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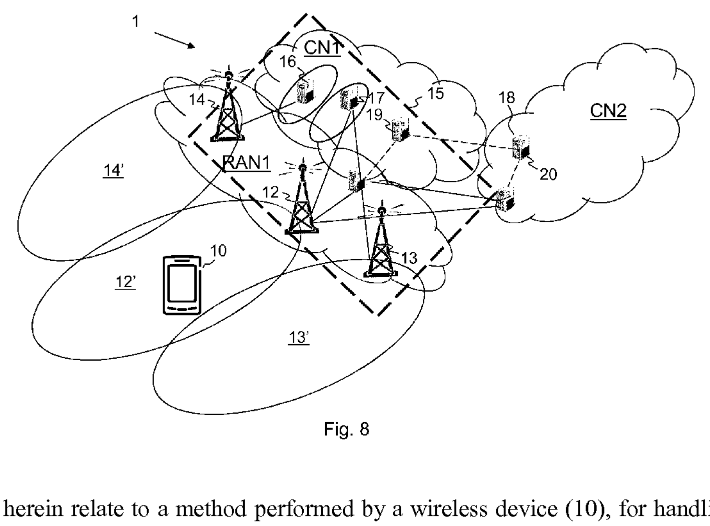


Fig. 8

(57) **Abstract**: Embodiments herein relate to a method performed by a wireless device (10), for handling a mobility procedure in a communication network (1). The communication network (1) comprises a first network, which first network is associated with a core network node (19). The first network is associated with a set of RAN nodes (12, 13, 14), each RAN node (12, 13, 14) supporting a set of cells. The first network comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device (10). The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device (10) is associated with the first network and the first network slice. The wireless device (10) receives a message comprising an indication of one or more network slices supported by each cell of the RAN nodes (12, 13, 14) from a network node. The wireless device (10) further selects a cell for camping on, based on the indication received from the network node, wherein the indication indicates that the cell supports the first slice associated with the wireless device (10).

WO 2017/140341 A1

NETWORK NODES AND METHODS PERFORMED THEREIN FOR ENABLING COMMUNICATION IN A COMMUNICATION NETWORK

TECHNICAL FIELD

Embodiments herein relate to a Radio Access Network, RAN, node, a core network node, a wireless device and methods performed therein for communication. Furthermore, a computer program and a computer readable storage medium are also provided herein. In particular, embodiments herein relate to enabling mobility procedures for a wireless device in a communication network.

BACKGROUND

In a typical communication network, wireless devices, also known as wireless communication devices, mobile stations, stations (STA) and/or user equipments (UE), communicate via a Radio Access Network (RAN) to one or more core networks (CN). The RAN covers a geographical area which is divided into service areas or cell areas, which may also be referred to as a beam or a beam group, with each service area or cell area being served by a radio network node such as a radio access node e.g., a Wi-Fi access point or a radio base station (RBS), which in some networks may also be denoted, for example, a “NodeB” or “eNodeB”. A service area or cell area is a geographical area where radio coverage is provided by the radio network node. The radio network node communicates over an air interface operating on radio frequencies with the wireless device within range of the radio network node.

A Universal Mobile Telecommunications System (UMTS) is a third generation telecommunication network, which evolved from the second generation (2G) Global System for Mobile Communications (GSM). The UMTS terrestrial radio access network (UTRAN) is essentially a RAN using wideband code division multiple access (WCDMA) and/or High Speed Packet Access (HSPA) for user equipments. In a forum known as the Third Generation Partnership Project (3GPP), telecommunications suppliers propose and agree upon standards for third generation networks, and investigate enhanced data rate and radio capacity. In some RANs, e.g. as in UMTS, several radio network nodes may be connected, e.g., by landlines or microwave, to a controller node, such as a radio network controller (RNC) or a base station controller (BSC), which supervises and coordinates various activities of the plural radio network nodes connected thereto. This type of connection is sometimes referred to as a backhaul connection. The RNCs and BSCs are typically connected to one or more core networks.

Specifications for the Evolved Packet System (EPS), also called a Fourth Generation (4G) network, have been completed within the 3rd Generation Partnership Project (3GPP) and this work continues in the coming 3GPP releases, for example to specify a Fifth Generation (5G) network. The EPS comprises the Evolved Universal Terrestrial Radio Access Network (E-UTRAN), also known as the Long Term Evolution (LTE) radio access network, and the Evolved Packet Core (EPC), also known as System Architecture Evolution (SAE) core network. E-UTRAN/LTE is a variant of a 3GPP radio access network wherein the radio network nodes are directly connected to the EPC core network rather than to RNCs. In general, in E-UTRAN/LTE the functions of an RNC are distributed between the radio network nodes, e.g. eNodeBs in LTE, and the core network. As such, the RAN of an EPS has an essentially “flat” architecture comprising radio network nodes connected directly to one or more core networks, i.e. they are not connected to RNCs. To compensate for that, the E-UTRAN specification defines a direct interface between the radio network nodes, this interface being denoted the X2 interface. EPS is the Evolved 3GPP Packet Switched Domain. **Figure 1** is an overview of the EPC architecture. This architecture is defined in 3GPP TS 23.401 v.13.4.0 wherein a definition of a Packet Data Network Gateway (PGW), a Serving Gateway (SGW), a Policy and Charging Rules Function (PCRF), a Mobility Management Entity (MME) and a wireless or mobile device (UE) is found. The LTE radio access, E-UTRAN, comprises one or more eNBs. **Figure 2** shows the overall E-UTRAN architecture and is further defined in for example 3GPP TS 36.300 v.13.1.0. The E-UTRAN comprises radio access nodes, such as eNBs, Home eNBs, which are also referred to as HeNBs, providing a user plane comprising the protocol layers Packet Data Convergence Protocol (PDCP)/Radio Link Control (RLC)/Medium Access Control (MAC)/Physical layer (PHY), and a control plane comprising Radio Resource Control (RRC) protocol in addition to the user plane protocols towards the wireless device. The radio network nodes are interconnected with each other by means of the X2 interface and/or via an X2 GW. The radio network nodes are also connected by means of the S1 interface to the EPC comprising EPC nodes, such as MME, S-GW and HeNB GateWays (GW). More specifically the radio network nodes are connected to the MME by means of an S1-MME interface and to the S-GW by means of an S1-U interface.

Figure 3 shows a management system architecture in the communications network. The node elements (NE), also referred to as eNodeB, are managed by a domain manager (DM), also referred to as the operation and support system (OSS). A DM may further be managed by a network manager (NM). Two NEs are interfaced by X2, whereas the interface between two DMs is referred to as Itf-P2P. The management system may configure the network elements, as well as receive observations associated to features in the network elements. For example, the DM observes and configures the NEs, while the NM observes and configures the DM, as well as the NE via the DM.

By means of configuration via the DM, NM and related interfaces, functions over the X2 and S1 interfaces can be carried out in a coordinated way throughout the RAN, eventually involving the Core Network, i.e. MMEs and S-GWs.

The S1-MME interface is used for control plane between eNodeB/E-UTRAN and MME. The main protocols used in this interface are S1 Application Protocol (S1AP) and Stream Control Transmission Protocol (SCTP). S1AP is the application Layer Protocol between the radio network node and the MME and SCTP for example guarantees delivery of signaling messages between MME and the radio network node. The transport network layer is based on Internet Protocol (IP).

A subset of the S1 interface provided functions are:

- S1-interface management functions such as S1 setup, error indication, reset and the radio network node and MME configuration update.
- UE Context Management functionality such as Initial Context Setup Function and UE Context Modification Function.
- E-UTRAN Radio Access Bearer (E-RAB) Service Management functions e.g. Setup, Modify, Release.
- Mobility Functions for wireless devices in EPS Connection Management (ECM)-CONNECTED, e.g. Intra-LTE Handover and inter-3GPP-Radio Access Technology (RAT) Handover.
- S1 Paging function.
- Non Access Stratum (NAS) Signaling Transport function.

In order to save energy a wireless device may enter RRC/ECM idle mode when it does not exchange data with a network, such as a Public Land Mobile Network (PLMN). When the wireless device is in RRC/ECM idle mode, several related mobility procedures will occur such as e.g. Cell selection, Cell Reselection and PLMN selection. These procedures are described in detailed way in 3GPP TS 36.304 and 3GPP TS 23.122.
When the UE is in idle mode, the UE will select a cell to camp on mainly based on:

- Allowed PLMNs, based on current registered PLMN and any possible Equivalent PLMNs.
- Radio conditions of cells in different frequency layers.

The wireless device is also able to initiate NAS procedures, such as e.g. Tracking Area Update (TAU) if necessary.

The wireless device, such as the UE, receives the following information from different entities which is useful in idle mode mobility functions.

From the core network node, such as an MME, the wireless devicemay receive information in e.g. “NAS: Attach Accept” or “NAS: Tracking Area Update Accept” messages, such as:

- List of Equivalent PLMNs, used for PLMN selection in case of loss of radio coverage of the registered PLMN.
- Tracking Area Identifier List, for checking if a NAS TAU procedure is needed once UE is re-selected to a new cell.

From the RAN node the wireless device may receive information, e.g. in a system information, such as a System Information Block (SIB), in a “RRCConnectionRelease” message, or by inheriting from another RAT at inter-RAT cell (re)selection. The information from the RAN node comprises:

- Absolute priorities of different E-UTRAN frequencies or inter-RAT frequencies, for prioritization of frequency layers the wireless device shall camp on. These absolute priorities may be common to all wireless devices, in case system information is used, or dedicated to a specific wireless device, in case dedicated RRC signaling is used. If the wireless device receives dedicated priorities then these have priority over the common priorities available over system information.

An example of the system information received from the RAN node is shown in **FIG 4**. All system information comprises a MasterInformationBlock (MIB) and multiple different SystemInformationBlock (SIB) Types. The main parts of existing LTE/E-UTRAN SystemInformationBlock Type1 (SIB1) are shown in Figure 4. The cellAccessRelatedInfo may contain up to 6 different PLMN-IDs to support network sharing. A single Tracking Area Code (TAC) is used for all the different PLMN-IDs to build up to 6 different Tracking Area Identities. In addition, Cell Identity and CSG related information are examples of additional information included in the SIB1. The SIB1 may further contain multiple other information elements as described in 3GPP TS 36.331.

An example on how idle mode mobility functions are performed in a prior art network is shown in **Fig. 5**.

Action 500: When the wireless device enters a network, e.g. when the wireless device is turned on, the wireless device has information about its home network (HPLMN). This information may for example be stored on a Subscriber Identity Module (SIM) and/or a Universal Subscriber Identity Module (USIM) that may also contain additional information about other networks, for example allowed visited networks (VPLMN). Further the core network nodes, such as the MME1 and the MME2, support different parts of the network which are identified using a Tracking Area Identifier (TAI), which comprises a network identity, such as a PLMN-ID, and a Tracking Area Code (TAC). This scenario is shown in step 500 in Fig. 5 where the UE has support for HPLMN=A, the MME1 has support for TAI=A-m and TAI=A-n, which indicates that MME1 supports the PLMN=A in the TACs m and n, and the MME2 has support for TAI=A-p, i.e. PLMN=A with tracking area code p.

Action 501: When the UE is switched on it will receive a broadcasted SIB from RAN nodes, such as the eNBs. The SIB comprises information on the networks supported by the eNB, indicated by the PLMN-ID, and the tracking area which the eNB is comprised in, indicated by the TAC and the PLMN-ID. In this case a first eNB supports the networks A and B as indicated by the PLMN-IDs of the first eNB and is located in the tracking area m as indicated by the TAC. Although there is no support for network B shown in a core network node in Fig. 5, the network may comprise further core network nodes, such as eNBs, supporting this and other networks.

Action 502: Since the first cell supports the network A which is the home network of the UE, the UE will camp on this eNB, which when the UE is camping on may be referred to as a source eNB, a current eNB or a serving eNB. The UE will further attach to the network A via the MME1. In step 502a the MME1 sends an Attach Accept response comprising a list of the TAIs supported by the MME1 and a list of equivalent PLMNs which indicates which networks are equivalent.

Action 503: When the UE is attached to a network but does not exchange any data with the network the UE or the eNB may release the connection between the UE and the eNB/MME. In step 3a the source eNB sends a RRCConnectionRelease message to the UE, which message may comprise IdleModeMobilityControlInfo dedicated for the UE.

Action 504: The UE enters RRC_IDLE mode and ECM_IDLE mode.

Action 505: When the UE is in IDLE_MODE it receives a broadcasted SIB comprising IdleModeMobilityControlInfo which is common for all UEs. The UE may use this broadcasted IdleModeMobilityControlInfo if it hasn’t received any IdleModeMobilityControlInfo in step 503.

Action 506: The UE stores the information obtained from the steps 500, 502a, 503a and 505 for enabling cell reselection decisions in idle mode.

Action 507: The UE further receives broadcasted SIBs from eNBs such as the target eNB, which SIBs comprises networks supported by the eNBs, indicated by PLMN-IDs and the tracking area which the eNB is comprised in, which is indicated by the TAC. In this case, target eNB supports network A and D and is comprised in tracking area p. Although there is no support for network B shown in a core network node in Fig. 5, the network may comprise further core network nodes, such as eNBs, supporting this and other networks.

Action 508: Since the target eNB supports network A, the UE may decide to perform a cell reselection to a cell in the target eNB based on the information stored in step 506 and radio measurements performed.

Action 509: The UE further checks if the TAI of the new cell in the target eNB is included in the TAI list received in step 502a.

Action 510: If the TAI of the new cell is not included in the TAI list received in step 502a, the UE performs a Tracking Area Update procedure via the cell in the target eNB and the PLMN-ID. In this case, since the TAI of the new cell is A-p, the UE will perform Tracking Area Update to the network to the MME2, which supports the TAI=A-p.

The wireless communication industry is at the verge of a unique business crossroads. The growing gap between capacity and demand is an urgent call for new approaches and alternative network technologies to enable mobile operators to achieve more with less. Today, mobile broadband data is growing at an annual rate of 40-50 percent per year in the U.S. and other regions globally. Mobile service providers address these rapidly expanding traffic volumes through deployment of additional network functions, which will be a significant capital expenditure (CAPEX) challenge. The nature of the mobile broadband data traffic is also evolving with new services including new video applications, connected cars and the Internet of Things (IoT). This rapid capacity growth and increasing traffic diversity in LTE networks stresses the assumptions of existing network architectures and operational paradigms.

As expected by leading operators and vendors in Next Generation Mobile Networks (NGMN) association, diverse applications or services are expected to be provided by 5G networks. 5G will support countless emerging use cases with a high variety of applications and variability of their performance attributes: from delay-sensitive video applications to ultra-low latency, from high speed entertainment applications in a vehicle to mobility on demand for connected objects, and from best effort applications to reliable and ultra-reliable ones such as health and safety. Furthermore, use cases will be delivered across a wide range of devices, e.g., smartphones, wearables, MTCs, and across a fully heterogeneous environment.

Network Functions Virtualization (NFV) provides a new path that can increase the flexibility required by mobile service providers and network operators to adapt and accommodate this dynamic market environment. NFV is a new operational approach applying well-known virtualization technologies to create a physical Commercial Off-the-Shelf (COTS) distributed platform for the delivery of end-to-end services in the context of the demanding environment of telecom network infrastructure and applications.

Because EPC is critical to the realization and management of all LTE traffic, it is important to consider use cases related to virtualization of the EPC elements. Each individual EPC element also has specific considerations that determine whether to deploy with NFV. Virtualized EPC (vEPC) is a good example: Multiple virtualized network functions (VNF) can be deployed and managed on a Network Functions Virtualization Infrastructure (NFVI) but must cater to performance scalability in both signaling/control plane and user plane, each potentially demanding different levels of NFVI resources.

vEPC elements can benefit from more agile deployment and scalability. However, virtual resource monitoring and orchestration, along with service awareness, are essential for implementing elasticity effectively. Due to the nature of telecom networks, service Level Agreements (SLA) will be a key issue for a virtualized mobile core network. Because virtualization usually leads to a performance trade-off, equipment vendors must optimize data-plane processing to satisfy carrier-grade bandwidth and latency requirements and sufficient control-plane performance for SLAs needed to ensure availability of regulatory services, such as emergency calls.

VNF is a virtualized network function which serves as a VNF Software for providing virtual network capabilities. A VNF could be decomposed and instantiated in roles such as Virtualized MME (vMME), Virtualized PCRF (vPCRF), Virtualized SGW (vSGW) or Virtualized PDN-GW (vPDN-GW).

NFV is seen as an enabler for network slicing and network sharing that is described herein.

Network slicing is about creating logically separated partitions of the network, which may also be referred to as slices or network slices, addressing different business purposes. These network slices are logically separated to a degree that they can be regarded and managed as networks of their own.

Network slicing is a new concept that applies to both LTE Evolution and New 5G RAT, which herein is referred to as NX. The key driver for introducing network slicing is business expansion, i.e. improving the operator’s ability to serve other industries, by offering connectivity services with different network characteristics, such as e.g. performance, security, robustness, and/or complexity.

The current main working assumption is that there will be one shared RAN infrastructure that will connect to several EPC instances, where one EPC instance relates to a network slice. As the EPC functions are being virtualized, it is assumed that an operator will instantiate a new CN when a new slice should be supported.

Network sharing, which is described in 3GPP TR 22.951 and 3GPP TS 23.251, is a way for operators to share the heavy deployment costs for mobile networks, especially in the roll-out phase. In the current mobile telephony marketplace, functionality that enables various forms of network sharing is becoming more and more important.

A network sharing architecture allows different core network operators to connect to a shared RAN. The operators do not only share the radio network elements, but may also share the radio resources themselves. In addition to this shared radio access network the operators may or may not have additional dedicated radio access networks.

The RAN sharing is based on the possibility for operators to share the same RAN and optionally the same spectrum by means of two standardized architectures, which are shown in **Fig. 6**. The first architecture is called Mobile Operator Core Network (MOCN) and consists of different participating operators which connect their CN infrastructure to a commonly shared RAN. In this case each participating operator can run CN-RAN procedures from its own managed RAN. In the MOCN configuration, the RAN routes the UE's initial access to the shared network to one of the available CN nodes. Supporting UEs shall inform the RAN of the chosen core network operator so that the RAN can route correctly.

A second architecture option is called Gateway Core Network (GWCN) and it consists of the shared RAN connecting to a single shared CN. Participating operators would therefore share the CN as well as the RAN.

The RAN may be managed by one of the participating operators or may be managed by a third party. It may also be possible that the CN infrastructure is managed by one of the participating operators or by a third party or it may be managed in part, i.e.

for some nodes, by a third party and in part by the participating operator. Each participating operator has access to a set of resources both in the CN and in the RAN.

When looking at the wide range of applications and use cases that are addressed with a 5G network, it is quite obvious these cannot effectively be addressed with a traditional approach of having a purpose built network for each application. This will lead to high cost for networks and devices as well as inefficient use of valuable frequency resources. Obviously, different use cases put different requirements to future networks. Examples of such requirements may include acceptable interruption time, reliability and availability, acceptable latency, data rate, as well as cost per user. It would be quite difficult or cost-wise impossible to deploy a common network service to fulfill such extremely diverse requirements. In the situation, network slicing was proposed as a concept to fulfill rich requirements from various 5G use cases. Meanwhile, the network slicing concept is getting widely recognition in NGMN. A network slice supports the communication service of a particular connection type with a specific way of handling C-plane and U-plane for the service. A 5G slice could be composed by a collection of 5G network functions and possibly specific RAT with specific settings that are combined together for the specific use case or business model. It should be noted that not all slices contain the same network functions. A specific network service can be instantiated according to on demand requirements for third party users/operators and the business policy between the network service providers and network the service consumers. Thus, an operator may have one physical network infrastructure and one pool of frequency bands, which may support many separate virtualized networks, also called network slices. Each network slice may have unique characteristics for meeting the specific requirements of the use case/s it serves.

A key function of 5G Core network is to allow for flexibility in network service creation, making use of different network functions suitable for the offered service in a specific network slice, e.g. Evolved Mobile Broadband (MBB), Massive Machine Type Communication (MTC), Critical MTC, Enterprise, etc.

In addition to Service optimized networks there are more drivers for Network slicing, such as;

- **Business expansion by low initial investment:** Given the physical infrastructure it is much easier to instantiate another Packet Core instance for the business expansion than to set up a new parallel infrastructure or even integrated nodes

- **Low risk by no/limited impact on legacy:** As the new instance is logically separated from the other network slices, the network slices can also provide resource isolation between each other. Thus introduction of a new isolated network slice will not impact the existing operator services and therefore only provide low risk
- **Short Time To Market (TTM)**: The operators are concerned about the time it takes to set up the network for a new service. Slicing of the network for different services/operator use cases provides a separation of concern that can result in a faster setup of a network slice for a certain service as it is separately managed and with limited impact on other network slices
- **Optimized use of resources:** Today the network is supporting many different services but with new use cases and more diverging requirements there is a need for optimize the network for the specific type use case. Network slicing allows to match services to optimized network instances, and it also allows for a more optimized use of those specific resources
- **Allows for individual network statistics:** With service specific network slices and possibly even on the level of individual enterprises, there is a possibility of collecting network statistics specific for a limited and well defined group of users of the network slice. This is not the key driver for slicing but rather a benefit that may be a useful tool

Slicing can also be used to isolate different services in an operator’s network. Future networks are expected to support new use cases going beyond the basic support for voice services and mobile broadband currently supported by existing cellular network, e.g. 2G/3G/4G. Some example use cases include:

- Evolution of MBB
    - › Evolved communication services
    - › Cloud services
    - › Extended mobility and coverage
- Mission critical Machine Type Communication
    - › Intelligent traffic systems
    - › Smart grid
    - › Industrial applications
- Massive Machine Type Communication
    - › Sensors/actuators
    - › Capillary networks

- Media
  - › Efficient on-demand media delivery
  - › Media awareness
  - › Efficient support for broadcast services

These use cases are expected to have different performance requirements, e.g. bit-rates, latencies, as well as other network requirements, e.g. mobility, availability, security etc., affecting the network architecture and protocols.

Supporting these use cases could also mean that new players and business relations are needed compared to existing cellular networks. For instance it is expected that future network should address the needs of

- Enterprise services
- Government services, e.g. national and/or public safety
- Verticals industries, e.g. automation, transportation
- Residential users

These different users and services are also expected to put new requirements on the network. **Fig. 7** shows an example of a network slicing for a case when there exists different network slices in the core network for MBB, Massive MTC and Critical MTC. In other words, the network slices may comprise separate core network instances supporting the different network slices. In addition, it is also possible that parts of the EPC are shared between the different network slices. One such example of shared EPC functionality may be a core network node, such as a MME.

A RAN in a sliced network may be implemented with the following pre-requisites:

- A RAN operator manages a number of eNBs which are comprised in the operators own transport network in the RAN.
- The RAN operator, CN operators and other participating parties in the shared system have mutual Service Level Agreements (SLA).
- The shared network supports a number of coexisting network slices, wherein each slice is served by part of the overall RAN/CN infrastructure. Each core network node, such as an MME, in the CN can handle one or several slices. Furthermore each cell of a RAN node, such as an eNB, can also handle one or several slices.

The aim of the network slicing is to provide a simple tool for cellular operators to introduce new services and features to different industries.

However, due to the highly increased number of network slices supported by each network, two cells and or RAN nodes supporting the same network, may not necessarily support the same slices of the network. This may for example be the case when there exists geographically and/or frequency layer limited network slices, i.e. network slices which are supported only in parts of the RAN. A wireless device supporting a first network slice which performs the mobility functions as described above for Fig. 5, will in step 508 perform a cell reselection based on information stored in step 506. The wireless device will try to perform a cell reselection for the network slice it supports. However, if the cell and/or the RAN node, to which the wireless device performs the cell selection and/or reselection, does not support the slice, a connection request from the wireless device may be denied. The wireless device will retry to connect to the same cell or to another cell supporting the home network of the wireless device until the connection request is accepted. This may lead to unnecessary signaling in the network and may also mean that the wireless device is out-of-service for both traffic terminating at the wireless device and traffic originating from the wireless device. Another problem is that the wireless device may be camping on a cell without knowing that it will not get any service for a specific slice from that cell. This may happen if the wireless device doesn’t trigger a normal tracking area update when entering the cell to camp on.

SUMMARY

An object of embodiments herein is to provide a mechanism for reducing the risk of erroneous and rejected connection requests for a wireless device and thereby improve the performance and reliability of the communications network in an efficient manner.

According to an aspect the object is achieved by a method, performed by a wireless device, for handling a mobility procedure in a communication network. The communication network comprises a first network, which first network is associated with a core network node. The first network is further associated with a set of Radio Access Network (RAN) nodes, wherein each RAN node is supporting a set of cells. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device is associated with the first network and the first network slice. The wireless device receives a message comprising an indication of one or more network slice supported by each cell of the RAN nodes from a network node. The wireless device selects a cell for camping on, based on the indication received from the network node, wherein the indication indicates that the cell supports the first slice associated with the wireless device.

According to another aspect the object is achieved by a method performed by a Radio Access Network (RAN) node, for enabling a mobility procedure for a wireless device in a communication network. The communication network comprises a first network, which first network is associated with a core network node. The RAN node is comprised in a set of RAN nodes associated with the first network. Each RAN node supports a set of cells. The first network further comprises partitioned sets of functionalities. A first set of functionalities belongs to a first network slice supporting the wireless device. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device is associated with the first network and the first network slice. The RAN node transmits, for each cell of the RAN node, a message to the wireless device, which message comprises an indication of networks supported and network slices supported by each cell.

According to yet another aspect the object is achieved by a method performed by a core network node, for enabling a mobility procedure for a wireless device in a communication network. The communication network comprises a first network, which first network is associated with the core network node. The first network is further associated with a set of Radio Access Network (RAN) nodes. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device is associated with the first network and the first network slice in a first cell of a first RAN node. The core network node transmits a message to the wireless device, which message comprises a list of identifiers indicating which cells are supporting the first network slice. The identifiers transmitted from the core network node are identifiers comprised in a broadcasted message to the wireless device from a RAN node.

According to still another aspect the object is achieved by providing a wireless device for handling a mobility procedure in a communication network. The communication network comprises a first network, which first network is associated with a core network node. The first network is further associated with a set of Radio Access Network (RAN) nodes. Each RAN node is supporting a set of cells. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device is associated with the first network and the first network slice. The wireless device is configured to receive a message comprising an indication of one or more network slice supported by each cell of the RAN nodes from a network node. The wireless device is further configured to select a cell for camping on. The selection is based on the indication received from the network node, wherein the indication indicates that the cell supports the first slice associated with the wireless device.

According to a further aspect the object is achieved by providing a RAN node for enabling a mobility procedure for a wireless device in a communication network. The communication network comprises a first network, which first network is associated with a core network node. The RAN node is comprised in a set of RAN nodes associated with the first network, wherein each RAN node supports a set of cells. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device is associated with the first network and the first network slice. The RAN node is configured to transmit, for each cell of the RAN node, a message to the wireless device, which message comprises an indication of networks supported and network slices supported by each cell.

According to yet a further aspect the object is achieved by providing a core network node for enabling a mobility procedure for a wireless device in a communication network. The communication network comprises a first network, which first network is associated with the core network node. The first network is further associated with a set of Radio Access Network (RAN) nodes. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device is associated with the first network and the first network slice in a first cell of a first RAN node. The core network node is configured to transmit a message to the wireless device. The message comprises a list of identifiers indicating which cells are supporting the first network slice, wherein the identifiers are identifiers are identifiers comprised in a broadcasted message to the wireless device from a RAN node.

It is furthermore provided herein a computer program comprising instructions, which, when executed on at least one processor, cause the at least one processor to carry out any of the methods above, as performed by the first network node or the second network node. It is additionally provided herein a computer-readable storage medium, having stored thereon a computer program comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method according to any of the methods above, as performed by the first network node or the second network node.

Embodiments herein introduce an efficient manner of reducing the risk of erroneous and rejected connection requests for a wireless device which is performing mobility procedures in a communications network. By indicating to the wireless device which cells support the network slice supported by the wireless device, the wireless device can take this information into account when performing the mobility procedures, such as cell selection and/or reselection, in order to find a cell to camp on. Thereby, unnecessary signaling from the wireless device to cells and/or RAN nodes which do not support the network slice of the wireless device is minimized, which increases the performance of the communications network. Furthermore, the risk of the wireless device camping on an erroneous cell is reduced which improves the reliability of the communications network.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments will now be described in more detail in relation to the enclosed drawings, in which:

Fig. 1 is a schematic overview depicting a communication network according to prior art;

Fig. 2 is a schematic overview depicting a radio access network in connection with a core network;

Fig. 3 is a schematic overview depicting a management system architecture for a communications network;

Fig. 4 is a schematic overview for a System Information transmitted in the network;

Fig. 5 is a signaling diagram depicting a mobility procedure according to prior art;

DETAILED DESCRIPTION

Embodiments herein relate to communication networks in general. **Fig. 8** is a schematic overview depicting **a communication network 1**. The communication network 1 comprises a RAN and a CN. The communication network 1 may use a number of different technologies, such as Wi-Fi, Long Term Evolution (LTE), LTE-Advanced, 5G, Wideband Code Division Multiple Access (WCDMA), Global System for Mobile communications/Enhanced Data rate for GSM Evolution (GSM/EDGE), Worldwide Interoperability for Microwave Access (WiMax), or Ultra Mobile Broadband (UMB), just to mention a few possible implementations. Embodiments herein relate to recent technology trends that are of particular interest in a 5G context, however, embodiments are applicable also in further development of the existing communication systems such as e.g. 3G and LTE.

In the communication network 1, wireless devices e.g. **a wireless device 10** such as a mobile station, a non-access point (non-AP) STA, a STA, a User Equipment (UE) and/or a wireless terminals, communicate via one or more Access Networks (AN), e.g. RAN, to one or more CNs. It should be understood by those skilled in the art that “wireless device” is a non-limiting term which means any terminal, wireless communication terminal, user equipment, Machine Type Communication (MTC) device, Device to Device (D2D) terminal, or node e.g. smart phone, laptop, mobile phone, sensor, relay, mobile tablets or even a base station communicating within a cell.

The communication network 1 comprises set of radio network nodes, such as **radio network nodes 12, 13, 14**, each providing radio coverage over one or more geographical areas, such as **a cell 12’, 13’, 14’**, of a radio access technology (RAT), such as LTE, UMTS, Wi-Fi or similar. The radio network node 12, 13, 14 may be a radio access network node such as radio network controller or an access point such as a wireless local area network (WLAN) access point or an Access Point Station (AP STA), an access controller, a base station, e.g. a radio base station such as a NodeB, an evolved Node B (eNB, eNodeB), a base transceiver station, Access Point Base Station, base station router, a transmission arrangement of a radio base station, a stand-alone access point or any other network unit capable of serving a wireless device within the cell, which may also be referred to as a service area, served by the radio network node 12, 13, 14 depending e.g. on the first radio access technology and terminology used. The radio network nodes 12, 13, 14 are comprised in a first radio access network (RAN1) of a first network.

Furthermore, the communication network 1 comprises a first core network (CN1) and a second core network (CN2). The radio network node 12 may communicate with both the CN1 and the CN2. The first network comprises the first core network CN1. The first network is a virtual network sliced into a number of network slices, the CN1 and/or the RAN1 may be a virtual network sliced into CN slices and/or RAN slices, each network slice or core network slice supports one or more type of wireless devices and/or one or more type of services i.e. each network slice supports a different set of functionalities. Network slicing introduces the possibility that the network slices are used for different services and use cases and these services and use cases may introduce differences in the functionality supported in the different network slices. Each network slice may comprise one or more network nodes or elements of network nodes providing the services/functionalities for the respective network slice. Each slice may comprise a network node such as a core network slice node or a RAN slice node. For example, a first network slice for e.g. MTC devices may comprise **a first network slice node 16**. A second network slice for e.g. MBB devices may comprise **a second network slice node 17.** Each network slice supports a set of functionalities out of a total set of functionalities in the communication network. E.g. the first network slice node 16 supports a first set of functionalities out of the total set of functionalities in the communication network 1. The first set of functionalities is separated from a different set of functionalities out of the total set of functionalities in the communication network 1. E.g. the first set of functionalities being associated with MTC devices is separated or logically separated, e.g. using separated data storage or processing resources, from a second set of functionalities of the second network slice being associated with MBB devices.

The first set of functionalities may use one or more resources in a core or RAN network of the communication network, which one or more resources are separated from other resources used by a different set of functionalities, i.e. different network slices, out of the total set of functionalities in the communication network 1. The resources may then be dedicated or virtually dedicated for each set of functionalities or network slice. Thus, the network slice node may be separated from other network slice nodes supporting a second set of functionalities out of the total set of functionalities in the communication network. Separated meaning herein physically separated wherein the network slice nodes may be executed on different hardware platforms and therefore using different resources of the hardware, and/or logically separated wherein the network slice nodes may be executed on a same hardware platform and use different resources such as memory parts or resources of processor capacity but may also use some same resources of the hardware e.g. a single physical network slice node may be partitioned into multiple virtual network slice nodes.

Hence, the first network slice node 16 supports the first set of functionalities out of the total set of functionalities in the first network of the communication network, which first set of functionalities belongs to the first network slice of the first network, and is separated from another set of functionalities out of the total set of functionalities in the first network.

A first network comprises one or more **first network nodes 15**, such as **first core network nodes 19** e.g. Radio Software Defined Networking (SDN) nodes, MMEs, S-GWs, Serving GPRS Support Nodes (SGSN), or corresponding nodes in e.g. a 5G network or similar. The GPRS meaning General Packet Radio Services. The first network node 15 may further be a radio access network node such as the first radio network node 12.

A second network comprises one or more **second network nodes 18**, such as **second core network nodes 20** e.g. Radio SDN nodes, MMEs, S-GWs, SGSNs, or corresponding nodes in e.g. a 5G network or similar. The second network node 18 may further be a radio access network node such as the first radio network node 12.

In one embodiment described herein, the wireless device is in IDLE Mode and is camping on a first cell 12' of the first RAN node 12. The RAN node 12 which the wireless device is camping on may be referred to as a source RAN node. When the wireless device is in IDLE mode it will continuously look for a more suitable cell to camp on. This mobility procedure is referred to as a cell reselection procedure.

In a further embodiment herein, which is not depicted in Fig. 8, the wireless device 10 may not yet be camping on a cell 12', 13', 14'. This may e.g. occur when the wireless device 10 is switched on for the first time and needs to select a first cell to camp on 12', 13', 14' before it can attach to the network via a core network node 19. This mobility procedure is referred to as a cell selection procedure.

Problems have been identified in relation to idle mode mobility, such as cell selection and cell reselection procedures, for the wireless device 10 supporting network slicing, especially in cases when there exist geographically and/or frequency layer limited network slices i.e. network slices which are supported only in parts of the RAN.

In case of cell reselection in the same frequency layer or other frequency layers, the wireless device 10 that is connected to a specific network slice needs to know in which cells in the network the slice is supported. If not, the wireless device 10 may easily loose connection towards the current slice if the wireless device 10 selects a cell that has no support for the current slice for the wireless device 10. A similar problem occurs during cell selection if the wireless device 10 selects a cell 12', 13' 14' not supporting the network slice for initial cell selection. In this case the connection request to the erroneous cell may be rejected.

For example, for a radio network configuration according to **Fig. 9**, where the cells in source RAN node 12 is supporting a network A identified by the PLMN and slices a and b, cells in target RAN node 1, such as the RAN node 14, is supporting PLMN=A; slice=b, and finally cells in target RAN node 2, such as the RAN node 13, is supporting PLMN=A; slice=a, and the wireless device 10 initially is connected to slice a through source the source RAN node 12. The problem arises in step 508 of Fig. 5 as following. In case the wireless device 10 detects that cells in the target RAN node does not support slice a, such as e.g. the target RAN node 1 in Fig. 9, then the wireless device 10 may reselect a cell in that target RAN node without knowing if slice a is supported. When the UE wants to request connection to slice a via any of the cells in the target RAN node 1, it will be rejected as the cell in the target RAN node 1 doesn't have any network connection towards a core network node that supports slice a. This behaviour is problematic for several reasons. It may result in the wireless device 10 attempting to access multiple cells and then being rejected. This may lead to unnecessary signalling in the network and may also mean that the wireless device 10 is out-of-service for both traffic terminating at the wireless device 10 and traffic originating from the wireless device 10. Another problem is that the wireless device 10 may be camping on a cell without knowing that it will not get any service for a specific slice. This may happen if the wireless device 10 doesn't trigger a normal tracking area update when entering the cell to camp on.

Embodiments herein introduce an efficient manner of reducing the risk of erroneous and rejected connection requests for a wireless device which is performing mobility procedures in a communications network. By indicating to the wireless device which cells support the network slice supported by the wireless device, the wireless device can take this information into account when performing the mobility procedures, such as cell selection and/or reselection, in order to find a cell to camp on. Thereby, unnecessary signaling from the UE to cells and/or RAN nodes which do not support the network slice of the UE is minimized, which increases the performance of the communications network. Furthermore, the risk of the UE camping on an erroneous cell is reduced which improves the reliability of the communications network.

A first aspect of embodiments herein therefore relate to a method for explicitly broadcasting a slice identity for a cell to the wireless device 10.

A broadcast “slice support information” may be added explicitly in the system information sent from the RAN node (12, 13, 14), for example in the SIB1 in the cell for every supported PLMN. In one embodiment herein, the “slice support information” may be added to the PLMN-IdentityList part of SIB1. In one embodiment herein, up to 10 different “slice support information” can be indicated for each PLMN and the maximum number of a numerical slice identity may be 256. The system information may further comprise a user-friendly slice name which may contain up to 40 characters.

The size of SIB1 is however constrained due to coverage reasons. Hence the addition of the slice support information to SIB1 may be undesirable in large cells. In a further embodiment, the additional information may thus be added in another existing or in a new SIB, which SIB may not be transmitted equally often as the SIB1. However, this embodiment will have a slower wireless device access, due to longer latency for reading of necessary information to judge cell suitability.

The signal flow when slice supported information is broadcasted explicitly is shown in **Fig.10**, where the identifiers introduced in the embodiments herein are indicated with bold font.

The problem mentioned earlier in step 8, where UE doesn't know if the target cell supports the slice or not, is solved as UE now can retrieve information on slice support on the target cell by reading the SIB from step 7.

Action 1000: Before the wireless device 10 selects a cell of a RAN node 12, 13, 14 to camp on and a network to attach to the wireless device 10 may have information about its home network indicated by a HPLMN-ID and a network slice, indicated by a slice-ID, supported by the wireless device 10. This information may be stored in the wireless device 10 in e.g. a memory or a SIM/USIM.

Action 1001: When the wireless device 10 is switched on or enters the communication network 1 it receives a broadcasted SIB from the RAN nodes 12, 13, 14 over the RRC protocol. The SIB according to this embodiment is updated to comprise information on the networks supported by each cell of the RAN node 12, 13, 14, indicated via the PLMN-ID, and the corresponding network slices supported by each cell for each supported network. The supported network and the corresponding supported slice may be indicated as following <PLMN-ID><Slice-ID>. In a scenario where the network only supports a single PLMN-ID the SIB may indicate only the slice-ID, since this information will be sufficient to identify the correct slice. For the scenario described in Fig. 10 the wireless device 10 receives a SIB from the RAN node 12, comprising the indication <PLMN-ID=A><Slice-ID=a><PLMN-ID=A><Slice-ID=b> which indicates that the cell of the RAN node 12 supports network A and the slices a and b in network A. Hence, the SIB received from the RAN node 12 explicitly indicates the slices supported by the cell of the RAN node 12 for each supported network. The wireless device may further receive a SIB from the RAN node 13 comprising the indication <PLMN-ID=A><Slice-ID=a> and a SIB from the RAN node 14 comprising the indication <PLMN-ID=A><Slice-ID=b>.

Action 1002: Since a first cell of the RAN node 12 supports the network A and the slice a, which is the home network and a network slice associated to the home network of the wireless device 10, the wireless device 10 will select this cell in the RAN node 12 to camp on. In case there are several cells available which supports the home network and slice, the wireless device may perform further radio measurements on the cell to select the cell which offers the best quality of connection. When the wireless device 10 is camping on a cell of a RAN node, this RAN node may be referred to as the source RAN node. The wireless device 10 will further attach to slice a of the network A via the first core network node 19.

Action 1002a: As a response to the attachment of the wireless device 10 the core network node 19 sends an Attach Accept response comprising a list of the TAIs supported by the core network node 1 and a list of equivalent PLMNs which indicates which networks are equivalent to network A.

Action 1003: When the wireless device 10 is attached to network A and slice a but does not exchange any data with the network, the wireless device 10 or the RAN node 12 may release the connection between the wireless device 10 and the RAN node/core network node.

Action 1003a: When the wireless device enters the source RAN node 12 sends a RRCConnectionRelease message to the wireless device 10, which message may comprise IdleModeMobilityControlInfo dedicated for the wireless device 10.

Action 1004: The wireless device 10 may enter RRC_IDLE mode and ECM_IDLE mode.

Action 1005: When the wireless device 10 is in IDLE_MODE it may receive a broadcasted SIB comprising IdleModeMobilityControlInfo which is common for all wireless device 10. The wireless device 10 may use this broadcasted IdleModeMobilityControlInfo if it hasn’t received any IdleModeMobilityControlInfo in step 1003.

Action 1006: The wireless device 10 may store the information obtained from the steps 1000, 1002a, 1003a and 1005 for enabling cell reselection decisions in idle mode. When the wireless device is in IDLE mode it continuously evaluates if there is a more suitable cell to camp on and may perform a cell reselection if a more suitable cell is identified. The cell reselection may e.g. be performed due to the wireless device moving away from the source cell.

Action 1007: The wireless device 10 receives broadcasted SIBs from the RAN nodes 12, 13, 14. The cells of the RAN nodes 13, 14 are cells which the wireless device isn’t currently camping on but which may be alternative cells to perform a cell reselection to. The RAN nodes 13, 14 may therefore be referred to as target RAN nodes. These broadcasted SIBs correspond to the SIBs received in Action 1001 and hence, also comprise the updated information on the networks supported by each cell of the RAN node 12, 13, 14, indicated via the PLMN-ID, and the corresponding network slices supported by each cell for each supported network. The supported network and the corresponding supported slice may be indicated as following <PLMN-ID><Slice-ID>. For the scenario described in Fig. 9 the wireless device 10 receives a SIB from the target RAN node 13, comprising the indication <PLMN-ID=A><Slice-ID=a> which indicates that a cell of the RAN node 13 supports network A and the slice a in network A. The wireless device 10 further receives a SIB from the target RAN node 14, comprising the indication <PLMN-ID=A><Slice-ID=b> which indicates that a cell of the RAN node 14 supports network A and the slice b in network A. Hence, the SIB received from the RAN nodes 13, 14 explicitly indicate the slices supported by the cells of the RAN nodes 13, 14 for each supported network. In a scenario where the network only supports a single PLMN-ID the SIB may indicate only the slice-ID, since this information will be sufficient to identify the correct slice.

Action 1008: The wireless device 10 may decide to perform a cell reselection to a cell in one of the target RAN nodes based on the information stored in step 1006, radio measurements performed and the information in the SIBs received from the target RAN node 13, 14. Since the target RAN node 13 is the only target RAN node supporting slice a in network A, the wireless device will perform a cell reselection procedure to a cell in the RAN node 13. Hence, it will not try to perform a cell reselection to the target RAN node 14 which does not support slice a. Thereby, unnecessary signaling from the wireless device 10 to the RAN node 14 is avoided. This also reduces the risk of the wireless device 10 wrongfully connecting to a cell in the RAN node 14 which is not able to support the wireless device.

Action 1009: The wireless device 10 may further check if the TAI of the new cell in the target RAN node 13 is included in the TAI list received in step 1002a.

Action 1010: If the TAI of the new cell is not included in the TAI list received in step 1002a, the wireless device 10 performs a Tracking Area Update procedure based on the cell in the target RAN node 13, the PLMN-ID and the slice ID. In this case, since the TAI of the new cell is A-p, the UE will perform TAU to the network to the MME2, which supports the TAI=A-p.

A second aspect of embodiments herein relate to a method for implicitly broadcasting a slice identity for a cell to the wireless device 10.

A broadcast “slice support information” may be implicitly added in the cell for every supported PLMN as a cell (re)selection criteria for the wireless device 10 supporting network slicing. The slice support information may be provided by reusing existing information elements in the system information sent by the RAN node, such as e.g. in

SIB1 which implicitly is associated to a slice. Further an association between the slice support information and an information element in a SIB, such as the SIB1, is provided to the wireless device 10. This association may be provided e.g. in Non-Access Stratum (NAS) signaling.

The slice support information is provided implicitly in one of the information elements in the SIB, such as in SIB1. This information could be e.g. a Tracking Area Identity (TAI) which comprises the PLMN-identity and a Tracking Area Code (TAC), a cell Identity, or a Closed Subscriber Group Identity (CSG-ID). In order to describe the embodiments herein, the TAI will be used as an example. However, the embodiments herein may also use any of the other information comprised in the SIB as stated above.

A new principle was introduced for location registration in the E-UTRAN/EPC networks. This principle is based on a Tracking Area (TA) concept in a similar way as Location Areas (LA) and Routing Areas (RA) in GSM and WCDMA networks. Each E-UTRAN cell belongs to a single TA and the Tracking Area Identity (TAI) is broadcasted as part of the System Information. The TAI consists of a Mobile Country Code (MCC), a Mobile Network Code (MNC) and a Tracking Area Code (TAC).

The main difference from the LA/RA concepts is that in SAE/LTE a concept called multiple TAs or TAI List has been introduced. This means that the network may return a TAI List to the wireless device 10 as part of some EPS Mobility Management (EMM) procedures such as e.g. Attach, Tracking Area Update (TAU) and GUTI Reallocation. As long as the wireless device 10 camps on a cell belonging to a TA whose TAI is included in the wireless device’s current TAI List, the wireless device 10 does not perform normal TAUs, however periodic TAUs may still be performed. The wireless device 10 performs normal TAU only when it moves to a cell that doesn’t belong to a TA in the TAI List. As part of this TAU the wireless device 10 will receive a new TAI List and the same procedure continues.

Since the network knows the wireless device’s location on the TAI List level, this means that the Paging Area is also normally all the TAs included in the TAI List. The Paging procedure is used to inform a wireless device in RRC-IDLE about an “incoming call” and the need for the wireless device to move to the RRC-CONNECTED state.

Hence, in an E-UTRAN/EPC network the user location, i.e. the location of the wireless device, in idle mode is known in by the core network node on TAI List level. A TA could be the coverage area of one or more cells served by RAN nodes, i.e. eNBs in an E-UTRAN. The core network node knows which RAN node(s) that provide coverage in a TA, so when a wireless device should be activated, the mobile core network orders the relevant RAN nodes to page the wireless device.

In some of the embodiments disclosed herein, the TAI and TAI List are modified to also indicate slice support information. When the wireless device 10 performs any of the above EMM procedures, such as e.g. Attach, Tracking Area Update (TAU) and GUTI Reallocation, the core network node provides a new TAI list to the wireless device 10, which list indicates in which TAs a specific network slice is available. The new TAI list may be referred to as a Slice supported TAI list. The Slice supported TAI list may include information about multiple TAIs, in which the slice which the wireless device 10 is currently attached to is available in the RAN. This also allows the possibility to indicate different PLMNs in which the slice is available, since the TAI also contains the PLMN-ID.

In one embodiment herein, the functionality of the existing TAI list is kept, and the Slice supported TAI list contains the values of {A-m, A-n, A-o, A-p, C-q}, which values indicate that a specific slice is available at the following TAIs:

- PLMN=A, TAC=m
- PLMN=A, TAC=n
- PLMN=A, TAC=o
- PLMN=A, TAC=p
- PLMN=C, TAC=q

In a further embodiment herein, both the existing TAI list and the Slice supported TAI list are returned to the wireless device 10 from the core network node 19, and both are used to indicate in which TAs a specific network slice is available. The TAI list indicates the TAIs supported by the core network node in which the slice is supported, and the Slice supported TAI list will indicate other TAIs not supported by the core network node 19 in which the slice will be supported. If the TAI list contains the values of {A-m, A-n) and the Slice supported TAI list contains the values of {A-o, A-p, C-q}, the values will indicate that a specific slice is available in the same TAIs as for the previous embodiment, namely:

- PLMN=A, TAC=m
- PLMN=A, TAC=n
- PLMN=A, TAC=o
- PLMN=A, TAC=p
- PLMN=C, TAC=q

The signal flow for the second aspect of embodiments is shown in Figure 11.

Action 1100: Before the wireless device 10 selects a cell of a RAN node 12, 13, 14 to camp on and a network to attach to the wireless device 10 may have information about its home network indicated by a HPLMN-ID and a network slice, indicated by a slice-ID, supported by the wireless device 10. This information may be stored in the wireless device 10 in e.g. a memory or a SIM/USIM.

Action 1101: When the wireless device 10 is switched on or enters the communication network 1 it will receive a broadcasted SIB from the RAN nodes 12, 13, 14. The SIB comprises information on the networks supported by the RAN node 12, 13, 14, indicated via the PLMN-ID, and the tracking area which the RAN node 12, 13, 14 is comprised in, indicated by the TAC. Although this embodiment only discloses the SIB comprising PLMN-IDs and TAC, the SIB may also comprise other information such as e.g. a cell Identity, or a Closed Subscriber Group Identity (CSG-ID). In this case a first RAN node 12 supports the networks A and B as indicated by the PLMN-IDs and is located in the tracking area m as indicated by the TAC. In a scenario where the network only supports a single PLMN-ID the SIB may indicate only the slice-ID, since this information will be sufficient to identify the correct slice.

Action 1102: Since the first cell supports the network A which is the home network of the wireless device 10, the wireless device 10 will select a cell of this RAN node 12 to camp on. In case there are several cells available which supports the home network and slice, the wireless device may perform further radio measurements on the cell to select the cell which offers the best quality of connection. When the wireless device 10 is camping on a cell of a RAN node, this RAN node may be referred to as the source RAN node. The wireless device 10 will further attach to slice a of the network A via the first core network node 19.

Action 1102a: As a response to the attachment of the wireless device 10 the core network node 19 sends an Attach Accept response comprising a list of the TAIs supported by the core network node 19 and a list of equivalent PLMNs which indicates the networks that are equivalent to network A. The Attach Accept response message in this embodiment is further updated to comprise information indicating the slices supported by each cell of the RAN nodes. This information may be added as a Slice supported TAI list which list comprises the TAIs supporting the slice which the wireless device is currently attached to via the core network node 19. The TAIs supporting the slice may be indicated as following in the message <PLMN-ID><TAC>. For the scenario described in Fig. 10 the wireless device 10 receives a message from the core network node, comprising the indication <PLMN-ID=A><TAC=m><PLMN-ID=A><TAC=n><PLMN-ID=A><TAC=o><PLMN-ID=A><TAC=p> in the Slice supported TAI list, which indicates that a cell of the RAN nodes 12, 13, 14, which supports network A and is comprised in a tracking area m, n, o and/or p supports slice a.

In a further embodiment both the Slice supported TAI list and the existing TAI list may be used to indicate which cells a specific network slice is available. The existing TAI list may indicate the TAIs supported by the core network node 19 in which the slice is supported, and the Slice supported TAI list will indicate other TAIs, not supported by the core network node 19, in which the slice will be supported. If the TAI list contains the indication <PLMN-ID=A><TAC=m><PLMN-ID=A><TAC=n> then the Slice supported TAI list may be reduced to only contain indications of other TAIs supporting the slice a, such as <PLMN-ID=A><TAC=o><PLMN-ID=A><TAC=p>. The indicators in both lists may be taken into account when determining which TAIs the specific slice is available. Hence, this will also indicate that a cell of the RAN nodes 12, 13, 14, which supports network A and is comprised in a tracking area m, n, o and/or p supports slice a.

Although this embodiment only discloses the indication being based on TAI, i.e. on PLMN-IDs and TAC, the supported slice may also be indicated based on other information such as e.g. a cell Identity, or a Closed Subscriber Group Identity (CSG-ID).

Action 1103: When the wireless device 10 is attached to network A and slice a but does not exchange any data with the network, the wireless device 10 or the RAN node 12 may release the connection between the wireless device 10 and the RAN node/core network node.

Action 1103a: When the wireless device enters the source RAN node 12 sends a RRCConnectionRelease message to the wireless device 10, which message may comprise IdleModeMobilityControlInfo dedicated for the wireless device 10.

Action 1104: The wireless device 10 may enter RRC_IDLE mode and ECM_IDLE mode.

Action 1105: When the wireless device 10 is in IDLE_MODE it receives a broadcasted SIB comprising IdleModeMobilityControlInfo which is common for all wireless device 10 from the source RAN node 12. The UE may use this broadcasted IdleModeMobilityControlInfo if it did not receive any IdleModeMobilityControlInfo in step 1103.

Action 1106: The wireless device 10 stores the information obtained from the steps 1100, 1102a, 1103a and 1105 for enabling cell reselection decisions in idle mode.

Action 1107: The wireless device 10 further receives broadcasted SIBs from the RAN nodes 12, 13, 14 such as from the target RAN nodes 13, 14, which SIBs comprise the network supported by the cells in the RAN nodes 12, 13, 14, indicated by PLMN-IDs, and the tracking area which the cell of the RAN node 12, 13, 14 is comprised in, which is indicated by the TAC. In the scenario depicted in Fig. 11, the target RAN node 13 supports the networks A and C and is comprised in tracking area p and the target RAN node 14 supports the network A and is comprised in tracking area r. From the message received in action 1102a, the wireless device knows that the slice a is supported by cells in network A and tracking area p, hence only a cell in the target RAN node 13 supports the network slice a. In a scenario where the network only supports a single PLMN-ID the SIB may indicate only the slice-ID, since this information will be sufficient to identify the correct slice.

Action 1108: The wireless device 10 may decide to perform a cell reselection to a cell in one of the target RAN nodes 13, 14 based on the information stored in step 1006, radio measurements performed and the information in the SIBs received from the target RAN nodes 13, 14. From the message received in action 1102a, the wireless device knows that the slice a is supported by cells in network A and tracking area p, hence only a cell in the target RAN 13 is relevant for a cell reselection. Since the target RAN node 13 is the only target RAN node supporting network A and is comprised in a tracking area supporting slice a, namely the tracking area p indicated by the TAC, the wireless device 10 will perform a cell reselection procedure to a cell in the RAN node 13. Hence, it will not try to perform a cell reselection to the target RAN node 14 which is not comprised in a tracking area supporting the slice which the wireless device is currently attached to, in this case slice a. Thereby, unnecessary signaling from the wireless device 10 to the RAN node 14 is avoided. This also reduces the risk of the wireless device 10 wrongfully connecting to a cell in the RAN node 14 which is not able to support slice a for the wireless device.

Although this embodiment only discloses the decision being based on TAI, i.e. on PLMN-IDs and TAC, the decision may also be based on other information such as e.g. a cell Identity, or a Closed Subscriber Group Identity (CSG-ID).

Action 1109: The wireless device 10 may further check if the TAI of the new cell in the target eNB is included in the TAI list received in step 1102a.

Action 1110: If the TAI of the new cell is not included in the TAI list received in step 1102a, the wireless device 10 performs a Tracking Area Update procedure based on the cell in the target RAN node 13, the PLMN-ID and the slice ID. In the scenario depicted in Fig. 11, since the TAI of the new cell is A-p, the wireless device perform TAU to the network to the second core network node 20, which supports the TAI=A-p.

The problem mentioned earlier, where the wireless device 10 doesn't know if the target cell supports the slice or not, is solved since the wireless device 10 retrieves the slice supported TAI list in step 1102a. The wireless device 10 matches the slice supported TAI list against the target cell's TAI received in the SIB from the target RAN node in step 1107. Thereby, the wireless device 10 may determine if the slice is supported by the target cell or not, in order to ensure that connectivity to a specific network slice is maintained during cell reselection.

The method actions performed by the wireless device 10, for handling a mobility procedure in a communication network 1 according to embodiments herein will now be described with reference to a flowchart depicted in **Fig. 12**. The actions do not have to be taken in the order stated below, but may be taken in any suitable order. Actions performed in some embodiments are marked with dashed boxes. The communication network 1 comprises a first network, which first network is associated with a core network node 19. The first network is further associated with a set of Radio Access Network (RAN) nodes 12, 13, 14. Each RAN node 12, 13, 14 is supporting a set of cells. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device 10 is associated with the first network and the first network slice. In the embodiments herein, being associated with shall be interpreted as somehow being related to, this may e.g. be the wireless device 10 camping on or being connected to a cell which has support for the network and the network slice and/or the wireless device having local information regarding the network and the network slice, such as e.g. having locally stored the network as a home network indicated with a HPLMN and the network slice being stored as a home network slice supporting the wireless device in the home network.

Action 1201: The wireless device 10 receives a message comprising an indication of one or more network slices supported by each cell of the RAN nodes 12, 13, 14 from a network node.

In one embodiment herein, the network node may be a RAN node 12, 13, 14. In this embodiment the message may be a System Information Block (SIB), which SIB comprises an indication of network slices supported by the RAN node 12, 13, 14. This indication may be a slice ID. The SIB may further comprise an indication of the networks supported by the RAN node 12, 13, 14, such as a PLMN-ID. The network slices supported by the RAN node 12, 13, 14 may be indicated for each supported network. Hence, the wireless device 10 may receive an explicit slice support indication, for each supported PLMN-ID of the cell, in the SIB.

In a further embodiment herein, the network node may be a core network node 19 and the message may comprise a list of identifiers indicating which cells are supporting the first network slice. The identifiers are identifiers which are also broadcasted to the wireless device 10 from a RAN node 12, 13, 14. The identifiers may e.g. be identifiers comprised in a system information message, such as a SIB, broadcasted to the wireless device 10 from the RAN node 12, 13, 14. The message received from the core network node 19 may be received by the wireless device 10 over a NAS protocol and may e.g. be an Attach Accept message. This message does not explicitly state the slices supported by each cell, however the supported slices for each cell are implicitly indicated.

In some embodiments herein, the list of identifiers received from the core network node 19 may be a list of Tracking Area Identifiers (TAI), which TAIs are supporting the first network slice associated with the wireless device 10. The TAI comprises a network identity, such as a PLMN-ID, and a Tracking Area Code, TAC. The TAI list may be referred to as a slice supported TAI List.

In another embodiment herein, the list of identifiers may be a list of CSG-IDs supporting the first network slice associated with the wireless device 10. The CSG-ID list may be referred to as a slice supported CSG-ID List.

In a further embodiment herein, the list of identifiers may be a list of cell identifiers, such as Cell-IDs. The Cell-ID list may be referred to as a slice supported Cell-ID List.

Action 1202: The wireless device may further, when the message in action 1201 is received from the core network node, further receive a broadcasted message from the RAN node 12, 13, 14. This message comprises one or more identifiers relating to the one or more cells of the RAN node 12, 13, 14.

In some embodiments herein, the one or more identifiers may comprise a TAI for each cell of the RAN node 12, 13, 14 and/or for the RAN node 12, 13, 14. The TAI may comprise a network identity, such as a PLMN-ID, and a Tracking Area Code, TAC.

In another embodiment herein, the one or more identifiers may comprise a CSG-ID for each cell of the RAN node 12, 13, 14 and/or for the RAN node 12, 13, 14.

In a further embodiment herein, the one or more identifiers may comprise a cell identifier, such as a Cell-ID, supporting the first network slice associated with the wireless device (10), for each cell of the RAN node 12, 13, 14 and/or for the RAN node 12, 13, 14.

Action 1203: The wireless device 10 selects a cell for camping on. The selection is based on the indication received from the network node, wherein the indication indicates that the cell supports the first slice associated with the wireless device 10. This action 1203 is similar to the 1008 described above in relation to Fig. 10 and action 1108 described above in relation to Fig. 11.

When the message received in action 1202 comprises a list of identifiers indicating which cells are supporting the first network slice, the wireless device 10 may further perform the following actions for selecting the cell for camping on:

Action 1204: The wireless device 10 may compare the one or more identifier relating to the one or more cells, received from the RAN node 12, 13, 14 in action 1202, with the identifier indicating which cells are supporting the first network slice, received from the core network node 19 in action 1201.

This action 1204 is similar to the action 1108 described above in relation to Fig. 11.

Action 1205: The wireless device may further select a cell for which the one or more identifier received from the RAN node 12, 13, 14 in action 1202, matches one or more of the identifiers in the list of identifiers received from the core network node 19 in action 1201.

This action 1205 is similar to the action 1108 described above in relation to Fig. 11.

The method actions performed by a Radio Access Network (RAN) node 12, 13, 14, for enabling a mobility procedure for a wireless device 10 in a communication network 1 according to embodiments herein will now be described with reference to a flowchart depicted in **Fig. 13**. The actions do not have to be taken in the order stated below, but may be taken in any suitable order. Actions performed in some embodiments are marked with dashed boxes. The communication network 1 comprises a first network, which first network is associated with a core network node 19. The RAN node 12, 13, 14 is comprised in a set of RAN nodes 12, 13, 14 associated with the first network, wherein each RAN node 12, 13, 14 in the set of RAN nodes supports a set of cells. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device 10. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device 10 is associated with the first network and the first network slice.

Action 1301: The RAN node 12, 13, 14 transmits a message to the wireless device 10, which message comprises an indication of networks and network slices supported by each cell, for each cell of the RAN node 12, 13, 14. The network supported by each cell may e.g. be indicated by a PLMN-ID, and the network slice supported may be indicated by a slice ID, in the form of <PLMN-ID><slice-ID>. Hence, the message explicitly indicates the network slices supported by each cell of the RAN node 12, 13, 14. In some embodiments herein, the message comprises system information. In some further embodiments the message may be a System Information Block, SIB, such as e.g. SIB1 or any other SIB.

The method actions performed by a core network node 19, for enabling a mobility procedure for a wireless device 10 in a communication network 1 according to embodiments herein will now be described with reference to a flowchart depicted in **Fig. 14**. The actions do not have to be taken in the order stated below, but may be taken in any suitable order. Actions performed in some embodiments are marked with dashed boxes. The communication network 1 comprises a first network, which first network is associated with the core network node 19. The first network is further associated with a set of RAN nodes 12, 13, 14. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device 10. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device 10 is associated with the first network and the first network slice in a first cell of a first RAN node 12.

Action 1401: The core network node 19 transmits a message to the wireless device 10, which message comprises a list of identifiers indicating which cells are supporting the first network slice. The identifiers comprised in the list may be identifiers comprised in a broadcasted message to the wireless device 10 from a RAN node 12, 13, 14. The identifiers may e.g. be identifiers comprised in a system information message, such as a SIB, broadcasted to the wireless device 10 from the RAN node 12, 13, 14.

In some embodiments herein, the list of identifiers may be a list of Tracking Area Identifiers, TAI, supporting the first network slice associated with the wireless device 10. Each TAI comprises a network identity, such as a PLMN-ID, and a Tracking Area Code, TAC.

In a further embodiment herein, the list of identifiers is a list of Closed Subscriber Groups (CSGs) supporting the first network slice associated with the wireless device 10.

In yet another embodiment herein, the list of identifiers may be a list of cell identifiers, supporting the first network slice associated with the wireless device 10.

Fig. 15 is a block diagram depicting the wireless device 10 for for handling a mobility procedure in a communication network 1. The communication network 1 comprises a first network, which first network is associated with a core network node 19. The first network is further associated with a set of RAN nodes 12, 13, 14, and each RAN node 12, 13, 14 is supporting a set of cells. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device 10. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device 10 is associated with the first network and the first network slice. The wireless device 10 may comprise a **processing unit 1501**, e.g. one or more processors, configured to perform the methods described herein.

The wireless device 10 is configured to, e.g. by means of a **receiving module 1502** and/or the processing unit 1501 being configured to, receive a message comprising an indication of one or more network slice supported by each cell of the RAN nodes 12, 13, 14 from a network node. The wireless device 10 may further be configured to, e.g. by means of the receiving module 1502 and/or the processing unit 1501 being configured to, receive the message from a RAN node 12, 13, 14, wherein the message is a System Information Block, SIB, which SIB comprises an indication of network slices supported by the RAN node 12, 13, 14. The SIB may further comprise an indication of networks supported by each cell in the RAN node 12, 13, 14, wherein the network slices supported by each cell in the RAN node 12, 13, 14 are indicated for each supported network.

The wireless device 10 may further be configured to, e.g. by means of the receiving module 1502 and/or the processing unit 1501 being configured to, receive the message from a core network node 19, wherein the message comprises a list of identifiers indicating which cells are supporting the first network slice. The identifiers in the list of identifiers are identifiers which are also broadcasted to the wireless device 10 from a RAN node 12, 13, 14.

The wireless device 10 is configured to, e.g. by means of a **selecting module 1503** and/or the processing unit 1501 being configured to, select a cell for camping on, based on the indication received from the network node, wherein the indication indicates that the cell supports the first slice associated with the wireless device 10.

The wireless device 10 may further be configured to, e.g. by means of the receiving module 1502 and/or the processing unit 1501 being configured to, receive a broadcasted message from the RAN node 12, 13, 14 comprising one or more identifiers relating to the one or more cells of the RAN node 12, 13, 14.

The wireless device 10 may further be configured to, e.g. by means of a **comparing module 1504** and/or the processing unit 1501 being configured to, compare the one or more identifiers relating to the one or more cells, received from the RAN node 12, 13, 14, with the identifier indicating which cells are supporting the first network slice, received from the core network node 19.

The wireless device 10 may further be configured to, e.g. by means of the selecting module 1503 and/or the processing unit 1501 being configured to, select a cell for which the received one or more identifier from the RAN node 12, 13, 14 matches one or more of the identifiers received from the core network node 19.

The wireless device 10 further comprises **a memory 1505**. The memory comprises one or more units to be used to store data on, such as system information, IDLE mode mobility information, network slice information, wireless device IDs, network slice and roaming policies, Slice IDs, applications to perform the methods disclosed herein when being executed, and similar.

The methods according to the embodiments described herein for the wireless device 10 are respectively implemented by means of e.g. **a computer program 1506** or a computer program product, comprising instructions, i.e., software code portions, which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the wireless device 10. The computer program 1506 may be stored on **a computer-readable storage medium 1507**, e.g. a disc or similar. The computer-readable storage medium 1507, having stored thereon the computer program, may comprise the instructions which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the wireless device 10. In some embodiments, the computer-readable storage medium may be a non-transitory computer-readable storage medium.

Fig. 16 is a block diagram depicting the RAN node 12, 13, 14 for enabling a mobility procedure for a wireless device 10 in a communication network 1. The communication network 1 comprises a first network, which first network is associated with a core network node 19. The RAN node 12, 13, 14 is comprised in a set of RAN nodes 12, 13, 14 associated with the first network, wherein each RAN node 12, 13, 14 supports a set of cells. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device 10. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device 10 is associated with the first network and the first network slice. The RAN node 12 may comprise a **processing unit 1601**, e.g. one or more processors, configured to perform the methods described herein.

The RAN node 12, 13, 14 is configured to, e.g. by means of a **transmitting module 1602** and/or the processing unit 1601 being configured to, transmit for each cell of the RAN node 12, 13, 14, a message to the wireless device 10, which message comprises an indication of networks supported and network slices supported by each cell.

The RAN node 12, 13, 14 may further be configured to, e.g. by means of the transmitting module 1602 and/or the processing unit 1601 being configured to, transmit the message as a System Information Block, SIB.

The RAN node 12 further comprises **a memory 1603**. The memory comprises one or more units to be used to store data on, such as system information, IDLE mode mobility information, network slice information, wireless device IDs, network slice and roaming policies, Slice IDs, applications to perform the methods disclosed herein when being executed, and similar.

The methods according to the embodiments described herein for the RAN node 12 are respectively implemented by means of e.g. **a computer program 1604** or a computer program product, comprising instructions, i.e., software code portions, which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the RAN node 12. The computer program 1604 may be stored on **a computer-readable storage medium 1605**, e.g. a disc or similar. The computer-readable storage medium 1605, having stored thereon the computer program, may comprise the instructions which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the RAN node 12. In some embodiments, the computer-readable storage medium may be a non-transitory computer-readable storage medium.

Fig. 17 is a block diagram depicting the core network node 19 for enabling a mobility procedure for the wireless device 10 in the communication network 1. The communication network 1 comprises a first network, which first network is associated with the core network node 19. The first network is further associated with a set of Radio Access Network, RAN, nodes 12, 13, 14. The first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device 10. The first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network. The wireless device 10 is associated with the first network and the first network slice in a first cell of a first RAN node 12. The core network node 19 may comprise a **processing unit 1701**, e.g. one or more processors, configured to perform the methods described herein.

The core network node 19 is configured to, e.g. by means of a **transmitting module 1702** and/or the processing unit 1701 being configured to, transmit a message to the wireless device 10, which message comprises a list of identifiers indicating which cells are supporting the first network slice. The identifiers comprised in the list of identifiers are identifiers which are also comprised in a broadcasted message to the wireless device 10 from a RAN node 12, 13, 14.

The core network node 19 further comprises **a memory 1703**. The memory comprises one or more units to be used to store data on, such as, system information, IDLE mode mobility information, network slice information, wireless device IDs, network slice and roaming policies, Slice IDs, applications to perform the methods disclosed herein when being executed, and similar.

The methods according to the embodiments described herein for the core network node 19 are respectively implemented by means of e.g. **a computer program 1704** or a computer program product, comprising instructions, i.e., software code portions, which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the core network node 19. The computer program 1704 may be stored on **a computer-readable storage medium 1705**, e.g. a disc or similar. The computer-readable storage medium 1705, having stored thereon the computer program, may comprise the instructions which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the core network node 19. In some embodiments, the computer-readable storage medium may be a non-transitory computer-readable storage medium.

A novel state model may be proposed for the 5G architecture enabling an efficient sleeping of a wireless device, a fast and lightweight transition from sleeping to active states and joint access optimizations. One likely model to be adopted is the following shown in Fig. 18.

The model consists of three states: “RRC Idle”, “RRC Connected” and “RRC Connected Inactive”. In the novel state model the state transitions from RRC Idle to RRC Connected are expected to occur mainly during the first initial access, such as e.g. when the UE attaches to the network, or as a fallback case, such as e.g. when the devices and/or the network cannot use the previously stored RAN context. As a consequence, this transition is not expected to occur as often as in LTE.

On the other hand, transitions from “RRC Connected Inactive” to “RRC Connected” are expected to occur quite often and should be optimized as a lightweight and fast transition. The novel “RRC Connected Inactive” state designed to be used as the primary sleep state for the 5G access has as one of the characteristics the maintenance of context information by the wireless device and the network when the moves from “RRC Connected” to “RRC Connected Inactive”. Some of these characteristics are currently being standardized by 3GPP for LTE as well and may be referred to as Suspended state.

Therefore, when it comes to the wireless device state model assumptions relevant for the embodiments described herein, the described cell selection and cell reselection enhancements may also occur for 5G devices in RRC Idle as currently in LTE. The described cell selection and cell reselection enhancements may also apply for wireless devices in the RRC Connected Inactive state, which may also be referred to as a Dormant state, and also for wireless devices in Suspended state. Although the embodiments herein are described for a wireless device in IDLE mode, the embodiments may be equally applicable in these similar states of the wireless device.

As will be readily understood by those familiar with communications design, the description applied to a 'cell' is equally applicable to all UE-based mobility, such as e.g. selection and re-selection, in NX even if the concept/term ‘cell’ is replaced by a corresponding concept/term such as e.g. a beam, a beam group or service area, which describes a geographical area covered by a RAN node.

Embodiments herein relate to a network with network slices i.e. a (core or RAN or both) network with partitioned sets of functionalities wherein the core network node 19, the wireless device 10 and/or the RAN node 12 may support the first set of functionalities out of the total set of functionalities in the network of the communication network. The first set of functionalities belongs to the first network slice of the network, and is separated from another set of functionalities out of the total set of functionalities in the network.

As will be readily understood by those familiar with communications design, that functions means or modules may be implemented using digital logic and/or one or more microcontrollers, microprocessors, or other digital hardware. In some embodiments, several or all of the various functions may be implemented together, such as in a single application-specific integrated circuit (ASIC), or in two or more separate devices with appropriate hardware and/or software interfaces between them. Several of the functions may be implemented on a processor shared with other functional components of a network node, for example.

Alternatively, several of the functional elements of the processing means discussed may be provided through the use of dedicated hardware, while others are provided with hardware for executing software, in association with the appropriate software or firmware. Thus, the term “processor” or “controller” as used herein does not exclusively refer to hardware capable of executing software and may implicitly include, without limitation, digital signal processor (DSP) hardware, read-only memory (ROM) for storing software, random-access memory for storing software and/or program or application data, and non-volatile memory. Other hardware, conventional and/or custom, may also be included. Designers of network nodes will appreciate the cost, performance, and maintenance trade-offs inherent in these design choices.

Although the embodiments herein are described for an LTE-like architecture it shall be noted that they are equally applicable to any architecture based on an evolution of the S1 interface.

When using the word "comprise" or “comprising” it shall be interpreted as non-limiting, i.e. meaning "consist at least of". When using the word “set” herein, it shall be interpreted as meaning “one or more”.

It will be appreciated that the foregoing description and the accompanying drawings represent non-limiting examples of the methods and apparatus taught herein.

As such, the apparatus and techniques taught herein are not limited by the foregoing description and accompanying drawings. Instead, the embodiments herein are limited only by the following claims and their legal equivalents.

CLAIMS

1. A method performed by a wireless device (10), for handling a mobility procedure in a communication network (1), which communication network (1) comprises a first network, which first network is associated with a core network node (19), and which first network is further associated with a set of Radio Access Network, RAN, nodes (12, 13, 14), each RAN node (12, 13, 14) supporting a set of cells, wherein the first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device (10), and which first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network, wherein the wireless device (10) is associated with the first network and the first network slice, the method comprising:
   - *receiving* (1201) a message comprising an indication of one or more network slice supported by each cell of the RAN nodes (12, 13, 14) from a network node; and
   - *selecting* (1203) a cell for camping on, based on the indication received from the network node, wherein the indication indicates that the cell supports the first slice associated with the wireless device (10).

2. The method according to claim 1, wherein the network node is a RAN node (12, 13, 14) and the message is a System Information Block, SIB, which SIB comprises an indication of network slices supported by the RAN node (12, 13, 14).

3. The method according to claim 2, wherein the SIB further comprises an indication of networks supported by the each cell in the RAN node (12, 13, 14) and wherein the network slices supported by each cell in the RAN node (12, 13, 14) are indicated for each supported network.

4. The method according to claim 1, wherein the network node is a core network node (19) and the message comprises a list of identifiers indicating which cells are supporting the first network slice, wherein the identifiers are identifiers broadcasted to the wireless device (10) from a RAN node (12, 13, 14).

5. The method according to claim 4, wherein the method further comprises:

- *receiving* (1202) a broadcasted message from the RAN node (12, 13, 14) comprising one or more identifiers relating to the one or more cells of the RAN node (12, 13, 14),

and wherein the selecting (1203) comprises:

- *comparing* (1204) the one or more identifier relating to the one or more cells, received from the RAN node (12, 13, 14), with the identifier indicating which cells are supporting the first network slice, received from the core network node (19), and
- *selecting* (1205) a cell for which the received one or more identifier from the RAN node (12, 13, 14) matches one or more of the identifiers received from the core network node (19).

6. The method according to claim 4 or 5, wherein the list of identifiers is a list of Tracking Area Identifiers, TAI, supporting the first network slice associated with the wireless device (10), which TAI comprises a network identity and a Tracking Area Code, TAC.

7. The method according to claim 4 or 5, wherein the list of identifiers is a list of Closed Subscriber Group Identities, CSG-IDs, supporting the first network slice associated with the wireless device (10).

8. The method according to claim 4 or 5, wherein the list of identifiers is a list of cell identifiers, supporting the first network slice associated with the wireless device (10).

9. A method performed by a Radio Access Network, RAN, node (12, 13, 14), for enabling a mobility procedure for a wireless device (10) in a communication network (1), which communication network (1) comprises a first network, which first network is associated with a core network node (19), and which RAN node (12, 13, 14) is comprised in a set of RAN nodes (12, 13, 14) associated with the first network, wherein each RAN node (12, 13, 14) supports a set of cells, wherein the first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device (10), and which first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network, wherein the wireless device (10) is associated with the first network and the first network slice, the method comprising:

- *transmitting* (1301) for each cell of the RAN node (12, 13, 14), a message to the wireless device (10), which message comprises an indication of networks supported and network slices supported by each cell.

10. The method according to claim 9, wherein the message is a System Information Block, SIB.

11. A method performed by a core network node (19), for enabling a mobility procedure for a wireless device (10) in a communication network (1), which communication network (1) comprises a first network, which first network is associated with the core network node (19), and which first network is further associated with a set of Radio Access Network, RAN, nodes (12, 13, 14), wherein the first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device (10), and which first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network, wherein the wireless device (10) is associated with the first network and the first network slice in a first cell of a first RAN node (12), the method comprising:
    - *transmitting* (1401) a message to the wireless device (10), which message comprises a list of identifiers indicating which cells are supporting the first network slice, wherein the identifiers are identifiers comprised in a broadcasted message to the wireless device (10) from a RAN node (12, 13, 14).

12. The method according to claim 11, wherein the list of identifiers is a list of Tracking Area Identifiers, TAI, supporting the first network slice associated with the wireless device (10), wherein each TAI comprises a network identity and a Tracking Area Code, TAC.

13. The method according to claim 11, wherein the list of identifiers is a list of Closed Subscriber Group Identities, CSG-IDs, supporting the first network slice associated with the wireless device (10).

14. The method according to claim 11, wherein the list of identifiers is a list of cell identifiers, supporting the first network slice associated with the wireless device (10).

15. A wireless device (10) for handling a mobility procedure in a communication network (1), which communication network (1) comprises a first network, which first network is associated with a core network node (19), and which first network is further associated with a set of Radio Access Network, RAN, nodes (12, 13, 14), each RAN node (12, 13, 14) supporting a set of cells, wherein the first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device (10), and which first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network, wherein the wireless device (10) is associated with the first network and the first network slice, the wireless device (10) being configured to:
    – receive a message comprising an indication of one or more network slice supported by each cell of the RAN nodes (12, 13, 14) from a network node; and
    – select a cell for camping on, based on the indication received from the network node, wherein the indication indicates that the cell supports the first slice associated with the wireless device (10).

16. The wireless device (10) according to claim 15, wherein the network node is a RAN node (12, 13, 14) and the message is a System Information Block, SIB, which SIB comprises an indication of network slices supported by the RAN node (12, 13, 14).

17. The method according to claim 16, wherein the SIB further comprises an indication of networks supported by each cell in the RAN node (12, 13, 14) and wherein the network slices supported by each cell in the RAN node (12, 13, 14) are indicated for each supported network.

18. The wireless device (10) according to claim 17, wherein the network node is a core network node (19) and the message comprises a list of identifiers indicating which cells are supporting the first network slice, wherein the identifiers are identifiers broadcasted to the wireless device (10) from a RAN node (12, 13, 14).

19. The wireless device (10) according to claim 18, wherein the wireless device (10) further is configured to:

- receive a broadcasted message from the RAN node (12, 13, 14) comprising one or more identifiers relating to the one or more cells of the RAN node (12, 13, 14),

and wherein the wireless device (10) is configured to determine by being configured to:

- compare the one or more identifiers relating to the one or more cells, received from the RAN node (12, 13, 14), with the identifier indicating which cells are supporting the first network slice, received from the core network node (19), and
- select a cell for which the received one or more identifier from the RAN node (12, 13, 14) matches one or more of the identifiers received from the core network node (19).

20. A RAN node (12, 13, 14) for enabling a mobility procedure for a wireless device (10) in a communication network (1), which communication network (1) comprises a first network, which first network is associated with a core network node (19), and which RAN node (12, 13, 14) is comprised in a set of RAN nodes (12, 13, 14) associated with the first network, wherein each RAN node (12, 13, 14) supports a set of cells, wherein the first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device (10), and which first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network, wherein the wireless device (10) is associated with the first network and the first network slice, the RAN node (12, 13, 14) being configured to:

- transmit for each cell of the RAN node (12, 13, 14), a message to the wireless device (10), which message comprises an indication of networks supported and network slices supported by each cell.

21. The RAN node (12, 13, 14) according to claim 20, wherein the message is a System Information Block, SIB.

22. A core network node (19) for enabling a mobility procedure for a wireless device (10) in a communication network (1), which communication network (1) comprises a first network, which first network is associated with the core network node (19), and which first network is further associated with a set of Radio Access Network, RAN, nodes (12, 13, 14), wherein the first network further comprises partitioned sets of functionalities, wherein a first set of functionalities belongs to a first network slice supporting the wireless device (10), and which first set of functionalities is separated from another set of functionalities out of a total set of functionalities in the first network, wherein the wireless device (10) is associated with the first network and the first network slice in a first cell of a first RAN node (12), the core network node (19) being configured to:

   - transmit a message to the wireless device (10), which message comprises a list of identifiers indicating which cells are supporting the first network slice, wherein the identifiers are identifiers are identifiers comprised in a broadcasted message to the wireless device (10) from a RAN node (12, 13, 14).

23. A computer program comprising instructions, which, when executed on at least one processor, cause the at least one processor to carry out any of the methods according to any of the claims 1-14, as performed by the wireless device, the core network node and the RAN node.

24. A computer-readable storage medium, having stored thereon a computer program comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method according to any of the claims 1-14, as performed by the wireless device, the core network node and the RAN node.

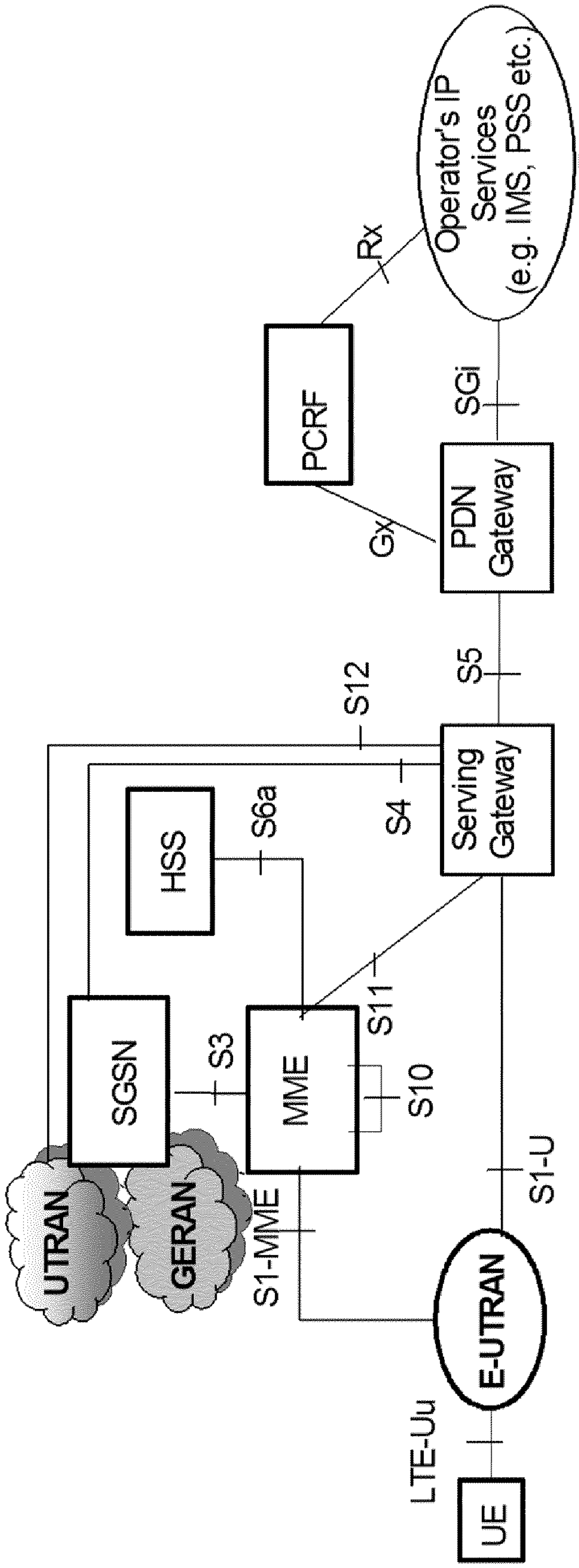
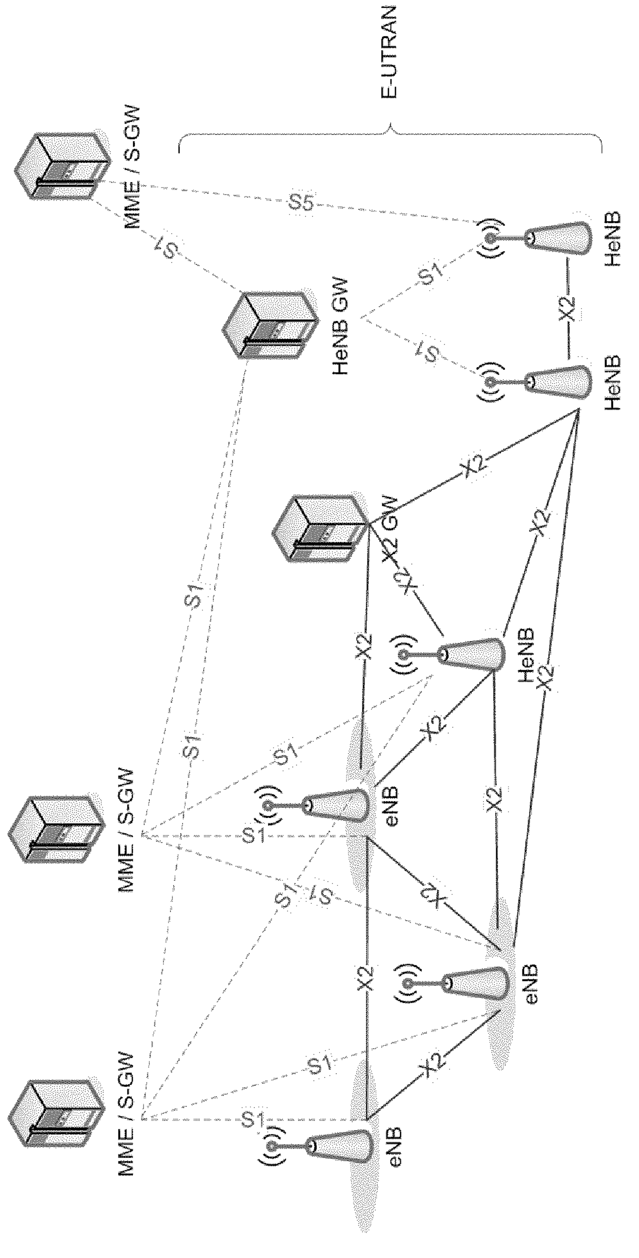

UE
LTE-Uu
E-UTRAN
S1-MME
S1-U
UTRAN
GERAN
SGSN
S3
MME
S10
S11
HSS
S6a
S4
S12
Serving Gateway
S5
PDN Gateway
Gx
PCRF
SGi
Rx
Operator's IP Services (e.g. IMS, PSS etc.)

Fig. 1



E-UTRAN
MME / S-GW
MME / S-GW
MME / S-GW
HeNB GW
X2 GW
HeNB
HeNB
HeNB
eNB
eNB
eNB
S1
S5
X2

Fig. 2

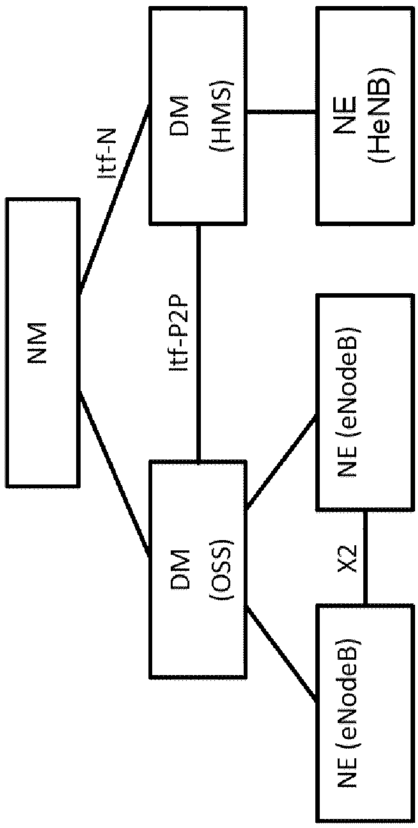


Fig. 3

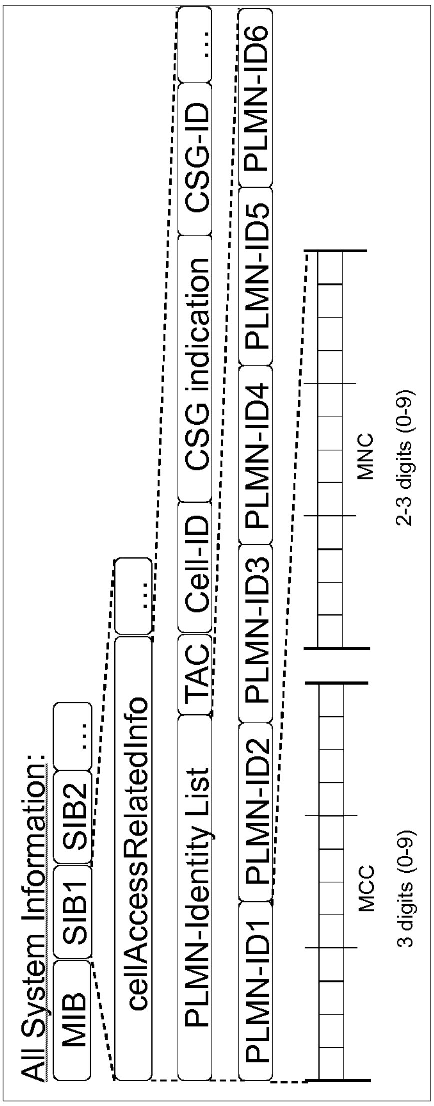

All System Information:
MIB
SIB1
SIB2
...
cellAccessRelatedInfo
...
PLMN-Identity List
TAC
Cell-ID
CSG indication
CSG-ID
...
PLMN-ID1
PLMN-ID2
PLMN-ID3
PLMN-ID4
PLMN-ID5
PLMN-ID6
MCC
3 digits (0-9)
MNC
2-3 digits (0-9)

Fig. 4

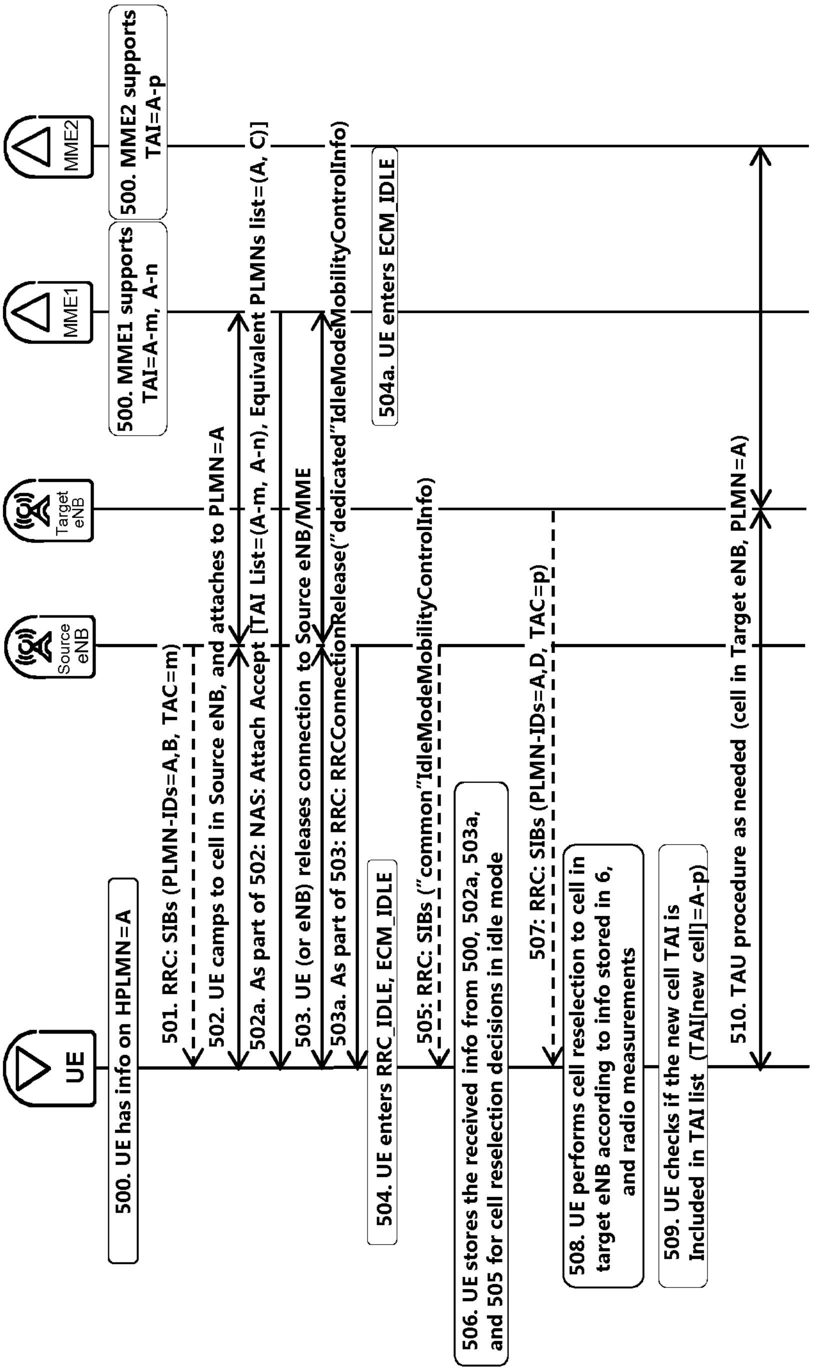

UE
Source eNB
Target eNB
MME1
MME2
500. UE has info on HPLMN=A
500. MME1 supports TAI=A-m, A-n
500. MME2 supports TAI=A-p
501. RRC: SIBs (PLMN-IDs=A,B, TAC=m)
502. UE camps to cell in Source eNB, and attaches to PLMN=A
502a. As part of 502: NAS: Attach Accept [TAI List=(A-m, A-n), Equivalent PLMNs list=(A, C)]
503. UE (or eNB) releases connection to Source eNB/MME
503a. As part of 503: RRC: RRCConnectionRelease("dedicated"IdleModeMobilityControlInfo)
504. UE enters RRC_IDLE, ECM_IDLE
504a. UE enters ECM_IDLE
505: RRC: SIBs ("common"IdleModeMobilityControlInfo)
506. UE stores the received info from 500, 502a, 503a, and 505 for cell reselection decisions in idle mode
507: RRC: SIBs (PLMN-IDs=A,D, TAC=p)
508. UE performs cell reselection to cell in target eNB according to info stored in 6, and radio measurements
509. UE checks if the new cell TAI is Included in TAI list (TAI[new cell]=A-p)
510. TAU procedure as needed (cell in Target eNB, PLMN=A)

Fig. 5

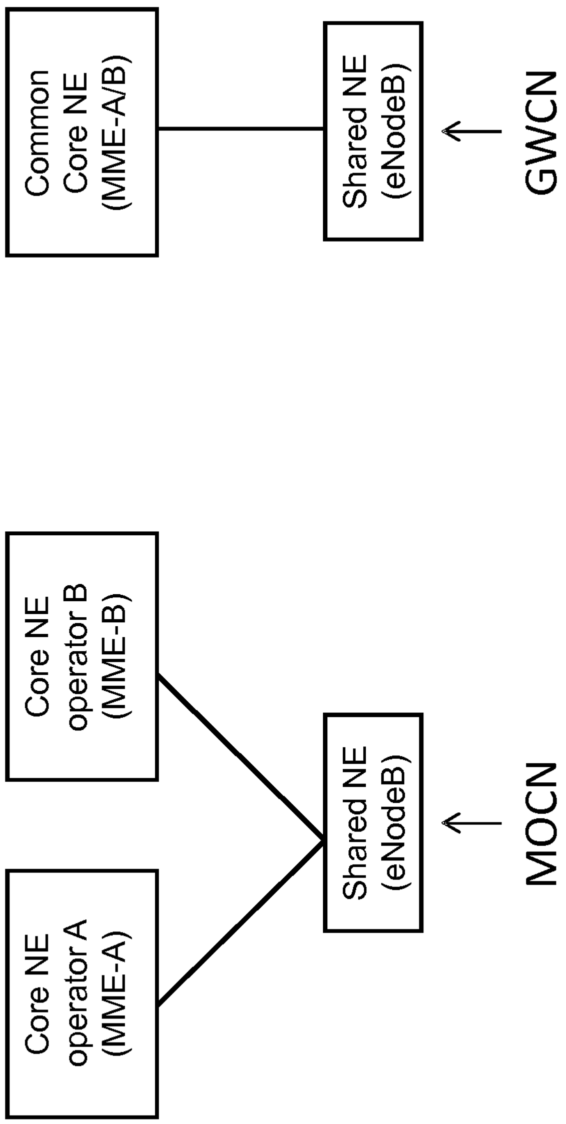

Common Core NE (MME-A/B)
Shared NE (eNodeB)
GWCN
Core NE operator B (MME-B)
Core NE operator A (MME-A)
Shared NE (eNodeB)
MOCN

Fig. 6

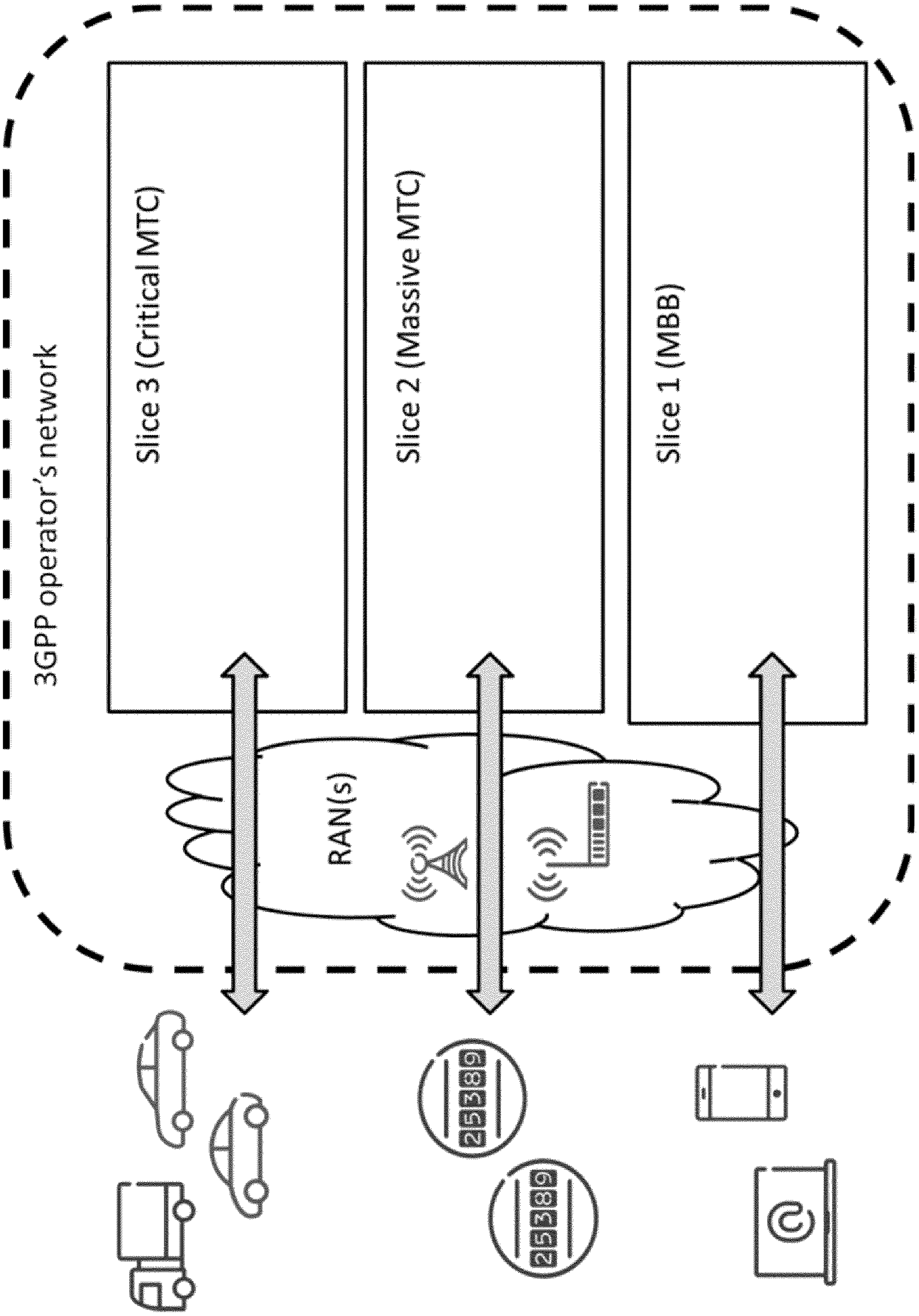

3GPP operator's network
Slice 3 (Critical MTC)
Slice 2 (Massive MTC)
Slice 1 (MBB)
RAN(s)
25389
25389

Fig. 7

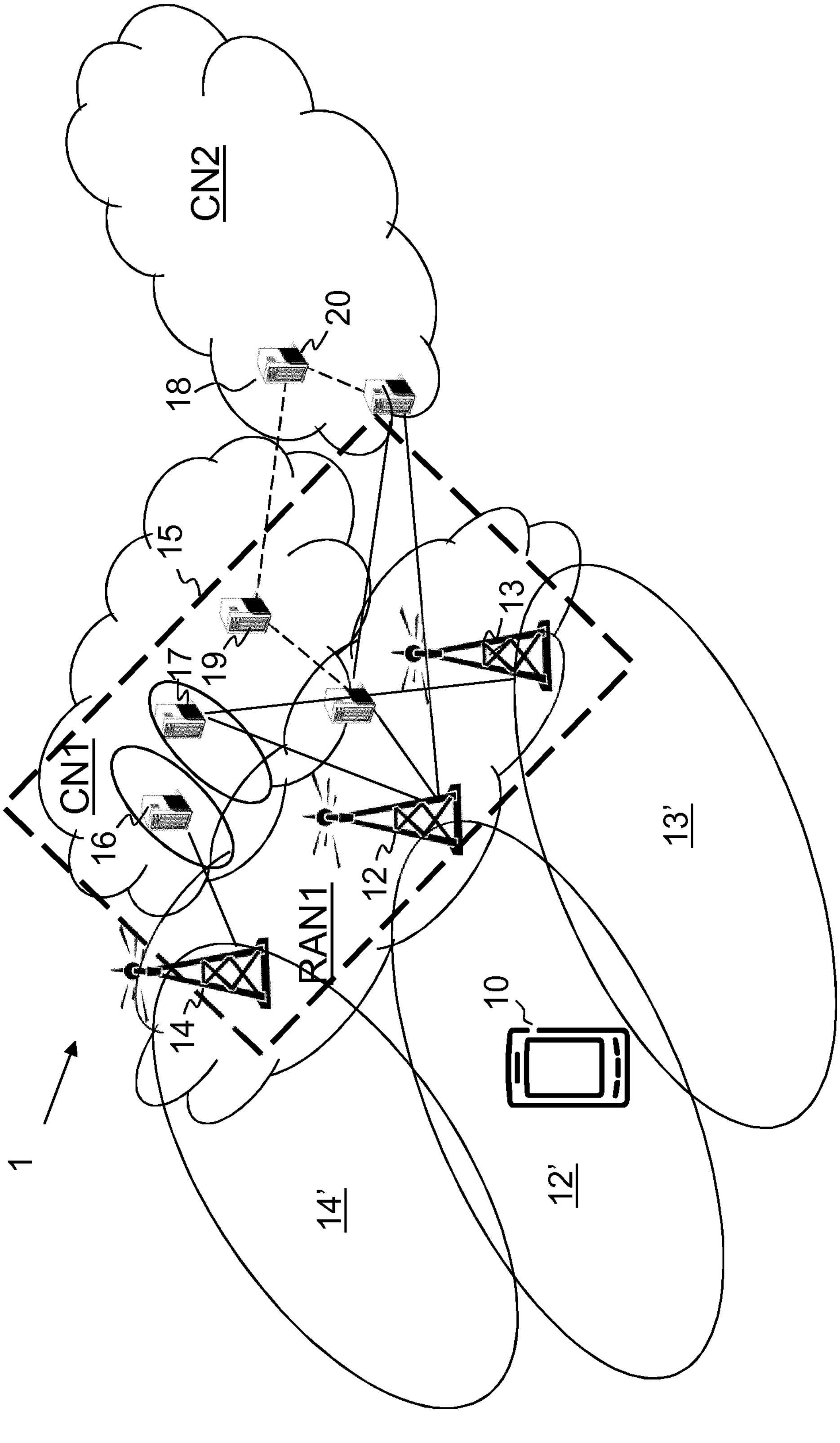


Fig. 8

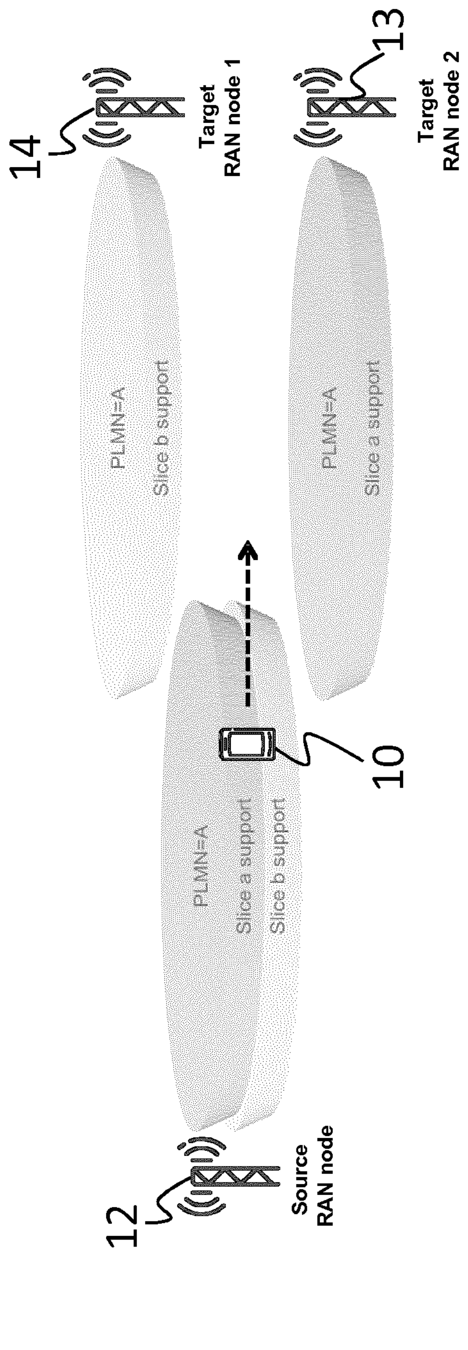

14
Target
RAN node 1
13
Target
RAN node 2
PLMN=A
Slice b support
PLMN=A
Slice a support
10
PLMN=A
Slice a support
Slice b support
12
Source
RAN node

Fig. 9

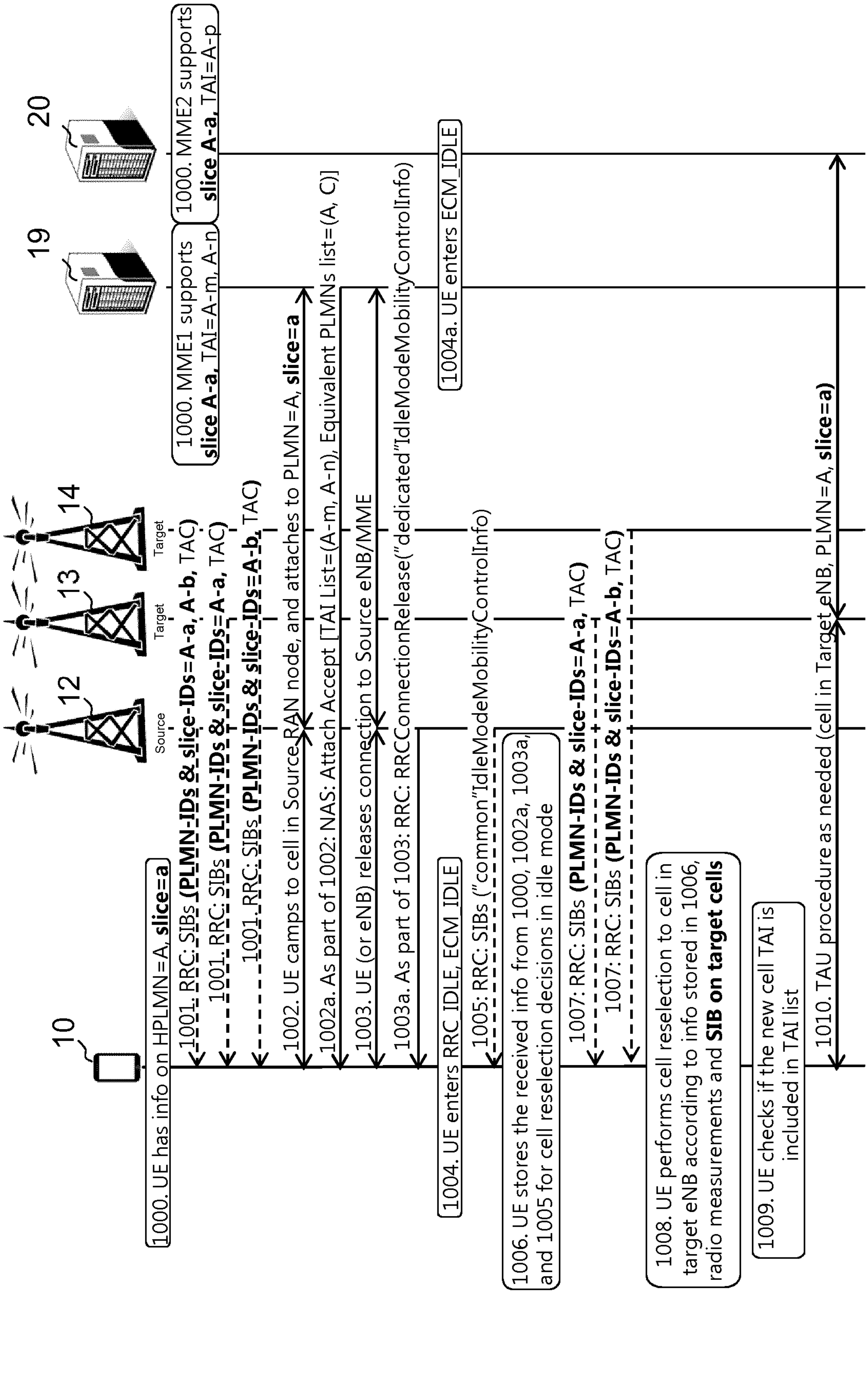

10
12
13
14
19
20
Source
Target
Target
1000. UE has info on HPLMN=A, slice=a
1000. MME1 supports slice A-a, TAI=A-m, A-n
1000. MME2 supports slice A-a, TAI=A-p
1001. RRC: SIBs (PLMN-IDs & slice-IDs=A-a, A-b, TAC)
1001. RRC: SIBs (PLMN-IDs & slice-IDs=A-a, TAC)
1001. RRC: SIBs (PLMN-IDs & slice-IDs=A-b, TAC)
1002. UE camps to cell in Source RAN node, and attaches to PLMN=A, slice=a
1002a. As part of 1002: NAS: Attach Accept [TAI List=(A-m, A-n), Equivalent PLMNs list=(A, C)]
1003. UE (or eNB) releases connection to Source eNB/MME
1003a. As part of 1003: RRC: RRCConnectionRelease("dedicated"IdleModeMobilityControlInfo)
1004. UE enters RRC IDLE, ECM IDLE
1004a. UE enters ECM_IDLE
1005: RRC: SIBs ("common"IdleModeMobilityControlInfo)
1006. UE stores the received info from 1000, 1002a, 1003a, and 1005 for cell reselection decisions in idle mode
1007: RRC: SIBs (PLMN-IDs & slice-IDs=A-a, TAC)
1007: RRC: SIBs (PLMN-IDs & slice-IDs=A-b, TAC)
1008. UE performs cell reselection to cell in target eNB according to info stored in 1006, radio measurements and SIB on target cells
1009. UE checks if the new cell TAI is included in TAI list
1010. TAU procedure as needed (cell in Target eNB, PLMN=A, slice=a)

Fig. 10

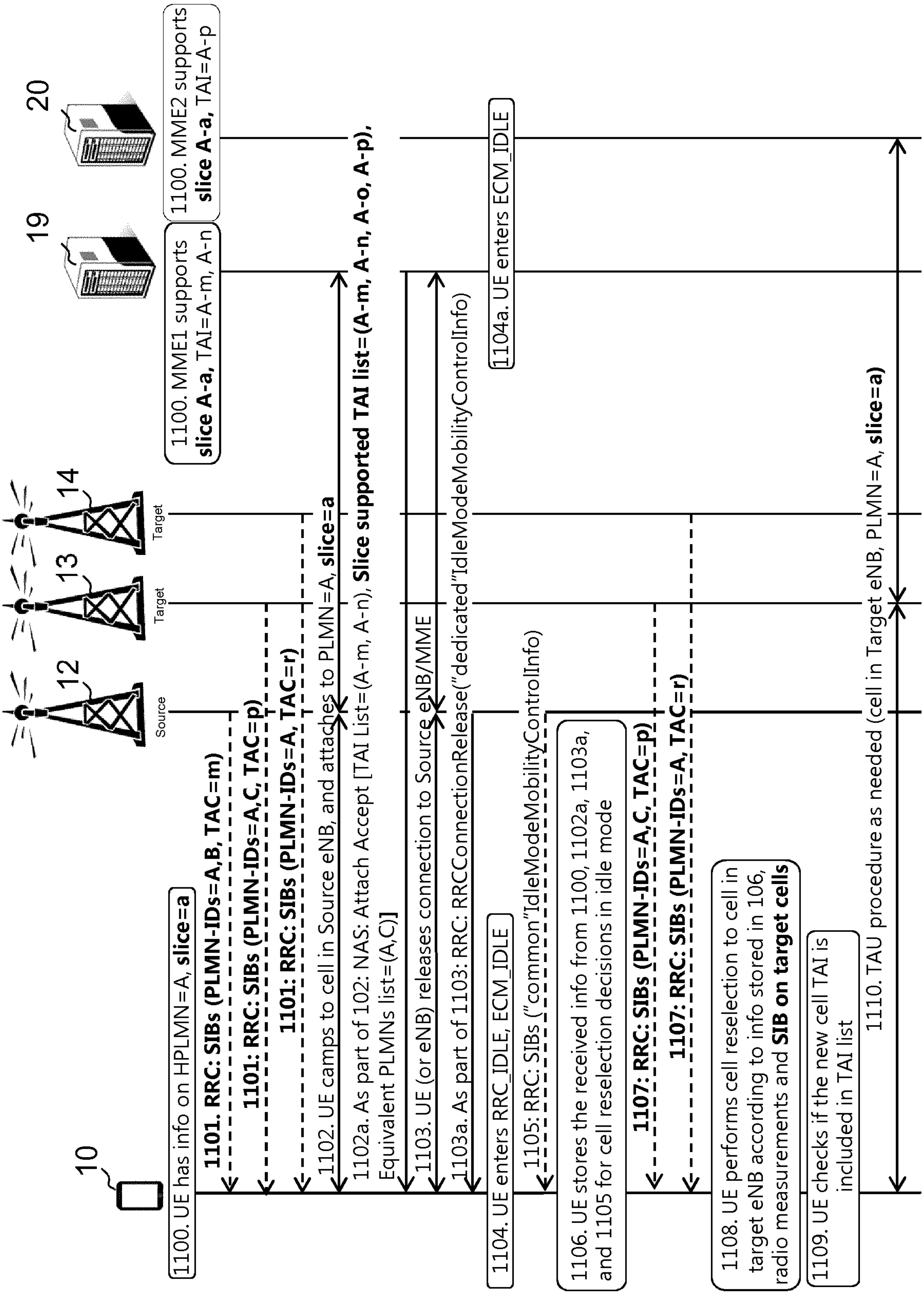

10
12
13
14
19
20
Source
Target
Target
1100. UE has info on HPLMN=A, slice=a
1100. MME1 supports slice A-a, TAI=A-m, A-n
1100. MME2 supports slice A-a, TAI=A-p
1101. RRC: SIBs (PLMN-IDs=A,B, TAC=m)
1101: RRC: SIBs (PLMN-IDs=A,C, TAC=p)
1101: RRC: SIBs (PLMN-IDs=A, TAC=r)
1102. UE camps to cell in Source eNB, and attaches to PLMN=A, slice=a
1102a. As part of 102: NAS: Attach Accept [TAI List=(A-m, A-n), Slice supported TAI list=(A-m, A-n, A-o, A-p), Equivalent PLMNs list=(A,C)]
1103. UE (or eNB) releases connection to Source eNB/MME
1103a. As part of 1103: RRC: RRCConnectionRelease("dedicated"IdleModeMobilityControlInfo)
1104. UE enters RRC_IDLE, ECM_IDLE
1104a. UE enters ECM_IDLE
1105: RRC: SIBs ("common"IdleModeMobilityControlInfo)
1106. UE stores the received info from 1100, 1102a, 1103a, and 1105 for cell reselection decisions in idle mode
1107: RRC: SIBs (PLMN-IDs=A,C, TAC=p)
1107: RRC: SIBs (PLMN-IDs=A, TAC=r)
1108. UE performs cell reselection to cell in target eNB according to info stored in 106, radio measurements and SIB on target cells
1109. UE checks if the new cell TAI is included in TAI list
1110. TAU procedure as needed (cell in Target eNB, PLMN=A, slice=a)

Fig. 11

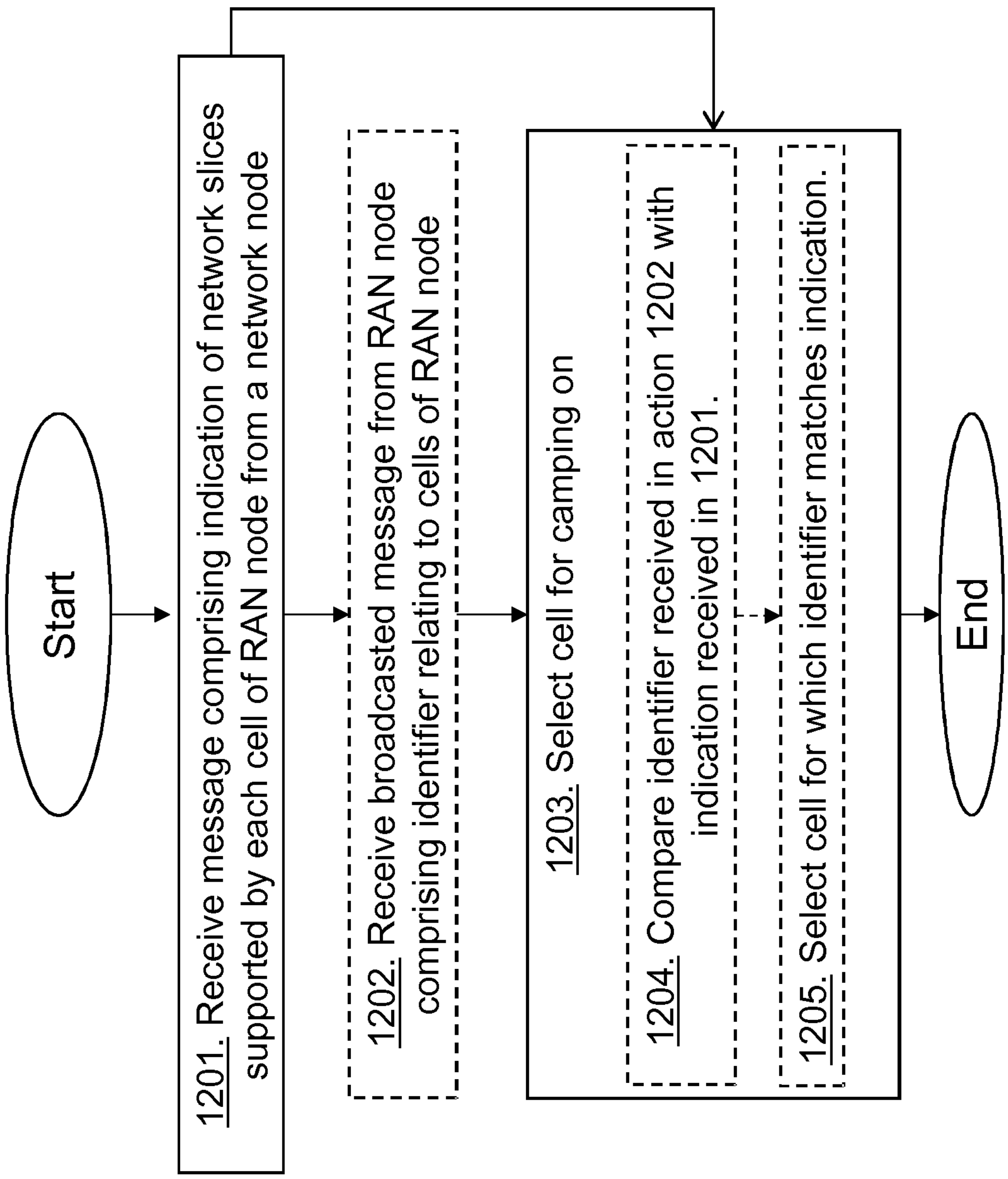

Start
1201. Receive message comprising indication of network slices supported by each cell of RAN node from a network node
1202. Receive broadcasted message from RAN node comprising identifier relating to cells of RAN node
1203. Select cell for camping on
1204. Compare identifier received in action 1202 with indication received in 1201.
1205. Select cell for which identifier matches indication.
End

Fig. 12

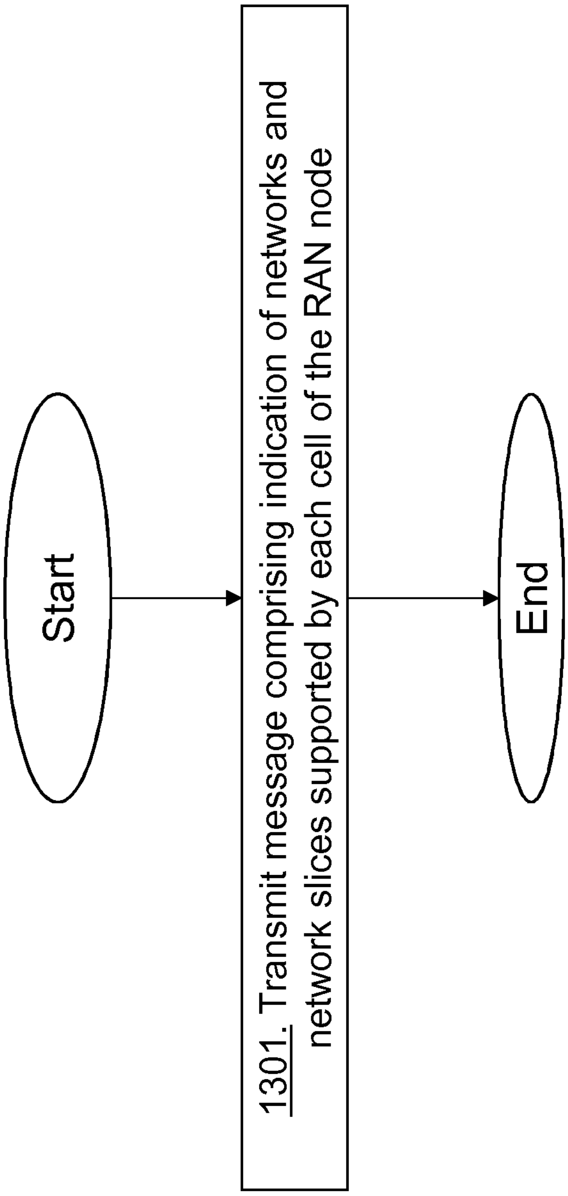

Start
1301. Transmit message comprising indication of networks and network slices supported by each cell of the RAN node
End

Fig. 13

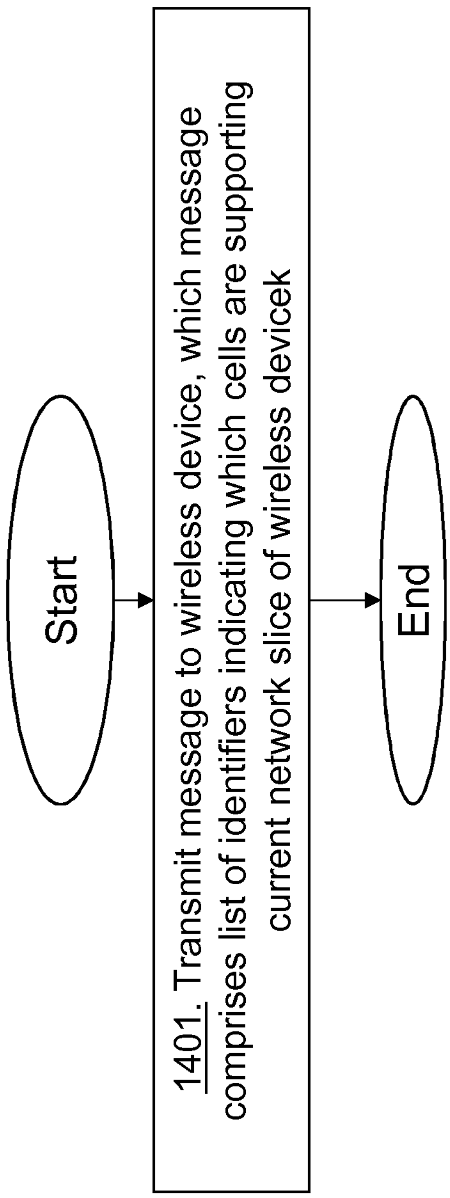

Start
1401. Transmit message to wireless device, which message comprises list of identifiers indicating which cells are supporting current network slice of wireless devicek
End

Fig. 14

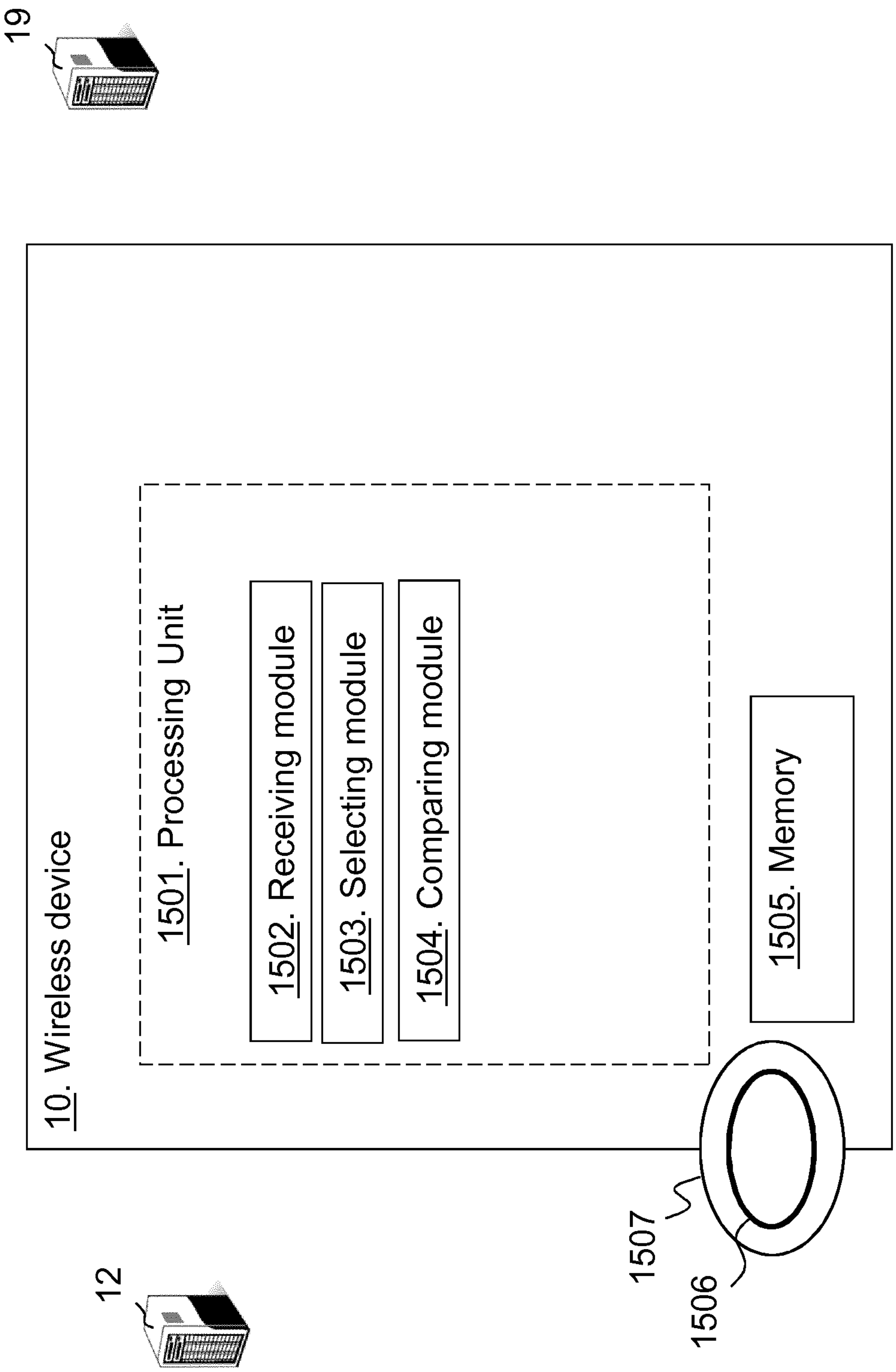

19
10. Wireless device
1501. Processing Unit
1502. Receiving module
1503. Selecting module
1504. Comparing module
1505. Memory
1507
1506
12

Fig. 15

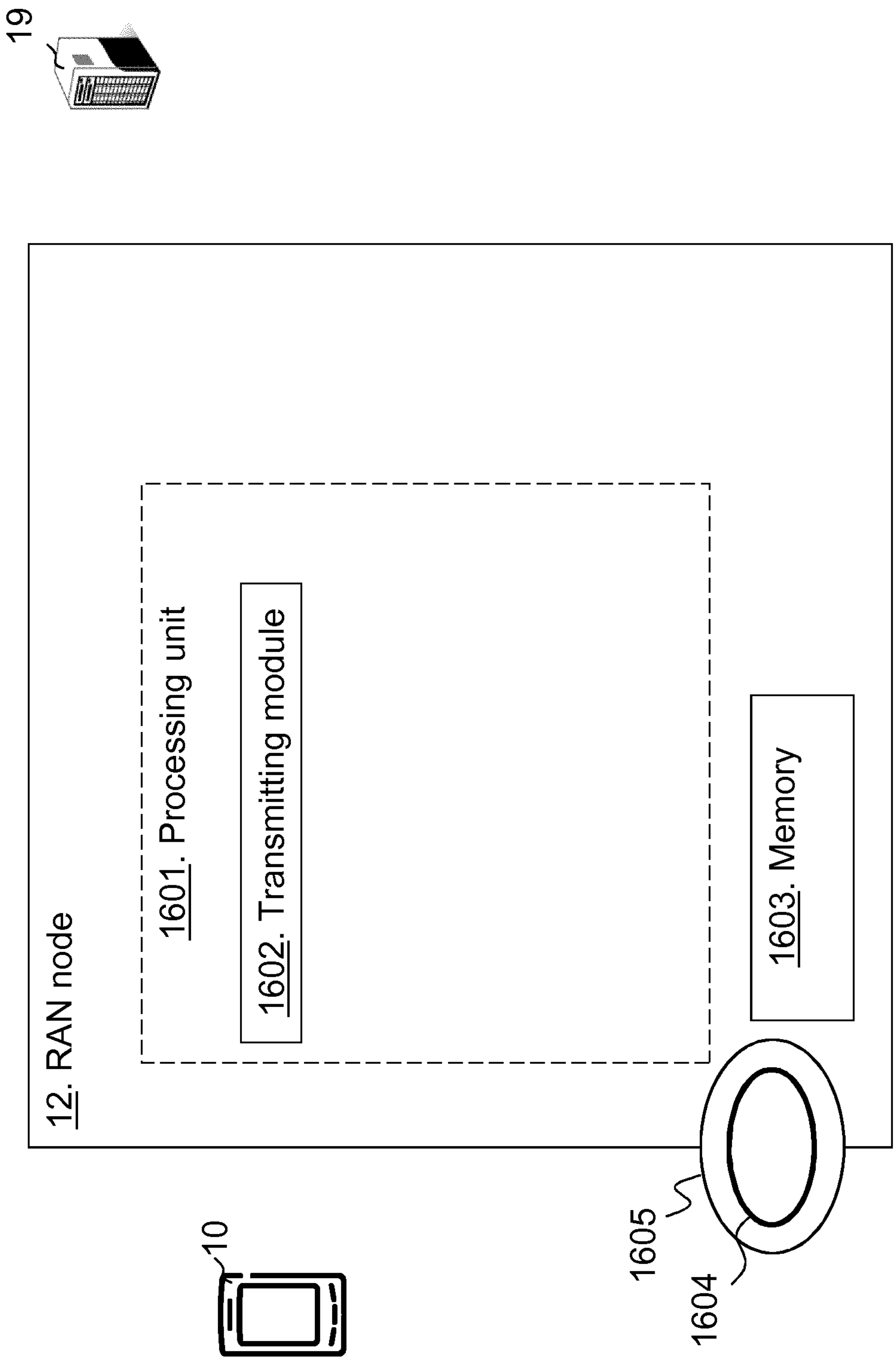

19
12. RAN node
1601. Processing unit
1602. Transmitting module
1603. Memory
10
1605
1604

Fig. 16

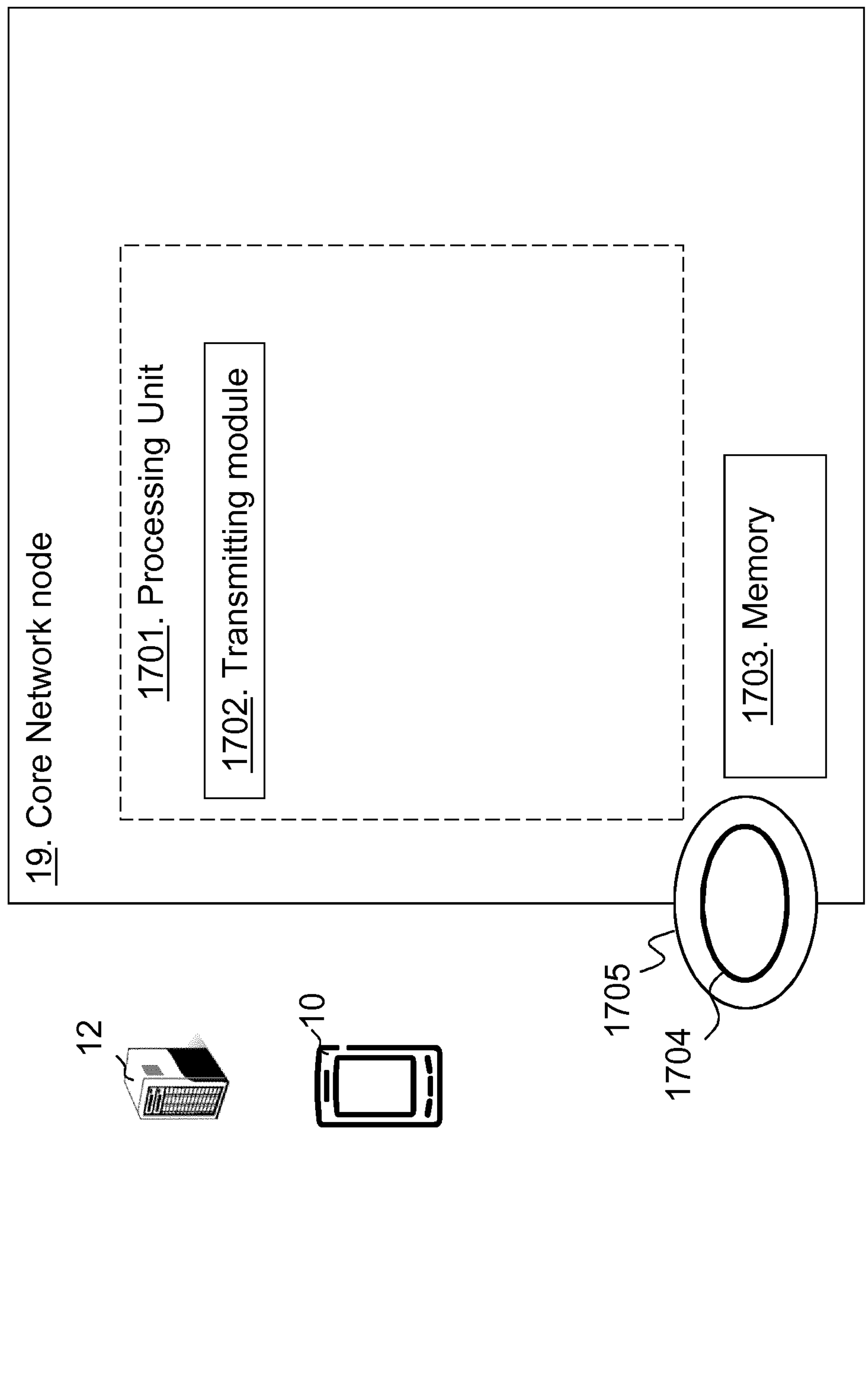

19. Core Network node
1701. Processing Unit
1702. Transmitting module
1703. Memory
1705
1704
12
10

Fig. 17

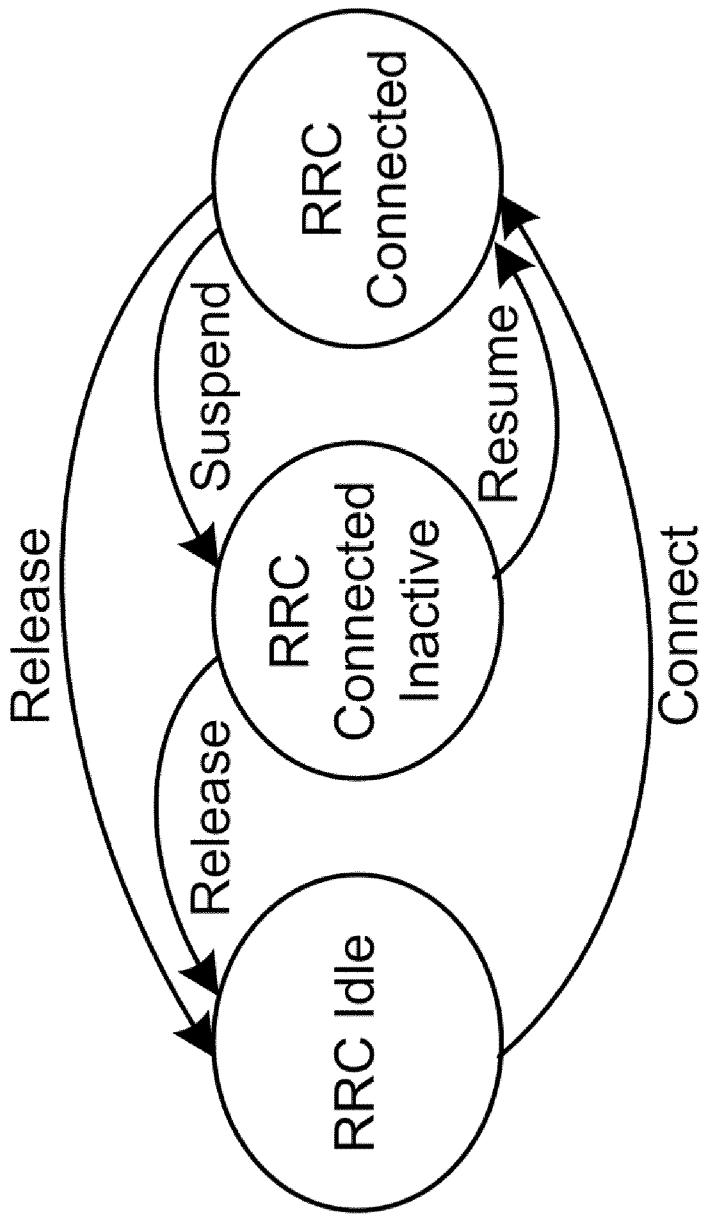

RRC Connected
Suspend
Resume
RRC Connected Inactive
Release
Release
Connect
RRC Idle

Fig. 18

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/053184

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W48/20
ADD. H04W36/08 H04W84/04

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	"3 rd 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; TR22 891-V130-RM, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , 8 February 2016 (2016-02-08), XP051071720, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_sa/WG1_Serv/TSGS1_73_Okinawa/docs/ [retrieved on 2016-02-08] 5.2 Network Slicing 5.69 Network Slicing / Roaming ----- -/--	1-24

[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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 October 2016	19/10/2016

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	Hodgins, Will

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Feasibility Study on New Services and Markets Technology Enablers - Network Operation; Stage 1 (Release 14)", 3GPP DRAFT; S1-154455 NEO TR 22.XXX V0.2.0 CL, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , 27 January 2016 (2016-01-27), XP051053266, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN/Docs/ [retrieved on 2016-01-27] 5.1.2 Potential Requirements -----	1-24
Y	ZTE CORPORATION ET AL: "update the network slicing use case in SMARTER", 3GPP DRAFT; S1-152395 REVISION OF S1-152074 ZTE SMARTER UPDATE THE NETWORK SLICING USE CASE REV3, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-0692 , vol. SA WG1, no. Belgrade, Serbia; 20150817 - 20150821 17 August 2015 (2015-08-17), XP050991537, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/SA1/Docsstatus/docs/ [retrieved on 2015-08-17] the whole document -----	1-24
Y	EP 2 421 302 A1 (VODAFONE HOLDING GMBH [DE]) 22 February 2012 (2012-02-22) abstract paragraph [0023] - paragraph [0050] figure 1 -----	1-24

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/053184

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2421302 A1	22-02-2012	EP 2421302 A1	22-02-2012
		US 2012046034 A1	23-02-2012

Form PCT/ISA/210 (patent family annex) (April 2005)