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REGISTRATION WITH NETWORK SLICES NOT SUPPORTED IN WHOLE REGISTRATION AREA

Abstract

Methods and apparatus in a telecommunication network are provided for handling not only network slices that are supported in the whole RA but network slices that are not supported in the whole RA. More specifically, the methods performed by the wireless device and network node (e.g., AMF in 5G) comprise in a registration procedure between the wireless device and the network node, the wireless device receiving from the network node a first list of one or more tracking areas identifiers (TAI list) for tracking areas representing a registration area (RA) and the associated one or more first network slices that are uniformly available across all the tracking areas of the first TAI list and receiving also at least one second TAI list for second tracking areas and associated one or more second network slices that are uniformly available across all the second tracking areas of the at least one second TAI list, wherein the at least one second TAI list identify the second tracking areas that are at least one of i) a subset of tracking areas included in the first TAI list and ii) different tracking areas that are not included in the first TAI list.

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Background/Summary

RELATED APPLICATIONS [0001] This application claims the benefit of provisional patent application Ser. No. 63/328,454, filed on Apr. 7, 2022, the disclosure of which is hereby incorporated herein by reference in its entirety.

TECHNICAL FIELD
[0002] The present disclosure relates to Network Slices in a telecommunication system and more specifically to network slice availability in the telecommunication system.
BACKGROUND
[0003] Generally, all terms used herein are to be interpreted according to their ordinary meaning in the relevant technical field, unless a different meaning is clearly given and/or is implied from the context in which it is used. All references to a/an/the element, apparatus, component, means, step, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any methods disclosed herein do not have to be performed in the exact order disclosed, unless a step is explicitly described as following or preceding another step and/or where it is implicit that a step must follow or precede another step. Any feature of any of the embodiments disclosed herein may be applied to any other embodiment, wherever appropriate. Likewise, any advantage of any of the embodiments may apply to any other embodiments, and vice versa. Other objectives, features, and advantages of the enclosed embodiments will be apparent from the following description.
[0004] Third Generation Partnership Project (3GPP) Technical Specification (TS) 23.501 V17.4.0 and TS 23.502 V17.4.0 define, among other things, describe network slices in 5G networks. In particular, a network slice is described as a logical network that provides specific network capabilities and network characteristics. Network slicing is also supported in telecommunication networks supporting 4G access (e.g., LTE) and is expected to be supported in telecommunications network supporting 6G access and subsequent generations of access technology. This document describes the solution based on the 5G network supporting 5G access (NR); however, as indicated, it will be understood to a skilled person in the art that the solution could be applicable to any of the telecommunication network supporting network slices over any cellular access network of different access technology (e.g., 4G, 5G, 6G, etc).
[0005] The telecommunication network currently known as 5G network is either a public Land Mobile Network, PLMN, or a Stand-alone Non-public networks (SNPN).
[0006] In 5G, a network slice is identified by an S-NSSAI, where an S-NSSAI is comprised of:
[0007] A Slice/Service type (SST), which refers to the expected Network Slice behavior in terms of features and services; [0008] A Slice Differentiator (SD), which is optional information that complements the Slice/Service type(s) to differentiate amongst multiple Network Slices of the same Slice/Service type.
[0009] There are different network slices including: [0010] a. Allowed network slices (NSSAI):

Indicating the S-NSSAIs values a wireless device/User Equipment (UE) could use in the Serving PLMN in the current Registration Area (RA). [0011] b. Configured NSSAI: NSSAI (indicating one or more S-NSSAI) provisioned in the UE applicable to one or more PLMNs. A Configured NSSAI may either be configured by a Serving PLMN (or SNPN) and apply to the Serving PLMN (or SNPN), or may be a Default Configured NSSAI configured by the HPLMN (or SNPN) and that applies to any PLMNs (or SNPNs) for which no specific Configured NSSAI has been provided to the UE. There is at most one Configured NSSAI per PLMN (or SNPN). [0012] c. Requested NSSAI: NSSAI (indicating one or more S-NSSAI) provided by the UE to the Serving PLMN (or SNPN) during registration. [0013] d. Rejected NSSAI for the current Registration Area or PLMN/SNPN.

[0014] Currently, in 5G, when providing a Requested NSSAI to the network upon registration, the S-NSSAIs in the Requested NSSAI are part of the Configured and/or Allowed NSSAIs applicable for this PLMN (or SNPN), when they are available. If no Configured NSSAI and Allowed NSSAI for the PLMN (or SNPN) are available, the S-NSSAIs in the Requested NSSAI correspond to the Default Configured NSSAI, if configured in the wireless device/UE. Upon successful completion of the wireless device/UE's Registration procedure over an Access Type, the wireless device/UE obtains from the AMF an Allowed NSSAI for this Access Type, which includes one or more S-NSSAIs and, if needed, their mapping to the HPLMN (or SNPN) S-NSSAIs. These S-NSSAIs are valid for the current Registration Area and Access Type provided by the Access and Mobility Management function (AMF), the wireless device/UE has registered with and can be used simultaneously by the wireless device/UE (up to the maximum number of simultaneous Network Slice instances or PDU Sessions).

[0015] The wireless device/UE might also obtain one or more rejected S-NSSAIs with cause and validity of rejection from the AMF. An S-NSSAI may be rejected: [0016] for the entire PLMN; or [0017] for the current Registration Area represented by a list of tracking area (TA identifier, TAI, list).

The S-NSSAIs that the wireless device/UE provides in the Requested NSSAI which are neither in the Allowed NSSAI nor provided as a rejected S-NSSAI, shall, by the wireless device/UE, not be regarded as rejected, i.e., the wireless device/UE may request to register these S-NSSAIs again next time the wireless device/UE sends a Requested NSSAI.

Furthermore, the Allowed NSSAI received in a Non Access Stratum (NAS) Registration Accept message or a NAS UE Configuration Update Command applies to a PLMN when at least a TAI of this PLMN is included in the Registration Area/TAI list included in this Registration Accept message or UE Configuration Update Command. If the UE Configuration Update Command contains an Allowed NSSAI but not a TAI List, then the last received RA/list of Tracking Area, TAI list, applies for the decision on which PLMN(s) the Allowed NSSAI is applicable. If received, the Allowed NSSAI for a PLMN and Access Type and any associated mapping of this Allowed NSSAI to HPLMN S-NSSAIs shall be stored in the wireless device/UE.

In addition, the AMF may provide the wireless device/UE with a new Configured NSSAI for the Serving PLMN, associated with mapping of the Configured NSSAI to HPLMN S-NSSAIs as specified in clause 5.15.4.1 of TS 23.501.

SUMMARY

[0018] Certain aspects of the present disclosure and their embodiments may provide solutions to the aforementioned or other challenges described within the context of a 5G network, although can be extended to other future networks such as 6G and beyond and even in legacy networks supporting network slices as dedicated networks in 4G networks.

[0019] Embodiments disclosed herein include methods and apparatus for enabling a wireless device/UE to obtain from a network function (Access and Mobility management in addition to network slices uniformly available across a whole RA, network slices that are not uniformly available in the whole registration area, but available in only one or more tracking areas that are

either part of the tracking areas forming the RA or one or more tracking areas that are outside the RA.

[0020] In one embodiment, a method in a wireless device for handling network slices in a telecommunication network is provided. The method comprises initiating by the wireless device a registration procedure with a network node in the telecommunication network where the wireless device may trigger a Registration Request message that includes requested network slices (NSSAI). The method comprises receiving by the wireless device/UE a first list of one or more tracking areas identifiers (TAI list) identifying tracking areas forming a registration area (RA) for the wireless device/UE and the tracking areas of the RA are associated to or support one or more first network slices that are uniformly available across all the tracking areas of the first TAI list (i.e., RA). The method further comprises receiving by the wireless device/UE at least one second TAI list for second tracking areas and associated one or more second network slices that are uniformly available across all the second tracking areas of the at least one second TAI list, wherein the at least one second TAI list is either a subset of the first TAI list identifying common tracking areas between the two lists or is a list of tracking areas that are disjoint from the tracking areas identified in the first TAI list, and hence identifying different tracking areas from the tracking areas identified in the first TAI list, or the wireless device can receive both, i.e., a list of common tracking areas and a list of disjoint tracking areas (i.e., tracking areas outside the RA).

[0021] In one example, the telecommunication network is one of a Public Land Mobile Network (PLMN) or a Stand-Alone Non-Public Network (SNPN).

[0022] In another example, the one or more first network slices associated to the tracking areas of the RA (first TAI list) corresponds one or more allowed first network slices available uniformly across all tracking areas of the first TAI list representing the RA or one or more configured first network slices available uniformly across all tracking areas of the first TAI list representing the RA supported by the serving PLMN, or both.

[0023] In another example, the one or more second network slices associated with the second tracking areas of the at least one second TAI list correspond to one or more allowed second network slices available uniformly across all second tracking areas of the at least one second TAI list or one or more configured second network slices available uniformly across all second tracking areas of the at least one second TAI list.

[0024] In one example, the registration procedure comprises sending by the wireless device/UE a Registration Request message including one or more requested network slices and receiving a Registration Accept message including the first TAI list representing the RA and the associated one or more first network slices, and the at least one second TAI list and the associated one or more second network slices. The Registration Accept may further include the one or more requested network slices that are rejected as not uniformly available across all the tracking areas of the first TAI list.

[0025] The one or more second network slices associated with the at least one second TAI list included in the Registration Accept correspond to at least one of the one or more requested network slices (of the Registration Request message) that are not uniformly supported in all tracking areas of the RA but are uniformly available across the tracking areas of the at least one second TAI list.

[0026] In one example, the associated one or more first network slices, the associated one or more second network slices or the requested one or more network slices are each indicated by a Single Network Slice Selection Assistance Information S-NSSAI.

[0027] In another example, the method in the wireless device/UE further comprises indicating to the network node a capability of the wireless device to support receiving the at least one second TAI list with the associated second network slices or support for network slice availability per secondary areas defined by a list of second TAI list. In yet another example the network may indicate to the wireless device that the similar capability in the network is enabled or disabled.

[0028] In one example, the method further comprises storing by the wireless device/UE the

associated one or more first network slices and the associated one or more second network slices as registered network slices by the network node (AMF).
[0029] In another example, the method further comprises upon moving to a tracking area outside the RA, the wireless device/UE sending a second Registration Request including requested one or more network slices comprising the associated one or more second network slices previously obtained and receiving by the wireless device/UE a Registration Accept message comprising the allowed one or more second network sliced as registered network slices.
[0030] In one example, the method comprises the step of establishing by the wireless device/UE a PDU session in an associated second network slice while in a tracking area of the second TAI list, moving to another tracking area where the associated second network slice is no longer supported and performing one of deactivating or suspending user plane associated to the PDU session or releasing the PDU session.
[0031] In another example, the wireless device/UE performs the step of re-establishing the PDU Session or resuming or reactivating the user plane upon moving back to a tracking area of the second TAI list (whether subset of or disjoint from the RA), supporting the associated second network slice.
[0032] In one example, the first TAI list or the second TAI list comprises at least one tracking area.
[0033] In another embodiment, a method in a network node (e.g., AMF in 5G network) for handling network slices in a serving telecommunication network, where the serving telecommunication network may be a PLMN or a SNPN, is provided. The method comprises receiving a Registration Request from a wireless device/UE in the serving telecommunication network and sending a Registration Response that includes a first list of one or more tracking areas identifiers (TAI list) for tracking areas representing a registration area (RA) and associated one or more first network slices that are uniformly available across all the tracking areas of the first TAI list and also includes at least one second TAI list for second tracking areas and associated one or more second network slices that are uniformly available across all the second tracking areas of the at least one second TAI list, wherein the at least one second TAI list identify the second tracking areas that are at least one of i) a subset of tracking areas included in the first TAI list and ii) different tracking areas that are not included in the first TAI list.
[0034] In one example, the associated one or more first network slices correspond to one or more allowed first network slices available uniformly across all tracking areas of the first TAI list representing the RA or one or more configured first network slices available uniformly across all tracking areas of the first TAI list representing the RA supported by the serving PLMN, or both.
[0035] In yet another example, the associated one or more second network slices correspond to one or more allowed second network slices available uniformly across all tracking areas of the at least one second TAI list; or one or more configured second network slices available uniformly across all tracking areas of the at least one second TAI list or both
[0036] In another example, the Registration Request comprises one or more requested network slices; and the Registration Response comprises the first TAI list of tracking areas representing the RA and the associated one or more first network slices, and the at least one second TAI list of second tracking areas and the associated one or more second network slices, wherein the one or more second network slices associated with the at least one second TAI list correspond to at least one of the one or more requested network slices that are indicated as rejected across the RA but are uniformly available across the second tracking areas of the at least one second TAI list.
[0037] According to an example, the Registration Response includes the one or more requested network slices that are rejected as not uniformly available across the RA.
[0038] According to another example, the method further comprises receiving from the wireless device/UE information indicating a capability of the wireless device/UE to support receiving the at least one second TAI list with the associated second network slices or support for network slice availability per secondary areas defined by a list of second TAI list.

[0039] In one example, the method comprises the step of sending to the wireless device/UE an indication that the capability of a second TAI list with the associated second network slices or the network slice availability per secondary areas defined by a list of second TAI list is enabled or disabled.
[0040] In another example, the method further comprises the step of sending to an access network node (e.g., gNB in 5G) serving the wireless device/UE information indicating one or more network slices available in each tracking area of the first and second list of tracking areas.
[0041] In one example, the method further comprises the step of registering by the network node (AMF) the associated one or more first network slices and the associated one or more second network slices as registered for the wireless device.
[0042] In another example, the method further comprises receiving by the network node from the wireless device/UE a second Registration Request comprising requested one or more network slices indicating the associated one or more second network slices when the wireless device moves to a TA disjoint from or outside the RA; and sending a Registration Accept message to the wireless device/UE message comprising the allowed one or more second network slices as registered network slices.
[0043] In yet another example, the method further comprises the step of determining that the wireless device is using a network slice for a PDU session and upon detecting the wireless device is moved into another tracking area of second TAI list that is not supporting the used network slice, the network node informing a Session Management Function controlling the PDU session to initiate deactivation or suspension of any user plane associated with the PDU session.
[0044] In one embodiment, a wireless device adapted to implement the embodiments described herein.
[0045] In another embodiment, a wireless device comprising one or more processor and memory for storing instructions which when executed by the one or more processors that performs the embodiments described herein is also provided.
[0046] In yet another embodiment, a Computer Readable medium containing program instructions for causing a one or more processor of a wireless device to perform the embodiments described herein is also provided.
[0047] According to an embodiment a network node (e.g., AMF in 5G) is adapted to implement the embodiments described herein or comprises one or more processor and memory for storing instructions which when executed by the one or more processors perform the embodiments described herein.
[0048] According to another embodiment, a Computer Readable medium containing program instructions for causing a one or more processor of a network node (e.g., AMF in 5G) to perform the embodiments described herein is also provided.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0049] The accompanying drawing figures incorporated in and forming a part of this specification illustrate several aspects of the disclosure, and together with the description serve to explain the principles of the disclosure.
[0050] FIG. **1** illustrates examples of RA and SRA deployment in accordance with some embodiments.
[0051] FIG. **2** illustrates one example of a cellular communications system in which embodiments of the present disclosure can be implemented;
[0052] FIG. **3** illustrate example embodiments in which the cellular communication system of FIG. **1** is a Fifth Generation (5G) System (5GS);

[0053] FIG. **4** illustrate the service-based interface (SBI) architecture view of the (5G) System (5GS) of FIG. **3**;
[0054] FIG. **5** illustrates a procedure in accordance with some embodiment of the present disclosure;
[0055] FIG. **6** illustrates a method in a wireless device in accordance another embodiment of the present disclosure;
[0056] FIG. **7** illustrates a method in a core network node in accordance with some embodiments of the present disclosure; and
[0057] FIGS. **8**, **9**, and **10** are schematic block diagrams of example embodiments of a network node.
[0058] FIG. **11**, **12** are schematic block diagrams of example embodiments of a wireless device.
DETAILED DESCRIPTION
[0059] The embodiments set forth below represent information to enable those skilled in the art to practice the embodiments and illustrate the best mode of practicing the embodiments. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the disclosure and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure.
[0060] Radio Node: As used herein, a "radio node" is either a radio access node or a wireless communication device.
[0061] Radio Access Node: As used herein, a "radio access node" or "radio network node" or "radio access network node" is any node in a Radio Access Network (RAN) of a cellular communications network that operates to wirelessly transmit and/or receive signals. Some examples of a radio access node include, but are not limited to, a base station (e.g., a New Radio (NR) base station (gNB) in a Third Generation Partnership Project (3GPP) Fifth Generation (5G) NR network or an enhanced or evolved Node B (eNB) in a 3GPP Long Term Evolution (LTE) network), a high-power or macro base station, a low-power base station (e.g., a micro base station, a pico base station, a home eNB, or the like), a relay node, a network node that implements part of the functionality of a base station (e.g., a network node that implements a gNB Central Unit (gNB-CU) or a network node that implements a gNB Distributed Unit (gNB-DU)) or a network node that implements part of the functionality of some other type of radio access node.
[0062] Core Network Node: As used herein, a "core network node" is any type of node in a core network or any node/server/distributed servers/dedicated platform that implements one or more core network function also referred to as Network Function. Some examples of Network Function include, e.g., a Mobility Management Entity (MME), a Packet Data Network Gateway (P-GW), a Service Capability Exposure Function (SCEF), a Home Subscriber Server (HSS), or the like. Some other examples of a Network Function include a node implementing an Access and Mobility Management Function (AMF), a User Plane Function (UPF), a Session Management Function (SMF), an Authentication Server Function (AUSF), a Network Slice Selection Function (NSSF), a Network Exposure Function (NEF), a Network Function (NF) Repository Function (NRF), a Policy Control Function (PCF), a Unified Data Management (UDM), SMF+PGW controller, and Network slice admission control function (NSACF) or the like. In general, a network function can be implemented either as a network element on a dedicated hardware, as a software instance running on a dedicated hardware, or as a virtualised function instantiated on an appropriate platform, e.g. on a cloud infrastructure.
[0063] Communication Device: As used herein, a "communication device" is any type of device that has access to an access network. Some examples of a communication device include, but are not limited to: mobile phone, smart phone, sensor device, meter, vehicle, household appliance, medical appliance, media player, camera, or any type of consumer electronic, for instance, but not limited to, a television, radio, lighting arrangement, tablet computer, laptop, or Personal Computer

(PC). The communication device may be a portable, hand-held, computer-comprised, or vehicle-mounted mobile device, enabled to communicate voice and/or data via a wireless or wireline connection.

[0064] Wireless Communication Device: One type of communication device is a wireless communication device, which may be any type of wireless device that has access to (i.e., is served by) a wireless network (e.g., a cellular network). Some examples of a wireless communication device include, but are not limited to: a User Equipment device (UE) in a 3GPP network, a Machine Type Communication (MTC) device, and an Internet of Things (IoT) device. Such wireless communication devices may be, or may be integrated into, a mobile phone, smart phone, sensor device, meter, vehicle, household appliance, medical appliance, media player, camera, or any type of consumer electronic, for instance, but not limited to, a television, radio, lighting arrangement, tablet computer, laptop, or PC. The wireless communication device may be a portable, hand-held, computer-comprised, or vehicle-mounted mobile device, enabled to communicate voice and/or data via a wireless connection.

[0065] Network Node: As used herein, a “network node” is any node that is either part of the RAN or the core network of a cellular communications network/system.

[0066] Note that the description given herein focuses on a 3GPP cellular communications system and, as such, 3GPP terminology or terminology similar to 3GPP terminology is oftentimes used. However, the concepts disclosed herein are not limited to a 3GPP system.

[0067] Note that, in the description herein, reference may be made to the term “cell”; however, particularly with respect to 5G NR concepts, beams may be used instead of cells and, as such, it is important to note that the concepts described herein are equally applicable to both cells and beams.

[0068] There currently exist certain challenge(s). More specifically, as indicated above, when a UE initiates initial Registration with the 5G Core network over NAS and receives back the Registration Accept message; the received allowed S-NSSAIs (allowed NSSAI) are assumed to be available in all the TAs of the Registration Area (RA). The received Rejected S-NSSAIs for the RA are assumed to not be available in the whole RA. Hence, the UE is currently not allowed to request to register the network slices that are rejected for the RA as long as the UE is located in the RA that is received in the Registration Accept. The UE is also not allowed to use the rejected network slice when requesting establishment of a Packet Data Unit (PDU) Session.

[0069] This poses certain limitations. Accommodating more of the subscribed/configured/requested slices requires the network node (e.g., AMF in 5G) to create a smaller smaller RA with TAs supporting all of the allowed network slices and the number of supported slices per UE may increase. This, however, has the drawback to increase mobility registration updates due to a smaller RA, causing signaling load in the AMF and for the UE and other network functions of the telecommunication network involved to handle the additional registration procedures.

[0070] An AMF may want to create a RA that considers the trade-off between being large enough to limit the signaling from Mobility Registration Updates of the UEs and small enough to limit the paging load in case the UE needs to be paged. In this trade-off, the AMF includes TAs supporting some of the UE's S-NSSAIs of the Configured NSSAI or Subscribed S-NSSAIs or requested S-NSSAIs which are not defined to be available/supported uniformly across the RA, i.e., in the current art, if the UE requests those S-NSSAIs they would be rejected by the network (AMF). Therefore, the solution enables the UE to request the S-NSSAIs, only where they are defined to be available/supported in at least one TA.

[0071] To enable the above, the notion of secondary Registration Area (SRA) is introduced herein. It will be understood that an SRA is used to describe an area defined by a list of one or more tracking areas where the UE is also considered registered. Two types of SRAs are described: SRA subset of RA. i.e., overlapping SRA, i.e., tracking areas of the SRA are also tracking areas of the RA and disjoint SRA, i.e., tracking areas of the SRA is/are not part of the RA. FIG. **1** illustrates some examples of RA and SRA deployment as described herein.

SRA Subset of RA (Overlapping SRA):

[0072] The current RA provided to the UE as a list of TAs, comprises one or more SRA. Each SRA, being subset of the RA, i.e., partially overlapping SRA where the coverage partially overlaps with the RA and is defined by one or more TA of the TA list describing the RA. The RA may be completely overlapped by two or more SRAs (not shown in FIG. **1**), or the RA may be partially overlapped by one or more SRA, e.g., SRA**1** and SRA**2** (FIG. **1**). The SRA supports S-NSSAIs that are uniformly available or supported across the SRA but not uniformly available across the whole RA. The S-NSSAI(s) that is uniformly available across one or more SRA is herein referred to as SRA network slice(s) and are provided to the UE in the Registration Accept message as allowed network slices in the one or more SRA and are considered, at completion of the registration procedure, as registered SRA network slice(s). The UE is allowed to use an SRA network slice as long as the UE is located in the SRA supporting the SRA network slice.

[0073] In addition to the SRA network slice, when the SRA is a subset of the RA (overlapping coverage), the SRA also inherits support of the uniformly available S-NSSAI across the RA (RA Allowed NSSAI) as the SRA is part of the RA (i.e., consists in part of one or more TA of the TAI List IE included in the Registration Accept message). The uniformly available S-NSSAI across the RA are described in the current Allowed NSSAI information element (IE) included in the NAS Registration Accept and optionally/or Configured NSSAI IE included in the NAS Registration Accept or NAS UE Configuration Command.

Disjoint SRA:

[0074] In addition to being able to provide to the UE one or more SRA that is a subset of the RA, the UE may be provided with one or more SRA that is disjoint from the RA. The one or more SRAs is referred to as disjoint SRA and is represented by other one or more tracking area (TA) that is not part of the RA. The disjoint SRA does not inherit support of the RA Allowed NSSAI and each disjoint SRA supports one more SRA network slice not supported uniformly across the RA and may include one or more S-NSSAI that is considered as rejected S-NSSAI in the RA and/or one or more S-NSSAI that is supported by the AMF but available in TAs outside the defined RA provided to the UE, e.g., SRA **3** in FIG. **1**

[0075] Regardless of the type of SRA (overlapping or disjoint), the Registration procedure may also include an indication of rejected slices per SRA indicating network slices (i.e., S-NSSAI(s)) that can't be used in the SRA. SRA network slices in one SRA are exclusive to the SRA, except for the inherited allowed NSSAI of the RA for the overlapping SRA.

[0076] The AMF provides the SRA information comprising the area description (SRA TA list, the SRA available (allowed) S-NSSAI and optionally SRA rejected S-NSSAI) in a separate Information Element (IE) referred to herein for example as SRA Information IE.

[0077] FIG. **2** illustrates one example of a cellular communications system **100** in which embodiments of the present disclosure may be implemented. In the embodiments described herein, the cellular communications system **100** is a 5G system (5GS) including a Next Generation RAN (NG-RAN) and a 5G Core (5GC); however, the present disclosure is not limited thereto. In this example, the RAN includes base stations **102-1** and **102-2**, which in the 5GS include NR base stations (gNBs) and optionally next generation eNBs (ng-eNBs) (e.g., LTE RAN nodes connected to the 5GC), controlling corresponding (macro) cells **104-1** and **104-2**. The base stations **102-1** and **102-2** are generally referred to herein collectively as base stations **102** and individually as base station **102**. Likewise, the (macro) cells **104-1** and **104-2** are generally referred to herein collectively as (macro) cells **104** and individually as (macro) cell **104**. The RAN may also include a number of low power nodes **106-1** through **106-4** controlling corresponding small cells **108-1** through **108-4**. The low power nodes **106-1** through **106-4** can be small base stations (such as pico or femto base stations) or RRHs, or the like. Notably, while not illustrated, one or more of the small cells **108-1** through **108-4** may alternatively be provided by the base stations **102**. The low power nodes **106-1** through **106-4** are generally referred to herein collectively as low power nodes **106**

and individually as low power node **106**. Likewise, the small cells **108-1** through **108-4** are generally referred to herein collectively as small cells **108** and individually as small cell **108**. The cellular communications system **100** also includes a core network **110**, which in the 5G System (5GS) is referred to as the 5GC. The base stations **102** (and optionally the low power nodes **106**) are connected to the core network **110**.

[0078] The base stations **102** and the low power nodes **106** provide service to wireless communication devices **112-1** through **112-5** in the corresponding cells **104** and **108**. The wireless communication devices **112-1** through **112-5** are generally referred to herein collectively as wireless communication devices **112** and individually as wireless communication device **112**. In the following description, the wireless communication devices **112** are oftentimes UEs and as such sometimes referred to herein as UEs **112**, but the present disclosure is not limited thereto.

[0079] FIG. **3** illustrates a wireless communication system represented as a 5G network architecture composed of core Network Functions (NFs), where interaction between any two NFs is represented by a point-to-point reference point/interface. FIG. **2** can be viewed as one particular implementation of the system **100** of FIG. **2**.

[0080] Seen from the access side the 5G network architecture shown in FIG. **3** comprises a plurality of UEs **112** connected to either a RAN **102** or an Access Network (AN) as well as an AMF **200**. Typically, the R(AN) **102** comprises base stations, e.g., such as eNBs or gNBs or similar. Seen from the core network side, the 5GC NFs shown in FIG. **3** include a NSSF **202**, an AUSF **204**, a UDM **206**, the AMF **200**, a SMF **208**, a PCF **210**, an NSACF (**400**) and an Application Function (AF) **212**.

[0081] Reference point representations of the 5G network architecture are used to develop detailed call flows in the normative standardization. The N1 reference point is defined to carry signaling between the UE **112** and AMF **200**. The reference points for connecting between the AN **102** and AMF **200** and between the AN **102** and UPF **214** are defined as N2 and N3, respectively. There is a reference point, N11, between the AMF **200** and SMF **208**, which implies that the SMF **208** is at least partly controlled by the AMF **200**. N4 is used by the SMF **208** and UPF **214** so that the UPF **214** can be set using the control signal generated by the SMF **208**, and the UPF **214** can report its state to the SMF **208**. N9 is the reference point for the connection between different UPFs **214**, and N14 is the reference point connecting between different AMFs **200**, respectively. N15 and N7 are defined since the PCF **210** applies policy to the AMF **200** and SMF **208**, respectively. N12 is required for the AMF **200** to perform authentication of the UE **112**. N8 and N10 are defined because the subscription data of the UE **112** is required for the AMF **200** and SMF **208**.

[0082] The 5GC network aims at separating UP and CP. The UP carries user traffic while the CP carries signaling in the network. In FIG. **3**, the UPF **214** is in the UP and all other NFs, i.e., the AMF **200**, SMF **208**, PCF **210**, AF **212**, NSSF **202**, AUSF **204**, and UDM **206**, are in the CP. Separating the UP and CP guarantees each plane resource to be scaled independently. It also allows UPFs to be deployed separately from CP functions in a distributed fashion. In this architecture, UPFs may be deployed very close to UEs to shorten the Round Trip Time (RTT) between UEs and data network for some applications requiring low latency.

[0083] The core 5G network architecture is composed of modularized functions. For example, the AMF **200** and SMF **208** are independent functions in the CP. Separated AMF **200** and SMF **208** allow independent evolution and scaling. Other CP functions like the PCF **210** and AUSF **204** can be separated as shown in FIG. **3**. Modularized function design enables the 5GC network to support various services flexibly.

[0084] Each NF interacts with another NF directly. However, indirect communication is also supported where it is possible to use intermediate functions to route messages from one NF to another NF. In the CP, a set of interactions between two NFs is defined as service so that its reuse is possible. This service enables support for modularity. The UP supports interactions such as forwarding operations between different UPFs.

[0085] The AMF **200** (FIG. **3**)) interacts with the Access Network via the N2 reference point and N1 reference point supporting NAS protocol with the wireless device/UE.
[0086] FIG. **4** illustrates a 5G network architecture using service-based interfaces between the NFs in the CP, instead of the point-to-point reference points/interfaces used in the 5G network architecture of FIG. **3**. However, the NFs described above with reference to FIG. **3** correspond to the NFs shown in FIG. **4**. The service(s) etc. that a NF provides to other authorized NFs can be exposed to the authorized NFs through the service-based interface. In FIG. **4** the service-based interfaces are indicated by the letter "N" followed by the name of the NF, e.g. Namf for the service based interface of the AMF **200** and Nsmf for the service based interface of the SMF **208**, etc. The NEF **300** and the NRF **302** in FIG. **4** are not shown in FIG. **3** discussed above. However, it should be clarified that all NFs depicted in FIG. **3** can interact with the NEF **300** and the NRF **302** of FIG. **4** as necessary, though not explicitly indicated in FIG. **3**.
[0087] Some properties of the NFs shown in FIGS. **3** and **4** may be described in the following manner. The AMF **200** provides UE-based authentication, authorization, mobility management, etc. A UE **112** even using multiple access technologies is basically connected to a single AMF **200** because the AMF **200** is independent of the access technologies. The SMF **208** is responsible for session management and allocates Internet Protocol (IP) addresses to UEs. It also selects and controls the UPF **214** for data transfer. If a UE **112** has multiple sessions, different SMFs **208** may be allocated to each session to manage them individually and possibly provide different functionalities per session. The AF **212** provides information on the packet flow to the PCF **210** responsible for policy control in order to support QoS. Based on the information, the PCF **210** determines policies about mobility and session management to make the AMF **200** and SMF **208** operate properly. The AUSF **204** supports authentication function for UEs or similar and thus stores data for authentication of UEs or similar while the UDM **206** stores subscription data of the UE **112**. The Data Network (DN), not part of the 5GC network, provides Internet access or operator services and similar.
[0088] Certain aspects of the present disclosure and their embodiments may provide solutions to the aforementioned or other challenges. FIG. **5** describe example implementation of the solution illustrating a registration request procedure followed by a PDU session establishment procedure in accordance with some embodiments.
Step 1: the UE registers in the 5G network and transmits to the core network node, hosting/supporting the AMF, a Registration Request message over NAS. The UE may include information indicating the capability of the UE to support Secondary RAs, i.e., receiving secondary list of tracking areas that support network slices not supported uniformly across the registration area. If the UE does not support SRA, the UE may omit including the capability, or it may include the capability information indicating the UE does not support SRAs. The AMF may determine that SRA, i.e., secondary list of tracking areas that support network slices not supported uniformly across the registration area, can be provided to the UE based on either the capability provided by the UE, UE subscription information indicating SRA can be provided to the UE, and/or network policies.
Step 2: Registration procedure follows steps 2-19c of clause 4.2.2 of 3GPP TS 23.502, however the embodiment herein requires the AMF to determine whether SRA information comprising secondary list of tracking areas that support network slices not supported uniformly across the registration area, should be provided to the UE based on one or more of the UE capability to support SRA, UE subscription or network policies. If the AMF supports SRA, it may also indicate to the UE, whether the feature is enabled or not.
Step 3: The AMF in addition to sending the RA information which may comprise the tracking area list (TAI list) and the allowed one or more network slices (S-NSSAIs) that are uniformly allowed across the RA (TAI list), determines that other S-NSSAIs can be made available/allowed for the UE over one or more secondary RA (SRA), where the SRA consists of one or more TA from either the

TAI list (subset of RA) and or TAs outside the RA (i.e., not in the TAI list) (disjoint SRA). The AMF creates a list of SRAs comprising one or more SRA and each SRA is described by an SRA information conveyed to the UE.
each SRA information comprises: [0089] List of TAs (comprising one or more TA). [0090] Allowed S-NSSAI and/or Configured S-NSSAIs of the SRA (not uniformly available in the RA) [0091] Rejected NSSAI in the SRA (optional). [0092] SRA id or index (optional)
The AMF stores the RA and the one or more SRA and the corresponding TAs including the TA where the UE is currently located and the associated SRA, if the UE registered in a TA of an SRA.
Step 4: which corresponds to step 21 in the Registration procedure in TS 23.502 and corresponds to the AMF sending the Registration Accept message including the list of SRAs and associated information as per step 3 above.
Step 5: the UE stores the information so it can be used when needed.
Step 6: the UE is in a TA of an SRA and wants to establish a PDU session, the UE sends a PDU Session establishment request based on existing procedures in clause 4.3.2 in TS 23.502 and indicates the network slice (S-NSSAI). The UE does not establish a PDU Session using an SRA network slice (S-NSSAI) unless the S-NSSAI is registered in the SRA. This UE behavior can be controlled by a feature capability indicator obtained by the network that can enable or disable the feature and/or if the UE indicated support of the SRA capability.
Step 7: the AMF verifies the TA where the UE is currently located based on the UE location as described in section 5.4.11.4 of TS 23.501. If the S-NSSAI used by the UE in step 6 is in the allowed slices associated with the RA or the allowed slices of the SRA associated with the TA where the UE location is confirmed by the AMF, then the AMF progresses the PDU session establishment procedure based on existing specification. Otherwise, an error message is returned to the UE. A dedicated error message associated with requesting use of an S-NSSAI not allowed in the SRA associated with current UE location may be used to guide the UE.
[0093] FIG. **6** illustrates a method in the wireless device/UE for handling network slices in accordance with some embodiments as described herein.
The method comprises the step **600** by the wireless device/UE initiating a registration procedure with a network node (e.g., 5G AMF) in the serving network (5G system), where the serving network is either a Public Land Mobile Network PLMN or a Standalone Non-Public Network (SNPN). As an example, the UE initiates the registration procedure by sending a Registration Request message to the AMF. The method further comprises step **610** of receiving from the network node (AMF in 5G) a Registration Accept message including a Tracking Area list (known as TAI list) describing the registration area (RA) within which the wireless device/UE can move without having to send a Registration Request to the AMF, the associated one or more RA network slice that is uniformly available in the RA for the UE to use (i.e., currently known Allowed S-NSSAIs uniformly allowed in the RA). The wireless device/UE may also receive configured NSSAI supported in the RA or the serving network. Note that RA network slice is a term used in this disclosure to describe network slices uniformly available across all the tracking areas of the RA.
In addition, the method comprises step **620** where the wireless device/UE receives secondary registration area (SRA) List information including one or more SRA information. Each SRA information specifies one or more tracking area (TA) defining the coverage of the SRA where each SRA is either: [0094] a subset of the RA (partially overlapping SRA), i.e., the SRA is represented by one or more TA that are also included in the the TAI list of the RA (see FIG. **1**), or [0095] a set of other tracking areas (TAs) that are disjoint from the RA (disjoint SRA), i.e., tracking areas that are not included in the TAI list of the RA (See FIG. **1**).
[0096] Each SRA information includes the associated one or more SRA network slice (SRA S-NSSAI) that is uniformly available and allowed for use by the wireless device/UE in the one or more SRA. More specifically, the SRA network slice (S-NSSAI) is a network slice (S-NSSAI) that

is not uniformly available across the whole RA and include for example: [0097] a. S-NSSAIs indicated as Rejected S-NSSAIs when requested by the wireless device/UE in the Registration Request message. The Rejected S-NSSAIs comprise network slices that are rejected as not uniformly available in the RA but are available in some regions (subset) of the RA (SRA) or one or more TA (Regions) outside the RA (disjoint SRA), and/or [0098] b. S-NSSAIs for other network slices that are not requested by the wireless device/UE but are available in one or more TA inside or outside the RA served by the AMF.

[0099] If the SRA is a subset of the RA, the SRA also supports the allowed S-NSSAIs of the RA by inheritance (e.g., SRA**1** and SRA**2** in FIG. **1** or **1**B). However, it is not required to explicitly indicate in the SRA information the allowed S-NSSAIs of the RA as they are already provided in the well-known Allowed NSSAI IE in the Registration Accept message as defined in TS 24.501. Alternatively, the proposed SRA list information IE could include them as well.

[0100] The associated one or more SRA network slice corresponds to one or more allowed network slice available uniformly across the tracking areas making up the SRA and optionally one or more configured network slice available uniformly across either the tracking areas making up the SRA or across the serving network.

[0101] In one aspect, when the wireless device/UE moves outside the RA into another TA (outside the RA) that may or may not be in the coverage area of a disjoint SRA, the wireless device/UE sends a Registration Request message which may further include one or more requested network slice (Requested S-NSSAI). If included, the one or more Requested S-NSSAI may further comprise at least one of: [0102] a. previously rejected S-NSSAI for the RA (which may be available in an SRA and/or, [0103] b. NSSAI previously indicated as supported in one or more SRAs, i.e., other S-NSSAIs available only within an SRA

and in response to the Registration Request, the wireless device/UE receives a Registration Accept message including SRA list information including at least one of the one or more SRA and the associated supported one or more allowed SRA network slice wherein the associated one or more SRA network slice indicates at least one of the one or more requested network slice that is only available and allowed in the SRA. One or more SRA implies including in the Registration Accept one or more tracking area lists where each list indicates the tracking areas that support uniformly one or more S-NSSAI.

[0104] In another aspect, when the wireless device/UE receives the Registration Accept message containing a RA (tracking areas list) with associated S-NSSAI(s) uniformly available across the RA, one or more allowed/available S-NSSAIs in at least one SRA (one or more tracking area), it may also receive the well-known Rejected NSSAI Information Element as defined in TS 24.501 and comprising one or more rejected S-NSSAIs as not uniformly available across the RA. Those one or more rejected S-NSSAIs may be comprised in the one or more allowed/available S-NSSAIs in at least one SRA.

[0105] The wireless device/UE stores the one or more S-NSSAIs uniformly available across the RA and the one or more S-NSSAIs available across at least an SRA. Those S-NSSAIs are also registered by the network node (AMF).

[0106] An example format of the SRA List Information Element and inclusion in the Registration accept message is described below. Note that another encoding format is possible: [0107]

Registration Accept

Message definition

The REGISTRATION ACCEPT message is sent by the AMF to the UE (based on the Registration Accept defined in TS 24.501)

Message type: REGISTRATION ACCEPT

Significance: dual

Direction: network to UE

TABLE-US-00001 REGISTRATION ACCEPT message content Information IEI Element

Type/Reference Presence Format Length Extended Extended M V 1 protocol protocol discriminator discriminator 9.2 of TS 24.501 Security Security M V ½ header header type type 9.3 of TS 24.501 [. . .] 54 TAI 5GS tracking O TLV 9-114 list area identity list 9.11.3.9 of TS 24.501 15 Allowed NSSAI 9.11.3.37 O TLV 4-74 NSSAI of TS 24.501 11 Rejected Rejected NSSAI O TLV 4-42 NSSAI 9.11.3.46 of TS 24.501 31 Configured NSSAI 9.11.3.37 O TLV 4-146 NSSAI of TS 24.501 Xx Secondary SRA List O TLV Registration Information Area List (section Information below) [. . .]

SRA List Information:

The purpose of the SRA information is to identify the tracking area identity from the TA list included in the secondary RA and the associated allowed S-NSSAI that are only available in the SRA (i.e., not included in the allowed NSSAI IE (9.11.3.46 of TS 24.501)) and may include other configured S-NSSAIs that are only available in the SRA (i.e., not included in the configured NSSAI IE (9.11.3.37 of TS 24.501)).

Note that the allowed NSSAI IE (9.11.3.46 of TS 24.501)), configured NSSAI IE (9.11.3.37 of TS 24.501)) and Rejected NSSAI 9.11.3.46 of TS 24.501 represent the uniformly allowed, configured and rejected NSSAI across the whole RA represented by the TAI list (9.11.3.9 of TS 24.501).

The SRA list information includes one or more SRA element. Each SRA element (SRA**1**, SRA**2**, . . .) represents a smaller area within the RA made up of one or more TA of the TAI list. Each SRA element includes other allowed NSSAI not included in the allowed NSSAI IE (9.11.3.46 of TS 24.501) and may include other configured NSSAI not included in the configured NSSAI IE (9.11.3.37 of TS 24.501)).

In addition, each SRA element may include rejected NSSAI within the SRA (which may be provided if the UE registers within the SRA). All the NSSAI information included in the SRA information element are not included in the Allowed NSSAI IE, Configured NSSAI IE and Rejected NSSAI IE that are at the Registration Accept message level and that are applicable across the RA.

The S-NSSAI in the Allowed NSSAI IE (9.11.3.46 of TS 24.501)) is allowed in any TA in the TAI list IE (9.11.3.9 of TS 24.501), i.e. the whole RA and in the SRA if the TA list in the SRA information element includes the same TAs as in the TAI list (9.11.3.9) (SRA subset of RA or overlapping SRA).

TABLE-US-00002 SRA list information element 8 7 6 5 4 3 2 1 SRA IEI Length of SRA contents SRA 1 SRA 2 . . . SRA p

TABLE-US-00003 SRA information element (in one SRA element) 8 7 6 5 4 3 2 1 SRA 1 Length of SRA contents TA List Other Allowed NSSAI Other configured NSSAI Rejected NSSAI in SRA

[0108] The method in FIG. **6** further comprises an optional step (not shown) of indicating by the wireless device/UE to the network node (AMF) in the Registration Request message a capability information indicating the wireless device/UE supports receiving tracking areas and associated network slices that are not uniformly available across the RA, i.e., it can support SRA or network slice availability per SRA. In response to sending the capability of handling and receiving SRA information, the wireless device/UE receives in the Registration Accept message from the network node (AMF) an indication that the SRA or the network slice availability per SRA is enabled or disabled (i.e., supported/not supported) in the network. The method further comprises the wireless device/UE receiving a notification from an access network node (e.g., gNB) that is connected to the network node (AMF) where the notification would indicate tracking area change (e.g., that a TA is included into an SRA (TAI list of the SRA)), in which case the SRA network slices will be available to be used in that TA as well.

[0109] In one aspect, the method in the wireless device/UE further comprises upon the wireless device/UE moving to a tracking area (TA) outside the RA, the wireless device/UE may send a second Registration Request including requested one or more network slice comprising the associated one or more SRA network slice and receiving a Registration Accept message comprising

the allowed one or more SRA network slice as registered network slices.
In another aspect, the method describes the wireless device/UE establishing a PDU session in an associated SRA network slice (SRA S-NSSAI) while the UE is located in a TA of an SRA. Once the PDU session is established, the wireless device/UE moves outside the coverage area of the SRA where the associated SRA network slice is no longer supported. The method then includes the step of one of deactivating or suspending user plane associated to the PDU session or releasing the PDU session. However, the wireless device/UE may start resuming or reactivating the user plane upon moving to an SRA, within or disjoint from the RA, supporting the PDU session SRA network slice.
[0110] FIG. **7** illustrates a method in the network node (e.g., AMF in 5G) for handling network slices in accordance with some embodiments as described herein. The method comprises step **710** the network node (e.g., AMF in 5G) participating in a registration procedure of a wireless device/UE in the serving network (5G system), where the serving network is either a Public Land Mobile Network PLMN or a Standalone Non-Public Network (SNPN). The network node (e.g., AMF in 5G) starts registering the wireless device/UE when receiving a Registration Request message from the wireless device/UE. The method further comprises, following the processing of the Registration Request, sending, at step **720**, by the network node (AMF in 5G) to the wireless device/UE a Registration Accept message including a Tracking Area list (known as TAI list) describing the registration area (RA) within which the UE can move without having to send a Registration Request to the AMF, the associated one or more RA network slice that is uniformly available in the RA for the UE to use (i.e., currently known Allowed S-NSSAIs uniformly allowed in the RA). The AMF may also indicate configured NSSAI supported in the RA or the serving network.
In addition, the network node (e.g., AMF in 5G) further sends to the wireless device/UE in the Registration Accept message secondary registration area (SRA) List information including one or more SRA information. Each SRA information specifies one or more tracking area (TA) defining the coverage of the SRA where each SRA is either: [0111] a subset of the RA (partially overlapping SRA), i.e., one or more TA of the TAI list (see FIG. **1**), or [0112] a set of other tracking areas (TAs) that are disjoint from the RA (disjoint SRA) (See FIG. **1**).
[0113] In addition, each SRA information includes the associated one or more SRA network slice (SRA S-NSSAI) that is uniformly available and allowed for use by the wireless device/UE in the one or more SRA. More specifically, the SRA network slice (S-NSSAI) is a network slice (S-NSSAI) that is not uniformly available across the whole RA and include for example: [0114] a. S-NSSAIs indicated as Rejected S-NSSAIs when requested by the wireless device/UE in the Registration Request message. The Rejected S-NSSAIs comprise network slices that are rejected as not uniformly available in the RA but are available in some regions (subset) of the RA (SRA) or one or more TA (Regions) outside the RA (disjoint SRA), and/or [0115] b. S-NSSAIs for other network slices that are not requested by the wireless device/UE but are available in one or more TA inside or outside the RA served by the AMF.
[0116] If the SRA is a subset of the RA, the SRA also supports the allowed S-NSSAIs of the RA by inheritance (e.g., SRA**1** and SRA**2** in FIG. **1**). However, the SRA information do not need to explicitly indicate them as they are already provided in the well-known Allowed NSSAI IE. Alternatively, the proposed IE could include them as well.
[0117] The associated one or more SRA network slice corresponds to one or more allowed network slice available uniformly across the SRA and optionally one or more configured network slice available uniformly across the SRA or serving network.
[0118] In one aspect, receiving a Registration Request message from the wireless device/UE includes one or more requested network slice (Requested S-NSSAI) (which may include i) previously rejected S-NSSAI for the RA, but available in an SRA and/or ii) other SRA NSSAI, i.e., other S-NSSAI available only in an SRA) and in response, sending a Registration Accept message including SRA list information including at least one of the one or more SRA and the associated

one or more allowed SRA network slice wherein the associated one or more SRA network slice indicates at least one of the one or more requested network slice that is only available and allowed in the SRA. Although, the available and allowed SRA S-NSSAI in the SRA may include S-NSSAI that is considered rejected in the RA, the Registration Accept message may in addition include the well-known Rejected NSSAI Information Element as defined in TS 24.501 and comprising the one or more rejected S-NSSAI as not uniformly available across the RA. The network node (AMF in 5G) stores the associated one or more RA network slice and the associated one or more SRA network slice as part of the UE context.

[0119] The method further comprises receiving by the network node (AMF in 5G) in the Registration Request message a capability of the wireless device indicating the wireless device/UE supports SRA or network slice availability per SRA and indicating in the Registration Accept message from the network node (AMF) an indication that the SRA or the network slice availability per SRA is enabled or disabled in the network taking into account the UE capability, or the UE subscription (that indicates SRA can be provided to the UE) or operator policy.

In another aspect, the method comprises the step of sending to an access network node (e.g., gNB) serving the wireless device/UE information such as an RRC inactive assistance information indicating the S-NSSAIs available or allowed in each tracking area of the list of tracking areas, where the S-NSSAIs include the associated one or more RA network slice available uniformly across all the TAs of the RA and the one or more SRA network slice available across the TAs of the one or more SRA.

The method further comprises receiving by the network node (AMF in 5G) a subsequent Registration Request including Requested NSSAI as the associated one or more SRA network slice (SRA S-NSSAI) when the wireless device moves to a TA in an SRA outside the RA and sending a Registration Accept message comprising the allowed one or more SRA network slice as registered network slices in the SRA. This is not necessary if the AMF provided the SRA as disjoint from the RA as part of the previous registration procedure and both the AMF and UE implicitly registers all the corresponding S-NSSAIs in the RA and disjoint SRAs and any SRA subset of the RA if any are included.

In accordance with another aspect, the method includes determining the UE has established a PDU session with an SMF over a network slice (a network slice of an RA or of an SRA), and upon detecting the wireless device has moved into a tracking area of an SRA not supporting the used network slice (S-NSSAI), the AMF initiates deactivation or suspension of any user plane associated with the PDU session using the used network slice (S-NSSAI). The AMF may do so by informing the corresponding Session Management Function, which controls the PDU session. The deactivation or suspension of the user plane may be performed by the SMF.

[0120] FIG. **8** is a schematic block diagram of a network node **800** according to some embodiments of the present disclosure. Optional features are represented by dashed boxes. The network node **800** may be, for example, a core network node that implements a NF (e.g., AMF **200**, SMF **206**, NSACF **400**, NSACF **500**, NSACF **600**, NSACF **700**, UDM/HSS **402**, UDM/HSS **502**, UDM/HSS **604**, or UDR **702**, or the like). As illustrated, the network node **800** includes a one or more processors **804** (e.g., Central Processing Units (CPUs), Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), and/or the like), memory **806**, and a network interface **808**. The one or more processors **804** are also referred to herein as processing circuitry. The one or more processors **804** operate to provide one or more functions of the network node **800** as described herein (e.g., one or more functions of the AMF **200**, SMF **206**, NSACF **400**, NSACF **600**, UDM/HSS **402**, UDM/HSS **502**, UDM/HSS **604**, or UDR **702**, or the like, as described herein). In some embodiments, the function(s) are implemented in software that is stored, e.g., in the memory **806** and executed by the one or more processors **804**.

[0121] FIG. **9** is a schematic block diagram that illustrates a virtualized embodiment of the network node **800** according to some embodiments of the present disclosure. Again, optional features are

represented by dashed boxes. As used herein, a "virtualized" network node is an implementation of the network node **800** in which at least a portion of the functionality of the network node **800** is implemented as a virtual component(s) (e.g., via a virtual machine(s) executing on a physical processing node(s) in a network(s)). As illustrated, in this example, the network node **800** includes one or more processing nodes **900** coupled to or included as part of a network(s) **902**. Each processing node **900** includes one or more processors **904** (e.g., CPUs, ASICs, FPGAs, and/or the like), memory **906**, and a network interface **908**. In this example, functions **910** of the network node **800** described herein (e.g., one or more functions of the AMF **200**, SMF **206**, NSACF **400**, NSACF **500**, NSACF **600**, NSACF **700**, UDM/HSS **402**, UDM/HSS **502**, UDM/HSS **604**, or UDR **702**, or the like, as described herein) are implemented at the one or more processing nodes **900** or distributed across the two or more processing nodes **900** in any desired manner. In some particular embodiments, some or all of the functions **910** of the network node **800** described herein are implemented as virtual components executed by one or more virtual machines implemented in a virtual environment(s) hosted by the processing node(s) **900**.

[0122] In some embodiments, a computer program including instructions which, when executed by at least one processor, causes the at least one processor to carry out the functionality of the network node **800** or a node (e.g., a processing node **900**) implementing one or more of the functions **910** of the network node **800** in a virtual environment according to any of the embodiments described herein is provided. In some embodiments, a carrier comprising the aforementioned computer program product is provided. The carrier is one of an electronic signal, an optical signal, a radio signal, or a computer readable storage medium (e.g., a non-transitory computer readable medium such as memory).

[0123] FIG. **10** is a schematic block diagram of the network node **800** according to some other embodiments of the present disclosure. The network node **800** includes one or more modules **1000**, each of which is implemented in software. The module(s) **1000** provide the functionality of the network node **800** described herein. This discussion is equally applicable to the processing node **900** of FIG. **9** where the modules **1000** may be implemented at one of the processing nodes **900** or distributed across multiple processing nodes **900**.

[0124] Any appropriate steps, methods, features, functions, or benefits disclosed herein may be performed through one or more functional units or modules of one or more virtual apparatuses. Each virtual apparatus may comprise a number of these functional units. These functional units may be implemented via processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include Digital Signal Processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as Read Only Memory (ROM), Random Access Memory (RAM), cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein. In some implementations, the processing circuitry may be used to cause the respective functional unit to perform corresponding functions according one or more embodiments of the present disclosure.

[0125] FIG. **11** is a schematic block diagram of a wireless communication device **2200** according to some embodiments of the present disclosure. As illustrated, the wireless communication device **2200** includes one or more processors **2202** (e.g., CPUs, ASICs, FPGAs, and/or the like), memory **2204**, and one or more transceivers **2206** each including one or more transmitters **2208** and one or more receivers **2210** coupled to one or more antennas **2212**. The transceiver(s) **2206** includes radio-front end circuitry connected to the antenna(s) **2212** that is configured to condition signals communicated between the antenna(s) **2212** and the processor(s) **2202**, as will be appreciated by on of ordinary skill in the art. The processors **2202** are also referred to herein as processing circuitry. The transceivers **2206** are also referred to herein as radio circuitry. In some embodiments, the

functionality of the wireless communication device **2200** described above may be fully or partially implemented in software that is, e.g., stored in the memory **2204** and executed by the processor(s) **2202**. Note that the wireless communication device **2200** may include additional components not illustrated in FIG. **22** such as, e.g., one or more user interface components (e.g., an input/output interface including a display, buttons, a touch screen, a microphone, a speaker(s), and/or the like and/or any other components for allowing input of information into the wireless communication device **2200** and/or allowing output of information from the wireless communication device **2200**), a power supply (e.g., a battery and associated power circuitry), etc.

[0126] In some embodiments, a computer program including instructions which, when executed by at least one processor, causes the at least one processor to carry out the functionality of the wireless communication device **2200** according to any of the embodiments described herein is provided. In some embodiments, a carrier comprising the aforementioned computer program product is provided. The carrier is one of an electronic signal, an optical signal, a radio signal, or a computer readable storage medium (e.g., a non-transitory computer readable medium such as memory).

[0127] FIG. **12** is a schematic block diagram of the wireless communication device **2200** according to some other embodiments of the present disclosure. The wireless communication device **2200** includes one or more modules **2300**, each of which is implemented in software. The module(s) **2300** provide the functionality of the wireless communication device **2200** described herein.

[0128] While processes in the figures may show a particular order of operations performed by certain embodiments of the present disclosure, it should be understood that such order is exemplary (e.g., alternative embodiments may perform the operations in a different order, combine certain operations, overlap certain operations, etc.).

[0129] Those skilled in the art will recognize improvements and modifications to the embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein.

[0130] Some example embodiments of the present disclosure are as follows:

[0131] A method in a wireless device for handling network slices in a telecommunication network, the method comprising: [0132] initiating a registration procedure with a network node in the telecommunication network; [0133] receiving (as part of the registration procedure) a registration area (RA) represented by a list of tracking areas (a TAI list) and associated one or more RA network slice that is uniformly available in the RA; [0134] receiving one or more secondary registration area (SRA) and associated one or more SRA network slice that is uniformly available for use in the one or more SRA and is not uniformly available across the RA, wherein each of the one or more SRA is one or more of (i.e., at least one of) [0135] a subset of the RA (overlapping SRA), hence additionally supporting the associated one or more RA network slice, and [0136] a set of other tracking areas (TAs) that are disjoint from the RA (disjoint SRA).

[0137] The method of embodiment 1 wherein the telecommunication network is one of a Public Land Mobile Network (PLMN) or a Stand-Alone Non Public Network (SNPN).

[0138] The method of embodiment 1 or 2 wherein the associated one or more RA network slice corresponds to at least one of: [0139] one or more allowed network slice available uniformly across the RA and [0140] one or more configured network slice available uniformly across the RA supported by the serving PLMN.

[0141] The method of embodiment 1 or 2 wherein the associated one or more SRA network slice corresponds to at least one of: [0142] one or more allowed network slice available uniformly across the SRA; [0143] one or more configured network slice available uniformly across the SRA.

[0144] The method of embodiment 1, wherein the registration procedure comprises: [0145] sending a Registration Request message to the network node including one or more requested network slice; [0146] receiving a Registration Accept message including: [0147] at least one of the one or more SRA and the associated one or more SRA network slice wherein the associated one or more SRA network slice indicates at least one of the one or more requested network slice that is

indicated as rejected across the RA (or not uniformly available across the RA) but is uniformly available across the one or more SRA.
[0148] The method of embodiments 1-5 wherein the associated one or more RA network slice, the associated one or more SRA network slice or the requested one or more network slice are each indicated by a Single Network Slice Selection Assistance Information S-NSSAI.
[0149] The method of embodiment 5, wherein the Registration Accept message further includes the one or more requested network slice that is rejected as not uniformly available across the RA.
[0150] The method of any of embodiments 1 to 7, wherein the method further comprises indicating to the network node a capability of the wireless device to support SRA or network slice availability per SRA.
[0151] The method of embodiment 8 wherein the method further comprises receiving from the network node an indication that the SRA or the network slice availability per SRA is enabled or disabled.
[0152] The method of embodiment 1 to 8 further comprises receiving a notification from an access network node connected to the network node indicating tracking area change (e.g., notification with that a TA is inside an SRA)
[0153] The method of any of embodiments 1 to 10 wherein the method further comprises storing the associated one or more RA network slice and the associated one or more SRA network slice as registered by the network node.
[0154] The method of any of embodiments 1 to 11 wherein the method further comprises upon moving to a tracking area outside the RA, sending a second Registration Request including requested one or more network slice comprising the associated one or more SRA network slice; and receiving a Registration Accept message comprising the allowed one or more SRA network slice as registered network slices.
[0155] The method of any of embodiments 1 to 10 further comprising: [0156] establishing a PDU session in an associated SRA network slice while in an SRA; [0157] moving outside the SRA where the associated SRA network slice is no longer supported; [0158] one of deactivating or suspending user plane associated to the PDU session or releasing the PDU session.
[0159] The method of embodiment 13, wherein the method further comprises resuming or reactivating the user plane upon moving to an SRA, within or disjoint from the RA, supporting the associated SRA network slice.
[0160] The method of embodiment 1-14, wherein the subset of the list of tracking areas (the TAI list) comprises at least one tracking area.
[0161] A method in a network node for handling network slices in a serving public Land Mobile Network (PLMN), the method comprising: [0162] receiving a Registration Request from a wireless device in the serving PLMN; [0163] sending a Registration Response including [0164] 1. a registration area (RA) represented by a list of tracking areas (TAI list) and associated one or more RA network slice that is uniformly available in the RA and [0165] 2. one or more secondary registration area (SRA) and associated one or more SRA network slice that is uniformly available in the one or more SRA for use by the wireless device, wherein each of the one or more SRA is one or more of (i.e., at least one of) [0166] a subset of the RA (overlapping SRA), hence additionally supporting the associated one or more RA network slice, and [0167] a set of other tracking areas (TAs) that are disjoint from the RA (disjoint SRA).
[0168] The method of embodiment 16 wherein the telecommunication network is one of a Public Land Mobile Network (PLMN) or a Stand-Alone Non Public Network (SNPN).
[0169] The method of embodiment 16 wherein the associated one or more RA network slice corresponds to at least one of: [0170] one or more allowed network slice available uniformly across the RA and [0171] one or more configured network slice available uniformly across the RA supported by the serving PLMN.
[0172] The method of embodiment 14 or 15 wherein the associated one or more SRA network slice

corresponds to at least one of: [0173] one or more allowed network slice available uniformly across the SRA; [0174] one or more configured network slice available uniformly across the SRA.
[0175] The method of embodiment 16, wherein the receiving of a Registration Request comprises receiving a Registration Request message including one or more requested network slice; [0176] sending a Registration Accept message including: [0177] 1. at least one of the one or more SRA and the associated one or more SRA network slice wherein the associated one or more SRA network slice indicates at least one of the one or more requested network slice that is indicated as rejected across the RA (or not uniformly available across the RA) but is uniformly available across the one or more SRA.
[0178] The method of embodiment 20, wherein the Registration Accept message includes the one or more requested network slice that is rejected as not uniformly available across the RA.
[0179] The method of any of embodiments 16 to 21, wherein the method further comprises receiving from the wireless device information indicating a capability of the wireless device to support SRA or network slice availability per SRA.
[0180] The method of embodiment 22 wherein the method further comprises sending to the wireless device an indication that the SRA or the network slice availability per SRA is enabled or disabled.
[0181] The method of embodiment 16 to 23 further comprises sending to an access network node serving the wireless device an RRC inactive assistance information for the wireless device indicating one or network slices available in each tracking area of the list of tracking areas, including the associated one or more RA network slice available uniformly across all the TAs of the RA and the one or more SRA network slice available across the TAs of the one or more SRA.
[0182] The method of any of embodiments 16 to 23 wherein the method further comprises registering the associated one or more RA network slice and the associated one or more SRA network slice as registered for the wireless device.
[0183] The method of any of embodiments 16 to 23 wherein the method further comprises receiving a second Registration Request comprising requested one or more network slice indicating the associated one or more SRA network slice when the wireless device moves to a TA outside the RA (disjoint SRA); and sending a Registration Accept message comprising the allowed one or more SRA network slice as registered network slices.
[0184] The method of any of embodiments 16 to 26 further comprising: [0185] monitoring tracking area of the wireless device while the wireless device is using a network slice in a PDU session (TA is part of an SRA); [0186] upon detecting the wireless device is moved into a tracking area of an SRA that is not supporting the used network slice; [0187] initiating (by informing the Session Management Function) deactivation or suspension of any user plane associated with the PDU session.
[0188] The method of embodiment 16, wherein the subset of the list of tracking areas (the TAI list) comprises at least one tracking area.
[0189] A wireless device adapted to implement any of embodiments 1 to 15.
[0190] A wireless device comprising one or more processor and memory for storing instructions which when executed by the one or more processors will perform any of the embodiments 1 to 15
[0191] A Computer Readable medium containing program instructions for causing a one or more processor of a wireless device to perform the method of embodiments 1 to 15.
[0192] A network node adapted to implement any of embodiments 16 to 28.
[0193] A network node comprising one or more processor and memory for storing instructions which when executed by the one or more processors will perform any of the embodiments 16 to 28.
[0194] A Computer Readable medium containing program instructions for causing a one or more processor of a network node to perform the method of embodiments 16 to 28.
[0195] The method of embodiment 16 to 28 wherein the associated one or more RA network slice, the associated one or more SRA network slices or the requested one or more network slice are each

identified by a Single Network Slice Selection Assistance Information S-NSSAI.
[0196] Those skilled in the art will recognize improvements and modifications to the embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein.

Claims

1. A method in a wireless device for handling network slices in a telecommunication network, the method comprising: sending a registration request to a network node in the telecommunication network; receiving a registration accept comprising a first list of one or more tracking areas identifiers (TAI list) of one or more tracking areas representing a registration area (RA) and associated one or more first network slices that are uniformly available across all the one or more tracking areas of the RA; and at least one second TAI list for second one or more tracking areas and associated one or more second network slices that are available across all the one or more second tracking areas of the at least one second TAI list, wherein the second one or more tracking areas are at least one of i) a subset of the one or more tracking areas included in the first TAI list representing the RA and ii) different tracking areas that are not included in the first TAI list; and wherein the one or more second network slices are not uniformly supported across all the RA represented by the one or more tracking areas of the first TAI list.
2. The method of claim 1 wherein the telecommunication network is one of a Public Land Mobile Network (PLMN) or a Stand-Alone Non-Public Network (SNPN).
3. The method of claim 1 wherein the associated one or more first network slices corresponds to at least one of: one or more allowed first network slices available uniformly across all tracking areas of the first TAI list representing the RA and one or more configured first network slices available uniformly across all tracking areas of the first TAI list representing the RA supported by the serving PLMN; and/or wherein the one or more second network slices associated with the second tracking areas of the at least one second TAI list correspond to at least one of: one or more allowed second network slices available uniformly across all second tracking areas of the at least one second TAI list; one or more configured second network slices available uniformly across all second tracking areas of the at least one second TAI list.
4. (canceled)
5. (canceled)
6. The method of claim 1 wherein the one or more second network slices associated with the at least one second TAI list correspond to at least one of the one or more requested network slices that are not uniformly supported in all tracking areas of the RA but are uniformly available across the tracking areas of the at least one second TAI list.
7. The method of claim 1 wherein the associated one or more first network slices, the associated one or more second network slices or the requested one or more network slices are each indicated by a Single Network Slice Selection Assistance Information S-NSSAI.
8. (canceled)
9. The method of claim 1, wherein the method further comprises indicating to the network node a capability of the wireless device to support receiving the at least one second TAI list with the associated second network slices or support for network slice availability per secondary areas defined by a list of second TAI list.
10. The method of claim 9 wherein the method further comprises receiving from the network node an indication that the capability of a second TAI list with the associated second network slices or the network slice availability per secondary areas defined by a list of second TAI list is enabled or disabled.
11. (canceled)
12. The method of claim 1 wherein the method further comprises upon moving to a tracking area

outside the RA, sending a second Registration Request including requested one or more network slices comprising the associated one or more second network slices; and receiving a Registration Accept message comprising the allowed one or more second network sliced as registered network slices.

13. The method of claim 1 further comprising: establishing a PDU session in an associated second network slice while in a tracking area of the second TAI list; moving to another tracking area where the associated second network slice is no longer supported; and performing one of deactivating or suspending user plane associated to the PDU session or releasing the PDU session.

14. The method of claim 13, wherein the method further comprises re-establishing the PDU Session, or resuming or reactivating the user plane upon moving back to a tracking area of the second TAI list supporting the associated second network slice.

15. (canceled)

16. A method in a network node for handling network slices in a serving telecommunication network, the method comprising: receiving a Registration Request from a wireless device in the serving telecommunication network; sending a Registration Response including a first list of one or more tracking areas identifiers (TAI list) of one or more tracking areas representing a registration area (RA) and associated one or more first network slices that are uniformly available across all the one or more tracking areas of the RA and at least one second TAI list for second one or more tracking areas and associated one or more second network slices that are available across all the second one or more tracking areas of the at least one second TAI list; wherein the second one or more tracking areas are at least one of i) a subset of the one or more tracking areas representing the RA and ii) different tracking areas that are not included in the first TAI list; and wherein the one or more second network slices are not uniformly supported across all the RA represented by the one or more tracking areas of the first TAI list.

17. The method of claim 16 wherein the telecommunication network is one of a Public Land Mobile Network (PLMN) or a Stand-Alone Non-Public Network (SNPN).

18. The method of claim 16 wherein the associated one or more first network slices correspond to at least one of: one or more allowed first network slices available uniformly across all tracking areas of the first TAI list representing the RA and one or more configured first network slices available uniformly across all tracking areas of the first TAI list representing the RA supported by the serving PLMN; and/or wherein the associated one or more second network slices correspond to at least one of: one or more allowed second network slices available uniformly across all second tracking areas of the at least one second TAI list; one or more configured second network slices available uniformly across all second tracking areas of the at least one second TAI list.

19. (canceled)

20. (canceled)

21. (canceled)

22. The method of claim 16 wherein the method further comprises receiving from the wireless device information indicating a capability of the wireless device to support receiving the at least one second TAI list with the associated second network slices or support for network slice availability per secondary areas defined by a list of second TAI list.

23. The method of claim 22 wherein the method further comprises sending to the wireless device an indication that the capability of a second TAI list with the associated second network slices or the network slice availability per secondary areas defined by a list of second TAI list is enabled or disabled.

24. The method of claim 16 further comprises sending to an access network node serving the wireless device information indicating one or more network slices available in each tracking area of the first and second list of tracking areas.

25. The method of claim 16 wherein the method further comprises registering the associated one or more first network slices and the associated one or more second network slices as registered for the

wireless device.
26. The method of claim 16 wherein the method further comprises receiving a second Registration Request comprising requested one or more network slices indicating the associated one or more second network slices when the wireless device moves to a TA disjoint from the RA; and sending a Registration Accept message comprising the allowed one or more second network slices as registered network slices.
27. The method of claim 16 further comprising: determining the wireless device is using a network slice for a PDU session; upon detecting the wireless device is moved into another tracking area of second TAI list that is not supporting the used network slice; informing a Session Management Function controlling the PDU session to initiate deactivation or suspension of any user plane associated with the PDU session.
28. (canceled)
29. (canceled)
30. (canceled)
31. A wireless device comprising one or more processor and memory for storing instructions which when executed by the one or more processors, the wireless device is configured to: send a registration request to a network node in the telecommunication network; receive a registration accept comprising: a first list of one or more tracking areas identifiers (TAI list) of one or more tracking areas representing a registration area (RA) and associated one or more first network slices that are uniformly available across all the one or more tracking areas of the RA; and at least one second TAI list for second one or more tracking areas and associated one or more second network slices that are available across all the one or more second tracking areas of the at least one second TAI list, wherein the second one or more tracking areas are at least one of i) a subset of the one or more tracking areas included in the first TAI list representing the RA and ii) different tracking areas that are not included in the first TAI list; and wherein the one or more second network slices are not uniformly supported across all the RA represented by the one or more tracking areas of the first TAI list.
32. (canceled)
33. (canceled)
34. (canceled)
35. (canceled)