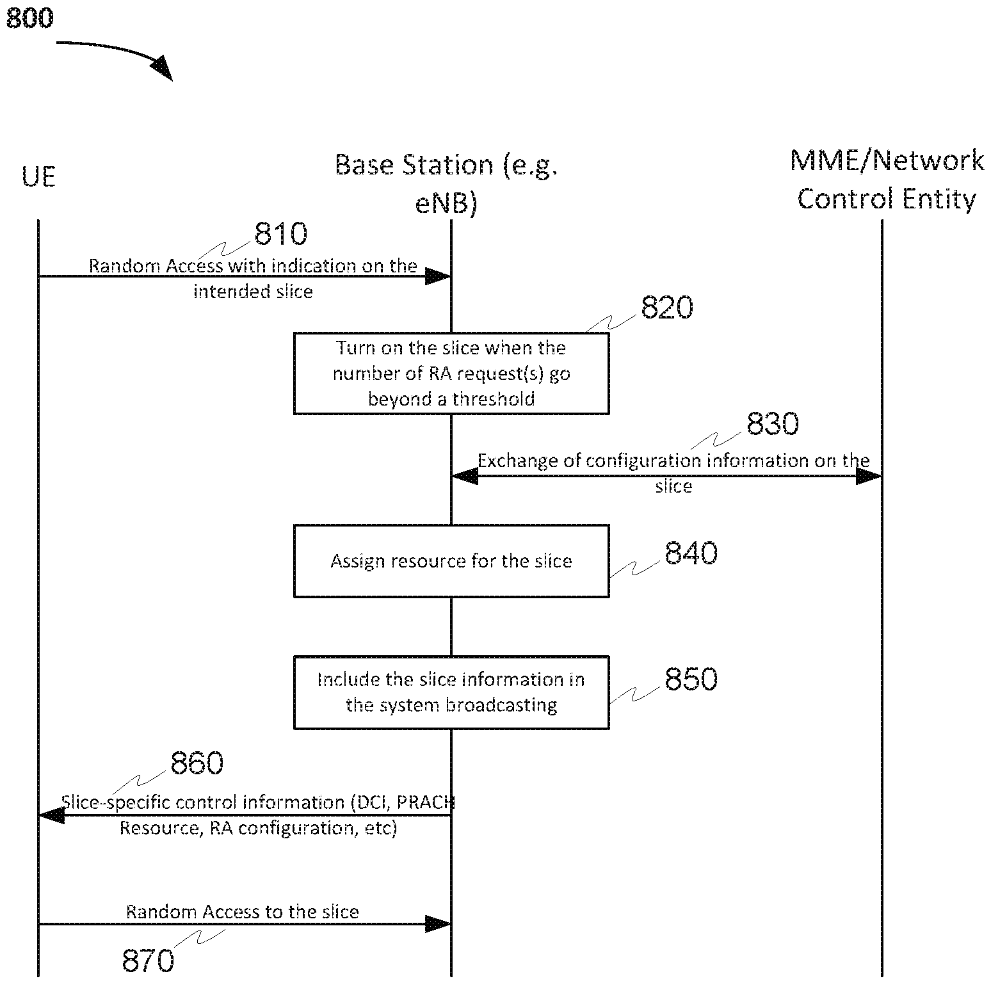
800
UE
Base Station (e.g. eNB)
MME/Network Control Entity
810
Random Access with indication on the intended slice
820
Turn on the slice when the number of RA request(s) go beyond a threshold
830
Exchange of configuration information on the slice
Assign resource for the slice
840
Include the slice information in the system broadcasting
850
860
Slice-specific control information (DCI, PRACH Resource, RA configuration, etc)
Random Access to the slice
870

Fig. 8

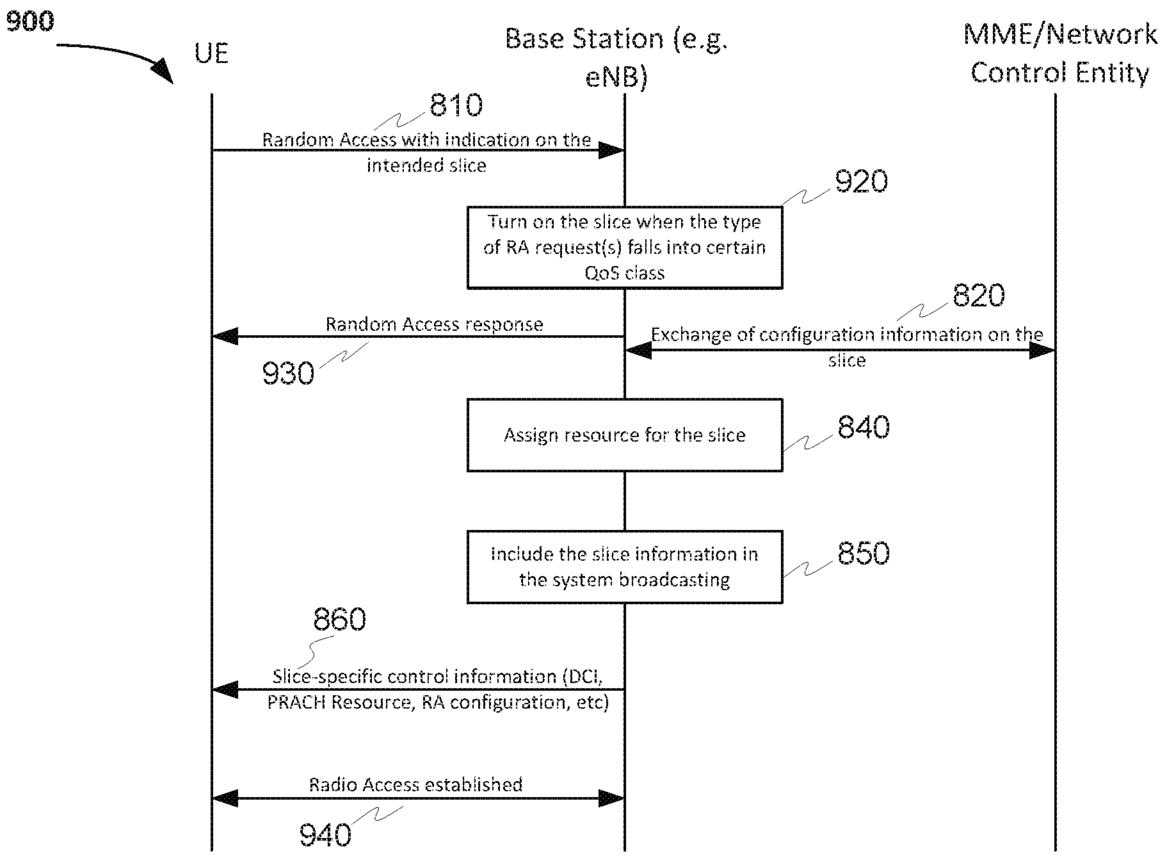
900
UE
Base Station (e.g. eNB)
MME/Network Control Entity
810
Random Access with indication on the intended slice
920
Turn on the slice when the type of RA request(s) falls into certain QoS class
820
Random Access response
Exchange of configuration information on the slice
930
Assign resource for the slice
840
Include the slice information in the system broadcasting
850
860
Slice-specific control information (DCI, PRACH Resource, RA configuration, etc)
Radio Access established
940

Fig. 9

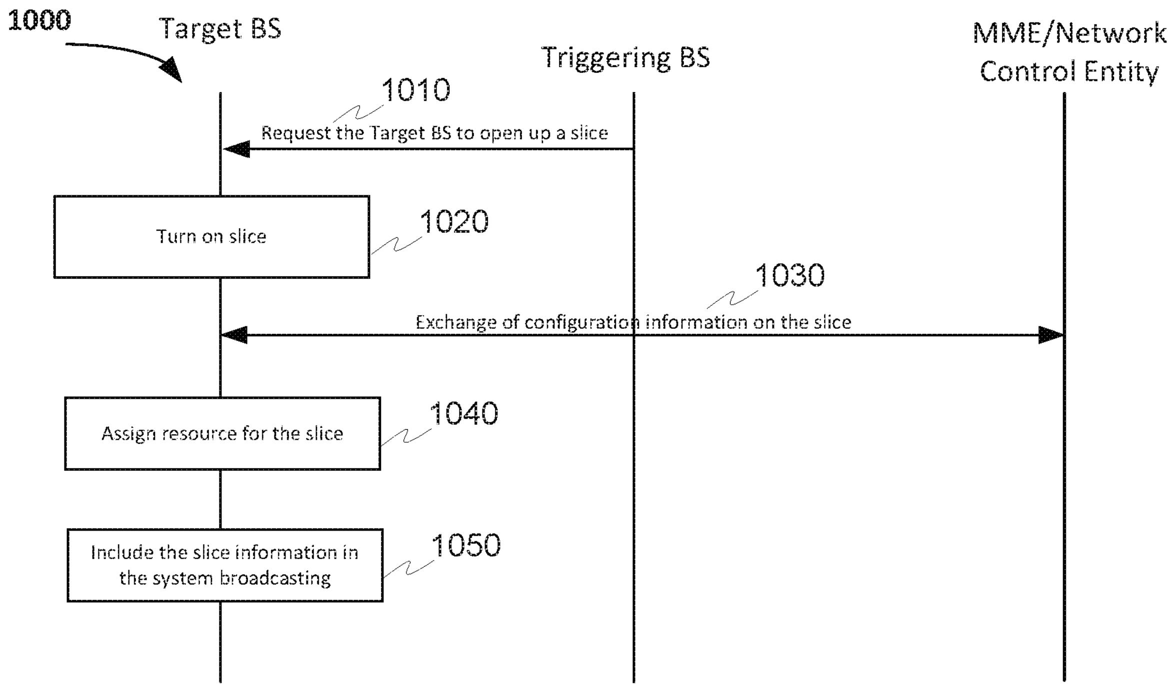
1000
Target BS
Triggering BS
MME/Network Control Entity
1010
Request the Target BS to open up a slice
Turn on slice
1020
1030
Exchange of configuration information on the slice
Assign resource for the slice
1040
Include the slice information in the system broadcasting
1050

Fig. 10

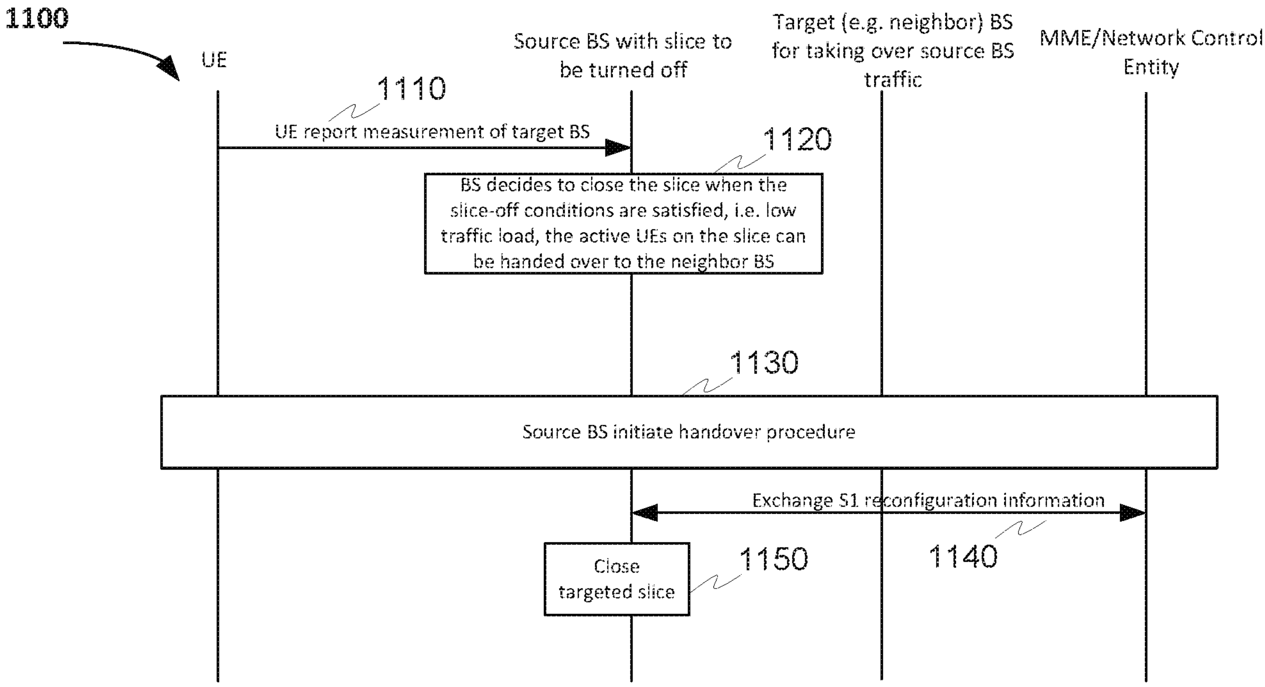
1100
UE
Source BS with slice to be turned off
Target (e.g. neighbor) BS for taking over source BS traffic
MME/Network Control Entity
1110
UE report measurement of target BS
1120
BS decides to close the slice when the slice-off conditions are satisfied, i.e. low traffic load, the active UEs on the slice can be handed over to the neighbor BS
1130
Source BS initiate handover procedure
Exchange S1 reconfiguration information
1140
Close targeted slice
1150

Fig. 11

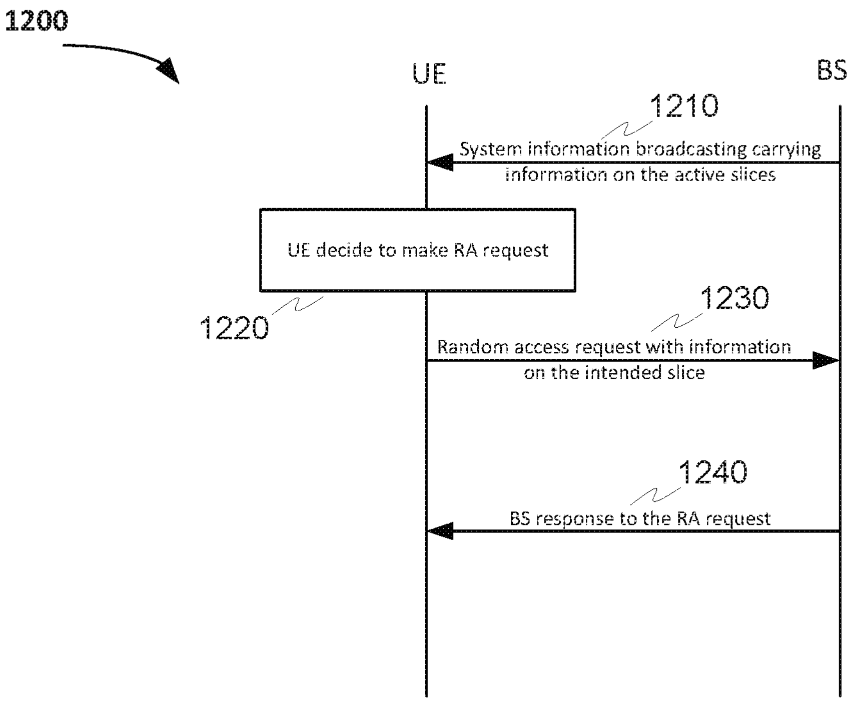
1200
UE
BS
1210
System information broadcasting carrying information on the active slices
UE decide to make RA request
1220
1230
Random access request with information on the intended slice
1240
BS response to the RA request

Fig. 12

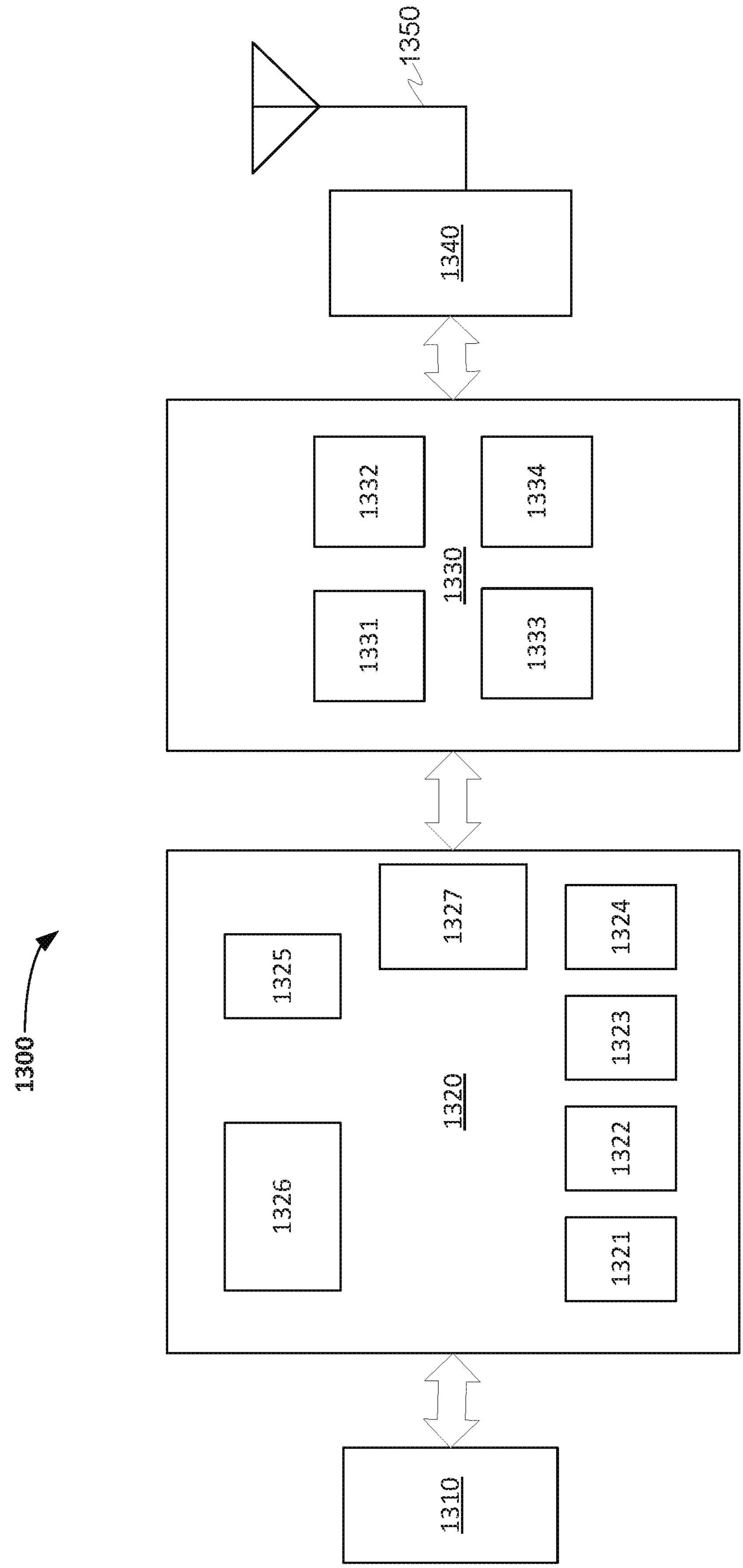
1300
1310
1320
1321
1322
1323
1324
1325
1326
1327
1330
1331
1332
1333
1334
1340
1350

Fig. 13

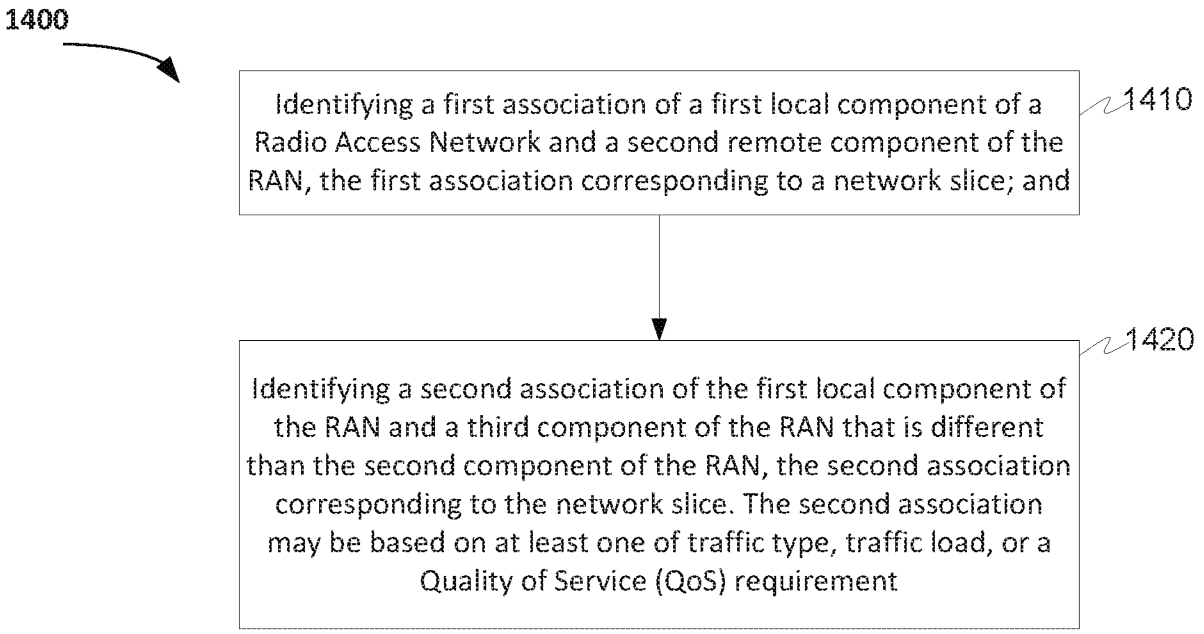
1400
Identifying a first association of a first local component of a Radio Access Network and a second remote component of the RAN, the first association corresponding to a network slice; and
1410
Identifying a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice. The second association may be based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement
1420

Fig. 14

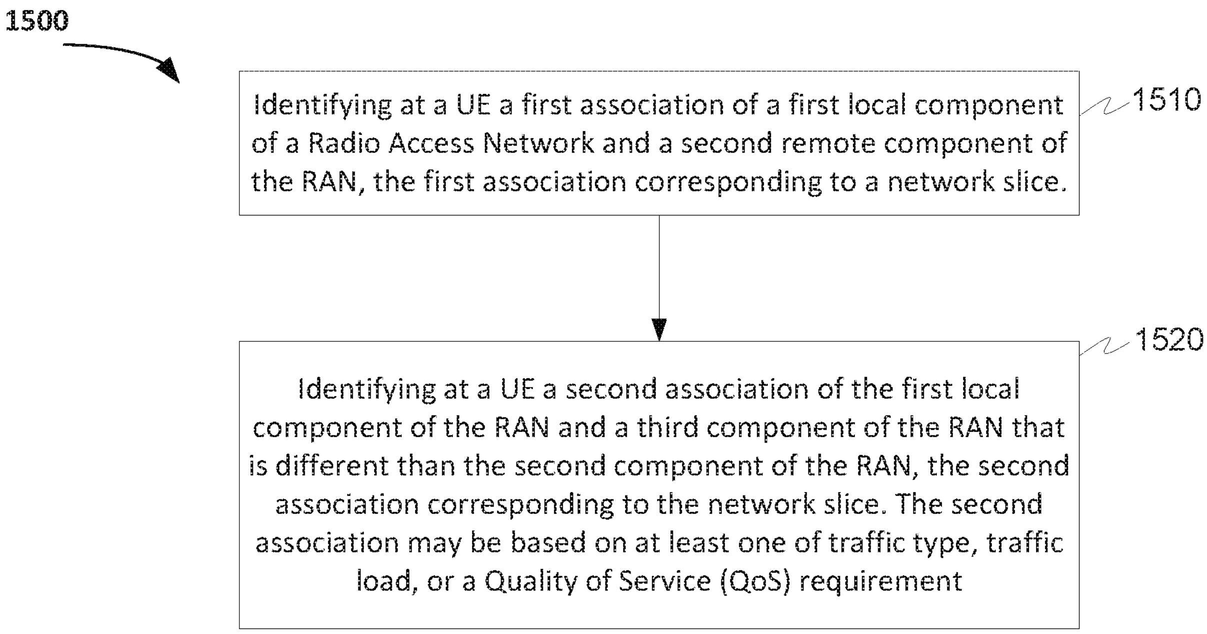
1500
Identifying at a UE a first association of a first local component of a Radio Access Network and a second remote component of the RAN, the first association corresponding to a network slice.
1510
Identifying at a UE a second association of the first local component of the RAN and a third component of the RAN that is different than the second component of the RAN, the second association corresponding to the network slice. The second association may be based on at least one of traffic type, traffic load, or a Quality of Service (QoS) requirement
1520

Fig. 15

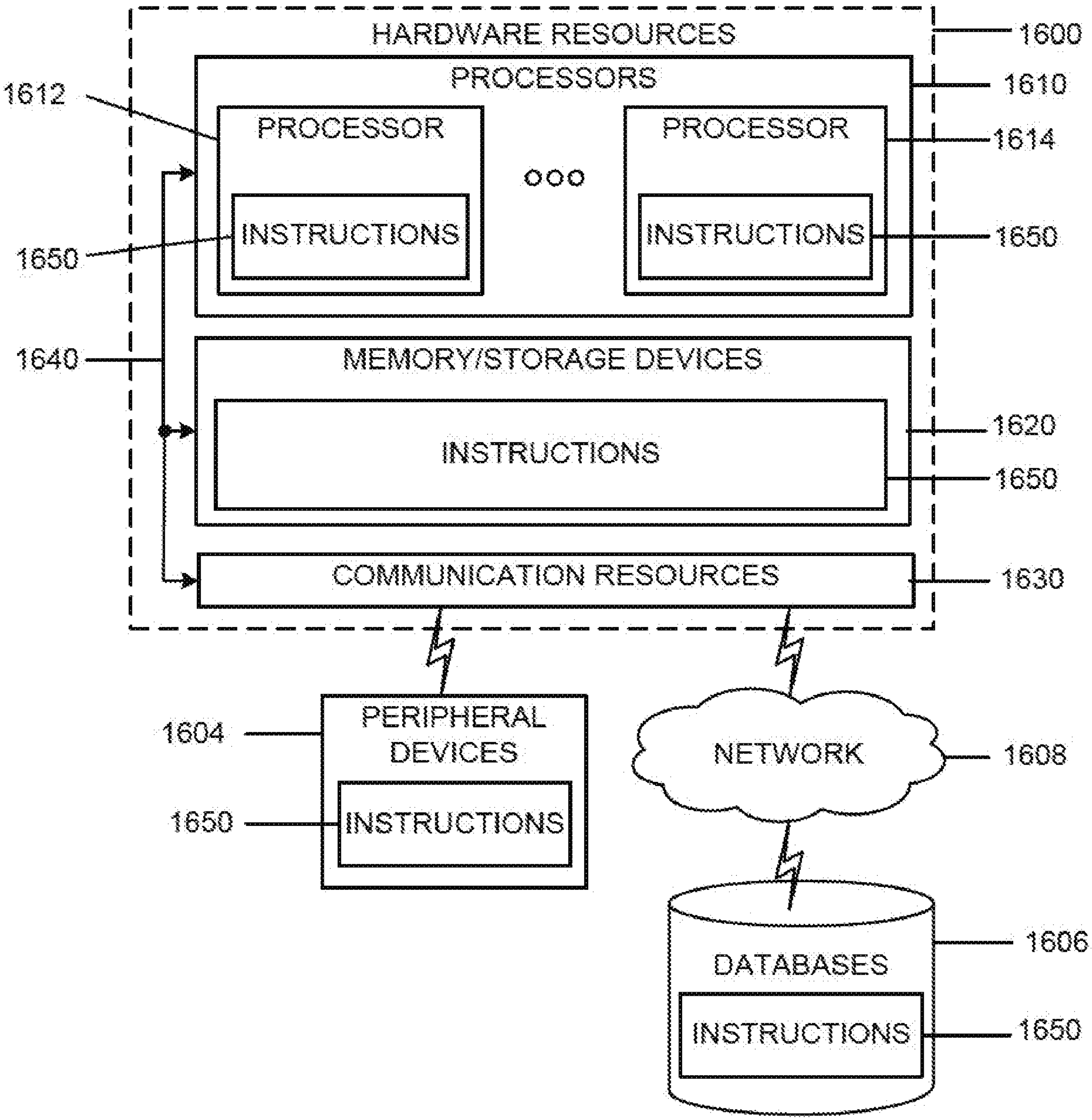
HARDWARE RESOURCES
1600
PROCESSORS
1610
1612
PROCESSOR
PROCESSOR
1614
ooo
INSTRUCTIONS
INSTRUCTIONS
1650
1650
1640
MEMORY/STORAGE DEVICES
INSTRUCTIONS
1620
1650
COMMUNICATION RESOURCES
1630
PERIPHERAL DEVICES
1604
INSTRUCTIONS
1650
NETWORK
1608
DATABASES
1606
INSTRUCTIONS
1650

Fig. 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/020027

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L12/801 H04L12/803 H04L12/851
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

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

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

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"NGMN_5G_White_Paper_Vl_0" , ETSI DRAFT; NGMN_5G_WHITE_PAPER_V1_0, EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI) , 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS ; FRANCE, vol . SmartM2M - Open , 25 June 2015 (2015-06-25) , pages 1-125 , XP014258882 , [retrieved on 2015-06-25] paragraph [001 .] - paragraph [004.] paragraph [04.3] paragraph [05 .3] - paragraph [05 .4] figure 9 -----	1-30

-/-

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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"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
12 May 2016	20/05/2016

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

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Feasibility Study on New Services and Markets Technology Enablers; Stage 1 (Release 14)", 3GPP DRAFT; Sl-151623, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE; 650, ROUTE DES LUCIOLES; F-06921 SOPHIA-ANTIPOLIS CEDEX; FRANCE, 23 April 2015 (2015-04-23), XP050961033, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_sa/WGl_Serv/TSGSl_70_Los_Cabos/Docs/ [retrieved on 2015-04-23] paragraph [05.2] -----	1-30
A	US 2015/257012 Al (ZHANG HANG [CA]) 10 September 2015 (2015-09-10) abstract paragraph [0002] - paragraph [0011] paragraph [0024] - paragraph [0025] paragraph [0029] - paragraph [0038] paragraph [0049] claims 1-3, 51 figures 1-5 -----	1-30

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/020027

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015257012 Al	10-09-2015	US 2015257012 Al	10-09-2015
		WO 2015134751 Al	11-09-2015