US 20250261085A1

(19) United States
(12) Patent Application Publication
Chun et al.

(10) Pub. No.: US 2025/0261085 A1
(43) Pub. Date: Aug. 14, 2025

(54) NETWORK SLICE MANAGEMENT

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(21) Appl. No.: **19/181,834**

(22) Filed: **Apr. 17, 2025**

**Related U.S. Application Data**

(63) Continuation of application No. PCT/US2024/010273, filed on Jan. 4, 2024.

(60) Provisional application No. 63/437,276, filed on Jan. 5, 2023.

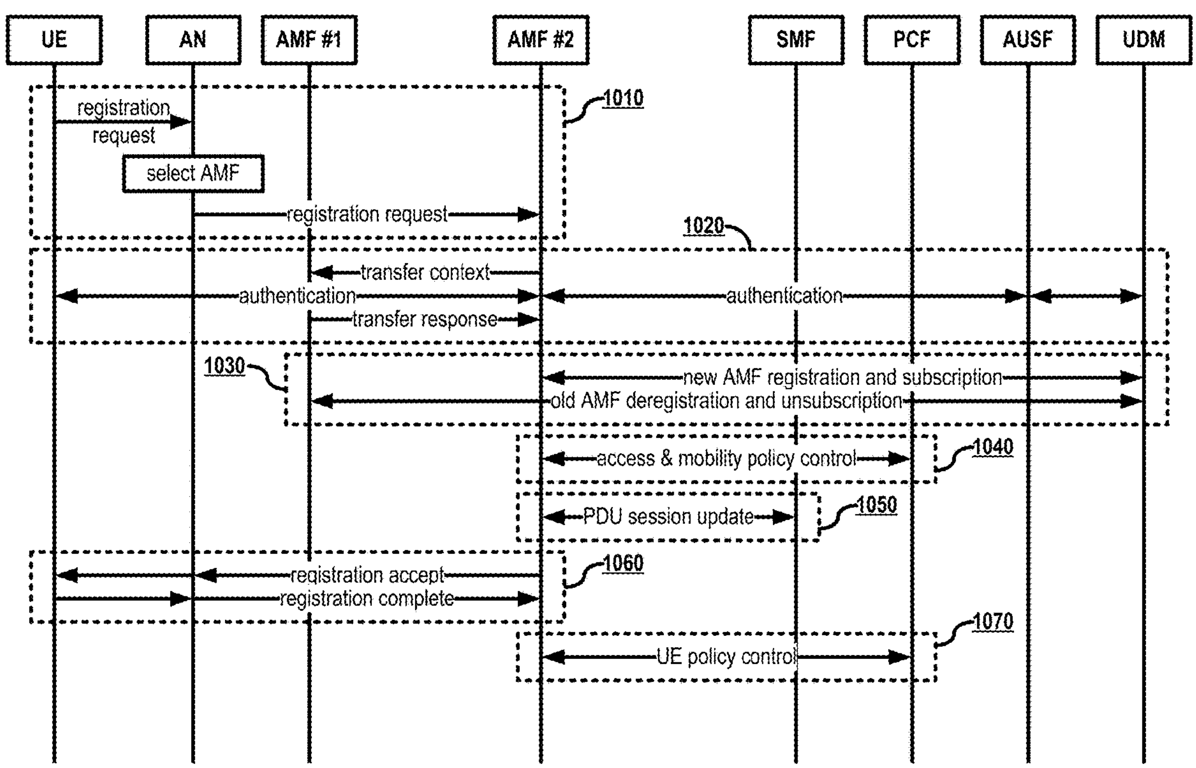
**Publication Classification**

(51) **Int. Cl.**
*H04W 48/02* (2009.01)
*H04W 8/22* (2009.01)
*H04W 60/04* (2009.01)

(52) **U.S. Cl.**
CPC ............ ***H04W 48/02*** (2013.01); ***H04W 8/22*** (2013.01); ***H04W 60/04*** (2013.01)

(57) **ABSTRACT**

A wireless device sends a first message requesting a requested network slice, wherein the first message comprises a capability indication indicating that the wireless device supports partially allowed network slices. The wireless device receives a response message comprising a partial network slice mode indicator set to indicate whether partially allowed network slices apply to the wireless device, and whether partially rejected network slices apply to the wireless device.



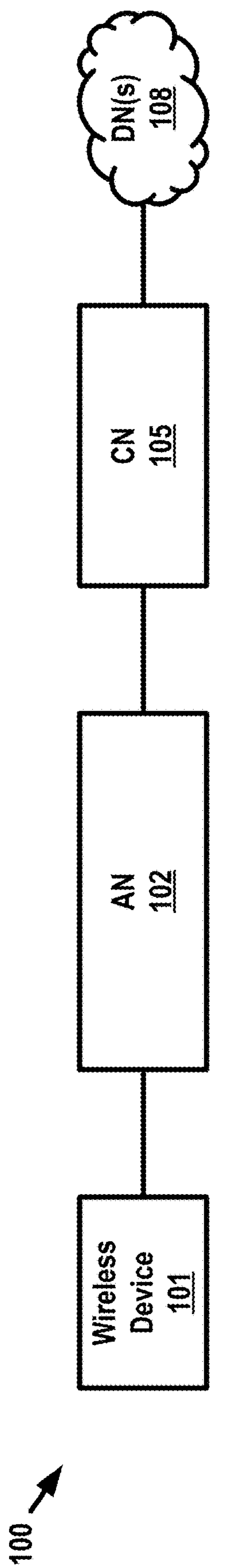

100
Wireless Device 101
AN 102
CN 105
DN(s) 108

FIG. 1A

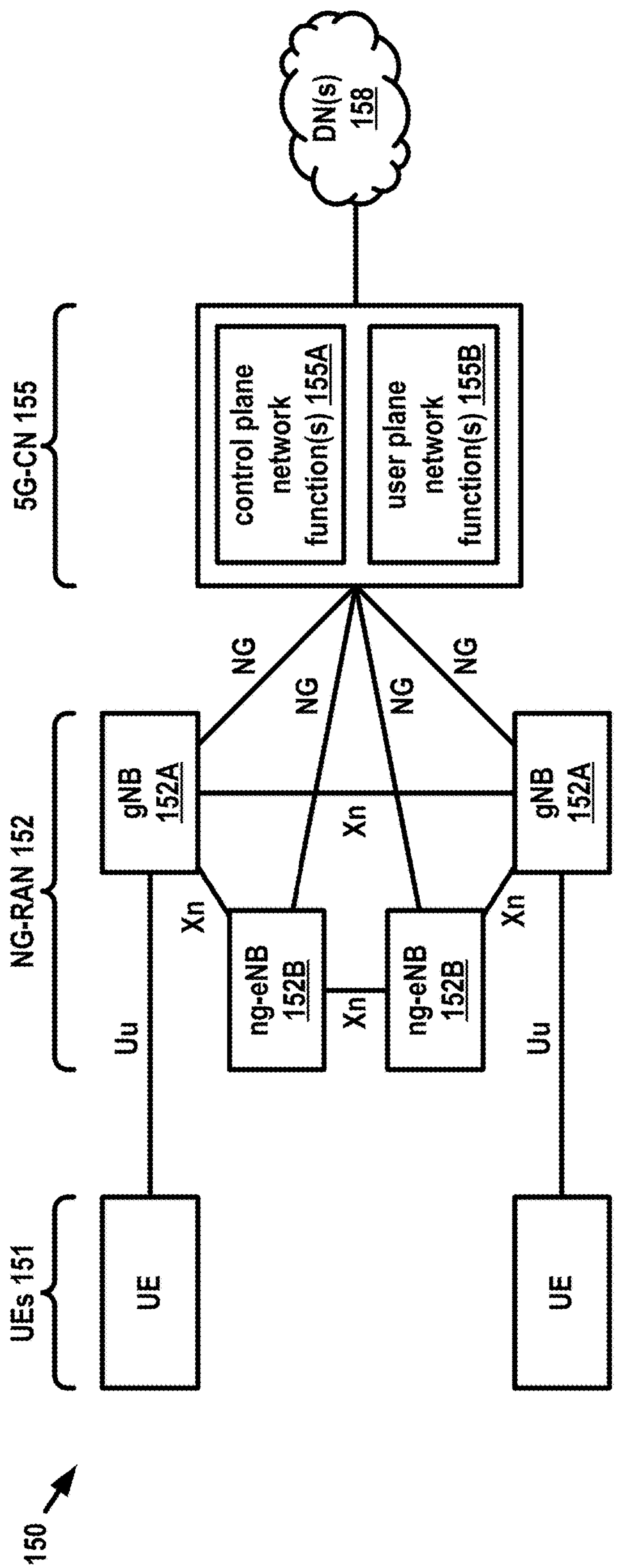

150
UEs 151
UE
UE
Uu
Uu
NG-RAN 152
gNB 152A
gNB 152A
ng-eNB 152B
ng-eNB 152B
Xn
Xn
Xn
Xn
NG
NG
NG
NG
5G-CN 155
control plane network function(s) 155A
user plane network function(s) 155B
DN(s) 158

FIG. 1B

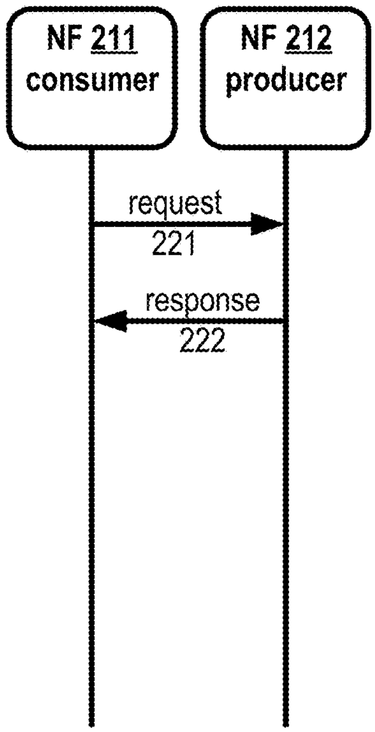



FIG. 2A

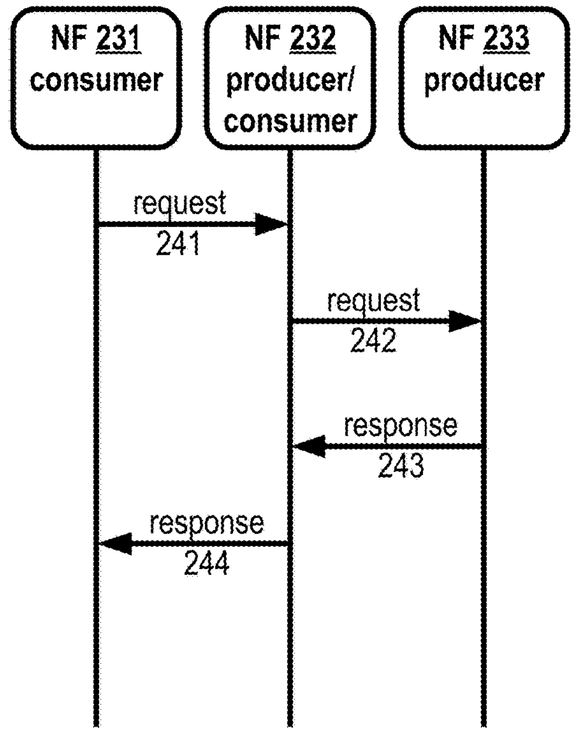



FIG. 2B

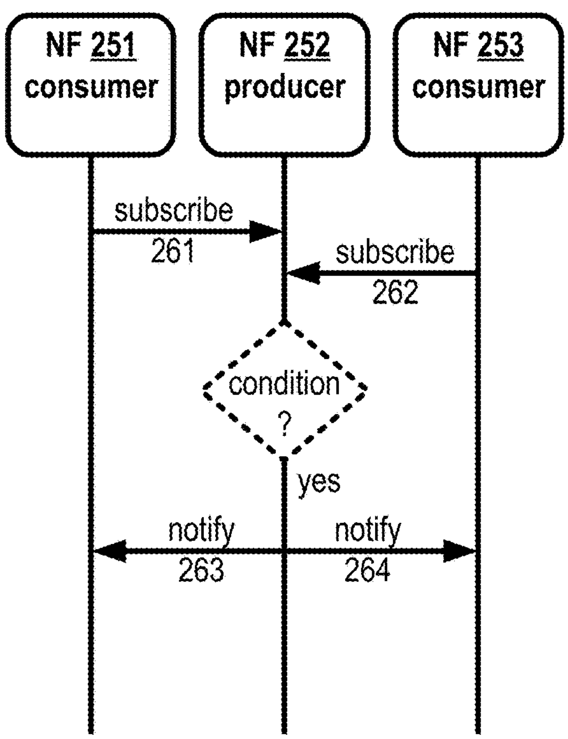



FIG. 2C

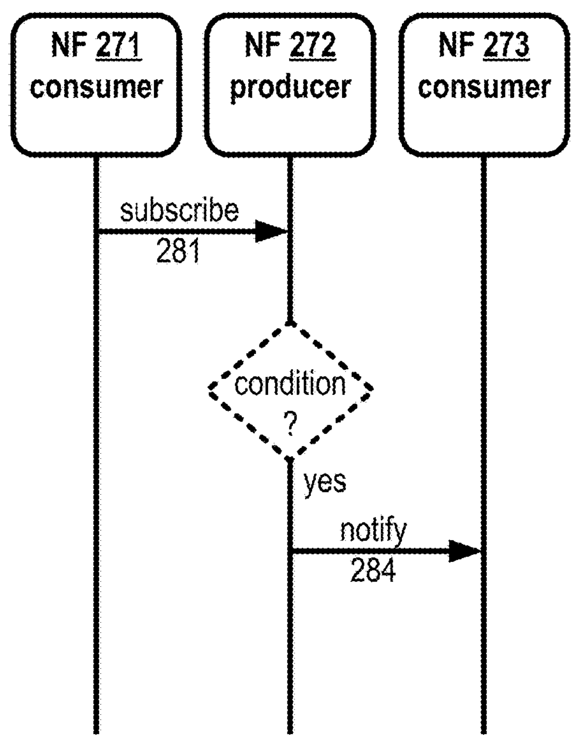
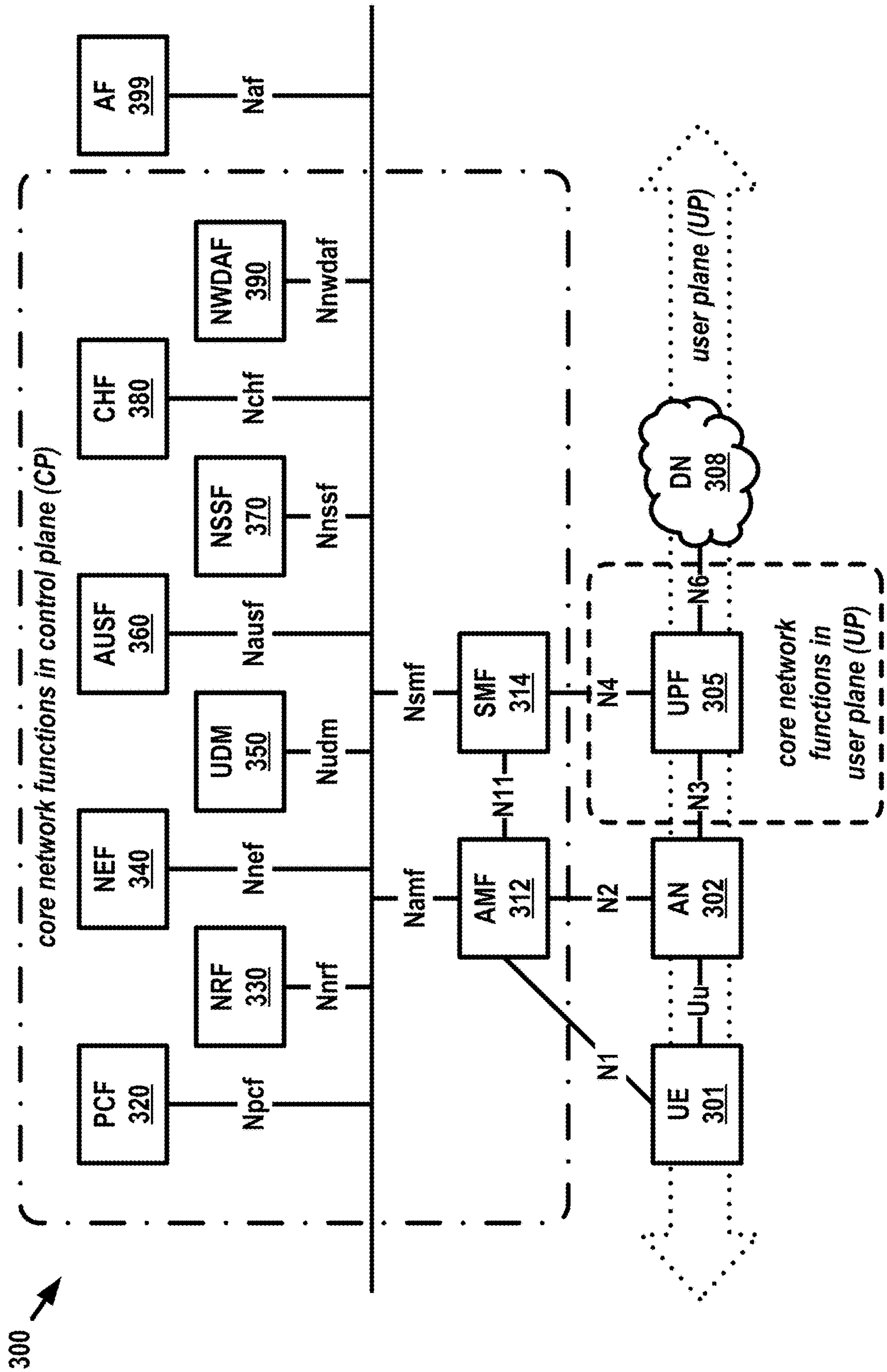



FIG. 2D



300
core network functions in control plane (CP)
PCF 320
NRF 330
NEF 340
UDM 350
AUSF 360
NSSF 370
CHF 380
NWDAF 390
AF 399
Npcf
Nnrf
Nnef
Nudm
Nausf
Nnssf
Nchf
Nnwdaf
Naf
Namf
Nsmf
AMF 312
SMF 314
N11
N2
N4
N1
UE 301
AN 302
UPF 305
DN 308
Uu
N3
N6
core network functions in user plane (UP)
user plane (UP)


FIG. 3

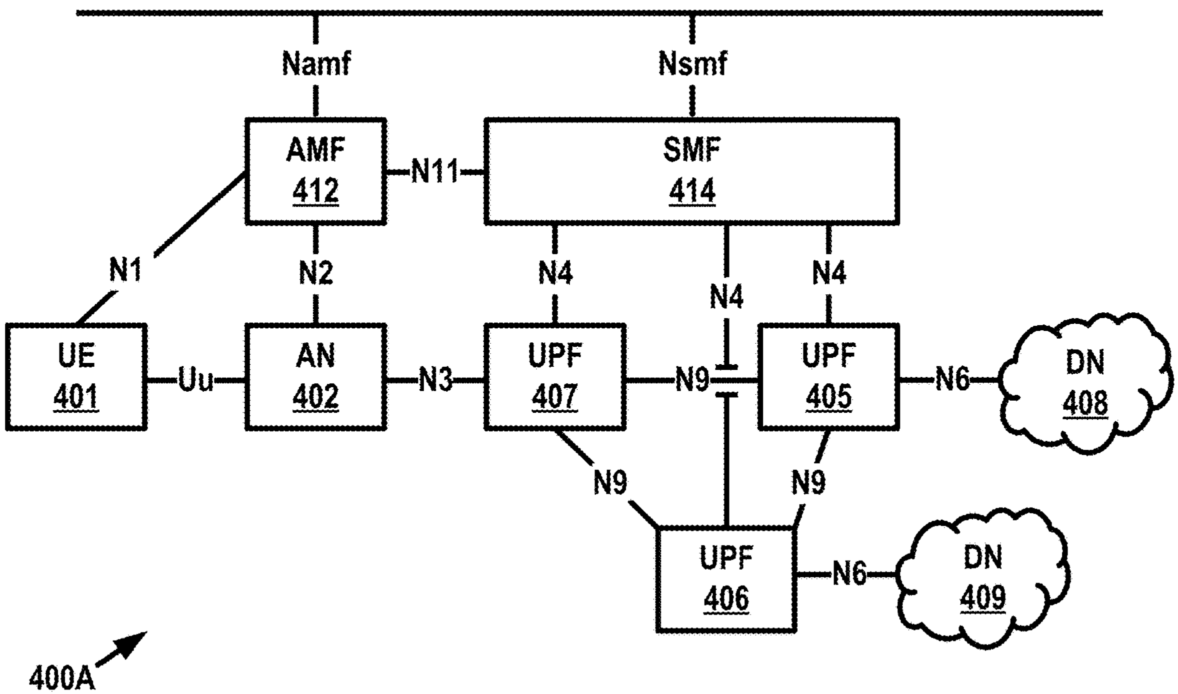

Namf
Nsmf
AMF 412
N11
SMF 414
N1
N2
N4
N4
N4
UE 401
Uu
AN 402
N3
UPF 407
N9
UPF 405
N6
DN 408
N9
N9
UPF 406
N6
DN 409
400A

FIG. 4A

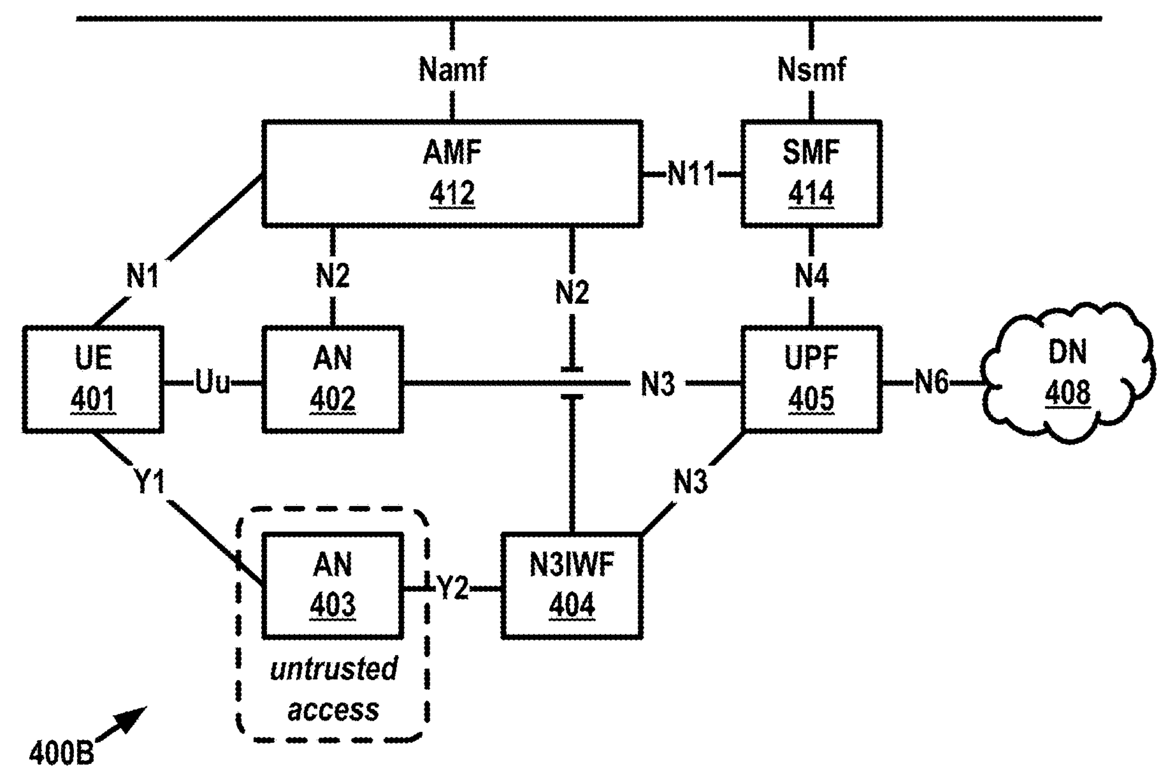

Namf
Nsmf
AMF 412
N11
SMF 414
N1
N2
N2
N4
UE 401
Uu
AN 402
N3
UPF 405
N6
DN 408
Y1
N3
AN 403
Y2
N3IWF 404
untrusted access
400B

FIG. 4B

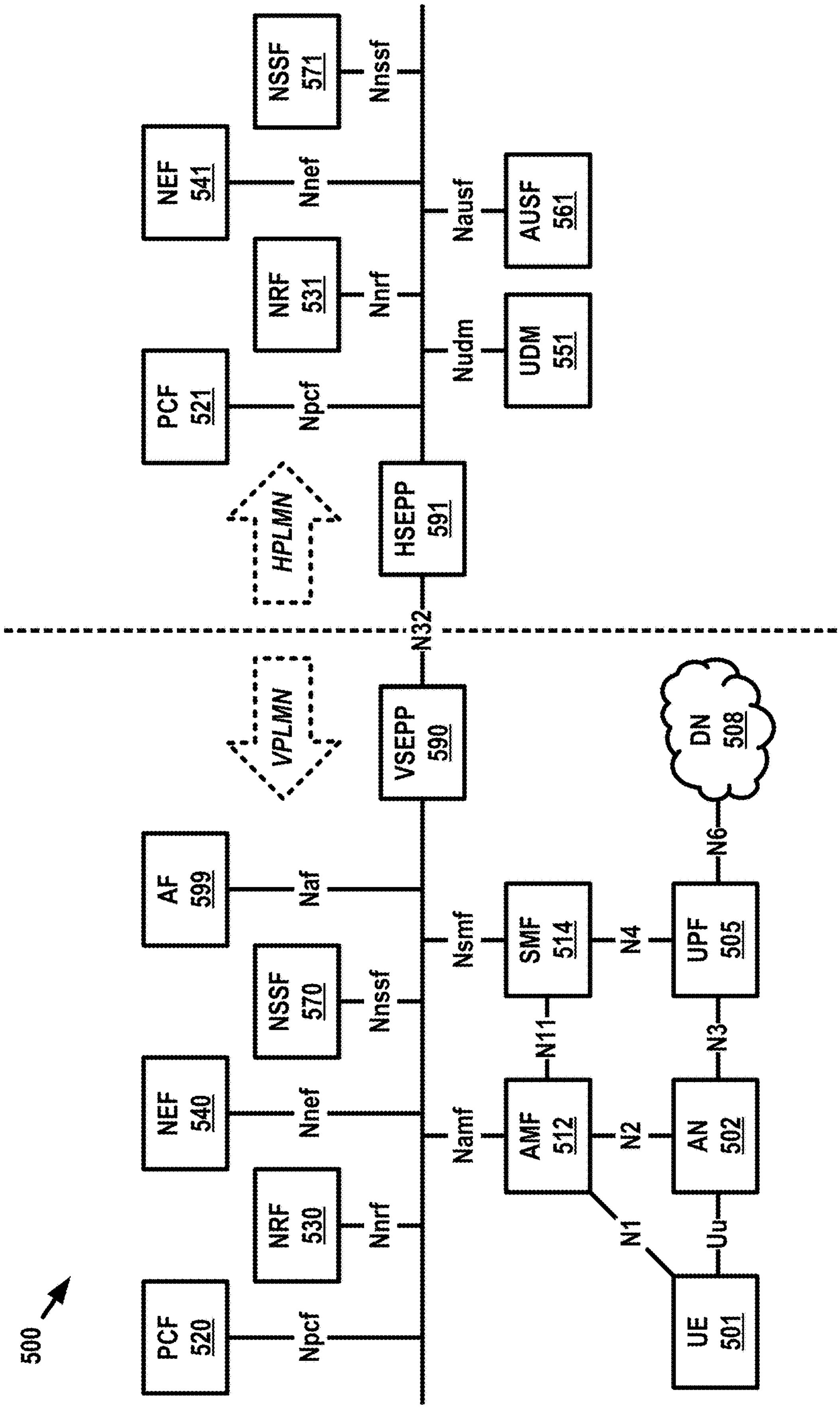

500
PCF 520
NRF 530
NEF 540
NSSF 570
AF 599
VPLMN
VSEPP 590
N32
HSEPP 591
HPLMN
PCF 521
NRF 531
NEF 541
NSSF 571
Npcf
Nnrf
Nnef
Nnssf
Naf
Namf
Nsmf
Nudm
Nausf
UDM 551
AUSF 561
AMF 512
SMF 514
N11
N2
N4
N1
Uu
N3
N6
UE 501
AN 502
UPF 505
DN 508

FIG. 5

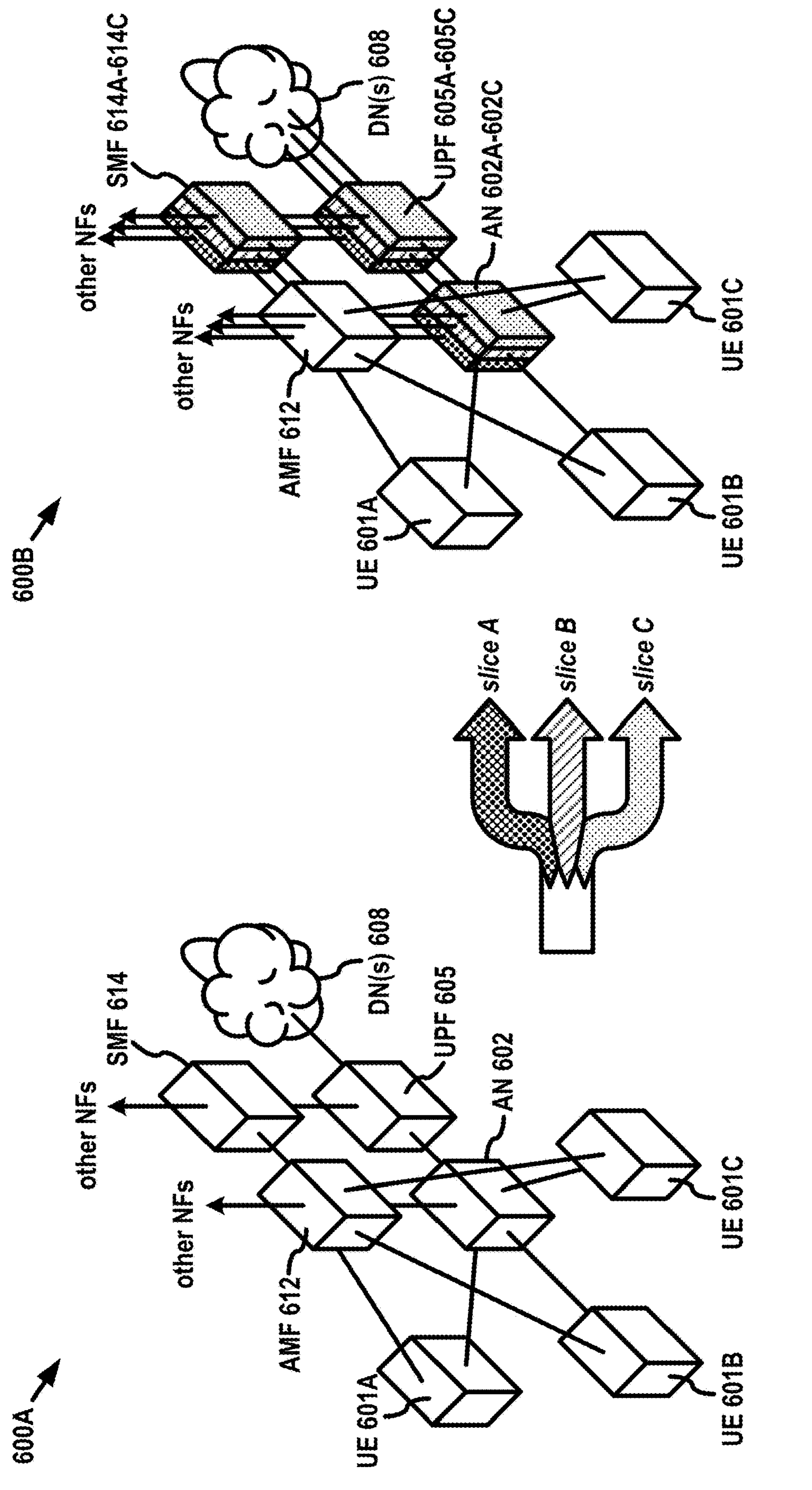

600A
UE 601A
AMF 612
other NFs
other NFs
SMF 614
UPF 605
DN(s) 608
AN 602
UE 601B
UE 601C
slice A
slice B
slice C
600B
UE 601A
AMF 612
other NFs
other NFs
SMF 614A-614C
UPF 605A-605C
DN(s) 608
AN 602A-602C
UE 601B
UE 601C

FIG. 6

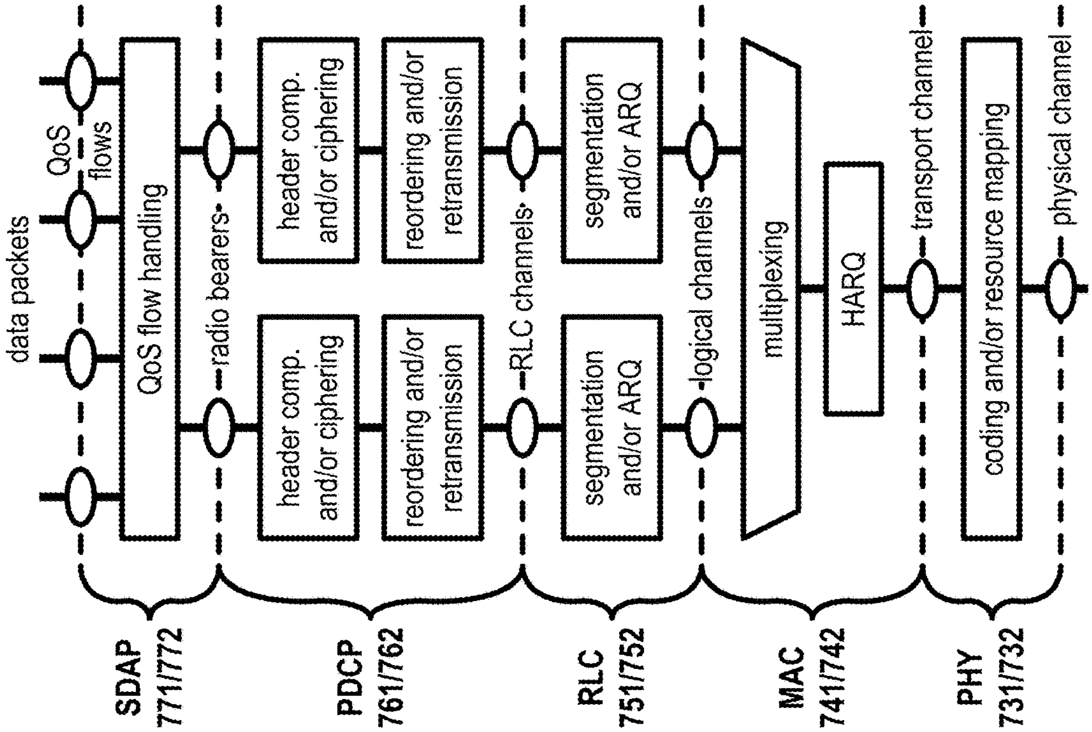



FIG. 7C

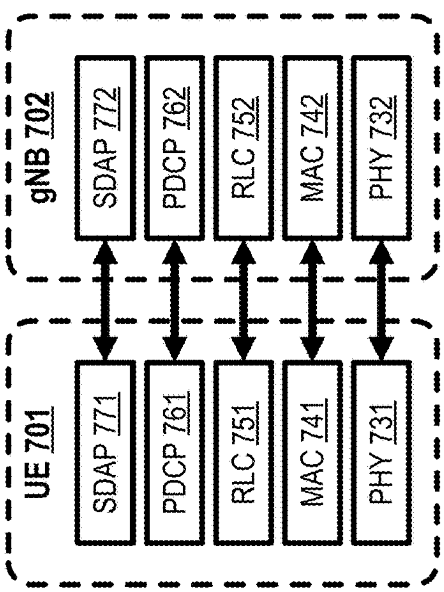



FIG. 7A

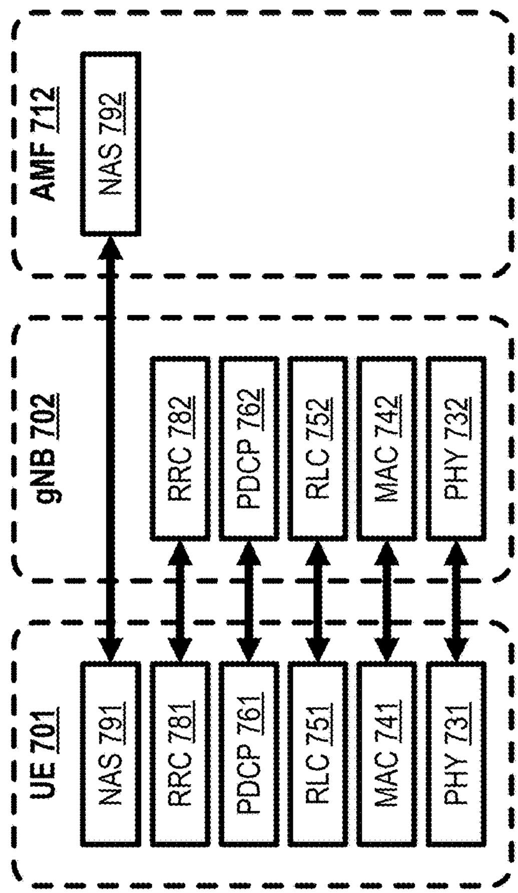



FIG. 7B

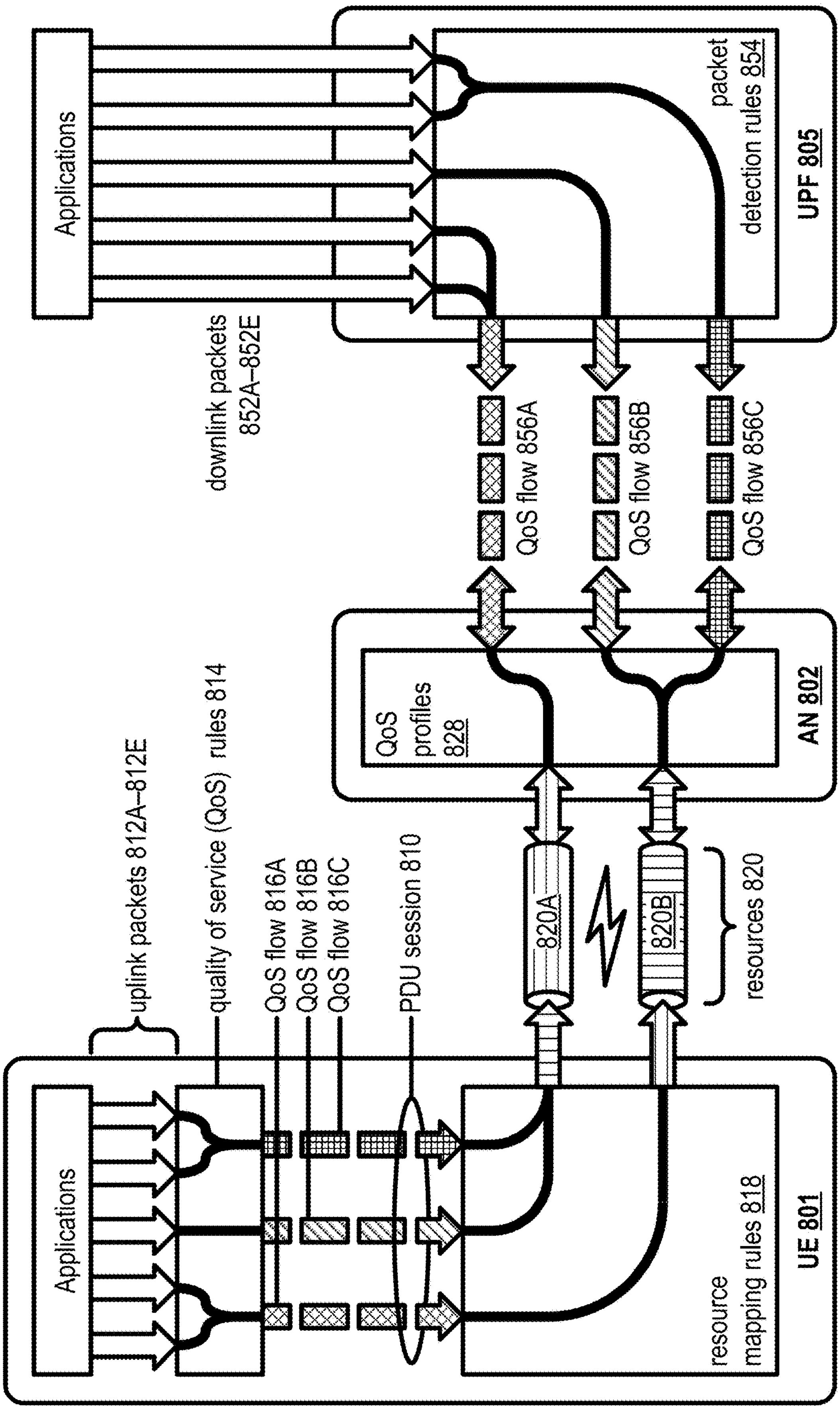

Applications
packet
detection rules 854
UPF 805
downlink packets
852A–852E
QoS flow 856A
QoS flow 856B
QoS flow 856C
QoS
profiles
828
AN 802
uplink packets 812A–812E
quality of service (QoS) rules 814
QoS flow 816A
QoS flow 816B
QoS flow 816C
PDU session 810
820A
820B
resources 820
Applications
resource
mapping rules 818
UE 801

FIG. 8

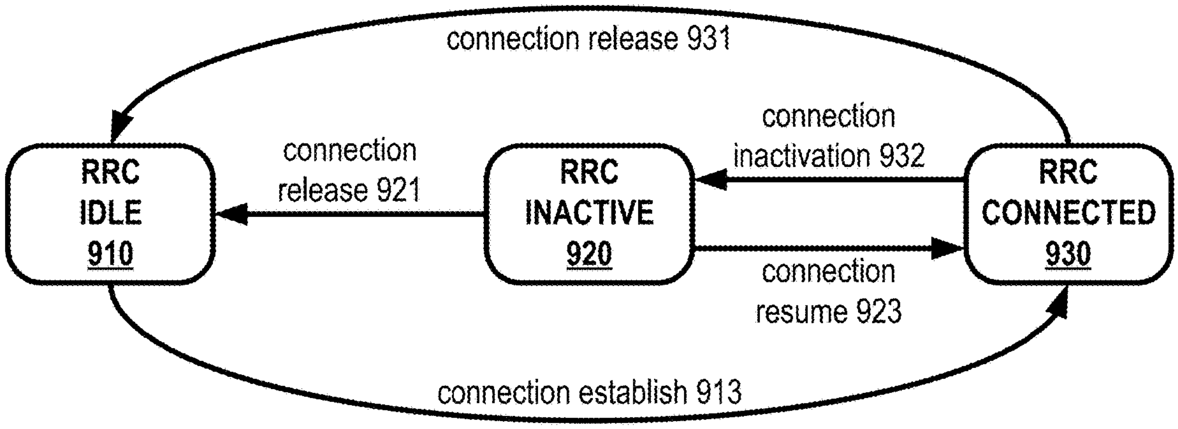



FIG. 9A

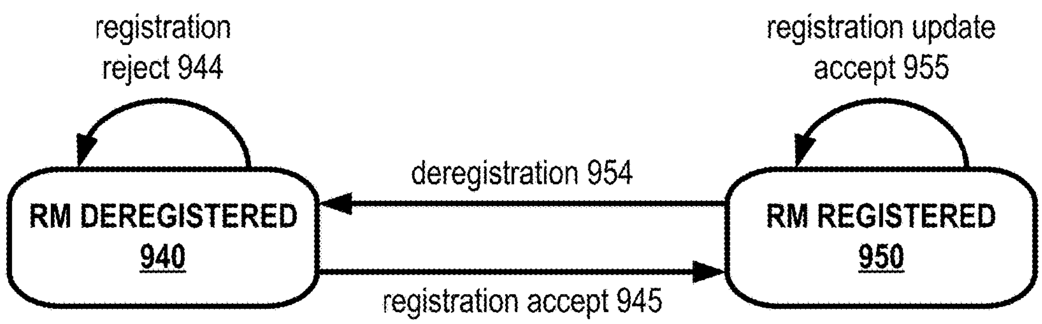



FIG. 9B

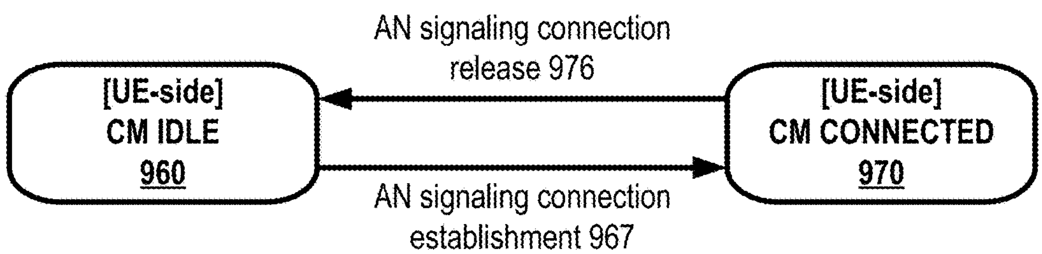



FIG. 9C

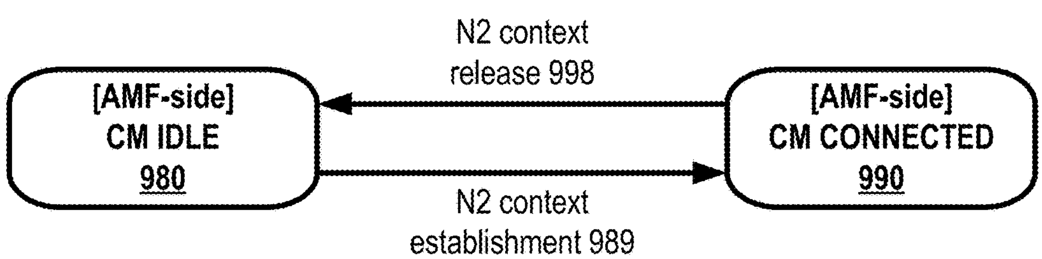



FIG. 9D

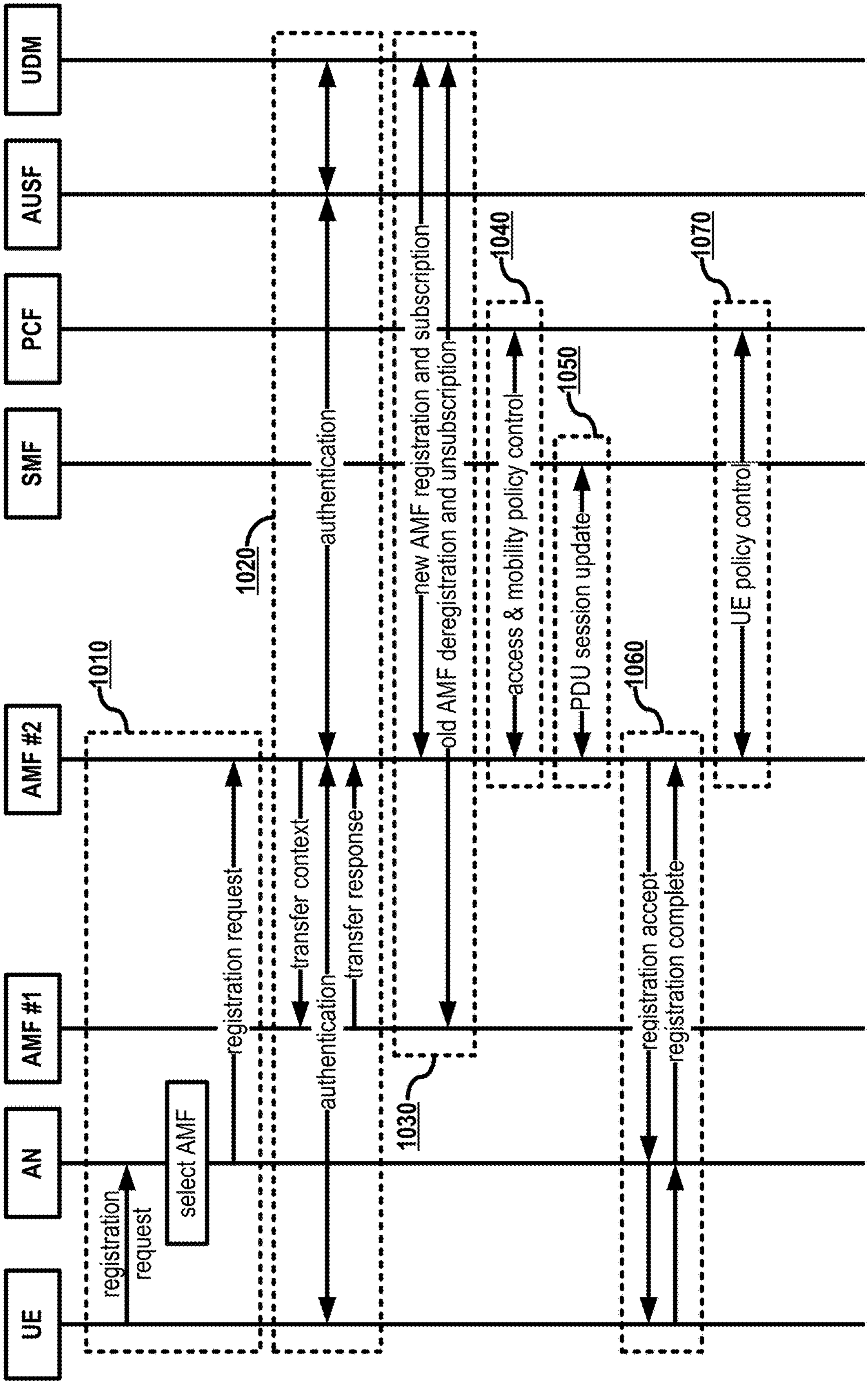

UE
AN
AMF #1
AMF #2
SMF
PCF
AUSF
UDM
1010
registration request
select AMF
registration request
1020
transfer context
authentication
transfer response
authentication
1030
new AMF registration and subscription
old AMF deregistration and unsubscription
1040
access & mobility policy control
1050
PDU session update
1060
registration accept
registration complete
1070
UE policy control

FIG. 10

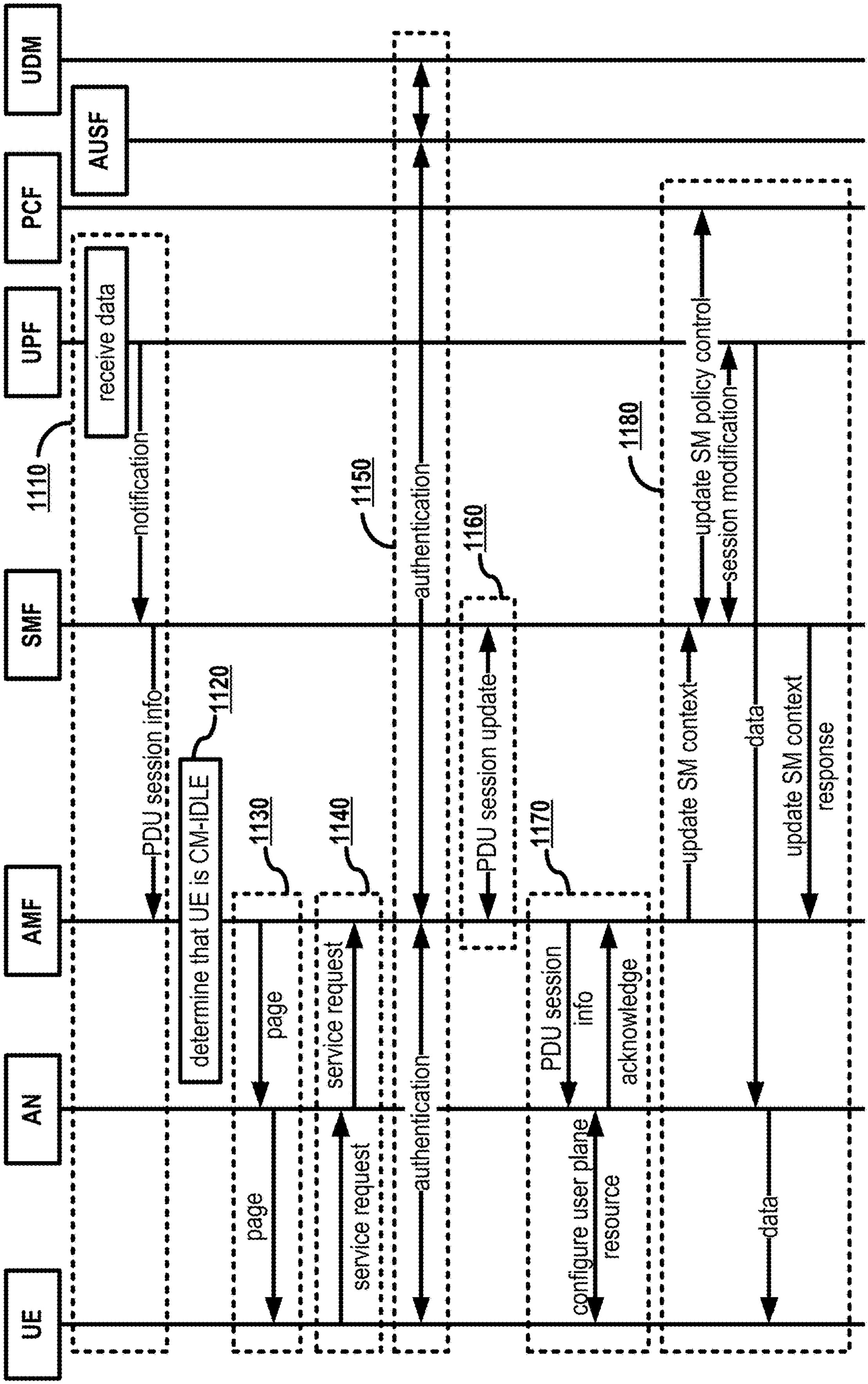

UE
AN
AMF
SMF
UPF
PCF
AUSF
UDM
1110
receive data
notification
PDU session info
determine that UE is CM-IDLE
1120
1130
page
page
1140
service request
service request
1150
authentication
authentication
authentication
1160
PDU session update
1170
PDU session info
acknowledge
configure user plane resource
1180
update SM context
update SM policy control
session modification
data
data
update SM context response
data

FIG. 11

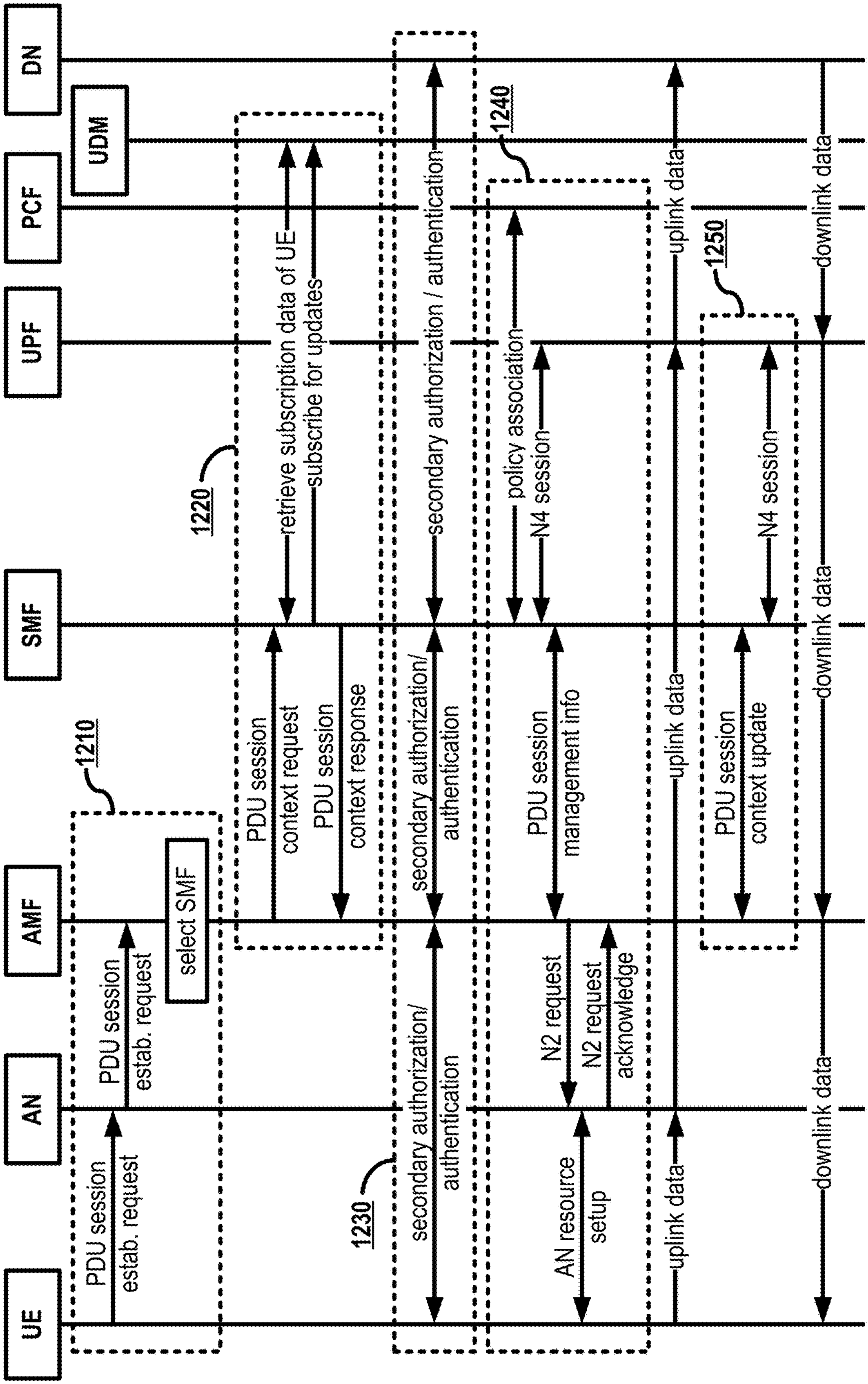

UE
AN
AMF
SMF
UPF
PCF
UDM
DN
1210
PDU session estab. request
PDU session estab. request
select SMF
1220
PDU session context request
PDU session context response
retrieve subscription data of UE
subscribe for updates
1230
secondary authorization/ authentication
secondary authorization/ authentication
secondary authorization / authentication
1240
AN resource setup
N2 request
N2 request acknowledge
PDU session management info
policy association
N4 session
uplink data
uplink data
uplink data
1250
PDU session context update
N4 session
downlink data
downlink data
downlink data

FIG. 12

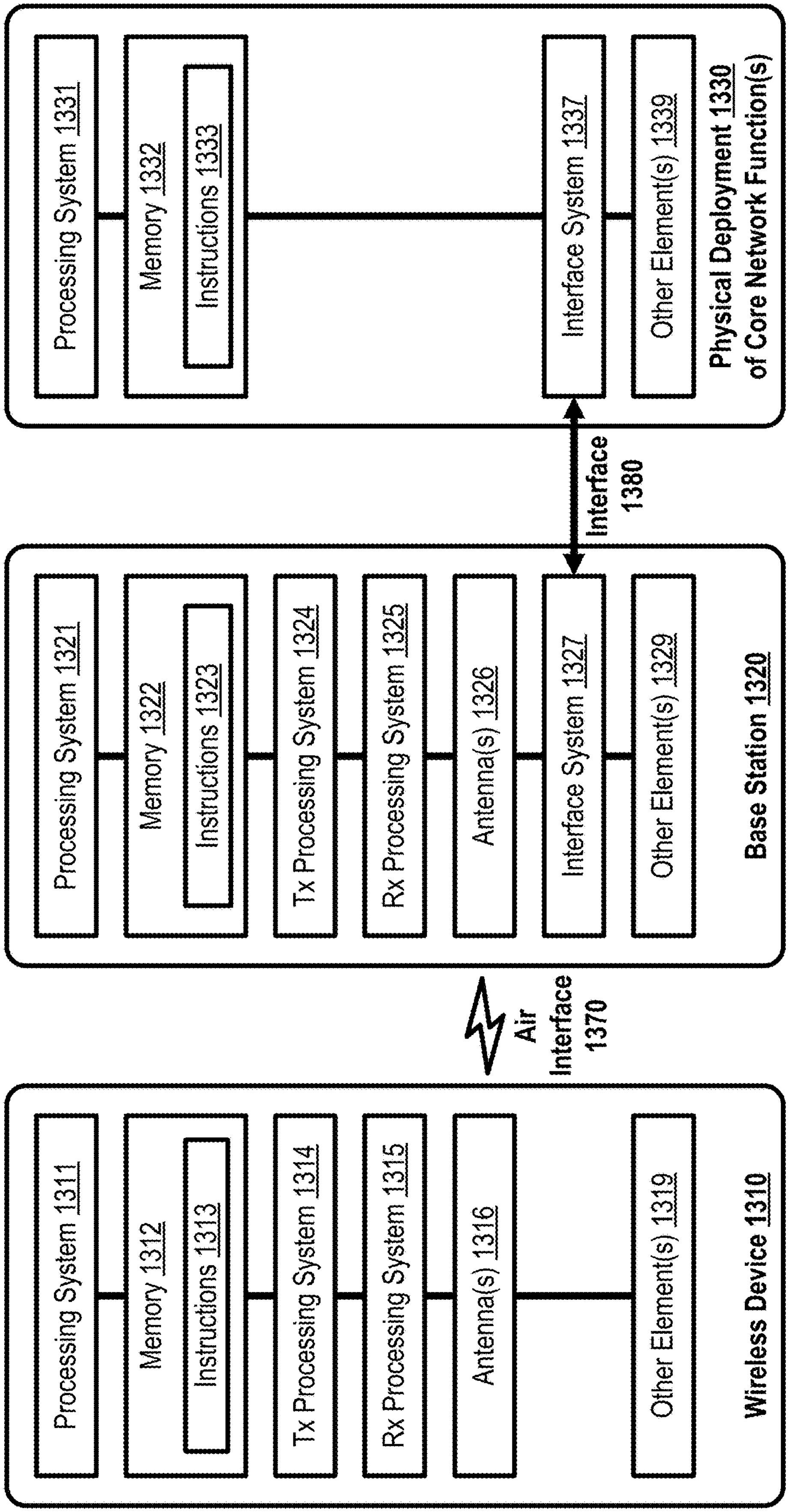

Processing System 1311
Memory 1312
Instructions 1313
Tx Processing System 1314
Rx Processing System 1315
Antenna(s) 1316
Other Element(s) 1319
Wireless Device 1310
Air Interface 1370
Processing System 1321
Memory 1322
Instructions 1323
Tx Processing System 1324
Rx Processing System 1325
Antenna(s) 1326
Interface System 1327
Other Element(s) 1329
Base Station 1320
Interface 1380
Processing System 1331
Memory 1332
Instructions 1333
Interface System 1337
Other Element(s) 1339
Physical Deployment 1330 of Core Network Function(s)

FIG. 13

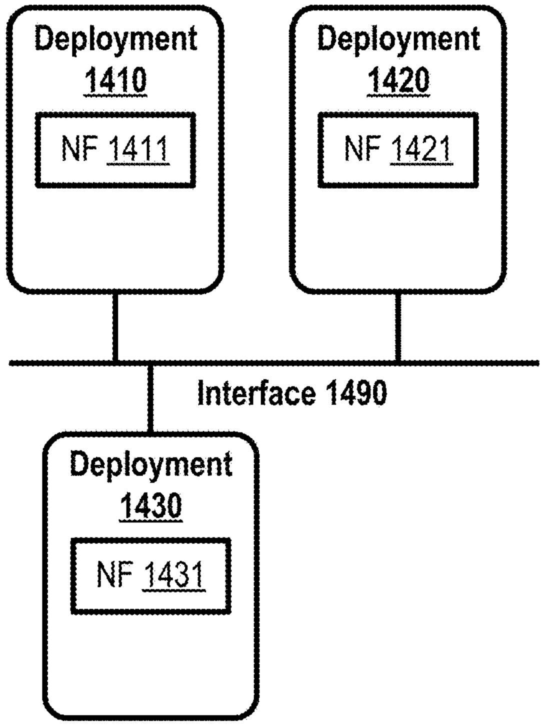



FIG. 14A

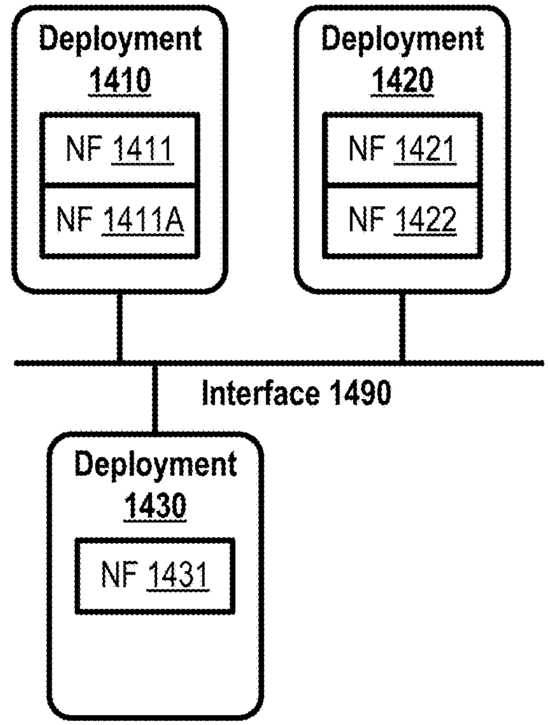



FIG. 14B

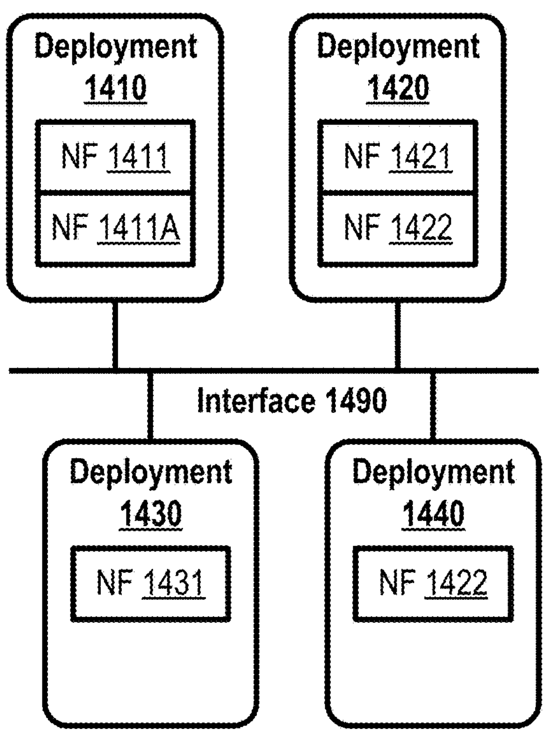



FIG. 14C

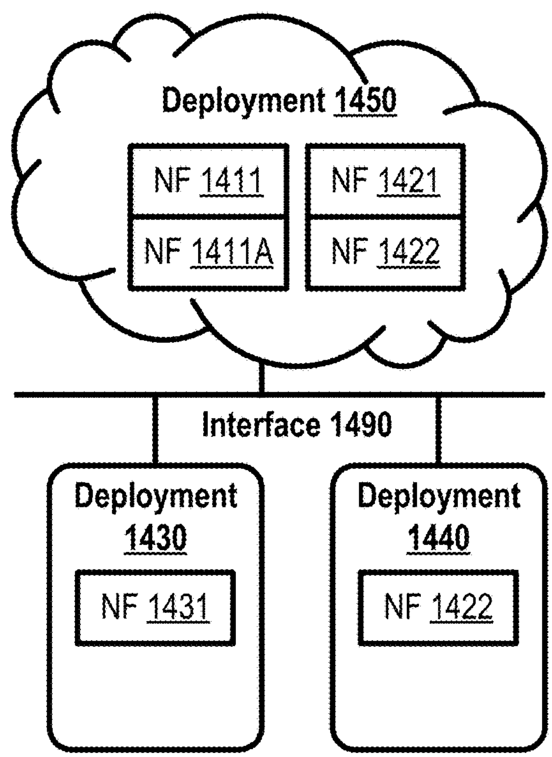



FIG. 14D

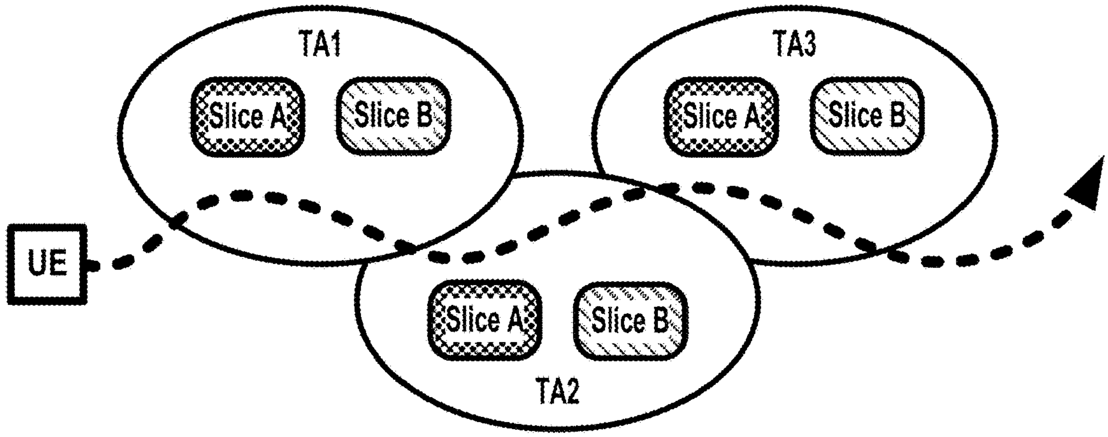



FIG. 15A

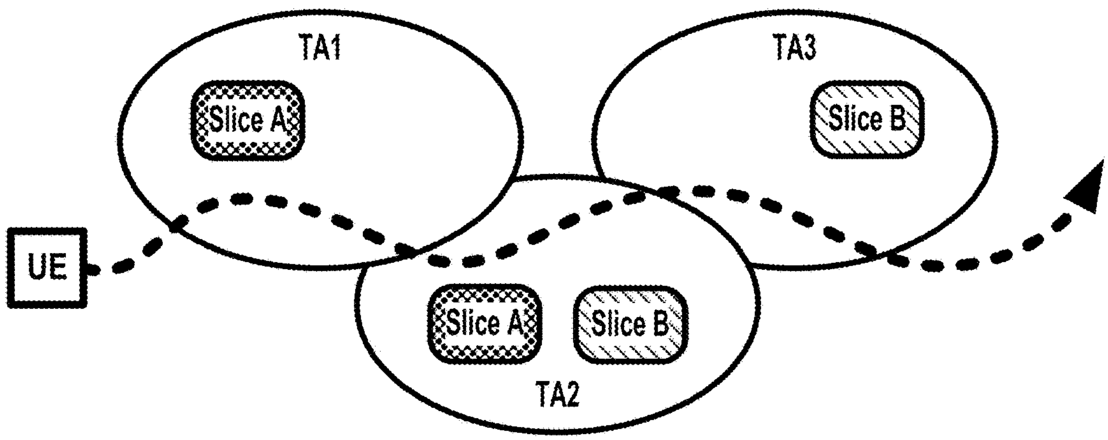



FIG. 15B

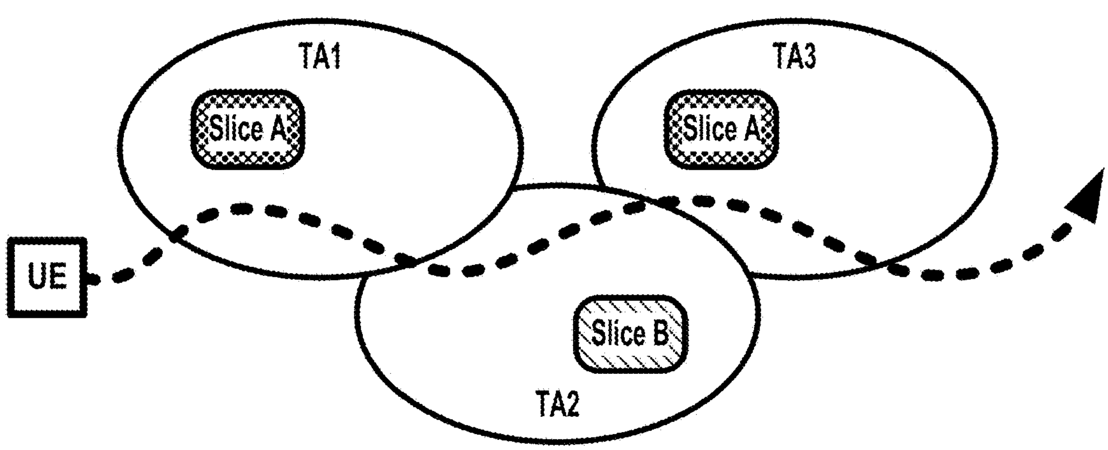



FIG. 15C

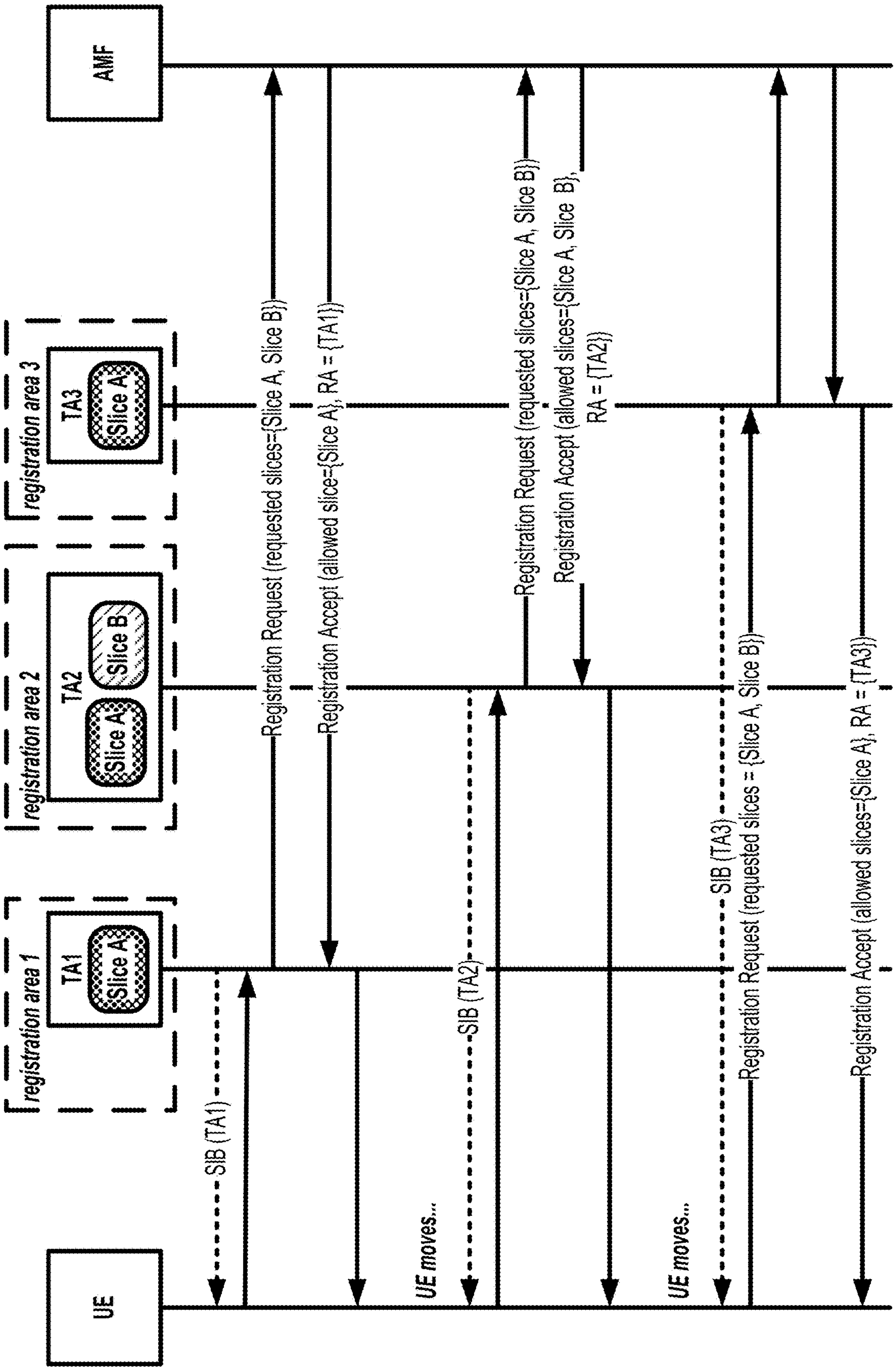

UE
registration area 1
TA1
Slice A
registration area 2
TA2
Slice A
Slice B
registration area 3
TA3
Slice A
AMF
SIB (TA1)
Registration Request (requested slices={Slice A, Slice B})
Registration Accept (allowed slice={Slice A}, RA = {TA1})
UE moves...
SIB (TA2)
Registration Request (requested slices={Slice A, Slice B})
Registration Accept (allowed slices={Slice A, Slice B}, RA = {TA2})
UE moves...
SIB (TA3)
Registration Request (requested slices = {Slice A, Slice B})
Registration Accept (allowed slices={Slice A}, RA = {TA3})

FIG. 16

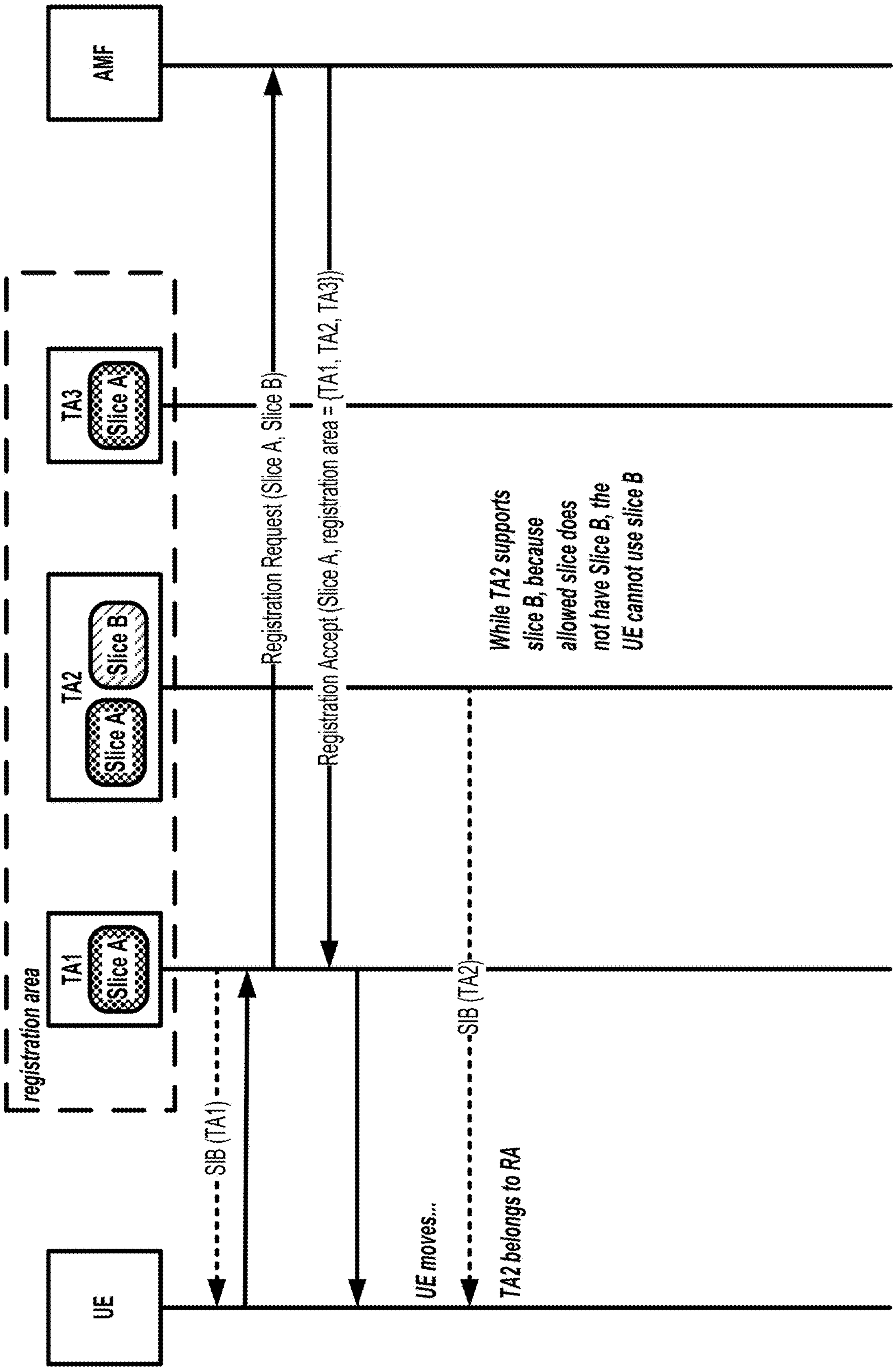
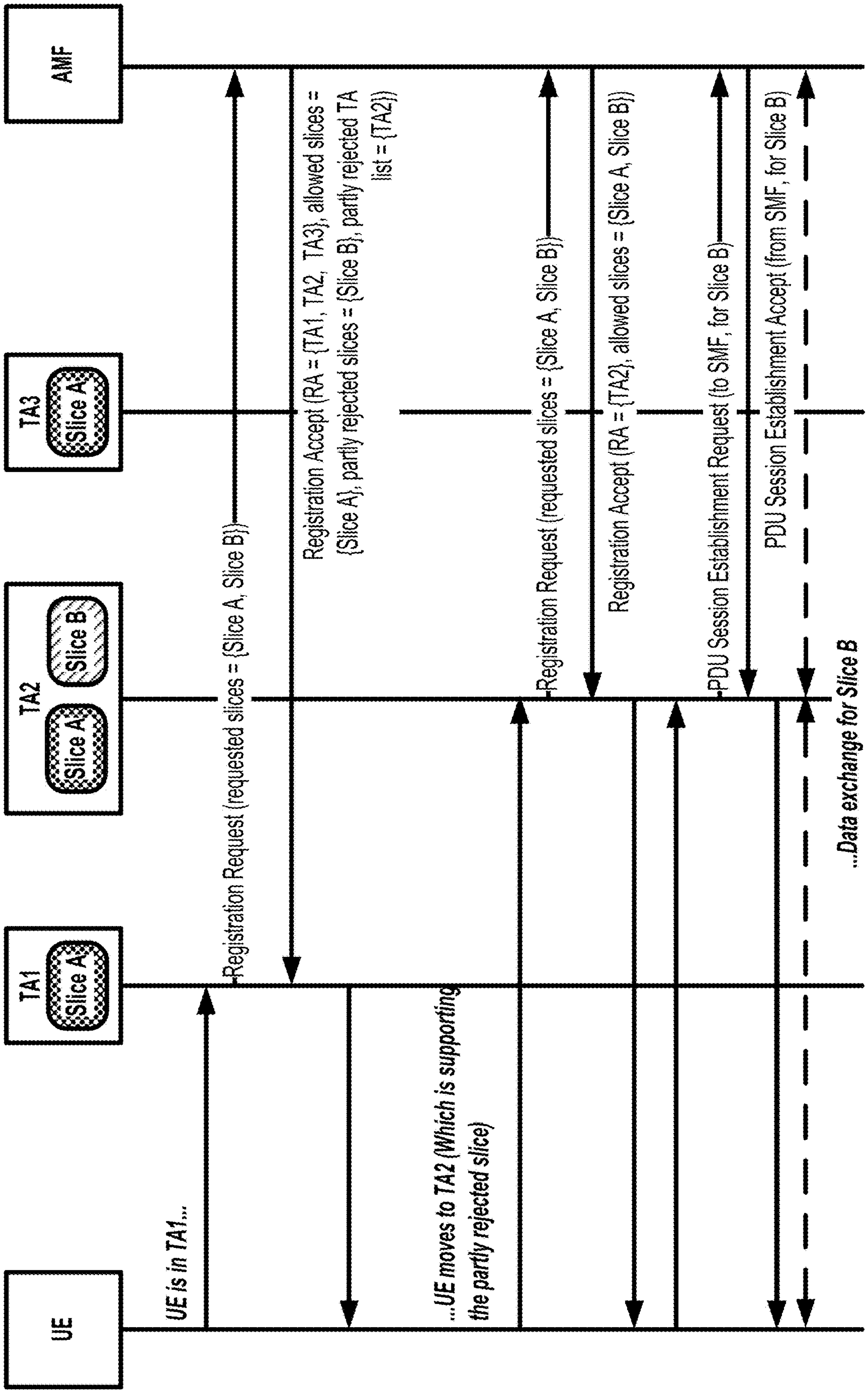

UE
TA1
Slice A
TA2
Slice A
Slice B
TA3
Slice A
AMF
registration area
SIB (TA1)
Registration Request (Slice A, Slice B)
Registration Accept (Slice A, registration area = {TA1, TA2, TA3})
UE moves...
SIB (TA2)
TA2 belongs to RA
While TA2 supports slice B, because allowed slice does not have Slice B, the UE cannot use slice B

FIG. 17



UE
TA1
Slice A
TA2
Slice A
Slice B
TA3
Slice A
AMF
UE is in TA1...
Registration Request (requested slices = {Slice A, Slice B})
Registration Accept (RA = {TA1, TA2, TA3}, allowed slices = {Slice A}, partly rejected slices = {Slice B}, partly rejected TA list = {TA2})
...UE moves to TA2 (Which is supporting the partly rejected slice)
Registration Request (requested slices = {Slice A, Slice B})
Registration Accept (RA = {TA2}, allowed slices = {Slice A, Slice B})
PDU Session Establishment Request (to SMF, for Slice B)
PDU Session Establishment Accept (from SMF, for Slice B)
...Data exchange for Slice B


FIG. 18

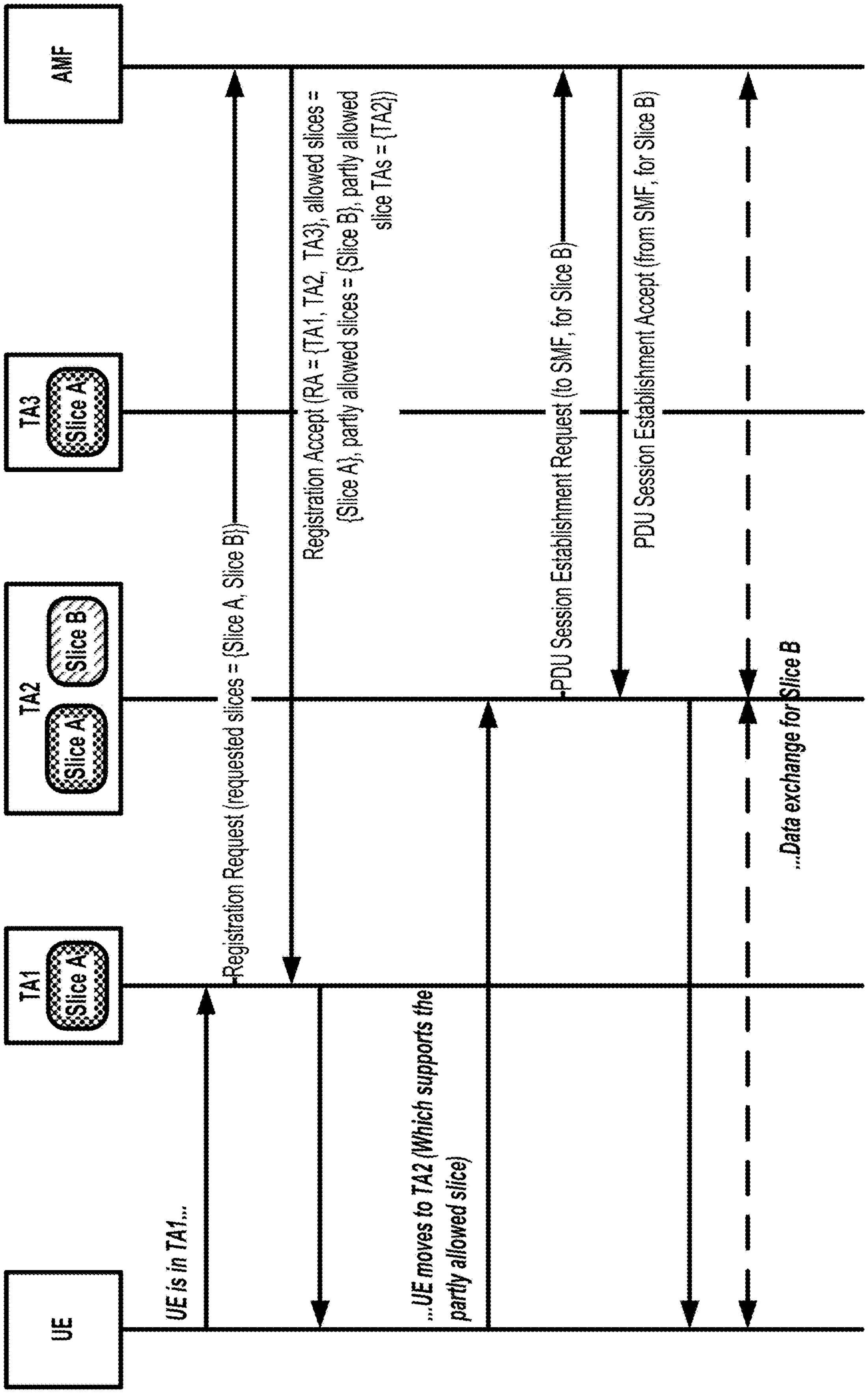

UE
TA1
Slice A
TA2
Slice A
Slice B
TA3
Slice A
AMF
UE is in TA1...
Registration Request (requested slices = {Slice A, Slice B})
Registration Accept (RA = {TA1, TA2, TA3}, allowed slices = {Slice A}, partly allowed slices = {Slice B}, partly allowed slice TAs = {TA2})
...UE moves to TA2 (Which supports the partly allowed slice)
PDU Session Establishment Request (to SMF, for Slice B)
PDU Session Establishment Accept (from SMF, for Slice B)
...Data exchange for Slice B

FIG. 19

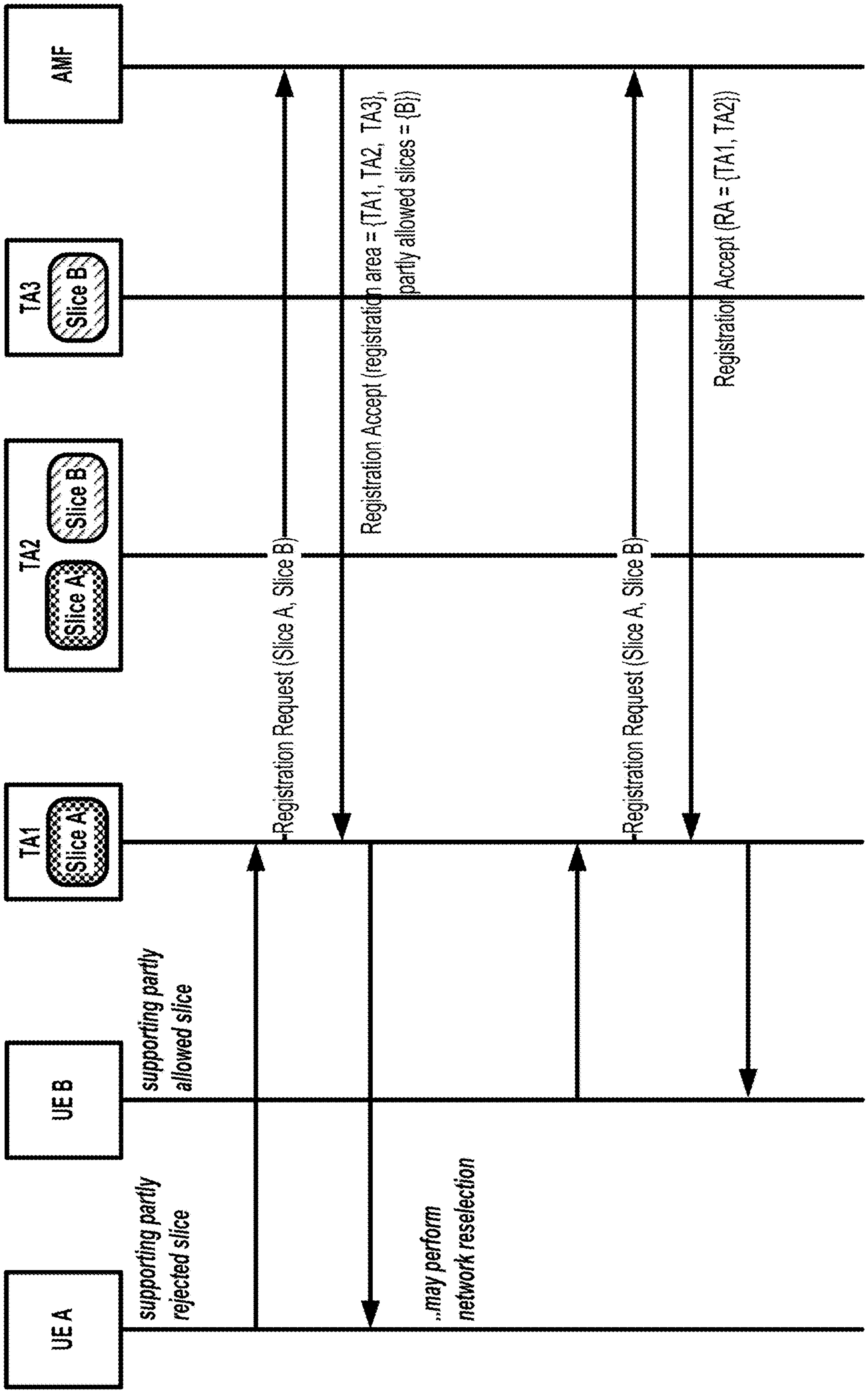

UE A
UE B
TA1
Slice A
TA2
Slice A
Slice B
TA3
Slice B
AMF
supporting partly rejected slice
supporting partly allowed slice
Registration Request (Slice A, Slice B)
Registration Accept (registration area = {TA1, TA2, TA3}, partly allowed slices = {B})
..may perform network reselection
Registration Request (Slice A, Slice B)
Registration Accept (RA = {TA1, TA2})

FIG. 20

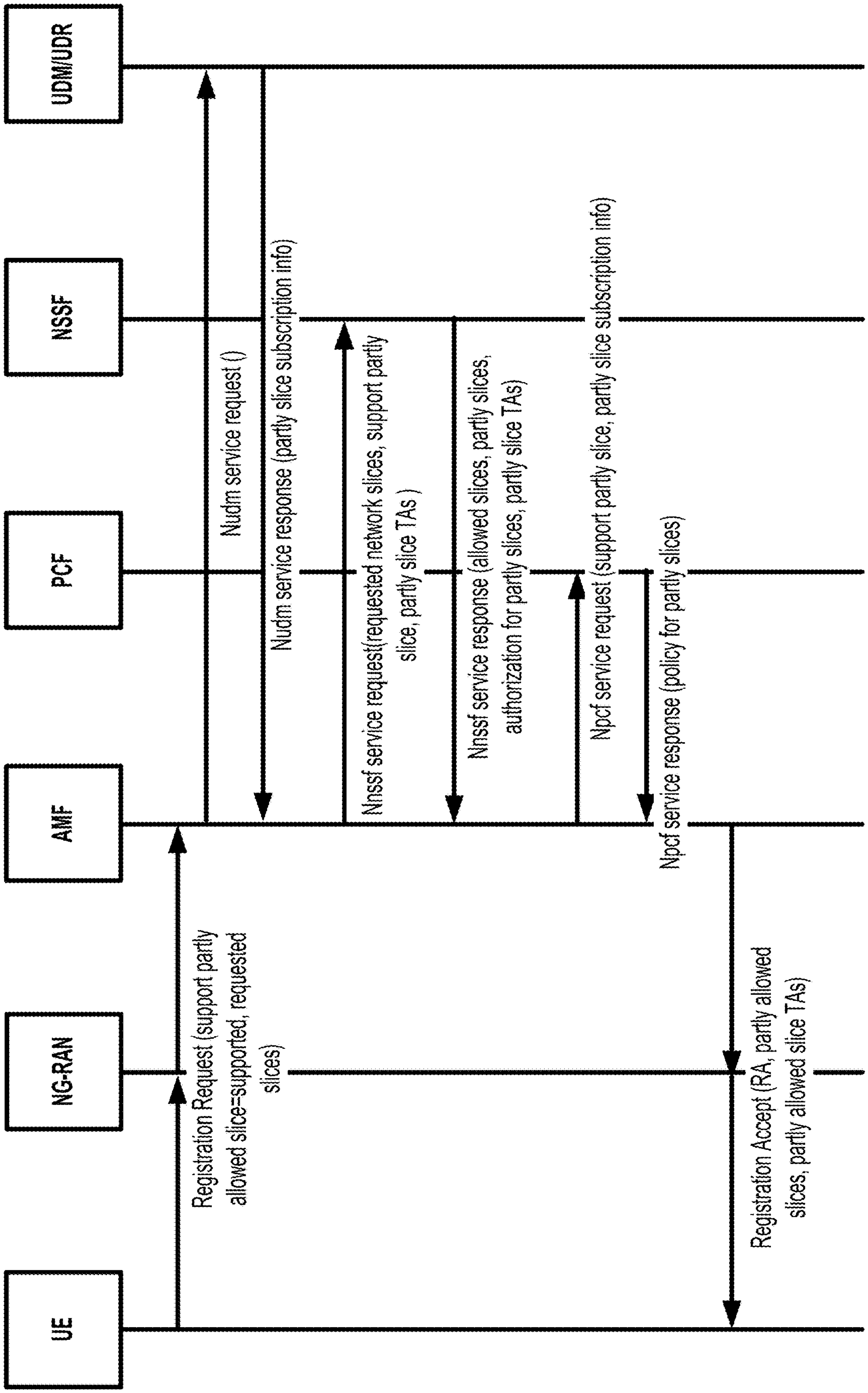

UE
NG-RAN
AMF
PCF
NSSF
UDM/UDR
Registration Request (support partly allowed slice=supported, requested slices)
Nudm service request ()
Nudm service response (partly slice subscription info)
Nnssf service request(requested network slices, support partly slice, partly slice TAs )
Nnssf service response (allowed slices, partly slices, authorization for partly slices, partly slice TAs)
Npcf service request (support partly slice, partly slice subscription info)
Npcf service response (policy for partly slices)
Registration Accept (RA, partly allowed slices, partly allowed slice TAs)

FIG. 21

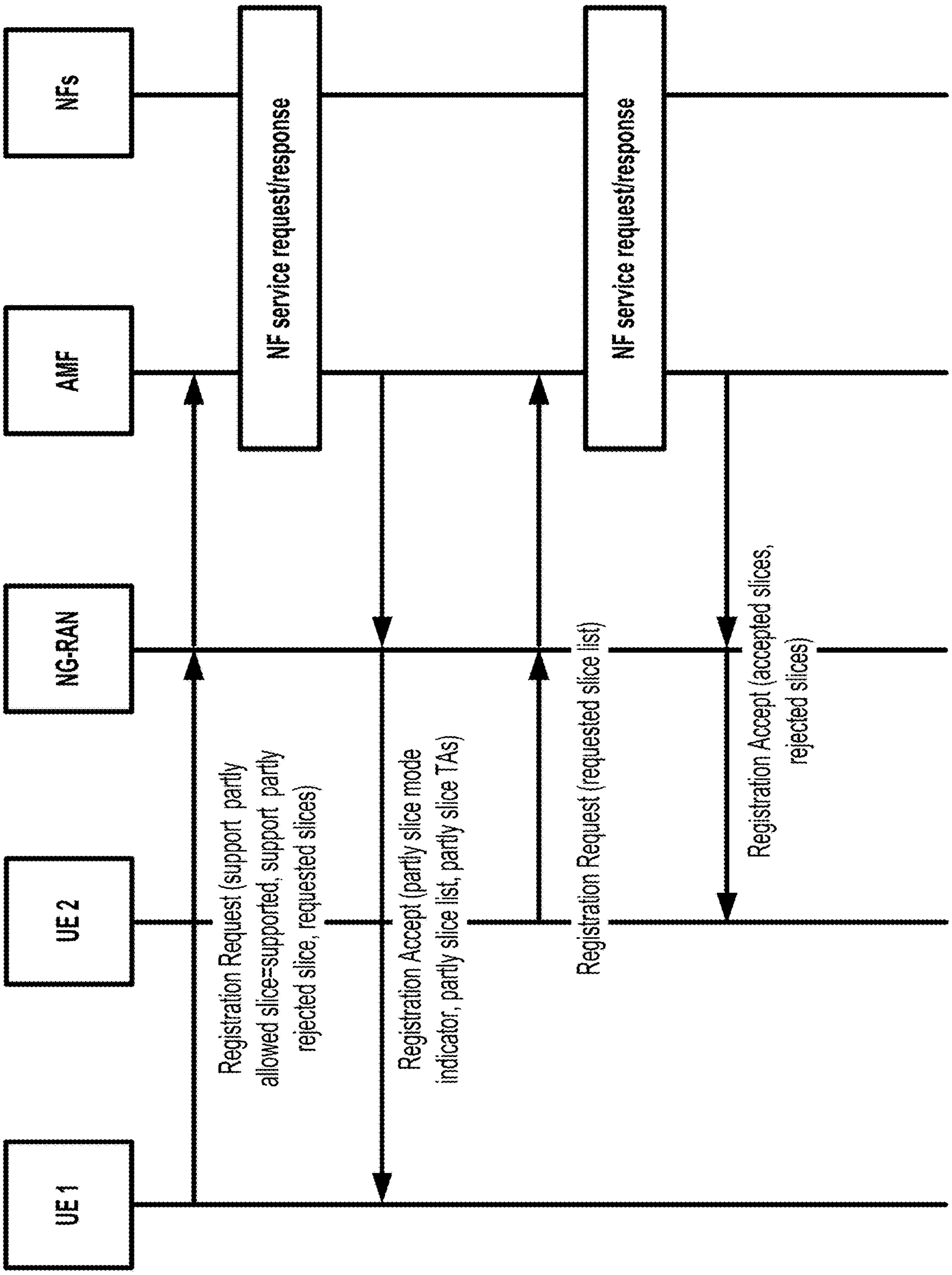

UE 1
UE 2
NG-RAN
AMF
NFs
Registration Request (support partly allowed slice=supported, support partly rejected slice, requested slices)
NF service request/response
Registration Accept (partly slice mode indicator, partly slice list, partly slice TAs)
Registration Request (requested slice list)
NF service request/response
Registration Accept (accepted slices, rejected slices)

FIG. 22

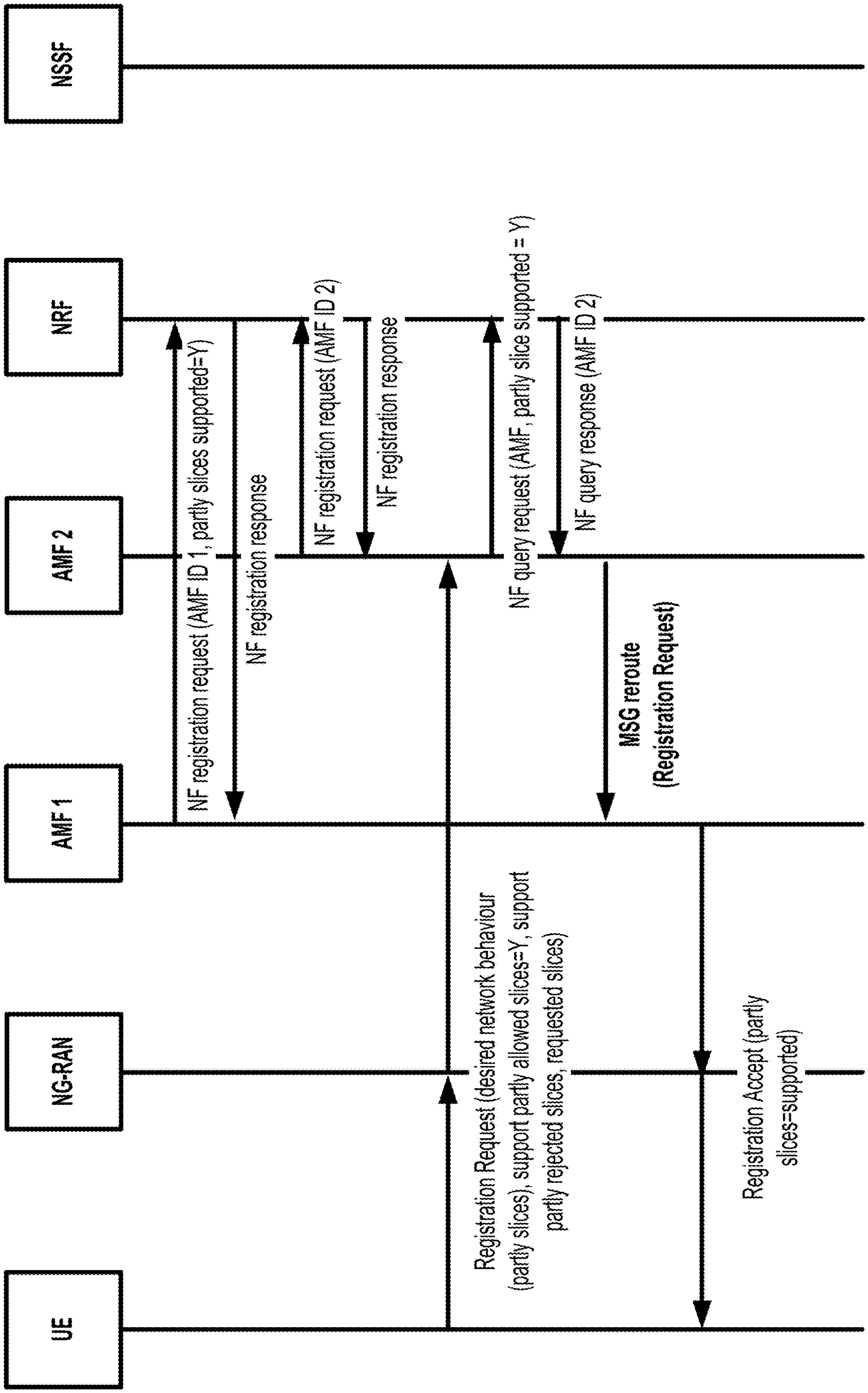

UE
NG-RAN
AMF 1
AMF 2
NRF
NSSF
NF registration request (AMF ID 1, partly slices supported=Y)
NF registration response
NF registration request (AMF ID 2)
NF registration response
Registration Request (desired network behaviour (partly slices), support partly allowed slices=Y, support partly rejected slices, requested slices)
NF query request (AMF, partly slice supported = Y)
NF query response (AMF ID 2)
MSG reroute (Registration Request)
Registration Accept (partly slices=supported)

FIG. 23

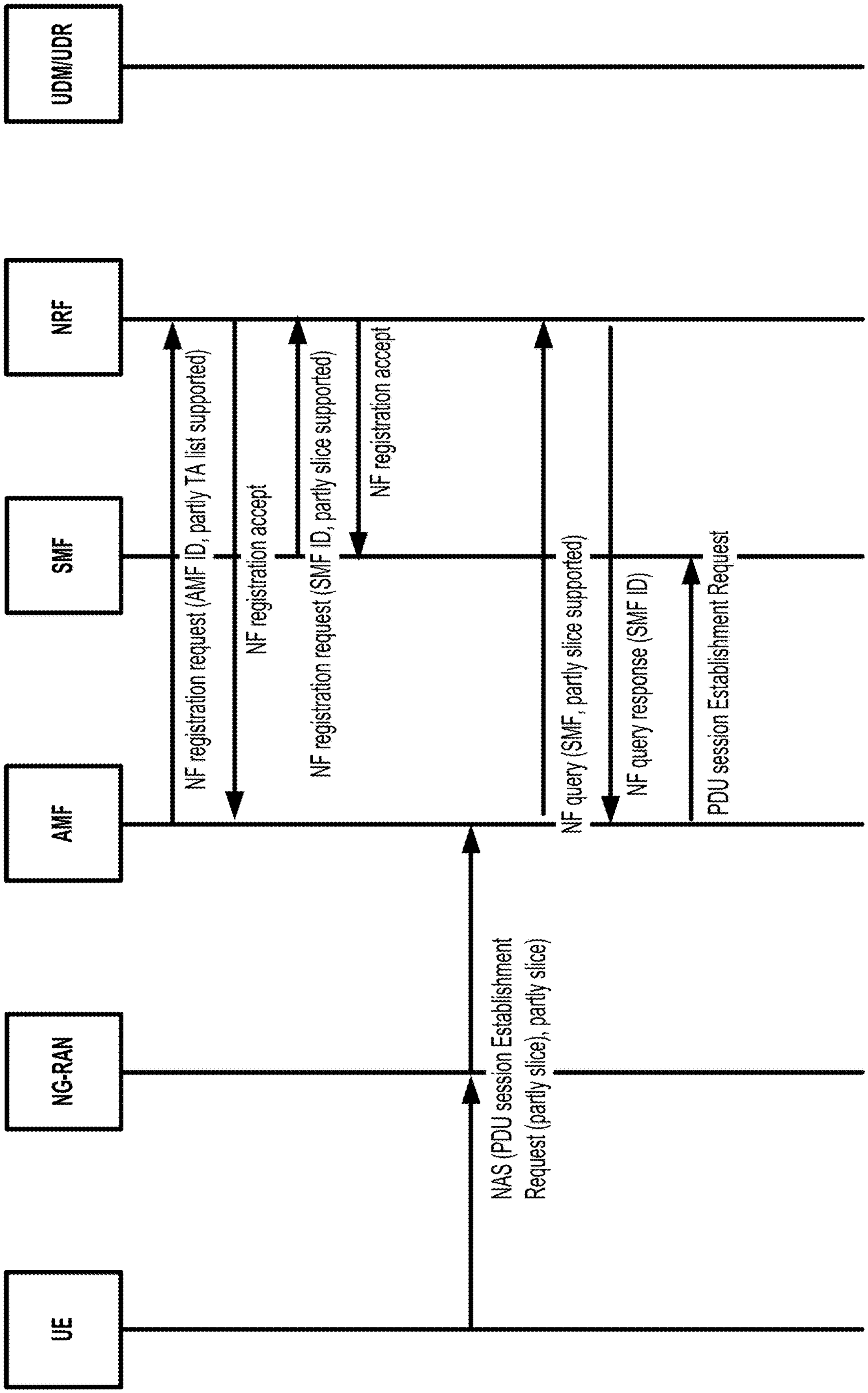

UE
NG-RAN
AMF
SMF
NRF
UDM/UDR
NF registration request (AMF ID, partly TA list supported)
NF registration accept
NF registration request (SMF ID, partly slice supported)
NF registration accept
NAS (PDU session Establishment Request (partly slice), partly slice)
NF query (SMF, partly slice supported)
NF query response (SMF ID)
PDU session Establishment Request

FIG. 24

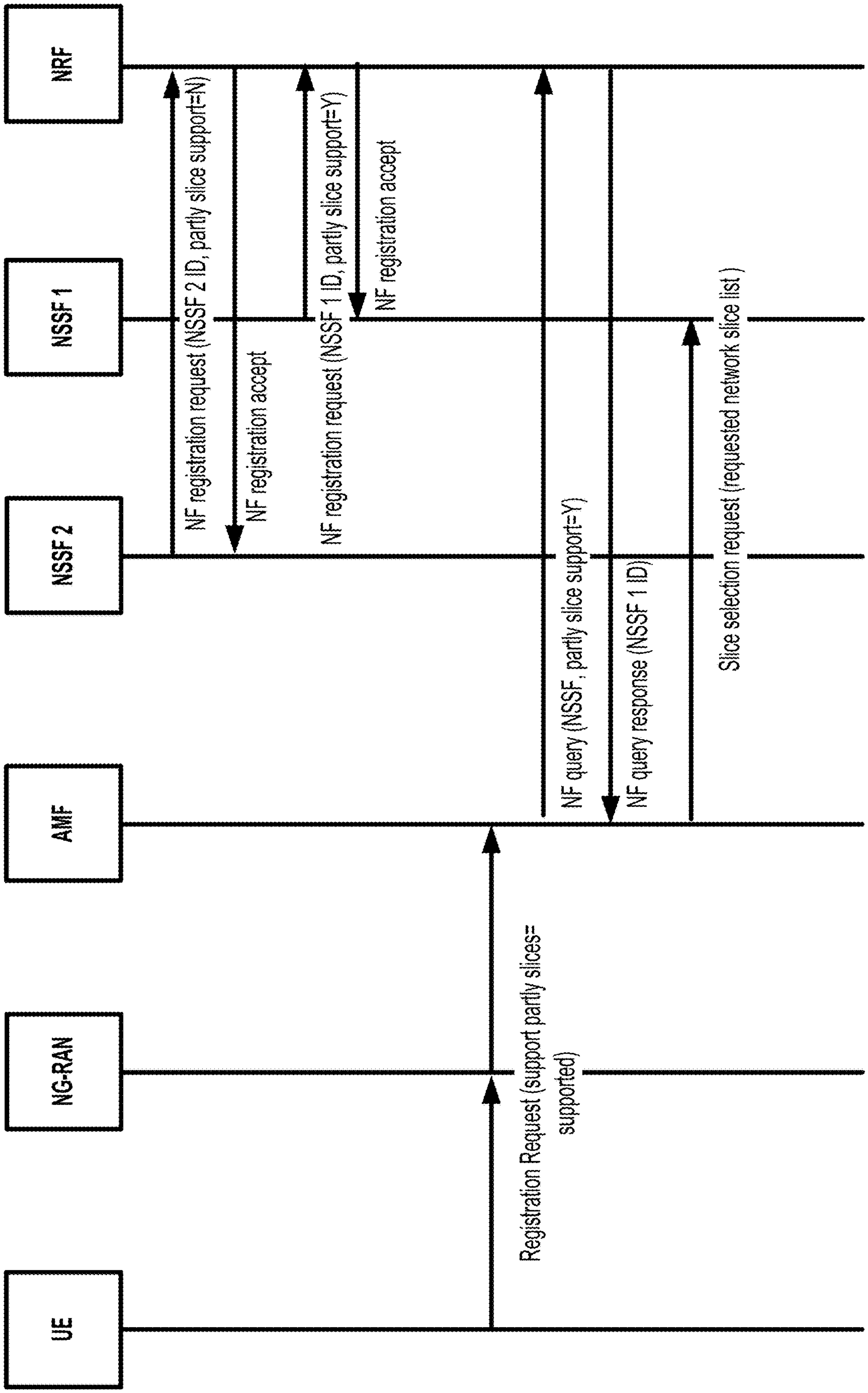

UE
NG-RAN
AMF
NSSF 2
NSSF 1
NRF
NF registration request (NSSF 2 ID, partly slice support=N)
NF registration accept
NF registration request (NSSF 1 ID, partly slice support=Y)
NF registration accept
Registration Request (support partly slices=
supported)
NF query (NSSF, partly slice support=Y)
NF query response (NSSF 1 ID)
Slice selection request (requested network slice list )

FIG. 25

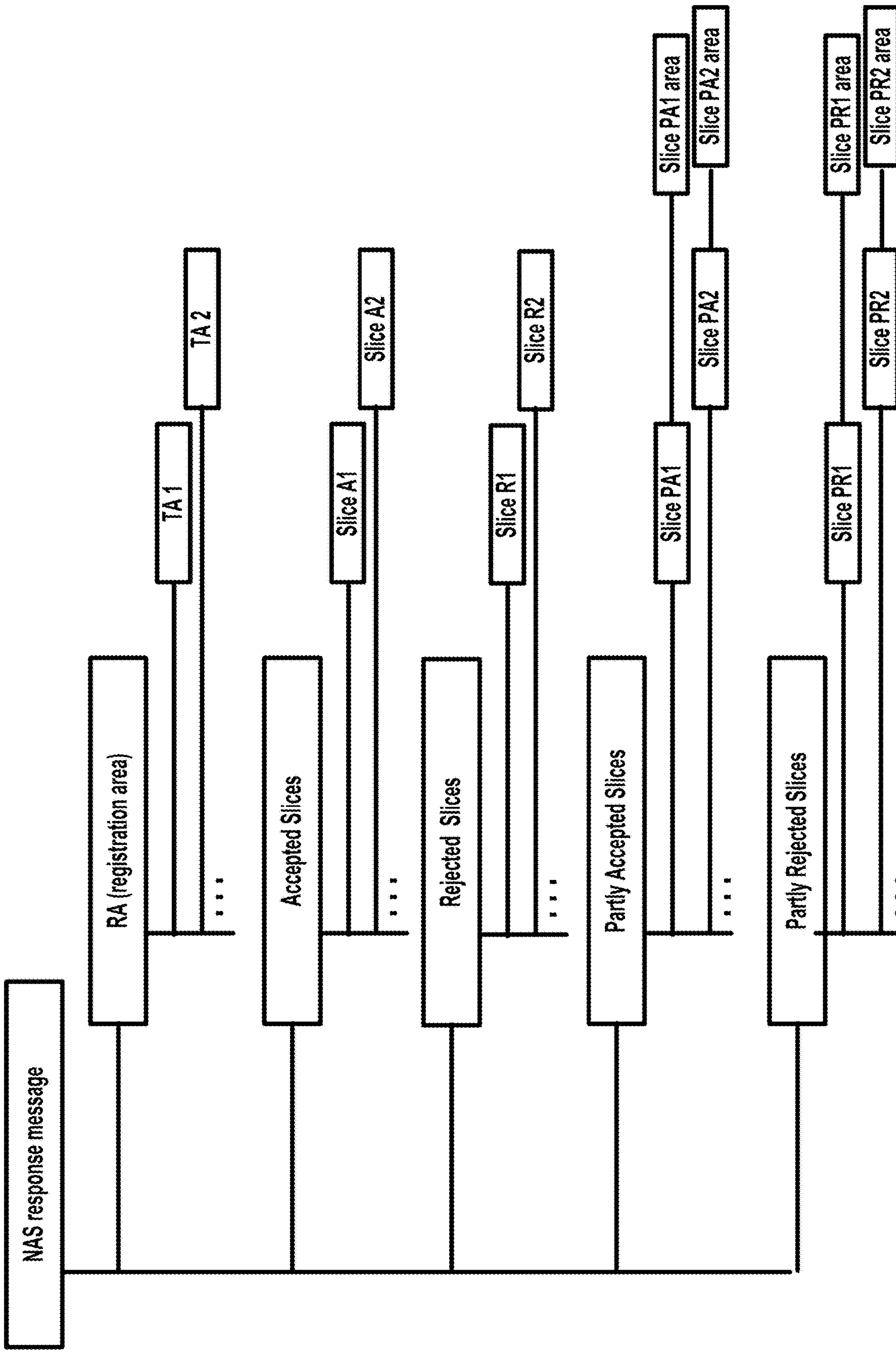

NAS response message
RA (registration area)
TA 1
TA 2
Accepted Slices
Slice A1
Slice A2
Rejected Slices
Slice R1
Slice R2
Partly Accepted Slices
Slice PA1
Slice PA2
Slice PA1 area
Slice PA2 area
Partly Rejected Slices
Slice PR1
Slice PR2
Slice PR1 area
Slice PR2 area

FIG. 26

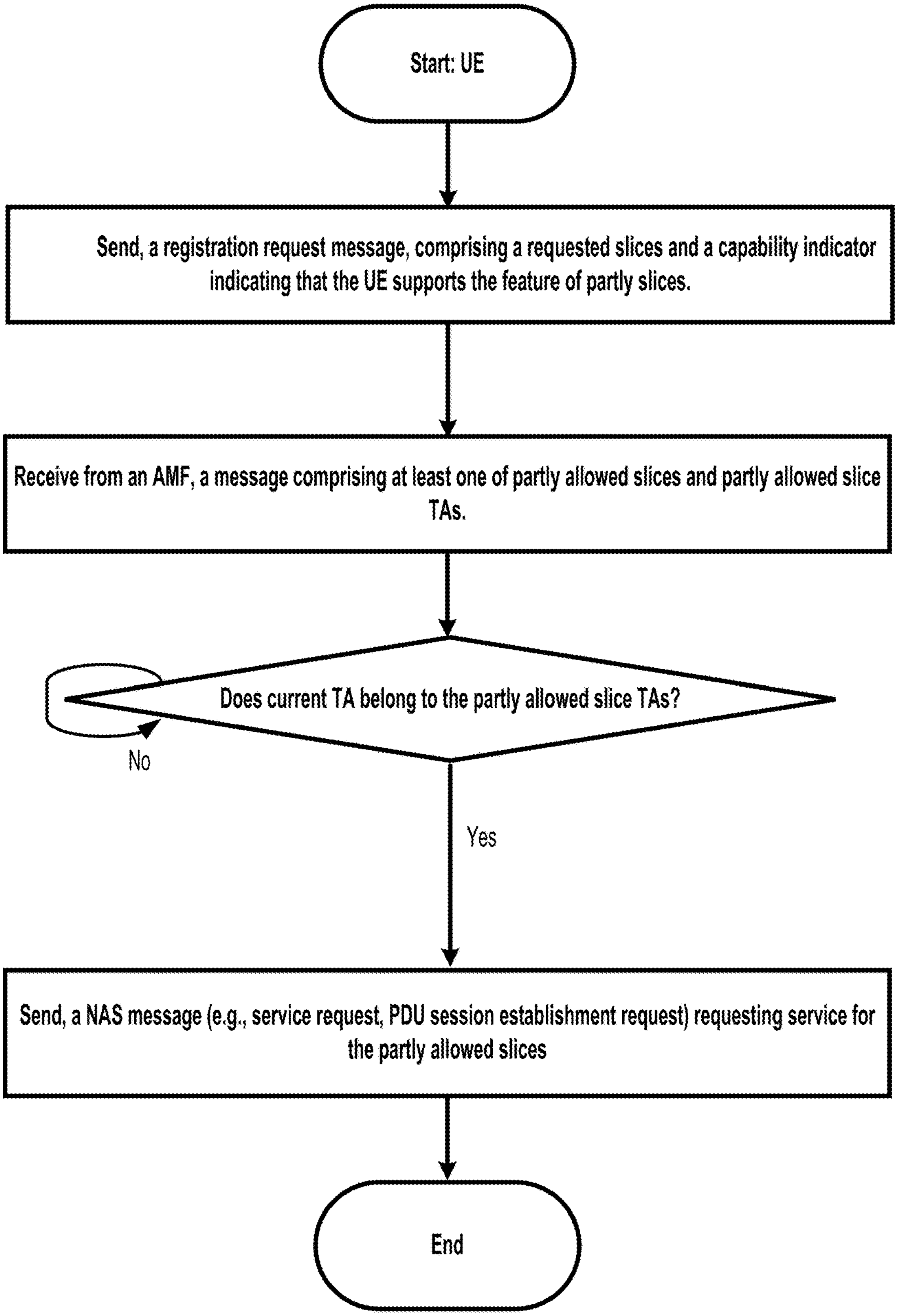

Start: UE
Send, a registration request message, comprising a requested slices and a capability indicator indicating that the UE supports the feature of partly slices.
Receive from an AMF, a message comprising at least one of partly allowed slices and partly allowed slice TAs.
Does current TA belong to the partly allowed slice TAs?
No
Yes
Send, a NAS message (e.g., service request, PDU session establishment request) requesting service for the partly allowed slices
End

FIG. 27

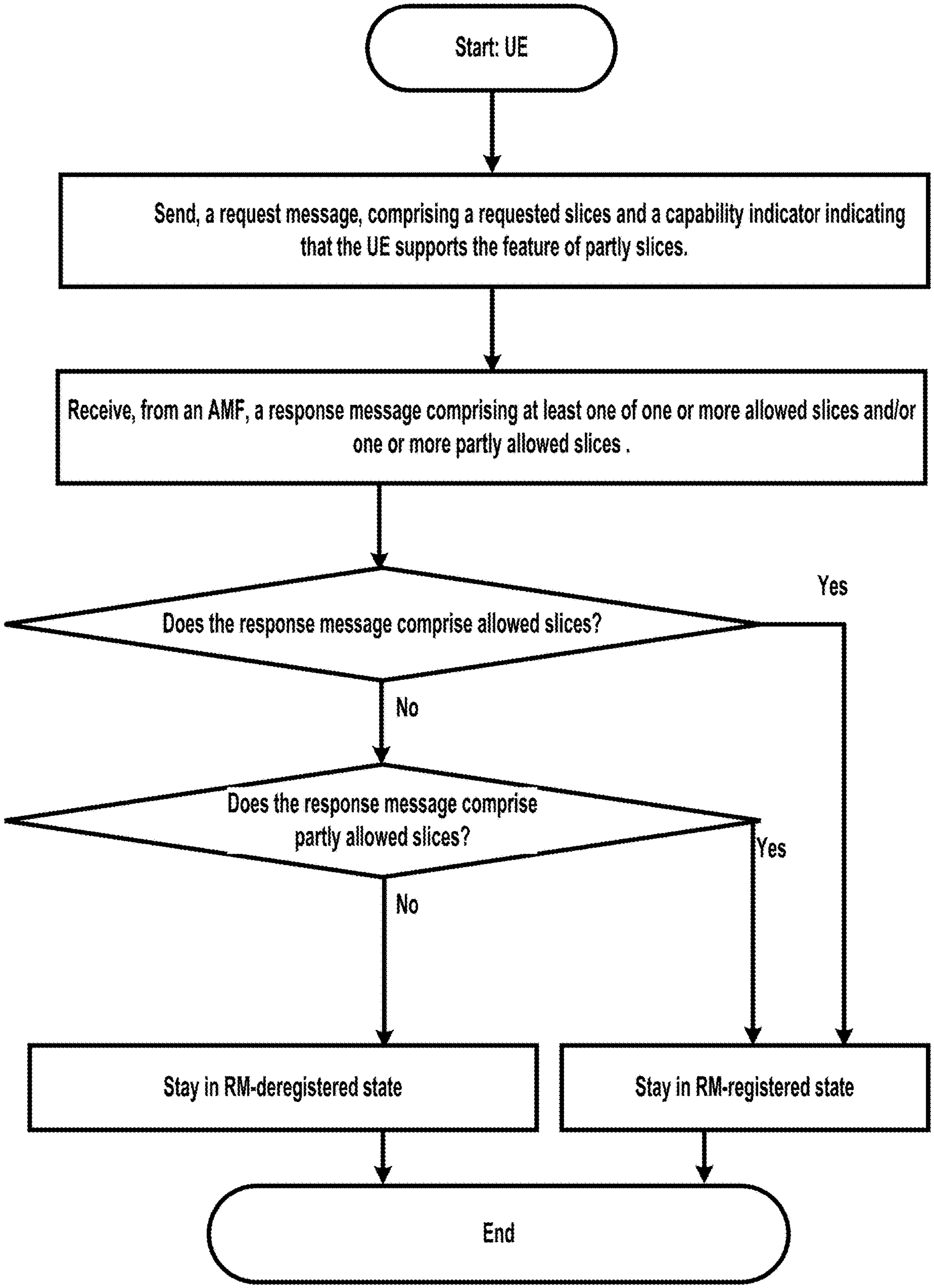

Start: UE
Send, a request message, comprising a requested slices and a capability indicator indicating that the UE supports the feature of partly slices.
Receive, from an AMF, a response message comprising at least one of one or more allowed slices and/or one or more partly allowed slices .
Does the response message comprise allowed slices?
Yes
No
Does the response message comprise partly allowed slices?
Yes
No
Stay in RM-deregistered state
Stay in RM-registered state
End

FIG. 28

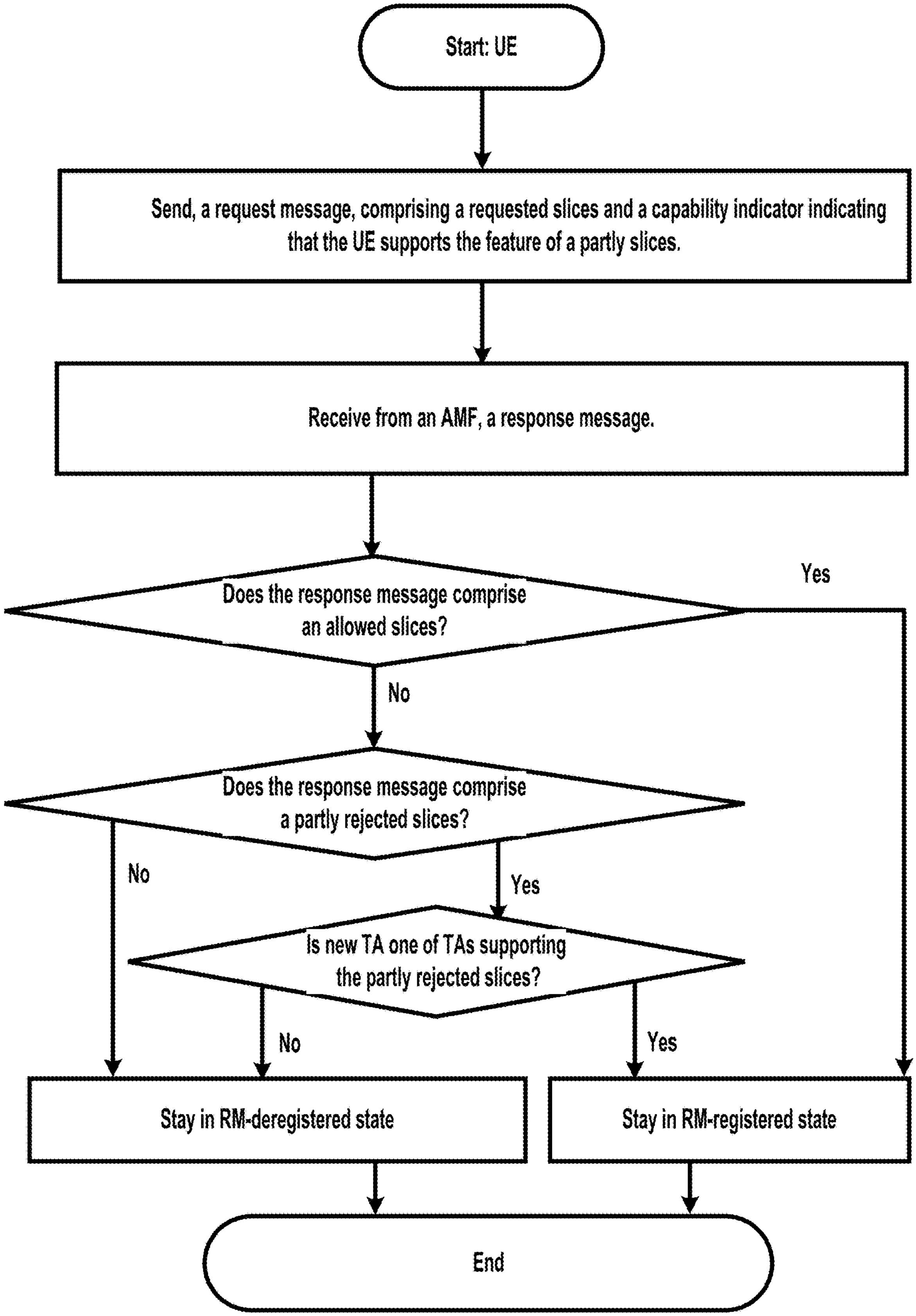

Start: UE
Send, a request message, comprising a requested slices and a capability indicator indicating that the UE supports the feature of a partly slices.
Receive from an AMF, a response message.
Does the response message comprise an allowed slices?
Yes
No
Does the response message comprise a partly rejected slices?
No
Yes
Is new TA one of TAs supporting the partly rejected slices?
No
Yes
Stay in RM-deregistered state
Stay in RM-registered state
End

FIG. 29

# NETWORK SLICE MANAGEMENT

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application is a continuation of International Application No. PCT/US2024/010273, filed Jan. 4, 2024, which claims the benefit of U.S. Provisional Application No. 63/437,276, filed Jan. 5, 2023, all of which are hereby incorporated by reference in their entireties.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0002]** Examples of several of the various embodiments of the present disclosure are described herein with reference to the drawings.

**[0003]** FIG. **1**A and FIG. **1**B illustrate example communication networks including an access network and a core network.

**[0004]** FIG. **2**A, FIG. **2**B, FIG. **2**C, and FIG. **2**D illustrate various examples of a framework for a service-based architecture within a core network.

**[0005]** FIG. **3** illustrates an example communication network including core network functions.

**[0006]** FIG. **4**A and FIG. **4**B illustrate example of core network architecture with multiple user plane functions and untrusted access.

**[0007]** FIG. **5** illustrates an example of a core network architecture for a roaming scenario.

**[0008]** FIG. **6** illustrates an example of network slicing.

**[0009]** FIG. **7**A, FIG. **7**B, and FIG. **7**C illustrate a user plane protocol stack, a control plane protocol stack, and services provided between protocol layers of the user plane protocol stack.

**[0010]** FIG. **8** illustrates an example of a quality of service model for data exchange.

**[0011]** FIG. **9**A, FIG. **9**B, FIG. **9**C, and FIG. **9**D illustrate example states and state transitions of a wireless device.

**[0012]** FIG. **10** illustrates an example of a registration procedure for a wireless device.

**[0013]** FIG. **11** illustrates an example of a service request procedure for a wireless device.

**[0014]** FIG. **12** illustrates an example of a protocol data unit session establishment procedure for a wireless device.

**[0015]** FIG. **13** illustrates examples of components of the elements in a communications network.

**[0016]** FIG. **14**A, FIG. **14**B, FIG. **14**C, and FIG. **14**D illustrate various examples of physical core network deployments, each having one or more network functions or portions thereof.

**[0017]** FIG. **15**A, FIG. **15**B, and FIG. **15**C are diagrams of an aspect of an example embodiment of the present disclosure.

**[0018]** FIG. **16** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0019]** FIG. **17** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0020]** FIG. **18** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0021]** FIG. **19** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0022]** FIG. **20** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0023]** FIG. **21** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0024]** FIG. **22** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0025]** FIG. **23** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0026]** FIG. **24** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0027]** FIG. **25** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0028]** FIG. **26** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0029]** FIG. **27** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0030]** FIG. **28** is a diagram of an aspect of an example embodiment of the present disclosure.

**[0031]** FIG. **29** is a diagram of an aspect of an example embodiment of the present disclosure.

## DETAILED DESCRIPTION

**[0032]** In the present disclosure, various embodiments are presented as examples of how the disclosed techniques may be implemented and/or how the disclosed techniques may be practiced in environments and scenarios. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the scope. In fact, after reading the description, it will be apparent to one skilled in the relevant art how to implement alternative embodiments. The present embodiments should not be limited by any of the described exemplary embodiments. The embodiments of the present disclosure will be described with reference to the accompanying drawings. Limitations, features, and/or elements from the disclosed example embodiments may be combined to create further embodiments within the scope of the disclosure. Any figures which highlight the functionality and advantages, are presented for example purposes only. The disclosed architecture is sufficiently flexible and configurable, such that it may be utilized in ways other than that shown. For example, the actions listed in any flowchart may be re-ordered or only optionally used in some embodiments.

**[0033]** Embodiments may be configured to operate as needed. The disclosed mechanism may be performed when certain criteria are met, for example, in a wireless device, a base station, a radio environment, a network, a combination of the above, and/or the like. Example criteria may be based, at least in part, on for example, wireless device or network node configurations, traffic load, initial system set up, packet sizes, traffic characteristics, a combination of the above, and/or the like. When the one or more criteria are met, various example embodiments may be applied. Therefore, it may be possible to implement example embodiments that selectively implement disclosed protocols.

**[0034]** A base station may communicate with a mix of wireless devices. Wireless devices and/or base stations may support multiple technologies, and/or multiple releases of the same technology. Wireless devices may have one or more specific capabilities. When this disclosure refers to a base station communicating with a plurality of wireless devices, this disclosure may refer to a subset of the total wireless devices in a coverage area. This disclosure may refer to, for example, a plurality of wireless devices of a given LTE or 5G release with a given capability and in a given sector of the base station. The plurality of wireless devices in this disclosure may refer to a selected plurality of wireless devices, and/or a subset of total wireless devices in a coverage area which perform according to disclosed methods, and/or the like. There may be a plurality of base stations or a plurality of wireless devices in a coverage area that may not comply with the disclosed methods, for example, those wireless devices or base stations may perform based on older releases of LTE or 5G technology.

**[0035]** In this disclosure, "a" and "an" and similar phrases refer to a single instance of a particular element, but should not be interpreted to exclude other instances of that element. For example, a bicycle with two wheels may be described as having "a wheel". Any term that ends with the suffix "(s)" is to be interpreted as "at least one" and/or "one or more." In this disclosure, the term "may" is to be interpreted as "may, for example." In other words, the term "may" is indicative that the phrase following the term "may" is an example of one of a multitude of suitable possibilities that may, or may not, be employed by one or more of the various embodiments. The terms "comprises" and "consists of", as used herein, enumerate one or more components of the element being described. The term "comprises" is interchangeable with "includes" and does not exclude unenumerated components from being included in the element being described. By contrast, "consists of" provides a complete enumeration of the one or more components of the element being described.

**[0036]** The phrases "based on", "in response to", "depending on", "employing", "using", and similar phrases indicate the presence and/or influence of a particular factor and/or condition on an event and/or action, but do not exclude unenumerated factors and/or conditions from also being present and/or influencing the event and/or action. For example, if action X is performed "based on" condition Y, this is to be interpreted as the action being performed "based at least on" condition Y. For example, if the performance of action X is performed when conditions Y and Z are both satisfied, then the performing of action X may be described as being "based on Y".

**[0037]** The term "configured" may relate to the capacity of a device whether the device is in an operational or non-operational state. Configured may refer to specific settings in a device that effect the operational characteristics of the device whether the device is in an operational or non-operational state. In other words, the hardware, software, firmware, registers, memory values, and/or the like may be "configured" within a device, whether the device is in an operational or nonoperational state, to provide the device with specific characteristics. Terms such as "a control message to cause in a device" may mean that a control message has parameters that may be used to configure specific characteristics or may be used to implement certain actions in the device, whether the device is in an operational or non-operational state.

**[0038]** In this disclosure, a parameter may comprise one or more information objects, and an information object may comprise one or more other objects. For example, if parameter J comprises parameter K, and parameter K comprises parameter L, and parameter L comprises parameter M, then J comprises L, and J comprises M. A parameter may be referred to as a field or information element. In an example embodiment, when one or more messages comprise a plurality of parameters, it implies that a parameter in the plurality of parameters is in at least one of the one or more messages, but does not have to be in each of the one or more messages.

**[0039]** This disclosure may refer to possible combinations of enumerated elements. For the sake of brevity and legibility, the present disclosure does not explicitly recite each and every permutation that may be obtained by choosing from a set of optional features. The present disclosure is to be interpreted as explicitly disclosing all such permutations. For example, the seven possible combinations of enumerated elements A, B, C consist of: (1) "A"; (2) "B"; (3) "C"; (4) "A and B"; (5) "A and C"; (6) "B and C"; and (7) "A, B, and C". For the sake of brevity and legibility, these seven possible combinations may be described using any of the following interchangeable formulations: "at least one of A, B, and C"; "at least one of A, B, or C"; "one or more of A, B, and C"; "one or more of A, B, or C"; "A, B, and/or C". It will be understood that impossible combinations are excluded. For example, "X and/or not-X" should be interpreted as "X or not-X". It will be further understood that these formulations may describe alternative phrasings of overlapping and/or synonymous concepts, for example, "identifier, identification, and/or ID number".

**[0040]** This disclosure may refer to sets and/or subsets. As an example, set X may be a set of elements comprising one or more elements. If every element of X is also an element of Y, then X may be referred to as a subset of Y. In this disclosure, only non-empty sets and subsets are considered. For example, if Y consists of the elements Y1, Y2, and Y3, then the possible subsets of Y are {Y1, Y2, Y3}, {Y1, Y2}, {Y1, Y3}, {Y2, Y3}, {Y1}, {Y2}, and {Y3}.

**[0041]** FIG. **1**A illustrates an example of a communication network **100** in which embodiments of the present disclosure may be implemented. The communication network **100** may comprise, for example, a public land mobile network (PLMN) run by a network operator. As illustrated in FIG. **1**A, the communication network **100** includes a wireless device **101**, an access network (AN) **102**, a core network (CN) **105**, and one or more data network (DNs) **108**.

**[0042]** The wireless device **101** may communicate with DNs **108** via AN **102** and CN **105**. In the present disclosure, the term wireless device may refer to and encompass any mobile device or fixed (non-mobile) device for which wireless communication is needed or usable. For example, a wireless device may be a telephone, smart phone, tablet, computer, laptop, sensor, meter, wearable device, Internet of Things (IoT) device, vehicle road side unit (RSU), relay node, automobile, unmanned aerial vehicle, urban air mobility, and/or any combination thereof. The term wireless device encompasses other terminology, including user equipment (UE), user terminal (UT), access terminal (AT), mobile station, handset, wireless transmit and receive unit (WTRU), and/or wireless communication device.

**[0043]** The AN **102** may connect wireless device **101** to CN **105** in any suitable manner. The communication direction from the AN **102** to the wireless device **101** is known as the downlink and the communication direction from the wireless device **101** to AN **102** is known as the uplink. Downlink transmissions may be separated from uplink transmissions using frequency division duplexing (FDD), time-division duplexing (TDD), and/or some combination of the two duplexing techniques. The AN **102** may connect to wireless device **101** through radio communications over an air interface. An access network that at least partially operates over the air interface may be referred to as a radio access network (RAN). The CN **105** may set up one or more end-to-end connection between wireless device **101** and the one or more DNs **108**. The CN **105** may authenticate wireless device **101** and provide charging functionality.

**[0044]** In the present disclosure, the term base station may refer to and encompass any element of AN **102** that facilitates communication between wireless device **101** and AN **102**. Access networks and base stations have many different names and implementations. The base station may be a terrestrial base station fixed to the earth. The base station may be a mobile base station with a moving coverage area. The base station may be in space, for example, on board a satellite. For example, WiFi and other standards may use the term access point. As another example, the Third-Generation Partnership Project (3GPP) has produced specifications for three generations of mobile networks, each of which uses different terminology. Third Generation (3G) and/or Universal Mobile Telecommunications System (UMTS) standards may use the term Node B. 4G, Long Term Evolution (LTE), and/or Evolved Universal Terrestrial Radio Access (E-UTRA) standards may use the term Evolved Node B (eNB). 5G and/or New Radio (NR) standards may describe AN **102** as a next-generation radio access network (NG-RAN) and may refer to base stations as Next Generation eNB (ng-eNB) and/or Generation Node B (gNB). Future standards (for example, 6G, 7G, 8G) may use new terminology to refer to the elements which implement the methods described in the present disclosure (e.g., wireless devices, base stations, ANs, CNs, and/or components thereof). A base station may be implemented as a repeater or relay node used to extend the coverage area of a donor node. A repeater node may amplify and rebroadcast a radio signal received from a donor node. A relay node may perform the same/similar functions as a repeater node but may decode the radio signal received from the donor node to remove noise before amplifying and rebroadcasting the radio signal.

**[0045]** The AN **102** may include one or more base stations, each having one or more coverage areas. The geographical size and/or extent of a coverage area may be defined in terms of a range at which a receiver of AN **102** can successfully receive transmissions from a transmitter (e.g., wireless device **101**) operating within the coverage area (and/or vice-versa). The coverage areas may be referred to as sectors or cells (although in some contexts, the term cell refers to the carrier frequency used in a particular coverage area, rather than the coverage area itself). Base stations with large coverage areas may be referred to as macrocell base stations. Other base stations cover smaller areas, for example, to provide coverage in areas with weak macrocell coverage, or to provide additional coverage in areas with high traffic (sometimes referred to as hotspots). Examples of small cell base stations include, in order of decreasing coverage area, microcell base stations, picocell base stations, and femtocell base stations or home base stations. Together, the coverage areas of the base stations may provide radio coverage to wireless device **101** over a wide geographic area to support wireless device mobility.

**[0046]** A base station may include one or more sets of antennas for communicating with the wireless device **101** over the air interface. Each set of antennas may be separately controlled by the base station. Each set of antennas may have a corresponding coverage area. As an example, a base station may include three sets of antennas to respectively control three coverage areas on three different sides of the base station. The entirety of the base station (and its corresponding antennas) may be deployed at a single location. Alternatively, a controller at a central location may control one or more sets of antennas at one or more distributed locations. The controller may be, for example, a baseband processing unit that is part of a centralized or cloud RAN architecture. The baseband processing unit may be either centralized in a pool of baseband processing units or virtualized. A set of antennas at a distributed location may be referred to as a remote radio head (RRH).

**[0047]** FIG. **1**B illustrates another example communication network **150** in which embodiments of the present disclosure may be implemented. The communication network **150** may comprise, for example, a PLMN run by a network operator. As illustrated in FIG. **1**B, communication network **150** includes UEs **151**, a next generation radio access network (NG-RAN) **152**, a 5G core network (5G-CN) **155**, and one or more DNs **158**. The NG-RAN **152** includes one or more base stations, illustrated as generation node Bs (gNBs) **152**A and next generation evolved Node Bs (ng eNBs) **152**B. The 5G-CN **155** includes one or more network functions (NFs), including control plane functions **155**A and user plane functions **155**B. The one or more DNs **158** may comprise public DNS (e.g., the Internet), private DNs, and/or intra-operator DNs. Relative to corresponding components illustrated in FIG. **1**A, these components may represent specific implementations and/or terminology.

**[0048]** The base stations of the NG-RAN **152** may be connected to the UEs **151** via Uu interfaces. The base stations of the NG-RAN **152** may be connected to each other via Xn interfaces. The base stations of the NG-RAN **152** may be connected to 5G CN **155** via NG interfaces. The Uu interface may include an air interface. The NG and Xn interfaces may include an air interface, or may consist of direct physical connections and/or indirect connections over an underlying transport network (e.g., an internet protocol (IP) transport network).

**[0049]** Each of the Uu, Xn, and NG interfaces may be associated with a protocol stack. The protocol stacks may include a user plane (UP) and a control plane (CP). Generally, user plane data may include data pertaining to users of the UEs **151**, for example, internet content downloaded via a web browser application, sensor data uploaded via a tracking application, or email data communicated to or from an email server. Control plane data, by contrast, may comprise signaling and messages that facilitate packaging and routing of user plane data so that it can be exchanged with the DN(s). The NG interface, for example, may be divided into an NG user plane interface (NG-U) and an NG control plane interface (NG-C). The NG-U interface may provide delivery of user plane data between the base stations and the one or more user plane network functions **155**B. The NG-C interface may be used for control signaling between the base stations and the one or more control plane network functions **155**A. The NG-C interface may provide, for example, NG interface management, UE context management, UE mobility management, transport of NAS messages, paging, PDU session management, and configuration transfer and/or warning message transmission. In some cases, the NG-C interface may support transmission of user data (for example, a small data transmission for an IoT device).

**[0050]** One or more of the base stations of the NG-RAN **152** may be split into a central unit (CU) and one or more distributed units (DUs). A CU may be coupled to one or more DUs via an F1 interface. The CU may handle one or more upper layers in the protocol stack and the DU may handle one or more lower layers in the protocol stack. For example, the CU may handle RRC, PDCP, and SDAP, and the DU may handle RLC, MAC, and PHY. The one or more DUs may be in geographically diverse locations relative to the CU and/or each other. Accordingly, the CU/DU split architecture may permit increased coverage and/or better coordination.

**[0051]** The gNBs **152**A and ng-eNBs **152**B may provide different user plane and control plane protocol termination towards the UEs **151**. For example, the gNB **154**A may provide new radio (NR) protocol terminations over a Uu interface associated with a first protocol stack. The ng-eNBs **152**B may provide Evolved UMTS Terrestrial Radio Access (E-UTRA) protocol terminations over a Uu interface associated with a second protocol stack.

**[0052]** The 5G-CN **155** may authenticate UEs **151**, set up end-to-end connections between UEs **151** and the one or more DNs **158**, and provide charging functionality. The 5G-CN **155** may be based on a service-based architecture, in which the NFs making up the 5G-CN **155** offer services to each other and to other elements of the communication network **150** via interfaces. The 5G-CN **155** may include any number of other NFs and any number of instances of each NF.

**[0053]** FIG. **2**A, FIG. **2**B, FIG. **2**C, and FIG. **2**D illustrate various examples of a framework for a service-based architecture within a core network. In a service-based architecture, a service may be sought by a service consumer and provided by a service producer. Prior to obtaining a particular service, an NF may determine where such as service can be obtained. To discover a service, the NF may communicate with a network repository function (NRF). As an example, an NF that provides one or more services may register with a network repository function (NRF). The NRF may store data relating to the one or more services that the NF is prepared to provide to other NFs in the service-based architecture. A consumer NF may query the NRF to discover a producer NF (for example, by obtaining from the NRF a list of NF instances that provide a particular service).

**[0054]** In the example of FIG. **2**A, an NF **211** (a consumer NF in this example) may send a request **221** to an NF **212** (a producer NF). The request **221** may be a request for a particular service and may be sent based on a discovery that NF **212** is a producer of that service. The request **221** may comprise data relating to NF **211** and/or the requested service. The NF **212** may receive request **221**, perform one or more actions associated with the requested service (e.g., retrieving data), and provide a response **221**. The one or more actions performed by the NF **212** may be based on request data included in the request **221**, data stored by NF **212**, and/or data retrieved by NF **212**. The response **222** may notify NF **211** that the one or more actions have been completed. The response **222** may comprise response data relating to NF **212**, the one or more actions, and/or the requested service.

**[0055]** In the example of FIG. **2**B, an NF **231** sends a request **241** to an NF **232**. In this example, part of the service produced by NF **232** is to send a request **242** to an NF **233**. The NF **233** may perform one or more actions and provide a response **243** to NF **232**. Based on response **243**, NF **232** may send a response **244** to NF **231**. It will be understood from FIG. **2**B that a single NF may perform the role of producer of services, consumer of services, or both. A particular NF service may include any number of nested NF services produced by one or more other NFs.

**[0056]** FIG. **2**C illustrates examples of subscribe-notify interactions between a consumer NF and a producer NF. In FIG. **2**C, an NF **251** sends a subscription **261** to an NF **252**. An NF **253** sends a subscription **262** to the NF **252**. Two NFs are shown in FIG. **2**C for illustrative purposes (to demonstrate that the NF **252** may provide multiple subscription services to different NFs), but it will be understood that a subscribe-notify interaction only requires one subscriber. The NFs **251**, **253** may be independent from one another. For example, the NFs **251**, **253** may independently discover NF **252** and/or independently determine to subscribe to the service offered by NF **252**. In response to receipt of a subscription, the NF **252** may provide a notification to the subscribing NF. For example, NF **252** may send a notification **263** to NF **251** based on subscription **261** and may send a notification **264** to NF **253** based on subscription **262**.

**[0057]** As shown in the example illustration of FIG. **2**C, the sending of the notifications **263**, **264** may be based on a determination that a condition has occurred. For example, the notifications **263**, **264** may be based on a determination that a particular event has occurred, a determination that a particular condition is outstanding, and/or a determination that a duration of time associated with the subscription has elapsed (for example, a period associated with a subscription for periodic notifications). As shown in the example illustration of FIG. **2**C, NF **252** may send notifications **263**, **264** to NFs **251**, **253** simultaneously and/or in response to the same condition. However, it will be understood that the NF **252** may provide notifications at different times and/or in response to different notification conditions. In an example, the NF **251** may request a notification when a certain parameter, as measured by the NF **252**, exceeds a first threshold, and the NF **252** may request a notification when the parameter exceeds a second threshold different from the first threshold. In an example, a parameter of interest and/or a corresponding threshold may be indicated in the subscriptions **261**, **262**.

**[0058]** FIG. **2**D illustrates another example of a subscribe-notify interaction. In FIG. **2**D, an NF **271** sends a subscription **281** to an NF **272**. In response to receipt of subscription **281** and/or a determination that a notification condition has occurred, NF **272** may send a notification **284**. The notification **284** may be sent to an NF **273**. Unlike the example in FIG. **2**C (in which a notification is sent to the subscribing NF), FIG. **2**D demonstrates that a subscription and its corresponding notification may be associated with different NFs. For example, NF **271** may subscribe to the service provided by NF **272** on behalf of NF **273**.

**[0059]** FIG. **3** illustrates another example communication network **300** in which embodiments of the present disclosure may be implemented. Communication network **300** includes a user equipment (UE) **301**, an access network (AN) **302**, and a data network (DN) **308**. The remaining elements depicted in FIG. **3** may be included in and/or associated with a core network. Each element of the core network may be referred to as a network function (NF).

**[0060]** The NFs depicted in FIG. **3** include a user plane function (UPF) **305**, an access and mobility management function (AMF) **312**, a session management function (SMF) **314**, a policy control function (PCF) **320**, a network repository function (NRF) **330**, a network exposure function (NEF) **340**, a unified data management (UDM) **350**, an authentication server function (AUSF) **360**, a network slice selection function (NSSF) **370**, a charging function (CHF) **380**, a network data analytics function (NWDAF) **390**, and an application function (AF) **399**. The UPF **305** may be a user-plane core network function, whereas the NFs **312**, **314**, and **320-390** may be control-plane core network functions. Although not shown in the example of FIG. **3**, the core network may include additional instances of any of the NFs depicted and/or one or more different NF types that provide different services. Other examples of NF type include a gateway mobile location center (GMLC), a location management function (LMF), an operations, administration, and maintenance function (OAM), a public warning system (PWS), a short message service function (SMSF), a unified data repository (UDR), and an unstructured data storage function (UDSF).

**[0061]** Each element depicted in FIG. **3** has an interface with at least one other element. The interface may be a logical connection rather than, for example, a direct physical connection. Any interface may be identified using a reference point representation and/or a service-based representation. In a reference point representation, the letter 'N' is followed by a numeral, indicating an interface between two specific elements. For example, as shown in FIG. **3**, AN **302** and UPF **305** interface via 'N3', whereas UPF **305** and DN **308** interface via 'N6'. By contrast, in a service-based representation, the letter 'N' is followed by letters. The letters identify an NF that provides services to the core network. For example, PCF **320** may provide services via interface 'Npcf'. The PCF **320** may provide services to any NF in the core network via 'Npcf'. Accordingly, a service-based representation may correspond to a bundle of reference point representations. For example, the Npcf interface between PCF **320** and the core network generally may correspond to an N7 interface between PCF **320** and SMF **314**, an N30 interface between PCF **320** and NEF **340**, etc.

**[0062]** The UPF **305** may serve as a gateway for user plane traffic between AN **302** and DN **308**. The UE **301** may connect to UPF **305** via a Uu interface and an N3 interface (also described as NG-U interface). The UPF **305** may connect to DN **308** via an N6 interface. The UPF **305** may connect to one or more other UPFs (not shown) via an N9 interface. The UE **301** may be configured to receive services through a protocol data unit (PDU) session, which is a logical connection between UE **301** and DN **308**. The UPF **305** (or a plurality of UPFs if desired) may be selected by SMF **314** to handle a particular PDU session between UE **301** and DN **308**. The SMF **314** may control the functions of UPF **305** with respect to the PDU session. The SMF **314** may connect to UPF **305** via an N4 interface. The UPF **305** may handle any number of PDU sessions associated with any number of UEs (via any number of ANs). For purposes of handling the one or more PDU sessions, UPF **305** may be controlled by any number of SMFs via any number of corresponding N4 interfaces.

**[0063]** The AMF **312** depicted in FIG. **3** may control UE access to the core network. The UE **301** may register with the network via AMF **312**. It may be necessary for UE **301** to register prior to establishing a PDU session. The AMF **312** may manage a registration area of UE **301**, enabling the network to track the physical location of UE **301** within the network. For a UE in connected mode, AMF **312** may manage UE mobility, for example, handovers from one AN or portion thereof to another. For a UE in idle mode, AMF **312** may perform registration updates and/or page the UE to transition the UE to connected mode.

**[0064]** The AMF **312** may receive, from UE **301**, non-access stratum (NAS) messages transmitted in accordance with NAS protocol. NAS messages relate to communications between UE **301** and the core network. Although NAS messages may be relayed to AMF **312** via AN **302**, they may be described as communications via the N1 interface. NAS messages may facilitate UE registration and mobility management, for example, by authenticating, identifying, configuring, and/or managing a connection of UE **301**. NAS messages may support session management procedures for maintaining user plane connectivity and quality of service (QOS) of a session between UE **301** and DN **309**. If the NAS message involves session management, AMF **312** may send the NAS message to SMF **314**. NAS messages may be used to transport messages between UE **301** and other components of the core network (e.g., core network components other than AMF **312** and SMF **314**). The AMF **312** may act on a particular NAS message itself, or alternatively, forward the NAS message to an appropriate core network function (e.g., SMF **314**, etc.)

**[0065]** The SMF **314** depicted in FIG. **3** may establish, modify, and/or release a PDU session based on messaging received UE **301**. The SMF **314** may allocate, manage, and/or assign an IP address to UE **301**, for example, upon establishment of a PDU session. There may be multiple SMFs in the network, each of which may be associated with a respective group of wireless devices, base stations, and/or UPFs. A UE with multiple PDU sessions may be associated with a different SMF for each PDU session. As noted above, SMF **314** may select one or more UPFs to handle a PDU session and may control the handling of the PDU session by the selected UPF by providing rules for packet handling (PDR, FAR, QER, etc.). Rules relating to QoS and/or charging for a particular PDU session may be obtained from PCF **320** and provided to UPF **305**.

**[0066]** The PCF **320** may provide, to other NFs, services relating to policy rules. The PCF **320** may use subscription data and information about network conditions to determine policy rules and then provide the policy rules to a particular NF which may be responsible for enforcement of those rules. Policy rules may relate to policy control for access and mobility, and may be enforced by the AMF. Policy rules may relate to session management, and may be enforced by the SMF **314**. Policy rules may be, for example, network-specific, wireless device-specific, session-specific, or data flow-specific.

**[0067]** The NRF **330** may provide service discovery. The NRF **330** may belong to a particular PLMN. The NRF **330** may maintain NF profiles relating to other NFs in the communication network **300**. The NF profile may include, for example, an address, PLMN, and/or type of the NF, a slice identifier, a list of the one or more services provided by the NF, and the authorization required to access the services.

**[0068]** The NEF **340** depicted in FIG. **3** may provide an interface to external domains, permitting external domains to selectively access the control plane of the communication network **300**. The external domain may comprise, for example, third-party network functions, application functions, etc. The NEF **340** may act as a proxy between external elements and network functions such as AMF **312**, SMF **314**, PCF **320**, UDM **350**, etc. As an example, NEF **340** may determine a location or reachability status of UE **301** based on reports from AMF **312**, and provide status information to an external element. As an example, an external element may provide, via NEF **340**, information that facilitates the setting of parameters for establishment of a PDU session. The NEF **340** may determine which data and capabilities of the control plane are exposed to the external domain. The NEF **340** may provide secure exposure that authenticates and/or authorizes an external entity to which data or capabilities of the communication network **300** are exposed. The NEF **340** may selectively control the exposure such that the internal architecture of the core network is hidden from the external domain.

**[0069]** The UDM **350** may provide data storage for other NFs. The UDM **350** may permit a consolidated view of network information that may be used to ensure that the most relevant information can be made available to different NFs from a single resource. The UDM **350** may store and/or retrieve information from a unified data repository (UDR). For example, UDM **350** may obtain user subscription data relating to UE **301** from the UDR.

**[0070]** The AUSF **360** may support mutual authentication of UE **301** by the core network and authentication of the core network by UE **301**. The AUSF **360** may perform key agreement procedures and provide keying material that can be used to improve security.

**[0071]** The NSSF **370** may select one or more network slices to be used by the UE **301**. The NSSF **370** may select a slice based on slice selection information. For example, the NSSF **370** may receive Single Network Slice Selection Assistance Information (S-NSSAI) and map the S-NSSAI to a network slice instance identifier (NSI).

**[0072]** The CHF **380** may control billing-related tasks associated with UE **301**. For example, UPF **305** may report traffic usage associated with UE **301** to SMF **314**. The SMF **314** may collect usage data from UPF **305** and one or more other UPFs. The usage data may indicate how much data is exchanged, what DN the data is exchanged with, a network slice associated with the data, or any other information that may influence billing. The SMF **314** may share the collected usage data with the CHF. The CHF may use the collected usage data to perform billing-related tasks associated with UE **301**. The CHF may, depending on the billing status of UE **301**, instruct SMF **314** to limit or influence access of UE **301** and/or to provide billing-related notifications to UE **301**.

**[0073]** The NWDAF **390** may collect and analyze data from other network functions and offer data analysis services to other network functions. As an example, NWDAF **390** may collect data relating to a load level for a particular network slice instance from UPF **305**, AMF **312**, and/or SMF **314**. Based on the collected data, NWDAF **390** may provide load level data to the PCF **320** and/or NSSF **370**, and/or notify the PC**220** and/or NSSF **370** if load level for a slice reaches and/or exceeds a load level threshold.

**[0074]** The AF **399** may be outside the core network, but may interact with the core network to provide information relating to the QoS requirements or traffic routing preferences associated with a particular application. The AF **399** may access the core network based on the exposure constraints imposed by the NEF **340**. However, an operator of the core network may consider the AF **399** to be a trusted domain that can access the network directly.

**[0075]** FIGS. **4**A, **4**B, and **5** illustrate other examples of core network architectures that are analogous in some respects to the core network architecture **300** depicted in FIG. **3**. For conciseness, some of the core network elements depicted in FIG. **3** are omitted. Many of the elements depicted in FIGS. **4**A, **4**B, and **5** are analogous in some respects to elements depicted in FIG. **3**. For conciseness, some of the details relating to their functions or operation are omitted.

**[0076]** FIG. **4**A illustrates an example of a core network architecture **400**A comprising an arrangement of multiple UPFs. Core network architecture **400**A includes a UE **401**, an AN **402**, an AMF **412**, and an SMF **414**. Unlike previous examples of core network architectures described above, FIG. **4**A depicts multiple UPFs, including a UPF **405**, a UPF **406**, and a UPF **407**, and multiple DNs, including a DN **408** and a DN **409**. Each of the multiple UPFs **405**, **406**, **407** may communicate with the SMF **414** via an N4 interface. The DNs **408**, **409** communicate with the UPFs **405**, **406**, respectively, via N6 interfaces. As shown in FIG. **4**A, the multiple UPFs **405**, **406**, **407** may communicate with one another via N9 interfaces.

**[0077]** The UPFs **405**, **406**, **407** may perform traffic detection, in which the UPFs identify and/or classify packets. Packet identification may be performed based on packet detection rules (PDR) provided by the SMF **414**. A PDR may include packet detection information comprising one or more of: a source interface, a UE IP address, core network (CN) tunnel information (e.g., a CN address of an N3/N9 tunnel corresponding to a PDU session), a network instance identifier, a quality of service flow identifier (QFI), a filter set (for example, an IP packet filter set or an ethernet packet filter set), and/or an application identifier.

**[0078]** In addition to indicating how a particular packet is to be detected, a PDR may further indicate rules for handling the packet upon detection thereof. The rules may include, for example, forwarding action rules (FARs), multi-access rules (MARs), usage reporting rules (URRs), QOS enforcement rules (QERs), etc. For example, the PDR may comprise one or more FAR identifiers, MAR identifiers, URR identifiers, and/or QER identifiers. These identifiers may indicate the rules that are prescribed for the handling of a particular detected packet.

**[0079]** The UPF **405** may perform traffic forwarding in accordance with a FAR. For example, the FAR may indicate that a packet associated with a particular PDR is to be forwarded, duplicated, dropped, and/or buffered. The FAR may indicate a destination interface, for example, "access" for downlink or "core" for uplink. If a packet is to be buffered, the FAR may indicate a buffering action rule (BAR). As an example, UPF **405** may perform data buffering of a certain number downlink packets if a PDU session is deactivated.

**[0080]** The UPF **405** may perform QoS enforcement in accordance with a QER. For example, the QER may indicate a guaranteed bitrate that is authorized and/or a maximum bitrate to be enforced for a packet associated with a particular PDR. The QER may indicate that a particular guaranteed and/or maximum bitrate may be for uplink packets and/or downlink packets. The UPF **405** may mark packets belonging to a particular QoS flow with a corresponding QFI. The marking may enable a recipient of the packet to determine a QoS of the packet.

**[0081]** The UPF **405** may provide usage reports to the SMF **414** in accordance with a URR. The URR may indicate one or more triggering conditions for generation and reporting of the usage report, for example, immediate reporting, periodic reporting, a threshold for incoming uplink traffic, or any other suitable triggering condition. The URR may indicate a method for measuring usage of network resources, for example, data volume, duration, and/or event.

**[0082]** As noted above, the DNs **408**, **409** may comprise public DNS (e.g., the Internet), private DNs (e.g., private, internal corporate-owned DNs), and/or intra-operator DNs. Each DN may provide an operator service and/or a third-party service. The service provided by a DN may be the Internet, an IP multimedia subsystem (IMS), an augmented or virtual reality network, an edge computing or mobile edge computing (MEC) network, etc. Each DN may be identified using a data network name (DNN). The UE **401** may be configured to establish a first logical connection with DN **408** (a first PDU session), a second logical connection with DN **409** (a second PDU session), or both simultaneously (first and second PDU sessions).

**[0083]** Each PDU session may be associated with at least one UPF configured to operate as a PDU session anchor (PSA, or "anchor"). The anchor may be a UPF that provides an N6 interface with a DN.

**[0084]** In the example of FIG. **4**A, UPF **405** may be the anchor for the first PDU session between UE **401** and DN **408**, whereas the UPF **406** may be the anchor for the second PDU session between UE **401** and DN **409**. The core network may use the anchor to provide service continuity of a particular PDU session (for example, IP address continuity) as UE **401** moves from one access network to another. For example, suppose that UE **401** establishes a PDU session using a data path to the DN **408** using an access network other than AN **402**. The data path may include UPF **405** acting as anchor. Suppose further that the UE **401** later moves into the coverage area of the AN **402**. In such a scenario, SMF **414** may select a new UPF (UPF **407**) to bridge the gap between the newly-entered access network (AN **402**) and the anchor UPF (UPF **405**). The continuity of the PDU session may be preserved as any number of UPFs are added or removed from the data path. When a UPF is added to a data path, as shown in FIG. **4**A, it may be described as an intermediate UPF and/or a cascaded UPF.

**[0085]** As noted above, UPF **406** may be the anchor for the second PDU session between UE **401** and DN **409**. Although the anchor for the first and second PDU sessions are associated with different UPFs in FIG. **4**A, it will be understood that this is merely an example. It will also be understood that multiple PDU sessions with a single DN may correspond to any number of anchors. When there are multiple UPFs, a UPF at the branching point (UPF **407** in FIG. **4**) may operate as an uplink classifier (UL-CL). The UL-CL may divert uplink user plane traffic to different UPFs.

**[0086]** The SMF **414** may allocate, manage, and/or assign an IP address to UE **401**, for example, upon establishment of a PDU session. The SMF **414** may maintain an internal pool of IP addresses to be assigned. The SMF **414** may, if necessary, assign an IP address provided by a dynamic host configuration protocol (DHCP) server or an authentication, authorization, and accounting (AAA) server. IP address management may be performed in accordance with a session and service continuity (SSC) mode. In SSC mode 1, an IP address of UE **401** may be maintained (and the same anchor UPF may be used) as the wireless device moves within the network. In SSC mode 2, the IP address of UE **401** changes as UE **401** moves within the network (e.g., the old IP address and UPF may be abandoned and a new IP address and anchor UPF may be established). In SSC mode 3, it may be possible to maintain an old IP address (similar to SSC mode 1) temporarily while establishing a new IP address (similar to SSC mode 2), thus combining features of SSC modes 1 and 2. Applications that are sensitive to IP address changes may operate in accordance with SSC mode 1.

**[0087]** UPF selection may be controlled by SMF **414**. For example, upon establishment and/or modification of a PDU session between UE **401** and DN **408**, SMF **414** may select UPF **405** as the anchor for the PDU session and/or UPF **407** as an intermediate UPF. Criteria for UPF selection include path efficiency and/or speed between AN **402** and DN **408**. The reliability, load status, location, slice support and/or other capabilities of candidate UPFs may also be considered.

**[0088]** FIG. **4**B illustrates an example of a core network architecture **400**B that accommodates untrusted access. Similar to FIG. **4**A, UE **401** as depicted in FIG. **4**B connects to DN **408** via AN **402** and UPF **405**. The AN **402** and UPF **405** constitute trusted (e.g., 3GPP) access to the DN **408**. By contrast, UE **401** may also access DN **408** using an untrusted access network, AN **403**, and a non-3GPP interworking function (N3IWF) **404**.

**[0089]** The AN **403** may be, for example, a wireless land area network (WLAN) operating in accordance with the IEEE 802.11 standard. The UE **401** may connect to AN **403**, via an interface Y1, in whatever manner is prescribed for AN **403**. The connection to AN **403** may or may not involve authentication. The UE **401** may obtain an IP address from AN **403**. The UE **401** may determine to connect to core network **400**B and select untrusted access for that purpose. The AN **403** may communicate with N3IWF **404** via a Y2 interface. After selecting untrusted access, the UE **401** may provide N3IWF **404** with sufficient information to select an AMF. The selected AMF may be, for example, the same AMF that is used by UE **401** for 3GPP access (AMF **412** in the present example). The N3IWF **404** may communicate with AMF **412** via an N2 interface. The UPF **405** may be selected and N3IWF **404** may communicate with UPF **405** via an N3 interface. The UPF **405** may be a PDU session anchor (PSA) and may remain the anchor for the PDU session even as UE **401** shifts between trusted access and untrusted access.

**[0090]** FIG. **5** illustrates an example of a core network architecture **500** in which a UE **501** is in a roaming scenario. In a roaming scenario, UE **501** is a subscriber of a first PLMN (a home PLMN, or HPLMN) but attaches to a second PLMN (a visited PLMN, or VPLMN). Core network architecture **500** includes UE **501**, an AN **502**, a UPF **505**, and a DN **508**. The AN **502** and UPF **505** may be associated with a VPLMN. The VPLMN may manage the AN **502** and UPF **505** using core network elements associated with the VPLMN, including an AMF **512**, an SMF **514**, a PCF **520**, an NRF **530**, an NEF **540**, and an NSSF **570**. An AF **599** may be adjacent the core network of the VPLMN.

**[0091]** The UE **501** may not be a subscriber of the VPLMN. The AMF **512** may authorize UE **501** to access the network based on, for example, roaming restrictions that apply to UE **501**. In order to obtain network services provided by the VPLMN, it may be necessary for the core network of the VPLMN to interact with core network elements of a HPLMN of UE **501**, in particular, a PCF **521**, an NRF **531**, an NEF **541**, a UDM **551**, and/or an AUSF **561**. The VPLMN and HPLMN may communicate using an N32 interface connecting respective security edge protection proxies (SEPPs). In FIG. **5**, the respective SEPPs are depicted as a VSEPP **590** and an HSEPP **591**.

**[0092]** The VSEPP **590** and the HSEPP **591** communicate via an N32 interface for defined purposes while concealing information about each PLMN from the other. The SEPPs may apply roaming policies based on communications via the N32 interface. The PCF **520** and PCF **521** may communicate via the SEPPs to exchange policy-related signaling. The NRF **530** and NRF **531** may communicate via the SEPPs to enable service discovery of NFs in the respective PLMNs. The VPLMN and HPLMN may independently maintain NEF **540** and NEF **541**. The NSSF **570** and NSSF **571** may communicate via the SEPPs to coordinate slice selection for UE **501**. The HPLMN may handle all authentication and subscription related signaling. For example, when the UE **501** registers or requests service via the VPLMN, the VPLMN may authenticate UE **501** and/or obtain subscription data of UE **501** by accessing, via the SEPPs, the UDM **551** and AUSF **561** of the HPLMN.

**[0093]** The core network architecture **500** depicted in FIG. **5** may be referred to as a local breakout configuration, in which UE **501** accesses DN **508** using one or more UPFs of the VPLMN (i.e., UPF **505**). However, other configurations are possible. For example, in a home-routed configuration (not shown in FIG. **5**), UE **501** may access a DN using one or more UPFs of the HPLMN. In the home-routed configuration, an N9 interface may run parallel to the N32 interface, crossing the frontier between the VPLMN and the HPLMN to carry user plane data. One or more SMFs of the respective PLMNs may communicate via the N32 interface to coordinate session management for UE **501**. The SMFs may control their respective UPFs on either side of the frontier.

**[0094]** FIG. **6** illustrates an example of network slicing. Network slicing may refer to division of shared infrastructure (e.g., physical infrastructure) into distinct logical networks. These distinct logical networks may be independently controlled, isolated from one another, and/or associated with dedicated resources.

**[0095]** Network architecture **600**A illustrates an un-sliced physical network corresponding to a single logical network. The network architecture **600**A comprises a user plane wherein UEs **601**A, **601**B, **601**C (collectively, UEs **601**) have a physical and logical connection to a DN **608** via an AN **602** and a UPF **605**. The network architecture **600**A comprises a control plane wherein an AMF **612** and a SMF **614** control various aspects of the user plane.

**[0096]** The network architecture **600**A may have a specific set of characteristics (e.g., relating to maximum bit rate, reliability, latency, bandwidth usage, power consumption, etc.). This set of characteristics may be affected by the nature of the network elements themselves (e.g., processing power, availability of free memory, proximity to other network elements, etc.) or the management thereof (e.g., optimized to maximize bit rate or reliability, reduce latency or power bandwidth usage, etc.). The characteristics of network architecture **600**A may change over time, for example, by upgrading equipment or by modifying procedures to target a particular characteristic. However, at any given time, network architecture **600**A will have a single set of characteristics that may or may not be optimized for a particular use case. For example, UEs **601**A, **601**B, **601**C may have different requirements, but network architecture **600**A can only be optimized for one of the three.

**[0097]** Network architecture **600**B is an example of a sliced physical network divided into multiple logical networks. In FIG. **6**, the physical network is divided into three logical networks, referred to as slice A, slice B, and slice C. For example, UE **601**A may be served by AN **602**A, UPF **605**A, AMF **612**, and SMF **614**A. UE **601**B may be served by AN **602**B, UPF **605**B, AMF **612**, and SMF **614**B. UE **601**C may be served by AN **602**C, UPF **605**C, AMF **612**, and SMF **614**C. Although the respective UEs **601** communicate with different network elements from a logical perspective, these network elements may be deployed by a network operator using the same physical network elements.

**[0098]** Each network slice may be tailored to network services having different sets of characteristics. For example, slice A may correspond to enhanced mobile broadband (eMBB) service. Mobile broadband may refer to internet access by mobile users, commonly associated with smartphones. Slice B may correspond to ultra-reliable low-latency communication (URLLC), which focuses on reliability and speed. Relative to eMBB, URLLC may improve the feasibility of use cases such as autonomous driving and telesurgery. Slice C may correspond to massive machine type communication (mMTC), which focuses on low-power services delivered to a large number of users. For example, slice C may be optimized for a dense network of battery-powered sensors that provide small amounts of data at regular intervals. Many mMTC use cases would be prohibitively expensive if they operated using an eMBB or URLLC network.

**[0099]** If the service requirements for one of the UEs **601** changes, then the network slice serving that UE can be updated to provide better service. Moreover, the set of network characteristics corresponding to eMBB, URLLC, and mMTC may be varied, such that differentiated species of eMBB, URLLC, and mMTC are provided. Alternatively, network operators may provide entirely new services in response to, for example, customer demand.

**[0100]** In FIG. **6**, each of the UEs **601** has its own network slice. However, it will be understood that a single slice may serve any number of UEs and a single UE may operate using any number of slices. Moreover, in the example network architecture **600**B, the AN **602**, UPF **605** and SMF **614** are separated into three separate slices, whereas the AMF **612** is unsliced. However, it will be understood that a network operator may deploy any architecture that selectively utilizes any mix of sliced and unsliced network elements, with different network elements divided into different numbers of slices. Although FIG. **6** only depicts three core network functions, it will be understood that other core network functions may be sliced as well. A PLMN that supports multiple network slices may maintain a separate network repository function (NFR) for each slice, enabling other NFs to discover network services associated with that slice.

**[0101]** Network slice selection may be controlled by an AMF, or alternatively, by a separate network slice selection function (NSSF). For example, a network operator may define and implement distinct network slice instances (NSIs). Each NSI may be associated with single network slice selection assistance information (S-NSSAI). The S-NSSAI may include a particular slice/service type (SST) indicator (indicating eMBB, URLLC, mMTC, etc.). as an example, a particular tracking area may be associated with one or more configured S-NSSAIs. UEs may identify one or more requested and/or subscribed S-NSSAIs (e.g., during registration). The network may indicate to the UE one or more allowed and/or rejected S-NSSAIs.

**[0102]** The S-NSSAI may further include a slice differentiator (SD) to distinguish between different tenants of a particular slice and/or service type. For example, a tenant may be a customer (e.g., vehicle manufacture, service provider, etc.) of a network operator that obtains (for example, purchases) guaranteed network resources and/or specific policies for handling its subscribers. The network operator may configure different slices and/or slice types, and use the SD to determine which tenant is associated with a particular slice.

**[0103]** FIG. **7**A, FIG. **7**B, and FIG. **7**C illustrate a user plane (UP) protocol stack, a control plane (CP) protocol stack, and services provided between protocol layers of the UP protocol stack.

**[0104]** The layers may be associated with an open system interconnection (OSI) model of computer networking functionality. In the OSI model, layer 1 may correspond to the bottom layer, with higher layers on top of the bottom layer. Layer 1 may correspond to a physical layer, which is concerned with the physical infrastructure used for transfer of signals (for example, cables, fiber optics, and/or radio frequency transceivers). In New Radio (NR), layer 1 may comprise a physical layer (PHY). Layer 2 may correspond to a data link layer. Layer 2 may be concerned with packaging of data (into, e.g., data frames) for transfer, between nodes of the network, using the physical infrastructure of layer 1. In NR, layer 2 may comprise a media access control layer (MAC), a radio link control layer (RLC), a packet data convergence layer (PDCP), and a service data application protocol layer (SDAP).

**[0105]** Layer 3 may correspond to a network layer. Layer 3 may be concerned with routing of the data which has been packaged in layer 2. Layer 3 may handle prioritization of data and traffic avoidance. In NR, layer 3 may comprise a radio resource control layer (RRC) and a non-access stratum layer (NAS). Layers 4 through 7 may correspond to a transport layer, a session layer, a presentation layer, and an application layer. The application layer interacts with an end user to provide data associated with an application. In an example, an end user implementing the application may generate data associated with the application and initiate sending of that information to a targeted data network (e.g., the Internet, an application server, etc.). Starting at the application layer, each layer in the OSI model may manipulate and/or repackage the information and deliver it to a lower layer. At the lowest layer, the manipulated and/or repackaged information may be exchanged via physical infrastructure (for example, electrically, optically, and/or electromagnetically). As it approaches the targeted data network, the information will be unpackaged and provided to higher and higher layers, until it once again reaches the application layer in a form that is usable by the targeted data network (e.g., the same form in which it was provided by the end user). To respond to the end user, the data network may perform this procedure in reverse.

**[0106]** FIG. **7**A illustrates a user plane protocol stack. The user plane protocol stack may be a new radio (NR) protocol stack for a Uu interface between a UE **701** and a gNB **702**. In layer 1 of the UP protocol stack, the UE **701** may implement PHY **731** and the gNB **702** may implement PHY **732**. In layer 2 of the UP protocol stack, the UE **701** may implement MAC **741**, RLC **751**, PDCP **761**, and SDAP **771**. The gNB **702** may implement MAC **742**, RLC **752**, PDCP **762**, and SDAP **772**.

**[0107]** FIG. **7**B illustrates a control plane protocol stack. The control plane protocol stack may be an NR protocol stack for the Uu interface between the UE **701** and the gNB **702** and/or an N1 interface between the UE **701** and an AMF **712**. In layer 1 of the CP protocol stack, the UE **701** may implement PHY **731** and the gNB **702** may implement PHY **732**. In layer 2 of the CP protocol stack, the UE **701** may implement MAC **741**, RLC **751**, PDCP **761**, RRC **781**, and NAS **791**. The gNB **702** may implement MAC **742**, RLC **752**, PDCP **762**, and RRC **782**. The AMF **712** may implement NAS **792**.

**[0108]** The NAS may be concerned with the non-access stratum, in particular, communication between the UE **701** and the core network (e.g., the AMF **712**). Lower layers may be concerned with the access stratum, for example, communication between the UE **701** and the gNB **702**. Messages sent between the UE **701** and the core network may be referred to as NAS messages. In an example, a NAS message may be relayed by the gNB **702**, but the content of the NAS message (e.g., information elements of the NAS message) may not be visible to the gNB **702**.

**[0109]** FIG. **7**C illustrates an example of services provided between protocol layers of the NR user plane protocol stack illustrated in FIG. **7**A. The UE **701** may receive services through a PDU session, which may be a logical connection between the UE **701** and a data network (DN). The UE **701** and the DN may exchange data packets associated with the PDU session. The PDU session may comprise one or more quality of service (QoS) flows. SDAP **771** and SDAP **772** may perform mapping and/or demapping between the one or more QoS flows of the PDU session and one or more radio bearers (e.g., data radio bearers). The mapping between the QoS flows and the data radio bearers may be determined in the SDAP **772** by the gNB **702**, and the UE **701** may be notified of the mapping (e.g., based on control signaling and/or reflective mapping). For reflective mapping, the SDAP **772** of the gNB **220** may mark downlink packets with a QoS flow indicator (QFI) and deliver the downlink packets to the UE **701**. The UE **701** may determine the mapping based on the QFI of the downlink packets.

**[0110]** PDCP **761** and PDCP **762** may perform header compression and/or decompression. Header compression may reduce the amount of data transmitted over the physical layer. The PDCP **761** and PDCP **762** may perform ciphering and/or deciphering. Ciphering may reduce unauthorized decoding of data transmitted over the physical layer (e.g., intercepted on an air interface), and protect data integrity (e.g., to ensure control messages originate from intended sources). The PDCP **761** and PDCP **762** may perform retransmissions of undelivered packets, in-sequence delivery and reordering of packets, duplication of packets, and/or identification and removal of duplicate packets. In a dual connectivity scenario, PDCP **761** and PDCP **762** may perform mapping between a split radio bearer and RLC channels.

**[0111]** RLC **751** and RLC **752** may perform segmentation, retransmission through Automatic Repeat Request (ARQ). The RLC **751** and RLC **752** may perform removal of duplicate data units received from MAC **741** and MAC **742**, respectively. The RLCs **213** and **223** may provide RLC channels as a service to PDCPs **214** and **224**, respectively.

**[0112]** MAC **741** and MAC **742** may perform multiplexing and/or demultiplexing of logical channels. MAC **741** and MAC **742** may map logical channels to transport channels. In an example, UE **701** may, in MAC **741**, multiplex data units of one or more logical channels into a transport block. The UE **701** may transmit the transport block to the gNB **702** using PHY **731**. The gNB **702** may receive the transport block using PHY **732** and demultiplex data units of the transport blocks back into logical channels. MAC **741** and MAC **742** may perform error correction through Hybrid Automatic Repeat Request (HARQ), logical channel prioritization, and/or padding.

**[0113]** PHY **731** and PHY **732** may perform mapping of transport channels to physical channels. PHY **731** and PHY **732** may perform digital and analog signal processing functions (e.g., coding/decoding and modulation/demodulation) for sending and receiving information (e.g., transmission via an air interface). PHY **731** and PHY **732** may perform multi-antenna mapping.

**[0114]** FIG. **8** illustrates an example of a quality of service (QoS) model for differentiated data exchange. In the QoS model of FIG. **8**, there are a UE **801**, a AN **802**, and a UPF **805**. The QoS model facilitates prioritization of certain packet or protocol data units (PDUs), also referred to as packets. For example, higher-priority packets may be exchanged faster and/or more reliably than lower-priority packets. The network may devote more resources to exchange of high-QoS packets.

**[0115]** In the example of FIG. **8**, a PDU session **810** is established between UE **801** and UPF **805**. The PDU session **810** may be a logical connection enabling the UE **801** to exchange data with a particular data network (for example, the Internet). The UE **801** may request establishment of the PDU session **810**. At the time that the PDU session **810** is established, the UE **801** may, for example, identify the targeted data network based on its data network name (DNN). The PDU session **810** may be managed, for example, by a session management function (SMF, not shown). In order to facilitate exchange of data associated with the PDU session **810**, between the UE **801** and the data network, the SMF may select the UPF **805** (and optionally, one or more other UPFs, not shown).

**[0116]** One or more applications associated with UE **801** may generate uplink packets **812**A-**812**E associated with the PDU session **810**. In order to work within the QoS model, UE **801** may apply QoS rules **814** to uplink packets **812**A-**812**E. The QoS rules **814** may be associated with PDU session **810** and may be determined and/or provided to the UE **801** when PDU session **810** is established and/or modified. Based on QoS rules **814**, UE **801** may classify uplink packets **812**A-**812**E, map each of the uplink packets **812**A-**812**E to a QoS flow, and/or mark uplink packets **812**A-**812**E with a QoS flow indicator (QFI). As a packet travels through the network, and potentially mixes with other packets from other UEs having potentially different priorities, the QFI indicates how the packet should be handled in accordance with the QoS model. In the present illustration, uplink packets **812**A, **812**B are mapped to QoS flow **816**A, uplink packet **812**C is mapped to QoS flow **816**B, and the remaining packets are mapped to QoS flow **816**C.

**[0117]** The QoS flows may be the finest granularity of QoS differentiation in a PDU session. In the figure, three QoS flows **816**A-**816**C are illustrated. However, it will be understood that there may be any number of QoS flows. Some QoS flows may be associated with a guaranteed bit rate (GBR QoS flows) and others may have bit rates that are not guaranteed (non-GBR QoS flows). QoS flows may also be subject to per-UE and per-session aggregate bit rates. One of the QoS flows may be a default QoS flow. The QoS flows may have different priorities. For example, QoS flow **816**A may have a higher priority than QoS flow **816**B, which may have a higher priority than QoS flow **816**C. Different priorities may be reflected by different QoS flow characteristics. For example, QoS flows may be associated with flow bit rates. A particular QoS flow may be associated with a guaranteed flow bit rate (GFBR) and/or a maximum flow bit rate (MFBR). QoS flows may be associated with specific packet delay budgets (PDBs), packet error rates (PERs), and/or maximum packet loss rates. QoS flows may also be subject to per-UE and per-session aggregate bit rates.

**[0118]** In order to work within the QoS model, UE **801** may apply resource mapping rules **818** to the QoS flows **816**A-**816**C. The air interface between UE **801** and AN **802** may be associated with resources **820**. In the present illustration, QoS flow **816**A is mapped to resource **820**A, whereas QoS flows **816**B, **816**C are mapped to resource **820**B. The resource mapping rules **818** may be provided by the AN **802**. In order to meet QoS requirements, the resource mapping rules **818** may designate more resources for relatively high-priority QoS flows. With more resources, a high-priority QoS flow such as QoS flow **816**A may be more likely to obtain the high flow bit rate, low packet delay budget, or other characteristic associated with QoS rules **814**. The resources **820** may comprise, for example, radio bearers. The radio bearers (e.g., data radio bearers) may be established between the UE **801** and the AN **802**. The radio bearers in 5G, between the UE **801** and the AN **802**, may be distinct from bearers in LTE, for example, Evolved Packet System (EPS) bearers between a UE and a packet data network gateway (PGW), S1 bearers between an eNB and a serving gateway (SGW), and/or an S5/S8 bearer between an SGW and a PGW.

**[0119]** Once a packet associated with a particular QoS flow is received at AN **802** via resource **820**A or resource **820**B, AN **802** may separate packets into respective QoS flows **856**A-**856**C based on QoS profiles **828**. The QoS profiles **828** may be received from an SMF. Each QoS profile may correspond to a QFI, for example, the QFI marked on the uplink packets **812**A-**812**E. Each QoS profile may include QoS parameters such as 5G QoS identifier (5QI) and an allocation and retention priority (ARP). The QoS profile for non-GBR QoS flows may further include additional QoS parameters such as a reflective QoS attribute (RQA). The QoS profile for GBR QoS flows may further include additional QoS parameters such as a guaranteed flow bit rate (GFBR), a maximum flow bit rate (MFBR), and/or a maximum packet loss rate. The 5QI may be a standardized 5QI which have one-to-one mapping to a standardized combination of 5G QoS characteristics per well-known services. The 5QI may be a dynamically assigned 5QI which the standardized 5QI values are not defined. The 5QI may represent 5G QoS characteristics. The 5QI may comprise a resource type, a default priority level, a packet delay budget (PDB), a packet error rate (PER), a maximum data burst volume, and/or an averaging window. The resource type may indicate a non-GBR QoS flow, a GBR QoS flow or a delay-critical GBR QoS flow. The averaging window may represent a duration over which the GFBR and/or MFBR is calculated. ARP may be a priority level comprising pre-emption capability and a pre-emption vulnerability. Based on the ARP, the AN **802** may apply admission control for the QoS flows in a case of resource limitations.

**[0120]** The AN **802** may select one or more N3 tunnels **850** for transmission of the QoS flows **856**A-**856**C. After the packets are divided into QoS flows **856**A-**856**C, the packet may be sent to UPF **805** (e.g., towards a DN) via the selected one or more N3 tunnels **850**. The UPF **805** may verify that the QFIs of the uplink packets **812**A-**812**E are aligned with the QoS rules **814** provided to the UE **801**. The UPF **805** may measure and/or count packets and/or provide packet metrics to, for example, a PCF.

**[0121]** The figure also illustrates a process for downlink. In particular, one or more applications may generate downlink packets **852**A-**852**E. The UPF **805** may receive downlink packets **852**A-**852**E from one or more DNs and/or one or more other UPFs. As per the QoS model, UPF **805** may apply packet detection rules (PDRs) **854** to downlink packets **852**A-**852**E. Based on PDRs **854**, UPF **805** may map packets **852**A-**852**E into QoS flows. In the present illustration, downlink packets **852**A, **852**B are mapped to QoS flow **856**A, downlink packet **852**C is mapped to QoS flow **856**B, and the remaining packets are mapped to QoS flow **856**C.

**[0122]** The QoS flows **856**A-**856**C may be sent to AN **802**. The AN **802** may apply resource mapping rules to the QoS flows **856**A-**856**C. In the present illustration, QoS flow **856**A is mapped to resource **820**A, whereas QoS flows **856**B, **856**C are mapped to resource **820**B. In order to meet QoS requirements, the resource mapping rules may designate more resources to high-priority QoS flows.

**[0123]** FIGS. **9**A-**9**D illustrate example states and state transitions of a wireless device (e.g., a UE). At any given time, the wireless device may have a radio resource control (RRC) state, a registration management (RM) state, and a connection management (CM) state.

**[0124]** FIG. **9**A is an example diagram showing RRC state transitions of a wireless device (e.g., a UE). The UE may be in one of three RRC states: RRC idle **910**, (e.g., RRC_IDLE), RRC inactive **920** (e.g., RRC_INACTIVE), or RRC connected **930** (e.g., RRC_CONNECTED). The UE may implement different RAN-related control-plane procedures depending on its RRC state. Other elements of the network, for example, a base station, may track the RRC state of one or more UEs and implement RAN-related control-plane procedures appropriate to the RRC state of each.

**[0125]** In RRC connected **930**, it may be possible for the UE to exchange data with the network (for example, the base station). The parameters necessary for exchange of data may be established and known to both the UE and the network. The parameters may be referred to and/or included in an RRC context of the UE (sometimes referred to as a UE context). These parameters may include, for example: one or more AS contexts; one or more radio link configuration parameters; bearer configuration information (e.g., relating to a data radio bearer, signaling radio bearer, logical channel, QoS flow, and/or PDU session); security information; and/or PHY, MAC, RLC, PDCP, and/or SDAP layer configuration information. The base station with which the UE is connected may store the RRC context of the UE.

**[0126]** While in RRC connected **930**, mobility of the UE may be managed by the access network, whereas the UE itself may manage mobility while in RRC idle **910** and/or RRC inactive **920**. While in RRC connected **930**, the UE may manage mobility by measuring signal levels (e.g., reference signal levels) from a serving cell and neighboring cells and reporting these measurements to the base station currently serving the UE. The network may initiate handover based on the reported measurements. The RRC state may transition from RRC connected **930** to RRC idle **910** through a connection release procedure **930** or to RRC inactive **920** through a connection inactivation procedure **932**.

**[0127]** In RRC idle **910**, an RRC context may not be established for the UE. In RRC idle **910**, the UE may not have an RRC connection with a base station. While in RRC idle **910**, the UE may be in a sleep state for a majority of the time (e.g., to conserve battery power). The UE may wake up periodically (e.g., once in every discontinuous reception cycle) to monitor for paging messages from the access network. Mobility of the UE may be managed by the UE through a procedure known as cell reselection. The RRC state may transition from RRC idle **910** to RRC connected **930** through a connection establishment procedure **913**, which may involve a random access procedure, as discussed in greater detail below.

**[0128]** In RRC inactive **920**, the RRC context previously established is maintained in the UE and the base station. This may allow for a fast transition to RRC connected **930** with reduced signaling overhead as compared to the transition from RRC idle **910** to RRC connected **930**. The RRC state may transition to RRC connected **930** through a connection resume procedure **923**. The RRC state may transition to RRC idle **910** though a connection release procedure **921** that may be the same as or similar to connection release procedure **931**.

**[0129]** An RRC state may be associated with a mobility management mechanism. In RRC idle **910** and RRC inactive **920**, mobility may be managed by the UE through cell reselection. The purpose of mobility management in RRC idle **910** and/or RRC inactive **920** is to allow the network to be able to notify the UE of an event via a paging message without having to broadcast the paging message over the entire mobile communications network. The mobility management mechanism used in RRC idle **910** and/or RRC inactive **920** may allow the network to track the UE on a cell-group level so that the paging message may be broadcast over the cells of the cell group that the UE currently resides within instead of the entire communication network. Tracking may be based on different granularities of grouping. For example, there may be three levels of cell-grouping granularity: individual cells; cells within a RAN area identified by a RAN area identifier (RAI); and cells within a group of RAN areas, referred to as a tracking area and identified by a tracking area identifier (TAI).

**[0130]** Tracking areas may be used to track the UE at the CN level. The CN may provide the UE with a list of TAIs associated with a UE registration area. If the UE moves, through cell reselection, to a cell associated with a TAI not included in the list of TAIs associated with the UE registration area, the UE may perform a registration update with the CN to allow the CN to update the UE's location and provide the UE with a new the UE registration area.

**[0131]** RAN areas may be used to track the UE at the RAN level. For a UE in RRC inactive **920** state, the UE may be assigned a RAN notification area. A RAN notification area may comprise one or more cell identities, a list of RAIs, and/or a list of TAIs. In an example, a base station may belong to one or more RAN notification areas. In an example, a cell may belong to one or more RAN notification areas. If the UE moves, through cell reselection, to a cell not included in the RAN notification area assigned to the UE, the UE may perform a notification area update with the RAN to update the UE's RAN notification area.

**[0132]** A base station storing an RRC context for a UE or a last serving base station of the UE may be referred to as an anchor base station. An anchor base station may maintain an RRC context for the UE at least during a period of time that the UE stays in a RAN notification area of the anchor base station and/or during a period of time that the UE stays in RRC inactive **920**.

**[0133]** FIG. **9**B is an example diagram showing registration management (RM) state transitions of a wireless device (e.g., a UE). The states are RM deregistered **940**, (e.g., RM-DEREGISTERED) and RM registered **950** (e.g., RM-REGISTERED).

**[0134]** In RM deregistered **940**, the UE is not registered with the network, and the UE is not reachable by the network. In order to be reachable by the network, the UE must perform an initial registration. As an example, the UE may register with an AMF of the network. If registration is rejected (registration reject **944**), then the UE remains in RM deregistered **940**. If registration is accepted (registration accept **945**), then the UE transitions to RM registered **950**. While the UE is RM registered **950**, the network may store, keep, and/or maintain a UE context for the UE. The UE context may be referred to as wireless device context. The UE context corresponding to network registration (maintained by the core network) may be different from the RRC context corresponding to RRC state (maintained by an access network, .e.g., a base station). The UE context may comprise a UE identifier and a record of various information relating to the UE, for example, UE capability information, policy information for access and mobility management of the UE, lists of allowed or established slices or PDU sessions, and/or a registration area of the UE (i.e., a list of tracking areas covering the geographical area where the wireless device is likely to be found).

**[0135]** While the UE is RM registered **950**, the network may store the UE context of the UE, and if necessary use the UE context to reach the UE. Moreover, some services may not be provided by the network unless the UE is registered. The UE may update its UE context while remaining in RM registered **950** (registration update accept **955**). For example, if the UE leaves one tracking area and enters another tracking area, the UE may provide a tracking area identifier to the network. The network may deregister the UE, or the UE may deregister itself (deregistration **954**). For example, the network may automatically deregister the wireless device if the wireless device is inactive for a certain amount of time. Upon deregistration, the UE may transition to RM deregistered **940**.

**[0136]** FIG. **9**C is an example diagram showing connection management (CM) state transitions of a wireless device (e.g., a UE), shown from a perspective of the wireless device. The UE may be in CM idle **960** (e.g., CM-IDLE) or CM connected **970** (e.g., CM-CONNECTED).

**[0137]** In CM idle **960**, the UE does not have a non access stratum (NAS) signaling connection with the network. As a result, the UE can not communicate with core network functions. The UE may transition to CM connected **970** by establishing an AN signaling connection (AN signaling connection establishment **967**). This transition may be initiated by sending an initial NAS message. The initial NAS message may be a registration request (e.g., if the UE is RM deregistered **940**) or a service request (e.g., if the UE is RM registered **950**). If the UE is RM registered **950**, then the UE may initiate the AN signaling connection establishment by sending a service request, or the network may send a page, thereby triggering the UE to send the service request.

**[0138]** In CM connected **970**, the UE can communicate with core network functions using NAS signaling. As an example, the UE may exchange NAS signaling with an AMF for registration management purposes, service request procedures, and/or authentication procedures. As another example, the UE may exchange NAS signaling, with an SMF, to establish and/or modify a PDU session. The network may disconnect the UE, or the UE may disconnect itself (AN signaling connection release **976**). For example, if the UE transitions to RM deregistered **940**, then the UE may also transition to CM idle **960**. When the UE transitions to CM idle **960**, the network may deactivate a user plane connection of a PDU session of the UE.

**[0139]** FIG. **9**D is an example diagram showing CM state transitions of the wireless device (e.g., a UE), shown from a network perspective (e.g., an AMF). The CM state of the UE, as tracked by the AMF, may be in CM idle **980** (e.g., CM-IDLE) or CM connected **990** (e.g., CM-CONNECTED). When the UE transitions from CM idle **980** to CM connected **990**, the AMF many establish an N2 context of the UE (N2 context establishment **989**). When the UE transitions from CM connected **990** to CM idle **980**, the AMF many release the N2 context of the UE (N2 context release **998**).

**[0140]** FIGS. **10-12** illustrate example procedures for registering, service request, and PDU session establishment of a UE.

**[0141]** FIG. **10** illustrates an example of a registration procedure for a wireless device (e.g., a UE). Based on the registration procedure, the UE may transition from, for example, RM deregistered **940** to RM registered **950**.

**[0142]** Registration may be initiated by a UE for the purposes of obtaining authorization to receive services, enabling mobility tracking, enabling reachability, or other purposes. The UE may perform an initial registration as a first step toward connection to the network (for example, if the UE is powered on, airplane mode is turned off, etc.). Registration may also be performed periodically to keep the network informed of the UE's presence (for example, while in CM-IDLE state), or in response to a change in UE capability or registration area. Deregistration (not shown in FIG. **10**) may be performed to stop network access.

**[0143]** At **1010**, the UE transmits a registration request to an AN. As an example, the UE may have moved from a coverage area of a previous AMF (illustrated as AMF #1) into a coverage area of a new AMF (illustrated as AMF #2). The registration request may be a NAS message. The registration request may include a UE identifier. The AN may select an AMF for registration of the UE. For example, the AN may select a default AMF. For example, the AN may select an AMF that is already mapped to the UE (e.g., a previous AMF). The NAS registration request may include a network slice identifier and the AN may select an AMF based on the requested slice. After the AMF is selected, the AN may send the registration request to the selected AMF.

**[0144]** At **1020**, the AMF that receives the registration request (AMF#2) performs a context transfer. The context may be a UE context, for example, an RRC context for the UE. As an example, AMF#2 may send AMF#1 a message requesting a context of the UE. The message may include the UE identifier. The message may be a Namf_Communication_UEContextTransfer message. AMF#1 may send to AMF#2 a message that includes the requested UE context. This message may be a Namf_Communication_ UEContextTransfer message. After the UE context is received, the AMF#2 may coordinate authentication of the UE. After authentication is complete, AMF#2 may send to AMF#1 a message indicating that the UE context transfer is complete. This message may be a Namf_Communication_UEContextTransfer Response message.

**[0145]** Authentication may require participation of the UE, an AUSF, a UDM and/or a UDR (not shown). For example, the AMF may request that the AUSF authenticate the UE. For example, the AUSF may execute authentication of the UE. For example, the AUSF may get authentication data from UDM. For example, the AUSF may send a subscription permanent identifier (SUPI) to the AMF based on the authentication being successful. For example, the AUSF may provide an intermediate key to the AMF. The intermediate key may be used to derive an access-specific security key for the UE, enabling the AMF to perform security context management (SCM). The AUSF may obtain subscription data from the UDM. The subscription data may be based on information obtained from the UDM (and/or the UDR). The subscription data may include subscription identifiers, security credentials, access and mobility related subscription data and/or session related data.

**[0146]** At **1030**, the new AMF, AMF#2, registers and/or subscribes with the UDM. AMF#2 may perform registration using a UE context management service of the UDM (Nudm_UECM). AMF#2 may obtain subscription information of the UE using a subscriber data management service of the UDM (Nudm_SDM). AMF#2 may further request that the UDM notify AMF#2 if the subscription information of the UE changes. As the new AMF registers and subscribes, the old AMF, AMF#1, may deregister and unsubscribe. After deregistration, AMF#1 is free of responsibility for mobility management of the UE.

**[0147]** At **1040**, AMF#2 retrieves access and mobility (AM) policies from the PCF. As an example, the AMF#2 may provide subscription data of the UE to the PCF. The PCF may determine access and mobility policies for the UE based on the subscription data, network operator data, current network conditions, and/or other suitable information. For example, the owner of a first UE may purchase a higher level of service than the owner of a second UE. The PCF may provide the rules associated with the different levels of service. Based on the subscription data of the respective UEs, the network may apply different policies which facilitate different levels of service.

**[0148]** For example, access and mobility policies may relate to service area restrictions, RAT/frequency selection priority (RFSP, where RAT stands for radio access technology), authorization and prioritization of access type (e.g., LTE versus NR), and/or selection of non-3GPP access (e.g., Access Network Discovery and Selection Policy (ANDSP). The service area restrictions may comprise a list of tracking areas where the UE is allowed to be served (or forbidden from being served). The access and mobility policies may include a UE route selection policy (URSP) that influences routing to an established PDU session or a new PDU session. As noted above, different policies may be obtained and/or enforced based on subscription data of the UE, location of the UE (i.e., location of the AN and/or AMF), or other suitable factors.

**[0149]** At **1050**, AMF#2 may update a context of a PDU session. For example, if the UE has an existing PDU session, the AMF#2 may coordinate with an SMF to activate a user plane connection associated with the existing PDU session. The SMF may update and/or release a session management context of the PDU session (Nsmf_PDUSession_UpdateSMContext, Nsmf_PDUSession_ReleaseSMContext).

**[0150]** At **1060**, AMF#2 sends a registration accept message to the AN, which forwards the registration accept message to the UE. The registration accept message may include a new UE identifier and/or a new configured slice identifier. The UE may transmit a registration complete message to the AN, which forwards the registration complete message to the AMF#2. The registration complete message may acknowledge receipt of the new UE identifier and/or new configured slice identifier.

**[0151]** At **1070**, AMF#2 may obtain UE policy control information from the PCF. The PCF may provide an access network discovery and selection policy (ANDSP) to facilitate non-3GPP access. The PCF may provide a UE route selection policy (URSP) to facilitate mapping of particular data traffic to particular PDU session connectivity parameters. As an example, the URSP may indicate that data traffic associated with a particular application should be mapped to a particular SSC mode, network slice, PDU session type, or preferred access type (3GPP or non-3GPP).

**[0152]** FIG. **11** illustrates an example of a service request procedure for a wireless device (e.g., a UE). The service request procedure depicted in FIG. **11** is a network-triggered service request procedure for a UE in a CM-IDLE state. However, other service request procedures (e.g., a UE-triggered service request procedure) may also be understood by reference to FIG. **11**, as will be discussed in greater detail below.

**[0153]** At **1110**, a UPF receives data. The data may be downlink data for transmission to a UE. The data may be associated with an existing PDU session between the UE and a DN. The data may be received, for example, from a DN and/or another UPF. The UPF may buffer the received data. In response to the receiving of the data, the UPF may notify an SMF of the received data. The identity of the SMF to be notified may be determined based on the received data. The notification may be, for example, an N4 session report. The notification may indicate that the UPF has received data associated with the UE and/or a particular PDU session associated with the UE. In response to receiving the notification, the SMF may send PDU session information to an AMF. The PDU session information may be sent in an NIN2 message transfer for forwarding to an AN. The PDU session information may include, for example, UPF tunnel endpoint information and/or QoS information.

**[0154]** At **1120**, the AMF determines that the UE is in a CM-IDLE state. The determining at **1120** may be in response to the receiving of the PDU session information. Based on the determination that the UE is CM-IDLE, the service request procedure may proceed to **1130** and **1140**, as depicted in FIG. **11**. However, if the UE is not CM-IDLE (e.g., the UE is CM-CONNECTED), then **1130** and **1140** may be skipped, and the service request procedure may proceed directly to **1150**.

**[0155]** At **1130**, the AMF pages the UE. The paging at **1130** may be performed based on the UE being CM-IDLE. To perform the paging, the AMF may send a page to the AN. The page may be referred to as a paging or a paging message. The page may be an N2 request message. The AN may be one of a plurality of ANs in a RAN notification area of the UE. The AN may send a page to the UE. The UE may be in a coverage area of the AN and may receive the page.

**[0156]** At **1140**, the UE may request service. The UE may transmit a service request to the AMF via the AN. As depicted in FIG. **11**, the UE may request service at **1140** in response to receiving the paging at **1130**. However, as noted above, this is for the specific case of a network-triggered service request procedure. In some scenarios (for example, if uplink data becomes available at the UE), then the UE may commence a UE-triggered service request procedure. The UE-triggered service request procedure may commence starting at **1140**.

**[0157]** At **1150**, the network may authenticate the UE. Authentication may require participation of the UE, an AUSF, and/or a UDM, for example, similar to authentication described elsewhere in the present disclosure. In some cases (for example, if the UE has recently been authenticated), the authentication at **1150** may be skipped.

**[0158]** At **1160**, the AMF and SMF may perform a PDU session update. As part of the PDU session update, the SMF may provide the AMF with one or more UPF tunnel endpoint identifiers. In some cases (not shown in FIG. **11**), it may be necessary for the SMF to coordinate with one or more other SMFs and/or one or more other UPFs to set up a user plane.

**[0159]** At **1170**, the AMF may send PDU session information to the AN. The PDU session information may be included in an N2 request message. Based on the PDU session information, the AN may configure a user plane resource for the UE. To configure the user plane resource, the AN may, for example, perform an RRC reconfiguration of the UE. The AN may acknowledge to the AMF that the PDU session information has been received. The AN may notify the AMF that the user plane resource has been configured, and/or provide information relating to the user plane resource configuration.

**[0160]** In the case of a UE-triggered service request procedure, the UE may receive, at **1170**, a NAS service accept message from the AMF via the AN. After the user plane resource is configured, the UE may transmit uplink data (for example, the uplink data that caused the UE to trigger the service request procedure).

**[0161]** At **1180**, the AMF may update a session management (SM) context of the PDU session. For example, the AMF may notify the SMF (and/or one or more other associated SMFs) that the user plane resource has been configured, and/or provide information relating to the user plane resource configuration. The AMF may provide the SMF (and/or one or more other associated SMFs) with one or more AN tunnel endpoint identifiers of the AN. After the SM context update is complete, the SMF may send an update SM context response message to the AMF.

**[0162]** Based on the update of the session management context, the SMF may update a PCF for purposes of policy control. For example, if a location of the UE has changed, the SMF may notify the PCF of the UE's a new location.

**[0163]** Based on the update of the session management context, the SMF and UPF may perform a session modification. The session modification may be performed using N4 session modification messages. After the session modification is complete, the UPF may transmit downlink data (for example, the downlink data that caused the UPF to trigger the network-triggered service request procedure) to the UE. The transmitting of the downlink data may be based on the one or more AN tunnel endpoint identifiers of the AN.

**[0164]** FIG. **12** illustrates an example of a protocol data unit (PDU) session establishment procedure for a wireless device (e.g., a UE). The UE may determine to transmit the PDU session establishment request to create a new PDU session, to hand over an existing PDU session to a 3GPP network, or for any other suitable reason.

**[0165]** At **1210**, the UE initiates PDU session establishment. The UE may transmit a PDU session establishment request to an AMF via an AN. The PDU session establishment request may be a NAS message. The PDU session establishment request may indicate: a PDU session ID; a requested PDU session type (new or existing); a requested DN (DNN); a requested network slice (S-NSSAI); a requested SSC mode; and/or any other suitable information. The PDU session ID may be generated by the UE. The PDU session type may be, for example, an Internet Protocol (IP)-based type (e.g., IPv4, IPv6, or dual stack IPv4/IPv6), an Ethernet type, or an unstructured type.

**[0166]** The AMF may select an SMF based on the PDU session establishment request. In some scenarios, the requested PDU session may already be associated with a particular SMF. For example, the AMF may store a UE context of the UE, and the UE context may indicate that the PDU session ID of the requested PDU session is already associated with the particular SMF. In some scenarios, the AMF may select the SMF based on a determination that the SMF is prepared to handle the requested PDU session. For example, the requested PDU session may be associated with a particular DNN and/or S-NSSAI, and the SMF may be selected based on a determination that the SMF can manage a PDU session associated with the particular DNN and/or S-NSSAI.

**[0167]** At **1220**, the network manages a context of the PDU session. After selecting the SMF at **1210**, the AMF sends a PDU session context request to the SMF. The PDU session context request may include the PDU session establishment request received from the UE at **1210**. The PDU session context request may be a Nsmf_PDUSession_CreateSMContext Request and/or a Nsmf_PDUSession_UpdateSMContext Request. The PDU session context request may indicate identifiers of the UE; the requested DN; and/or the requested network slice. Based on the PDU session context request, the SMF may retrieve subscription data from a UDM. The subscription data may be session management subscription data of the UE. The SMF may subscribe for updates to the subscription data, so that the PCF will send new information if the subscription data of the UE changes. After the subscription data of the UE is obtained, the SMF may transmit a PDU session context response to the AMG. The PDU session context response may be a Nsmf_PDUSession_CreateSMContext Response and/or a Nsmf_PDUSession_UpdateSMContext Response. The PDU session context response may include a session management context ID.

**[0168]** At **1230**, secondary authorization/authentication may be performed, if necessary. The secondary authorization/authentication may involve the UE, the AMF, the SMF, and the DN. The SMF may access the DN via a Data Network Authentication, Authorization and Accounting (DN AAA) server.

**[0169]** At **1240**, the network sets up a data path for uplink data associated with the PDU session. The SMF may select a PCF and establish a session management policy association. Based on the association, the PCF may provide an initial set of policy control and charging rules (PCC rules) for the PDU session. When targeting a particular PDU session, the PCF may indicate, to the SMF, a method for allocating an IP address to the PDU Session, a default charging method for the PDU session, an address of the corresponding charging entity, triggers for requesting new policies, etc. The PCF may also target a service data flow (SDF) comprising one or more PDU sessions. When targeting an SDF, the PCF may indicate, to the SMF, policies for applying QoS requirements, monitoring traffic (e.g., for charging purposes), and/or steering traffic (e.g., by using one or more particular N6 interfaces).

**[0170]** The SMF may determine and/or allocate an IP address for the PDU session. The SMF may select one or more UPFs (a single UPF in the example of FIG. **12**) to handle the PDU session. The SMF may send an N4 session message to the selected UPF. The N4 session message may be an N4 Session Establishment Request and/or an N4 Session Modification Request. The N4 session message may include packet detection, enforcement, and reporting rules associated with the PDU session. In response, the UPF may acknowledge by sending an N4 session establishment response and/or an N4 session modification response.

**[0171]** The SMF may send PDU session management information to the AMF. The PDU session management information may be a session service request (e.g., Namf_Communication_N1N2MessageTransfer) message. The PDU session management information may include the PDU session ID. The PDU session management information may be a NAS message. The PDU session management information may include N1 session management information and/or N2 session management information. The N1 session management information may include a PDU session establishment accept message. The PDU session establishment accept message may include tunneling endpoint information of the UPF and quality of service (QoS) information associated with the PDU session.

**[0172]** The AMF may send an N2 request to the AN. The N2 request may include the PDU session establishment accept message. Based on the N2 request, the AN may determine AN resources for the UE. The AN resources may be used by the UE to establish the PDU session, via the AN, with the DN. The AN may determine resources to be used for the PDU session and indicate the determined resources to the UE. The AN may send the PDU session establishment accept message to the UE. For example, the AN may perform an RRC reconfiguration of the UE. After the AN resources are set up, the AN may send an N2 request acknowledge to the AMF. The N2 request acknowledge may include N2 session management information, for example, the PDU session ID and tunneling endpoint information of the AN.

**[0173]** After the data path for uplink data is set up at **1240**, the UE may optionally send uplink data associated with the PDU session. As shown in FIG. **12**, the uplink data may be sent to a DN associated with the PDU session via the AN and the UPF.

**[0174]** At **1250**, the network may update the PDU session context. The AMF may transmit a PDU session context update request to the SMF. The PDU session context update request may be a Nsmf_PDUSession_UpdateSMContext Request. The PDU session context update request may include the N2 session management information received from the AN. The SMF may acknowledge the PDU session context update. The acknowledgement may be a Nsmf_PDUSession_UpdateSMContext Response. The acknowledgement may include a subscription requesting that the SMF be notified of any UE mobility event. Based on the PDU session context update request, the SMF may send an N4 session message to the UPF. The N4 session message may be an N4 Session Modification Request. The N4 session message may include tunneling endpoint information of the AN. The N4 session message may include forwarding rules associated with the PDU session. In response, the UPF may acknowledge by sending an N4 session modification response.

**[0175]** After the UPF receives the tunneling endpoint information of the AN, the UPF may relay downlink data associated with the PDU session. As shown in FIG. **12**, the downlink data may be received from a DN associated with the PDU session via the AN and the UPF.

**[0176]** FIG. **13** illustrates examples of components of the elements in a communications network. FIG. **13** includes a wireless device **1310**, a base station **1320**, and a physical deployment of one or more network functions **1330** (henceforth "deployment **1330**"). Any wireless device described in the present disclosure may have similar components and may be implemented in a similar manner as the wireless device **1310**. Any other base station described in the present disclosure (or any portion thereof, depending on the architecture of the base station) may have similar components and may be implemented in a similar manner as the base station **1320**. Any physical core network deployment in the present disclosure (or any portion thereof, depending on the architecture of the base station) may have similar components and may be implemented in a similar manner as the deployment **1330**.

**[0177]** The wireless device **1310** may communicate with base station **1320** over an air interface **1370**. The communication direction from wireless device **1310** to base station **1320** over air interface **1370** is known as uplink, and the communication direction from base station **1320** to wireless device **1310** over air interface **1370** is known as downlink. Downlink transmissions may be separated from uplink transmissions using FDD, TDD, and/or some combination of duplexing techniques. FIG. **13** shows a single wireless device **1310** and a single base station **1320**, but it will be understood that wireless device **1310** may communicate with any number of base stations or other access network components over air interface **1370**, and that base station **1320** may communicate with any number of wireless devices over air interface **1370**.

**[0178]** The wireless device **1310** may comprise a processing system **1311** and a memory **1312**. The memory **1312** may comprise one or more computer-readable media, for example, one or more non-transitory computer readable media. The memory **1312** may include instructions **1313**. The processing system **1311** may process and/or execute instructions **1313**. Processing and/or execution of instructions **1313** may cause wireless device **1310** and/or processing system **1311** to perform one or more functions or activities. The memory **1312** may include data (not shown). One of the functions or activities performed by processing system **1311** may be to store data in memory **1312** and/or retrieve previously-stored data from memory **1312**. In an example, downlink data received from base station **1320** may be stored in memory **1312**, and uplink data for transmission to base station **1320** may be retrieved from memory **1312**. As illustrated in FIG. **13**, the wireless device **1310** may communicate with base station **1320** using a transmission processing system **1314** and/or a reception processing system **1315**. Alternatively, transmission processing system **1314** and reception processing system **1315** may be implemented as a single processing system, or both may be omitted and all processing in the wireless device **1310** may be performed by the processing system **1311**. Although not shown in FIG. **13**, transmission processing system **1314** and/or reception processing system **1315** may be coupled to a dedicated memory that is analogous to but separate from memory **1312**, and comprises instructions that may be processed and/or executed to carry out one or more of their respective functionalities. The wireless device **1310** may comprise one or more antennas **1316** to access air interface **1370**.

**[0179]** The wireless device **1310** may comprise one or more other elements **1319**. The one or more other elements **1319** may comprise software and/or hardware that provide features and/or functionalities, for example, a speaker, a microphone, a keypad, a display, a touchpad, a satellite transceiver, a universal serial bus (USB) port, a hands-free headset, a frequency modulated (FM) radio unit, a media player, an Internet browser, an electronic control unit (e.g., for a motor vehicle), and/or one or more sensors (e.g., an accelerometer, a gyroscope, a temperature sensor, a radar sensor, a lidar sensor, an ultrasonic sensor, a light sensor, a camera, a global positioning sensor (GPS) and/or the like). The wireless device **1310** may receive user input data from and/or provide user output data to the one or more one or more other elements **1319**. The one or more other elements **1319** may comprise a power source. The wireless device **1310** may receive power from the power source and may be configured to distribute the power to the other components in wireless device **1310**. The power source may comprise one or more sources of power, for example, a battery, a solar cell, a fuel cell, or any combination thereof.

**[0180]** The wireless device **1310** may transmit uplink data to and/or receive downlink data from base station **1320** via air interface **1370**. To perform the transmission and/or reception, one or more of the processing system **1311**, transmission processing system **1314**, and/or reception system **1315** may implement open systems interconnection (OSI) functionality. As an example, transmission processing system **1314** and/or reception system **1315** may perform layer 1 OSI functionality, and processing system **1311** may perform higher layer functionality. The wireless device **1310** may transmit and/or receive data over air interface **1370** using one or more antennas **1316**. For scenarios where the one or more antennas **1316** include multiple antennas, the multiple antennas may be used to perform one or more multi-antenna techniques, such as spatial multiplexing (e.g., single-user multiple-input multiple output (MIMO) or multi-user MIMO), transmit/receive diversity, and/or beamforming.

**[0181]** The base station **1320** may comprise a processing system **1321** and a memory **1322**. The memory **1322** may comprise one or more computer-readable media, for example, one or more non-transitory computer readable media. The memory **1322** may include instructions **1323**. The processing system **1321** may process and/or execute instructions **1323**. Processing and/or execution of instructions **1323** may cause base station **1320** and/or processing system **1321** to perform one or more functions or activities. The memory **1322** may include data (not shown). One of the functions or activities performed by processing system **1321** may be to store data in memory **1322** and/or retrieve previously-stored data from memory **1322**. The base station **1320** may communicate with wireless device **1310** using a transmission processing system **1324** and a reception processing system **1325**. Although not shown in FIG. **13**, transmission processing system **1324** and/or reception processing system **1325** may be coupled to a dedicated memory that is analogous to but separate from memory **1322**, and comprises instructions that may be processed and/or executed to carry out one or more of their respective functionalities. The wireless device **1320** may comprise one or more antennas **1326** to access air interface **1370**.

**[0182]** The base station **1320** may transmit downlink data to and/or receive uplink data from wireless device **1310** via air interface **1370**. To perform the transmission and/or reception, one or more of the processing system **1321**, transmission processing system **1324**, and/or reception system **1325** may implement OSI functionality. As an example, transmission processing system **1324** and/or reception system **1325** may perform layer 1 OSI functionality, and processing system **1321** may perform higher layer functionality. The base station **1320** may transmit and/or receive data over air interface **1370** using one or more antennas **1326**. For scenarios where the one or more antennas **1326** include multiple antennas, the multiple antennas may be used to perform one or more multi-antenna techniques, such as spatial multiplexing (e.g., single-user multiple-input multiple output (MIMO) or multi-user MIMO), transmit/receive diversity, and/or beamforming.

**[0183]** The base station **1320** may comprise an interface system **1327**. The interface system **1327** may communicate with one or more base stations and/or one or more elements of the core network via an interface **1380**. The interface **1380** may be wired and/or wireless and interface system **1327** may include one or more components suitable for communicating via interface **1380**. In FIG. **13**, interface **1380** connects base station **1320** to a single deployment **1330**, but it will be understood that wireless device **1310** may communicate with any number of base stations and/or CN deployments over interface **1380**, and that deployment **1330** may communicate with any number of base stations and/or other CN deployments over interface **1380**. The base station **1320** may comprise one or more other elements **1329** analogous to one or more of the one or more other elements **1319**.

**[0184]** The deployment **1330** may comprise any number of portions of any number of instances of one or more network functions (NFs). The deployment **1330** may comprise a processing system **1331** and a memory **1332**. The memory **1332** may comprise one or more computer-readable media, for example, one or more non-transitory computer readable media. The memory **1332** may include instructions **1333**. The processing system **1331** may process and/or execute instructions **1333**. Processing and/or execution of instructions **1333** may cause the deployment **1330** and/or processing system **1331** to perform one or more functions or activities. The memory **1332** may include data (not shown). One of the functions or activities performed by processing system **1331** may be to store data in memory **1332** and/or retrieve previously-stored data from memory **1332**. The deployment **1330** may access the interface **1380** using an interface system **1337**. The deployment **1330** may comprise one or more other elements **1339** analogous to one or more of the one or more other elements **1319**.

**[0185]** One or more of the systems **1311**, **1314**, **1315**, **1321**, **1324**, **1325**, and/or **1331** may comprise one or more controllers and/or one or more processors. The one or more controllers and/or one or more processors may comprise, for example, a general-purpose processor, a digital signal processor (DSP), a microcontroller, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) and/or other programmable logic device, discrete gate and/or transistor logic, discrete hardware components, an on-board unit, or any combination thereof. One or more of the systems **1311**, **1314**, **1315**, **1321**, **1324**, **1325**, and/or **1331** may perform signal coding/processing, data processing, power control, input/output processing, and/or any other functionality that may enable wireless device **1310**, base station **1320**, and/or deployment **1330** to operate in a mobile communications system.

**[0186]** Many of the elements described in the disclosed embodiments may be implemented as modules. A module is defined here as an element that performs a defined function and has a defined interface to other elements. The modules described in this disclosure may be implemented in hardware, software in combination with hardware, firmware, wetware (e.g. hardware with a biological element) or a combination thereof, which may be behaviorally equivalent. For example, modules may be implemented as a software routine written in a computer language configured to be executed by a hardware machine (such as C, C++, Fortran, Java, Basic, Matlab and/or the like) or a modeling/simulation program such as Simulink, Stateflow, GNU Octave, or LabVIEWMathScript. It may be possible to implement modules using physical hardware that incorporates discrete or programmable analog, digital and/or quantum hardware. Examples of programmable hardware comprise computers, microcontrollers, microprocessors, DSPs, ASICS, FPGAs, and complex programmable logic devices (CPLDs). Computers, microcontrollers and microprocessors may be programmed using languages such as assembly, C, C++ and/or the like. FPGAs, ASICs and CPLDs are often programmed using hardware description languages (HDL) such as VHSIC hardware description language (VHDL) or Verilog that configure connections between internal hardware modules with lesser functionality on a programmable device. The mentioned technologies are often used in combination to achieve the result of a functional module.

**[0187]** The wireless device **1310**, base station **1320**, and/or deployment **1330** may implement timers and/or counters. A timer/counter may start at an initial value. As used herein, starting may comprise restarting. Once started, the timer/counter may run. Running of the timer/counter may be associated with an occurrence. When the occurrence occurs, the value of the timer/counter may change (for example, increment or decrement). The occurrence may be, for example, an exogenous event (for example, a reception of a signal, a measurement of a condition, etc.), an endogenous event (for example, a transmission of a signal, a calculation, a comparison, a performance of an action or a decision to so perform, etc.), or any combination thereof. In the case of a timer, the occurrence may be the passage of a particular amount of time. However, it will be understood that a timer may be described and/or implemented as a counter that counts the passage of a particular unit of time. A timer/counter may run in a direction of a final value until it reaches the final value. The reaching of the final value may be referred to as expiration of the timer/counter. The final value may be referred to as a threshold. A timer/counter may be paused, wherein the present value of the timer/counter is held, maintained, and/or carried over, even upon the occurrence of one or more occurrences that would otherwise cause the value of the timer/counter to change. The timer/counter may be un-paused or continued, wherein the value that was held, maintained, and/or carried over begins changing again when the one or more occurrence occur. A timer/counter may be set and/or reset. As used herein, setting may comprise resetting. When the timer/counter sets and/or resets, the value of the timer/counter may be set to the initial value. A timer/counter may be started and/or restarted. As used herein, starting may comprise restarting. In some embodiments, when the timer/counter restarts, the value of the timer/counter may be set to the initial value and the timer/counter may begin to run.

**[0188]** FIGS. **14**A, **14**B, **14**C, and **14**D illustrate various example arrangements of physical core network deployments, each having one or more network functions or portions thereof. The core network deployments comprise a deployment **1410**, a deployment **1420**, a deployment **1430**, a deployment **1440**, and/or a deployment **1450**. Each deployment may be analogous to, for example, the deployment **1330** depicted in FIG. **13**. In particular, each deployment may comprise a processing system for performing one or more functions or activities, memory for storing data and/or instructions, and an interface system for communicating with other network elements (for example, other core network deployments). Each deployment may comprise one or more network functions (NFs). The term NF may refer to a particular set of functionalities and/or one or more physical elements configured to perform those functionalities (e.g., a processing system and memory comprising instructions that, when executed by the processing system, cause the processing system to perform the functionalities). For example, in the present disclosure, when a network function is described as performing X, Y, and Z, it will be understood that this refers to the one or more physical elements configured to perform X, Y, and Z, no matter how or where the one or more physical elements are deployed. The term NF may refer to a network node, network element, and/or network device.

**[0189]** As will be discussed in greater detail below, there are many different types of NF and each type of NF may be associated with a different set of functionalities. A plurality of different NFs may be flexibly deployed at different locations (for example, in different physical core network deployments) or in a same location (for example, co-located in a same deployment). A single NF may be flexibly deployed at different locations (implemented using different physical core network deployments) or in a same location. Moreover, physical core network deployments may also implement one or more base stations, application functions (AFs), data networks (DNs), or any portions thereof. NFs may be implemented in many ways, including as network elements on dedicated or shared hardware, as software instances running on dedicated or shared hardware, or as virtualized functions instantiated on a platform (e.g., a cloud-based platform).

**[0190]** FIG. **14**A illustrates an example arrangement of core network deployments in which each deployment comprises one network function. A deployment **1410** comprises an NF **1411**, a deployment **1420** comprises an NF **1421**, and a deployment **1430** comprises an NF **1431**. The deployments **1410**, **1420**, **1430** communicate via an interface **1490**. The deployments **1410**, **1420**, **1430** may have different physical locations with different signal propagation delays relative to other network elements. The diversity of physical locations of deployments **1410**, **1420**, **1430** may enable provision of services to a wide area with improved speed, coverage, security, and/or efficiency.

**[0191]** FIG. **14**B illustrates an example arrangement wherein a single deployment comprises more than one NF. Unlike FIG. **14**A, where each NF is deployed in a separate deployment, FIG. **14**B illustrates multiple NFs in deployments **1410**, **1420**. In an example, deployments **1410**, **1420** may implement a software-defined network (SDN) and/or a network function virtualization (NFV).

**[0192]** For example, deployment **1410** comprises an additional network function, NF **1411**A. The NFs **1411**, **1411**A may consist of multiple instances of the same NF type, co-located at a same physical location within the same deployment **1410**. The NFs **1411**, **1411**A may be implemented independently from one another (e.g., isolated and/or independently controlled). For example, the NFs **1411**, **1411**A may be associated with different network slices. A processing system and memory associated with the deployment **1410** may perform all of the functionalities associated with the NF **1411** in addition to all of the functionalities associated with the NF **1411**A. In an example, NFs **1411**, **1411**A may be associated with different PLMNs, but deployment **1410**, which implements NFs **1411**, **1411**A, may be owned and/or operated by a single entity.

**[0193]** Elsewhere in FIG. **14**B, deployment **1420** comprises NF **1421** and an additional network function, NF **1422**. The NFs **1421**, **1422** may be different NF types. Similar to NFs **1411**, **1411**A, the NFs **1421**, **1422** may be co-located within the same deployment **1420**, but separately implemented. As an example, a first PLMN may own and/or operate deployment **1420** having NFs **1421**, **1422**. As another example, the first PLMN may implement NF **1421** and a second PLMN may obtain from the first PLMN (e.g., rent, lease, procure, etc.) at least a portion of the capabilities of deployment **1420** (e.g., processing power, data storage, etc.) in order to implement NF **1422**. As yet another example, the deployment may be owned and/or operated by one or more third parties, and the first PLMN and/or second PLMN may procure respective portions of the capabilities of the deployment **1420**. When multiple NFs are provided at a single deployment, networks may operate with greater speed, coverage, security, and/or efficiency.

**[0194]** FIG. **14**C illustrates an example arrangement of core network deployments in which a single instance of an NF is implemented using a plurality of different deployments. In particular, a single instance of NF **1422** is implemented at deployments **1420**, **1440**. As an example, the functionality provided by NF **1422** may be implemented as a bundle or sequence of subservices. Each subservice may be implemented independently, for example, at a different deployment. Each subservices may be implemented in a different physical location. By distributing implementation of subservices of a single NF across different physical locations, the mobile communications network may operate with greater speed, coverage, security, and/or efficiency.

**[0195]** FIG. **14**D illustrates an example arrangement of core network deployments in which one or more network functions are implemented using a data processing service. In FIG. **14**D, NFs **1411**, **1411**A, **1421**, **1422** are included in a deployment **1450** that is implemented as a data processing service. The deployment **1450** may comprise, for example, a cloud network and/or data center. The deployment **1450** may be owned and/or operated by a PLMN or by a non-PLMN third party. The NFs **1411**, **1411**A, **1421**, **1422** that are implemented using the deployment **1450** may belong to the same PLMN or to different PLMNs. The PLMN(s) may obtain (e.g., rent, lease, procure, etc.) at least a portion of the capabilities of the deployment **1450** (e.g., processing power, data storage, etc.). By providing one or more NFs using a data processing service, the mobile communications network may operate with greater speed, coverage, security, and/or efficiency.

**[0196]** As shown in the figures, different network elements (e.g., NFs) may be located in different physical deployments, or co-located in a single physical deployment. It will be understood that in the present disclosure, the sending and receiving of messages among different network elements is not limited to inter-deployment transmission or intra-deployment transmission, unless explicitly indicated.

**[0197]** In an example, a deployment may be a ‘black box’ that is preconfigured with one or more NFs and preconfigured to communicate, in a prescribed manner, with other ‘black box’ deployments (e.g., via the interface **1490**). Additionally or alternatively, a deployment may be configured to operate in accordance with open-source instructions (e.g., software) designed to implement NFs and communicate with other deployments in a transparent manner. The deployment may operate in accordance with open RAN (O-RAN) standards.

**[0198]** In example embodiments as depicted in FIG. **15**A, FIG. **15**B, FIG. **15**C, different tracking areas may support different slices (e.g., different network slices, different network services, etc.) and/or different combinations of slices. In one example, a tracking area (TA) may correspond to the (combined) coverage areas of one or more cells of one or more base stations. In other example, a base station may cover one or more cells of one or more TAs. A TA may comprise one or more NG-RANs, one or more gNBs, and/or one or more ng-eNBs and/or the like. A NG-RAN (or a gNB, a ng-eNB, a base station) may comprise one or more TAs. A NG-RAN may comprise one or more gNBs, and/or one or more ng-eNBs, one or more N3IWFs and/or the like. A gNB may comprise one or more gNB-CU and/or one or more gNB-DUs. A gNB-CU may comprise a gNB-CU-CP and/or one or more gNB-CU-UPs.

**[0199]** FIG. **15**A illustrates an example of TAs that are undifferentiated with respect to slice support. For example, all the TAs depicted in FIG. **15**A (TA1, TA2, TA3) support the same combination of slices (slice A and slice B). When a wireless device (e.g., UE) enters a TA (e.g., TA1), the UE may send a registration request, in TA1 (e.g., via a base station associated with TA1, via a cell of TA1), to an access and mobility management function (e.g., AMF, etc.). The registration request may indicate a requested slice (e.g., slice A). The AMF may determine that TA1 supports the requested slice (slice A) and may determine to accept the registration. The AMF may determine a registration area of the UE. The registration area includes TA1 and may include other TAs. Support for the requested slice (slice A) may be one factor for determining the addition of other TAs to the registration area. For example, the AMF may add TA2 and TA3 to the registration area for the UE, based on TA2 and TA3 both supporting the requested slice (slice A). The AMF may send a registration accept to the UE. The registration accept may indicate the registration area. For example, the registration accept may comprise a TA list indicating the TAs in the registration area (e.g., TA1, TA2, and TA3). If the UE exits the registration area, it may need to perform the registration update procedure. The UE may be able to avoid registration update procedures for as long as it remains in the registration area.

**[0200]** FIG. **15**B illustrates an example of TAs that are differentiated with respect to slice support. In particular, the TAs support different slices and/or combinations of slices. When the UE enters TA1, the UE may send a registration request, in TA1, to the AMF. The registration request may indicate a request for slice A. The AMF may determine that TA1 supports slice A and may determine to accept the registration. The AMF may determine that an adjacent TA also supports slice A (e.g., TA2), and that some other TAs do not support slice A (e.g., TA3). The AMF may send a registration accept to the UE indicating a registration area that is restricted to TAs which support slice A (TA1 and TA2).

**[0201]** FIG. **15**C illustrates another example of TAs that are differentiated with respect to slice support. When the UE enters TA1, the UE may send a registration request, via TA1, to the AMF. The registration request may indicate a request for slice A. The AMF may determine that TA1 supports slice A and may determine to accept the registration. The AMF may determine that there are no adjacent TAs which support slice A. The AMF may send a registration accept to the wireless device indicating a registration area that is restricted to adjacent TAs which support slice A (TA1 only).

**[0202]** In existing technologies, the network may be substantially undifferentiated with respect to slice support. However, as new use cases emerge, it is possible that differentiation based on slice support increases. For example, as shown in FIG. **15**A, from the perspective of slice support, one TA may be no more or less suitable than the others. This may enable the AMF to indicate a wide registration area (including TA1, TA2, TA3). However, there may be advantages to network differentiation, which may lead to the scenarios depicted in FIG. **15**B and FIG. **15**C. For example, a network operator may customize and/or fine-tune one or more network components of a first TA (e.g., base stations) to serve a particular network slice (e.g., slice A). As network components are increasingly customized to support a specific slice (e.g., slice A), they may become less suited to serve other slices (e.g., slice B). To compensate, the network operator may customize a different set of network components to serve slice B. In this way, slice support differentiation may proliferate within the network. Slice support differentiation may improve network service in many respects. But many existing mechanisms assume that TAs are undifferentiated. Existing approaches fail to address the unintended consequences of network differentiation with respect to slice support, as will be discussed in greater detail below.

**[0203]** FIG. **16** illustrates an example of wireless device registration update as the UE moves through several tracking areas (TA1, TA2, TA3). In FIG. **16**, the TAs may have the same slice support characteristics as depicted in FIG. **15**B. In particular, TA1 supports only slice A, TA2 supports slice A and slice B, and TA3 supports only slice A. Due to the high level of slice differentiation among the TAs, they can not be added to the same registration area. As a result, every movement of the UE from one TA to another TA necessitates a registration update procedure. This causes high levels of power consumption and signaling overhead.

**[0204]** For example, when a wireless device (e.g., UE) moves into TA1, the UE may send a registration request to the network via TA1. In an example, the registration request may be based on reception of a system information block (SIB) received from a cell of a base station associated (supporting) with the TA1. The SIB may indicate that the base station and/or the cell is associated with the TA1.

**[0205]** The registration request may indicate that the UE requests a requested slices. A requested slices may be a list of slices that the UE wants to use. For example, the requested slices may comprise slice A and slice B. The registration request may be received by an access and mobility management function (e.g., AMF). The AMF may determine that one or more slices (e.g., slice A) of the requested slices is supported by TA1. The AMF may send a registration accept indicating that the slice A is allowed. The registration accept may also indicate a registration area (e.g., registration 1, first registration area) of the UE. The registration area may comprise a TA list. The TA list may include TA1, because the registration request is received via TA1 and/or because TA1 supports one or more slices of the requested slices. Because TA1 does not support slice B, the AMF may not allow the UE for slice B. The TA list may exclude TA2 because TA2 support different set of slices than TA1.

**[0206]** The UE may later move into TA2. Because the UE's registration area (registration area 1) does not include TA2, the UE may be forced to re-register (e.g., initiate/perform a registration update procedure). As shown in FIG. **16**, a registration request may be sent to the AMF via TA2, and may indicate that the UE requests slice A and slice B. The AMF may send a registration accept indicating allowance of slice A and slice B. The registration accept may indicate a new registration area (registration area 2) of the UE. The new registration area (registration area 2) includes TA2, because the registration request was received via TA2 and because TA2 supports one or more slices of the requested slices (slice A, slice B). The tracking area list may exclude TA1 and TA3 because TA1 and TA3 do not support slice B.

**[0207]** The UE may later move into TA3. Because the UE's registration area (registration area 2) does not include TA3, the UE may be forced to re-register (e.g., initiate/perform a registration update procedure). As shown in FIG. **16**, yet another registration request may be sent to the AMF via TA3, and may indicate that the UE requests slice A and slice B. The AMF may send a registration accept indicating slice A. The registration accept may indicate that the registration area (registration area 3) of the UE includes TA3, because the registration request was received via TA3 and because TA3 supports one or more slices of the requested slice. The tracking area list may exclude TA2 because TA2 supports different set of slices than TA3.

[0208] The example of FIG. 16 illustrates the challenges presented by a highly differentiated network. In existing, undifferentiated networks (e.g., analogous to FIG. 15A), a registration area may encompass several adjacent tracking areas, and a UE can move from TA1 to TA2 to TA3 without leaving the registration area. Increased slice differentiation may have benefits, but as FIG. 16 demonstrates, there are new issues which arise.

[0209] FIG. 17 illustrates one possible method of addressing the problem of over-frequent registration updates. In particular, registration areas may be determined without necessarily considering slice support. For example, TA1, TA2, TA3 may be added to a single registration area, even though support of network slices by TA1, TA2, TA3 are not uniform. This approach reduces the number of registration updates because a UE which leaves TA1 and enters TA2 has not changed its registration area. However, this approach can cause problems with service interruption, as will be discussed in greater detail below.

[0210] In the example of FIG. 17, a wireless device (e.g., UE) registers in TA1. The UE sends a registration request message, requesting support for slice A and slice B. The access and mobility management function (e.g., AMF) accepts the registration request and sends a registration accept message. The registration accept message may indicate that the allowed network slices for the UE is slice A, and that registration area for the UE comprises TA1, TA2 and TA3. The allowed network slices and/or the registration area may be determined, based on support for slice A within TA1, TA2 and TA3. The AMF indicates that the registration area corresponds to a tracking area list which includes TA1, TA2, and TA3.

[0211] The UE may later move to TA2. Because TA2 is in the UE's registration area (i.e., in the UE's TA list), there is no need for the UE to perform a registration update procedure. This helps to alleviate the problem of over-frequent registration update, but creates a new problem relating to service interruption.

[0212] For example, the UE may start an application within TA2. The application may require using slice B, because slice B can meet service requirement of the application. To deliver traffic for the application, the UE needs to establish a PDU session over the slice B. However, based on the registration performed in TA1, the allowed network slices for the UE does not comprise the slice B. Because the slice B is not allowed for the UE, the UE cannot request PDU establishment for the slice B. Accordingly, the application cannot send or receive data, in TA2 where the slice B supporting the application is deployed, because slice B is not allowed. Moreover, the problem may not be recognized, so the network and UE may not attempt to communicate, causing service degradation to the application. In the existing technologies, differentiated support for network slices may cause frequent signaling procedure with impact on UE battery and/or may not provide data communication services at locations where a network slice for the data communication service can be provided.

[0213] FIG. 18 may depict one example embodiment. By receiving information of TAs where a network slice is allowed and/or rejected (e.g., not allowed) to a UE, the UE may be able to use a network slice at places where the network slice is available, while reducing signaling overhead.

[0214] In an example, a UE may send a registration request message while staying in TA1. The registration request message may comprise at least one of:

[0215] an identifier of the UE. This may identify the UE sending the registration request message and/or the like. For example, this may be a SUPI, Subscription Concealed Identifier (SUCI), 5G Globally Unique Temporary Identifier (5G-GUTI), TMSI, IMSI, IMEI, and/or the like

[0216] a requested slices. This may indicate one or more network slices that the UE requests for registration. This may comprise one or more identifiers of the one or more network slices. For example, this may be one or more S-NSSAIs, one or more NSSAI and/or the like. This may be a list indicating one or more network slices requested by the UE.

[0217] In an example, the UE may send the registration request message via a cell of the TA1. For example, the UE may send a RRC message comprising the registration request message to a NG-RAN via the cell. The NG-RAN may receive the RRC message from the UE via the cell. The NG-RAN may send to an AMF, a N2 request message comprising the registration request message.

[0218] In an example, the AMF may receive the registration request message of the N2 request message. Based on the registration request message, the AMF may send a registration response message to the UE. For example, the registration response message may be at least one of a registration accept message, UE configuration update message, a registration reject message, a NAS message, and/or the like. The registration response may comprise at least one of:

[0219] A registration area (RA). This may indicate an area where the UE is registered. For example, this may comprise one or more identifiers of TAs. For example, this may be a list of TAs where the UE is registered.

[0220] An allowed slices. This may be a list of one or more allowed network slices. This may comprise one or more identifiers of the one or more allowed network slices. This may indicate one or more network slices for which the UE is allowed to use. For example, this may be a list of the one or more allowed network slices. For example, this may indicate one or more identifiers of the one or more allowed network slices for which the UE is allowed. For example, the UE may be allowed to use the one or more allowed network slices, in any/all TAs of the RA. For example, if a RA for the UE includes a TA A, TA B, and TA C and/or if slice Z is one of the one or more allowed network slices, the UE may be allowed to use slice Z in TA A, TA B, and TA C.

[0221] Partly rejected slices. This may be one or more partly (partially) rejected S-NSSAIs, one or more partly rejected NSSAIs, and/or the like. For example, this may indicate one or more network slices that are rejected (not allowed to use) in one or more TAs of the RA and/or that are allowed in other one or more TAs of the RA. For example, the partly rejected slices may not be allowed in the TA where the UE sends the registration request message. For example, this may indicate one or more network slices that are rejected (not allowed to use) in one or more TAs indicated by (based on) the partly rejected TA list. The AMF may send the partly rejected slices to the UE, to enable the UE to register/request one or more network slices of the partly rejected slices, when the UE moves to a TA supporting the one or more partly rejected slices.

**[0222]** Partly rejected TA list. This may indicate one or more TAs from the RA. This may be one or more identifiers of the one or more TAs from the RA. This may indicate at least one of one or more TAs where the partly rejected slices are supported and/or one or more TAs where the partly rejected (not allowed) slices are not supported. For example, if the partly rejected TA list indicates the one or more TAs (e.g., TA K1) where the partly rejected slices are supported, other one or more TAs (e.g., TA K2, TA K3) of the RA (e.g., TA K1, TA K2, TA K3) may be the one or more TAs where the partly rejected slice are not supported. For example, if the partly rejected TA list indicates the one or more TAs (TA K2, TA K3) where the partly rejected slices are rejected (e.g., not supported, not allowed), other one or more TAs (e.g., TA K1) of the RA (e.g., TA K2, TA K3) may be the one or more TAs where the partly rejected slice are supported (allowed). For example, the one or more TAs of the partly rejected TA list may belong to the RA. In one example, the partly rejected TA list may indicate one or more first TAs for a first network slice and/or one or more second TAs for a second network slice. In one example, the partly rejected TA list may indicate one or more third TAs for both a third network slice and a fourth network slice. For example, the RA may comprise TA111, TA112 and TA 113. If the partly rejected TA list for slice K indicates that the TA112 supports the partly rejected slices (e.g., slice K), the slice K may not be supported (allowed) in TA 111, TA113. If the partly rejected TA list for slice K indicates that TA113 and TA111 do not support the partly rejected slices (e.g., slice K), the slice K may be supported in TA 112.

**[0223]** For example, the registration response message may indicate that the RA comprises TA1, TA2 and TA3, that the allowed network slices comprises the slice A, that partly rejected slices comprises the slice B, and/or that the partly rejected TA list comprises TA2 (e.g., that TA 2 supports the slice B). For example, based on that the UE sends the registration request message from TA1, that the TA1 supports slice A, that the TA2 supports slice A and slice B, and/or that the TA 3 supports the slice A, the AMF may comprise the registration response as such.

**[0224]** In an example, the UE may receive the registration response message. Based on the registration response message, the UE in TA1 may establish a PDU session for the slice A. Based on the registration response message, the UE in TA1 may not establish a PDU session for the slice B. For example, based on that the partly rejected slices comprises the slice B, based on that the UE is in one or more TAs (e.g., TA1) where the partly rejected slices are not supported, the UE may not establish the PDU session for the slice B.

**[0225]** In an example, the UE may move from TA1 (supporting slice A) to TA2 (supporting slice A and slice B). Based on the partly rejected slice and/or the partly rejected TA list, the UE may determine that one or more slices (e.g., slice B) of the partly rejected slices is supported in TA2. Based on that slice B is supported in TA2, to request one or more slices of the partly rejected slices, and/or to make the slice B allowed, the UE may perform a registration update procedure. For example, the UE may send a second registration request message to the AMF. For example, the second registration request message may comprise the requested network slices (e.g., slice A and slice B).

**[0226]** In an example, the AMF may receive the second registration request message. In response to the second registration request message, the AMF may send a second registration response message to the UE. Based on that the second registration request message is received via the TA2 supporting the slice A and the slice B, the AMF may determine to allow the slice A and slice B. For example, the second registration response message may comprise a second RA, and/or a second allowed slices. For example, the second RA may comprise the TA2, and/or the second allowed slices may comprise the slice A and slice B.

**[0227]** In an example, the UE may receive the second registration response message from the AMF. Based on that the second registration response indicates that the slice B is allowed, the UE may send to SMF (via AMF) a PDU session establishment request message for the slice B. The SMF may send to the UE, a PDU session establishment accept message for the slice B. Via the established PDU session for the slice B, the UE may send and receive data for applications over the slice B.

**[0228]** As shown in the example of FIG. **18**, by using the partly rejected slices and/or the partly rejected TA list, the UE can determine whether/where a network slice is supported in a TA/RA, reducing unnecessary signaling.

**[0229]** FIG. **19** may depict one example embodiment. By delivering information of TAs where a network slice is allowed and/or rejected (e.g., not allowed) to a UE, the UE may be able to use a network slice at places where the network slice is available, while reducing signaling overhead.

**[0230]** In an example, a UE may send a registration request message while staying in TA1. The registration request message may comprise at least one of:

**[0231]** The identifier of the UE.

**[0232]** The requested slices.

**[0233]** In an example, the UE may send the registration request message via the cell of the TA1. For example, the UE may send the RRC message comprising the registration request message to the NG-RAN via the cell. The NG-RAN may receive the RRC message from the UE. The NG-RAN may send to the AMF, the N2 request message comprising the registration request message.

**[0234]** In an example, the AMF may receive the registration request message of the N2 request message. Based on the registration request message, the AMF may send a registration response message to the UE. The registration response may comprise at least one of:

**[0235]** The registration area (RA). The RA may comprise one or more first-type TAs and/or one or more second-type TAs. For example, in the one or more first-type TAs, the UE may be allowed to use one or more network slices indicated by the allowed slices and/or one or more network slices indicated by a partly allowed slices. For example, in the one or more second-type TAs, the UE may be allowed to use the one or more network slices indicated by the allowed slices and/or may be not allowed to use the one or more network slices indicated by the partly allowed slices.

**[0236]** The allowed slices.

**[0237]** A partly allowed slices. This may be one or more partly allowed S-NSSAIs, a partly allowed NSSAI, and/or the like. This may indicate one or more partly allowed (accepted) network slices. This may be a list of one or more partly allowed (accepted) network slices. For example, this may indicate one or more network slices that are allowed in one or more first-type TAs of the RA, and/or that are not allowed in one or more second-type TAs of the RA.

**[0238]** A partly allowed TA list. This may indicate one or more TAs, and/or may be one or more identifiers of the one or more TAs. This may indicate at least one of one or more TAs (e.g., first-type TAs) where the partly allowed slices are supported and/or one or more TAs (e.g., second-type TAs) where the partly allowed slices are not supported. For example, if the partly allowed TA list indicates the one or more TAs where the partly allowed slices are supported, other (or remaining) one or more TAs (e.g., second-type TAs) of the RA may be the one or more TAs where the partly allowed slices are not supported. For example, if the partly allowed TA list indicates the one or more TAs (e.g., second-type TAs) where the partly allowed slices are rejected (e.g., not supported, not allowed), other (or remaining) one or more TAs (e.g., first-type TAs) of the RA may be the one or more TAs where the partly allowed slice are supported (allowed). For example, the one or more TAs of the partly allowed TA list may belong to the RA. In one example, the partly allowed TA list may indicate one or more fifth TAs for a fifth network slice and/or one or more sixth TAs for a sixth network slice. In one example, the partly allowed TA list may indicate one or more seventh TAs for both a seventh network slice and an eighth network slice.

**[0239]** For example, the registration response message may indicate that the RA comprises TA1, TA2, TA3, that the allowed network slices comprises the slice A, that the partly allowed slices comprises the slice B, and/or that the partly allowed TA list comprises TA2 (e.g., TA2 supports the slice B). For example, based on that the UE sends the registration request message from TA1, that the TA1 supports slice A, that the TA2 supports slice A and slice B, and/or that the TA 3 supports the slice A, the AMF may comprise the registration response as such.

**[0240]** In an example, the UE may receive the registration response message. Based on the registration response message, the UE may establish a PDU session for the slice A from TA1. Based on the registration response message, the UE in TA1 may not establish a PDU session for the slice B. For example, based on that the partly allowed slices comprises the slice B, based on the partly allowed TA list, and/or based on that the UE is in one or more TAs where the partly allowed slices are not supported, the UE may not establish the PDU session for the slice B from TA1.

**[0241]** In an example, the UE may move from TA1 (supporting slice A) to TA2 (supporting slice A and slice B). Based on the partly allowed slices and/or the partly allowed TA list, the UE may determine that the partly allowed slice (e.g., slice B) is supported in TA2. Based on that TA2 is one of TAs in the RA, the UE may not perform a registration update procedure. In an example, based on that the slice B is one of network slices of the partly allowed slices, based on the partly allowed TA list, and/or based on that the TA2 is one of TAs supporting the slice B, the UE in TA2 may send to SMF (via AMF) a PDU session establishment request message for the slice B. The SMF may send to the UE, a PDU session establishment accept message for the slice B.

**[0242]** As shown in the example of FIG. **19**, by using the partly allowed slices and/or the partly allowed TA list, the UE can determine whether a network slice is supported in a TA, reducing unnecessary signaling.

**[0243]** The embodiments as shown in examples of FIG. **18** and FIG. **19** may reduce unnecessary signaling from a UE, and/or may assist UE to get a network service (slice) where the network service is provided. Based on the processing capabilities, usage scenarios, network deployment, and/or the like, the UE may support the example of FIG. **18** and/or the example of FIG. **19**. Similarly, a network may support the example of FIG. **18** and/or FIG. **19**.

**[0244]** FIG. **20** may show one example scenario. For example, different UE may support different mode (e.g., partly allowed slices, partly rejected slices) of operations.

**[0245]** In an example, UE A may support partly rejected slices and/or UE B may support partly allowed slices. For example, the UE A may support the feature of the partly rejected slices (e.g., be able to receive information associated with the partly rejected slices and/or may be able to process information associated with the partly rejected slices). For example, the UE B may support the feature of the partly allowed slices (e.g., be able to receive information associated with the partly allowed slices and/or may be process information associated with the partly allowed slices).

**[0246]** In an example, the UE A may send a registration request message to the AMF. For example, the AMF may support the feature of partly allowed slices. Based on the registration request message, the AMF may send a registration accept message. For example, the registration accept message may comprise a RA, a partly allowed slices and/or a partly allowed TA list. For example, the RA may comprise TA1, TA2, TA3. For example, the partly allowed slices may comprise slice B.

**[0247]** In an example, the UE A may receive the registration accept message. Because the UE A does not support the feature of partly allowed slice, the UE A may not be able to interpret the registration accept message and/or may discard the registration accept message. For example, because the UE A may not be able to process the registration accept message, the UE A may trigger another registration procedure and/or may perform selection of other networks. This may cause signaling congestion and/or may waste battery of the UE.

**[0248]** In an example, the UE may send information of supported mode of operation. This may assist the network to determine which information to send to the UE. This may reduce configuration leading to service interruption time of the UE.

**[0249]** In the specification, support of partly rejected slices may be support of a feature of partly rejected slices. Whether a node supports the feature of partly rejected slices may mean whether the node (e.g., a UE, a NG-RAN, a core network node) can process/send/receive/handle/interpret information related to partly rejected slices, can support functionalities (e.g., processing, sending, receiving, handling, acting) associated with partly rejected slices, and/or can act based on the information related to partly rejected slices. For example, the information related to the partly rejected slices may be one or more identifiers of the one or more partly rejected slices, the partly rejected slice TAs, and/or the like. For example, acting based on the information related to partly rejected slices may be, e.g., sending a registration request message for a partly rejected slice in TAs where the partly rejected slice is supported, not sending a request for the partly rejected slice in TA where the partly rejected slice is not supported, and/or the like. For example, a capability indicator for the feature of the partly rejected slices may indicate whether a node supports the feature of the partly rejected slices. For example, the capability indicator for the partly rejected slices may indicate that the node supports a feature of the partly rejected slices (functionalities) and/or that the node does not support a feature of the partly rejected slices (functionalities). For example, if a node does not send the capability indicator for the partly rejected slices, this may indicate that the node does not support the feature of the partly rejected slices (functionalities). For example, the feature of the partly rejected slices (function alities) may be e.g., sending/receiving information associated with the partly rejected slices, performing registration based on the information associated with the partly rejected slices.

**[0250]** In the specification, support of partly allowed (accepted) slices may be support of a feature of partly allowed slices. Whether a node supports the feature of partly allowed slices may mean whether a node (e.g., a UE, a NG-RAN, a core network node) can process/send/receive/handle/interpret information related to partly allowed slices, can support functionalities (e.g., processing, sending, receiving, handling, acting) associated with partly allowed slices, and/or can act based on the information related to partly allowed slices. The support of partly allowed slices may be a support of a feature of partly allowed slices. The support of partly allowed slices may be a support of a feature of partly allowed slices functionalities. For example, the information related to the partly allowed slices may be the partly allowed slices, the partly allowed slice TAs, and/or the like. For example, acting based on the information related to partly allowed slices may be sending a request message (e.g., a service request, a registration request, a PDU session request message) in a TA of the partly allowed slice TAs where the partly allowed slice is supported, not sending a request message (e.g., a service request, a registration request, a PDU session request message) in TAs where the partly allowed slice is not supported, and/or the like. For example, a capability indicator for the partly allowed slices may indicate whether a node supports a feature of the partly allowed slices. For example, that a node supports the feature of the partly allowed slices may be that the node supports the feature of partly allowed slices functionalities. For example, the capability indicator for the partly allowed slices may indicate that the node supports a feature of the partly allowed slices (functionalities) and/or that the node does not support a feature of the partly allowed slices (functionalities). For example, if a node does not send the capability indicator for the feature of the partly allowed slices, this may indicate that the node does not support the feature of the partly allowed slices (functionalities). For example, the feature of the partly allowed slices (functionalities) may be e.g., sending/receiving information associated with the partly allowed slices, and/or performing actions (e.g., registration, resource allocation, determining, selecting a node, and/or the like) based on the information associated with the partly rejected slices. For example, the partly allowed network slices may be the partly allowed slices. For example, the partly rejected network slices may be the partly rejected slices.

**[0251]** In the specification, the term "NG-RAN" may be interpreted as a base station, which may comprise at least one of a gNB, an eNB, a ng-eNB, a NodeB, an access node, an access point, an N3IWF, a relay node, a base station central unit (e.g., gNB-CU), a base station distributed unit (e.g., gNB-DU), and/or the like. In the specification, a gNB may be interpreted as a base station. In the specification, a gNB-CU may be interpreted as a base station central unit. In the specification, a gNB-DU may be interpreted as a base station distributed unit.

**[0252]** In the specification, the term "core network" node may be interpreted as a core network device, which may comprise at least one of an AMF, a SMF, a NSSF, a UPF, a NRF a UDM, a PCF, a SoR-AF, an AF, an DDNMF, an MB-SMF, an MB-UPF and/or the like. A term of core network may be interpreted as a core network node. In the specification, a term of an access node may be interpreted as a base station, which may comprise a NG-RAN, and/or the like.

**[0253]** In the specification, the term "network node" may be interpreted as a core network node, an access node, a NG-RAN, a UE, and/or the like. A network may comprise one or more network nodes.

**[0254]** FIG. **21** may depict one example embodiment of the present disclosure. Similar to the previous figure (e.g., FIG. **19**), a UE may send a registration request message and may receive a registration response message. By informing whether the UE supports partly allowed slices, a network node (e.g., AMF) can send to the UE, a configuration for one or more network slices, reducing unnecessary signaling. For brevity, redundant details will be omitted.

**[0255]** In an example, a UE may send a registration request message to an AMF via a NG-RAN. The registration request message may comprise at least one of:

- **[0256]** The identifier of the UE.
- **[0257]** The requested slices.
- **[0258]** Capability indicator for the partly allowed slices. This may indicate support of the partly allowed slices. This may indicate whether a node supports the feature of the partly allowed slices. For example, if the UE supports the partly allowed slices, the UE may set this to supported. For example, if the UE does not support the partly allowed slices, the UE may set this to not supported, the UE may not set this indicator, and/or may not send the capability indicator for the partly allowed slices.

**[0259]** For example, the UE may construct the registration request message and may set capability indicator for the partly allowed slices to supported.

**[0260]** In an example, the AMF may receive the registration request message. Based on the registration request message, the AMF may send a registration response message to the UE. For example, the registration response message may be at least one of a registration accept message, a UE configuration update message, a registration reject message, a NAS message, and/or the like. For example, based on the capability indicator for the partly allowed slices of the registration request message and/or based on whether the AMF supports the partly allowed slices, the AMF may determine whether to apply/use the partly allowed slices and/or the partly allowed slice TAs or not. For example, based on that the AMF supports the partly allowed slices and/or based on that the capability indicator for the partly allowed slices is set to supported, the AMF may determine to apply/use the partly allowed slices and/or the partly allowed slice TAs for the UE. For example, to apply/use the partly allowed slices and/or the partly allowed slice TAs for the UE may be that the AMF constructs the registration response message comprising information related to partly allowed slices. For example, the registration response may comprise at least one of:

**[0261]** The registration area (RA).

**[0262]** The allowed slices.

**[0263]** The partly allowed slices.

**[0264]** The partly allowed TA list.

**[0265]** For example, the registration response message may indicate that the RA comprises TA1, TA2, TA3, that the allowed network slices comprises the slice A, that partly allowed slices comprises the slice B, and/or that the partly allowed TA list comprises TA2.

**[0266]** In an example, in response to the registration request message, the UE may receive the registration response message from the AMF. Based on the registration response message, the UE may establish a new PDU session for the slice A within TA1 and/or may continue to use an established PDU session for the slice A within TA1. Based on the registration response message, the UE may not establish a new PDU session for the slice B and/or may not use an established PDU session for the slice B, within TA1. For example, based on that the partly allowed slices comprises the slice B, based on that the partly allowed TA list does not comprise TA1 (e.g., TA1 does not support the slice B), based on that the UE is within TA1, and/or based on that the UE is in one or more TAs where the partly allowed slices are not supported, the UE may not establish the new PDU session for the slice B and/or may not use the established PDU session for the slice B within TA1.

**[0267]** In an example, the UE may move from TA1 (supporting slice A) to TA2 (supporting slice A and slice B). Based on the partly allowed slices and/or the partly allowed TA list, the UE may determine that the partly allowed slice (e.g., slice B) is supported in TA2. Based on that TA2 is one of TAs in the RA, and/or slice B is partly allowed, the UE may not perform a registration update procedure. In an example, based on that the slice B is one of network slices of the partly allowed slices, based on the partly allowed TA list, and/or based on that the TA2 is one of TAs supporting the slice B, the UE may send to a SMF (and/or via the AMF) a PDU session establishment request message for the slice B and/or a service request message activating a PDU session over the slice B. The SMF (and/or via the AMF) may send to the UE, a PDU session establishment accept message for the slice B and/or a service accept message. The UE may send one or more data over the PDU session.

**[0268]** In the example of FIG. **21**, based on receiving the registration request from the UE, the AMF may send a Nudm service request message to a UDM, to fetch subscription information of the UE. This may assist the AMF to determine whether the UE is eligible for using the feature of partly allowed (rejected) slices. For example, the Nudm service request message may be a Nudm_SDM_Get request and/or the like. The Nudm service request message may comprise the identifier of the UE. In response to the Nudm service request, the UDM may respond to the AMF, with a Nudm service response. The Nudm service response may be a Nudm_SDM_Get response and/or the like. The Nudm service response may comprise subscription information for partly allowed slices. For example, the subscription information for partly allowed slices may indicate whether the UE has a subscription for partly allowed slices (the feature of partly allowed slices), and/or whether the UE can be configured with information related to the partly allowed slices. The AMF may receive the Nudm service response. Based on the subscription information for partly allowed slices, the AMF may determine whether to send to the UE with the information related to the partly allowed slices (e.g., the partly allowed slices, the partly allowed slice TAs). For example, based on that the subscription information for partly allowed slices indicates that the UE has subscription for the partly allowed slices, the AMF may determine to send to the UE with the information related to the partly allowed slices. For example, based on the determination, the AMF may construct the registration accept message with the information related to the partly allowed slices.

**[0269]** In the example of FIG. **21**, based on receiving the registration request from the UE, the AMF may send a Npcf service request message to a PCF, to determine whether a policy for the UE allows to use the feature of partly allowed slices. For example, the Npcf service request message may be a Npcf_AMPolicyControl_Create request, Npcf_UEPolicyControl_Create request, and/or the like. The Npcf service request message may comprise at least one of the identifier of the UE, a subscription information (e.g., subscription information of the partly allowed slices) of the UE, the capability indicator for the partly allowed slices, and/or one or more identifiers of the one or more network slices. In response to the Npcf service request, the PCF may respond to the AMF, with a Npcf service response. The Npcf service response may be a Npcf_AMPolicyControl_Create response, a Npcf_UEPolicyControl_Create response, and/or the like. The Npcf service response may comprise a network slice policy information for the UE. For example, the network slice policy information may indicate whether the UE is allowed to be configured with information related to the partly allowed slices. The AMF may receive the Npcf service response. Based on the network slice policy information, the AMF may determine whether to send to the UE with the information related to the partly allowed slices. For example, based on that the network slice policy information indicates that the UE is allowed to be configured with the information related to the partly allowed slices, the AMF may determine to send to the UE with the information related to the partly allowed slices. For example, based on the determination, the AMF may construct the registration accept message with the information related to the partly allowed slices.

**[0270]** In the example of FIG. **21**, based on receiving the registration request from the UE, the AMF may send a Nnssf service request message to a NSSF, to get assistance from the NSSF. For example, the Nnssf service request message may be a Nnssf_NSSelection_Get request, and/or the like. The Nnssf service request message may comprise at least one of one or more identifiers of one or more subscribed network slices, a subscription information (e.g., subscription information of the partly allowed slices) of the UE, a list of rejected network slices, a list of allowed (accepted) network slices, a list of partly allowed (accepted) network slices, a list of partly rejected network slices, and/or the capability indicator for the partly allowed slices. In response to the Nnssf service request, the NSSF may determine which network slices are (partially) allowed and/or which network slices are (partially) rejected. Based on the determination, the NSSF may respond to the AMF, with Nnssf service response. The Nnssf service response may be a Nnssf_NSSelection_Get response, and/or the like. The Nnssf service response may comprise selection information of network slices. For example, the selection information of network slices may comprise at least one of a list of allowed network slices, a list of partly allowed network slices, a list of partly rejected network slices, a list of rejected network slices, a list of configured network slices, an indication of whether the UE is allowed to be configured with information related to the partly allowed slices. The AMF may receive the Nnssf service response. Based on the selection information of network slices, the AMF may determine whether to send to the UE with the information related to the partly allowed slices. For example, based on that the selection information of network slices indicates that the UE is allowed to be configured with the information related to the partly allowed slices, the AMF may determine to send to the UE with the information related to the partly allowed slices. For example, based on that the selection information of network slices comprises a list of partly allowed network slices, the AMF may determine to send to the UE with the information related to the partly allowed slices. For example, based on the determination, the AMF may construct the registration accept message with the information related to the partly allowed slices.

**[0271]** FIG. **22** may depict one example embodiment of the present disclosure. Similar to the previous figure (e.g., FIG. **21**), a UE may send a registration request message and may receive a registration response message. By informing whether the UE supports partly allowed slices and/or whether the UE supports partly rejected slices, a network node (e.g., AMF) can send to the UE, a relevant configuration for one or more network slices, reducing unnecessary signaling. For brevity, redundant details will be omitted.

**[0272]** In an example, the UE may send a registration request message to an AMF via a NG-RAN. The registration request message may comprise at least one of:

- **[0273]** The identifier of the UE.
- **[0274]** The requested slices.
- **[0275]** Capability indicator for the partly allowed slices.
- **[0276]** Capability indicator for the partly rejected slices. This may indicate whether a node (e.g., a UE) support the feature of partly rejected slices. For example, if the UE supports the partly rejected slices, the UE may set this to supported. For example, if the UE does not support the partly rejected slices, the UE may set this to not supported, the UE may not set this indicator, and/or may not send the capability indicator for the partly rejected slices.

**[0277]** For example, the UE may construct the registration request message. Based on that the UE supports the feature of partly rejected slices, the UE may set capability indicator for the partly allowed slices to supported, and/or may set capability indicator for the partly rejected slices to supported.

**[0278]** In an example, the AMF may receive the registration request message. Based on the registration request message, the AMF may send the registration response (e.g., registration accept message, registration reject message, and/or the like) message to the UE. For example, based on the capability indicator for the partly allowed slices of the registration request message, based on whether the AMF supports the partly allowed slices, based on the capability indicator for the partly rejected slices of the registration request message, and/or based on whether the AMF supports the partly rejected slices, the AMF may determine whether to apply/use the partly allowed slices, whether to apply/use the partly allowed slice TAs, whether to apply/use the partly rejected slices, and/or whether to apply/use the partly rejected slice TAs. For example, the AMF may determine to use the partly allowed slices, based on that the UE supports the feature of partly allowed slices. For example, based on the capability indicator for the partly allowed slices of the registration request message, based on whether the AMF supports the partly allowed slices, based on the capability indicator for the partly rejected slices of the registration request message, and/or based on whether the AMF supports the partly rejected slices, the AMF may determine a partly slice mode indicator. For example, the partly slice mode indicator may indicate to the UE whether partly allowed slices (and/or partly allowed slice TAs) applies for the UE and/or whether partly rejected slices (and/or partly rejected slice TAs) applies (or used) for the UE. For example, the AMF may set partly slice mode indicator to partly allowed slices mode, if the AMF supports the partly allowed slices. For example, the AMF may set partly slice mode indicator to partly rejected slices mode, if the AMF does not support the partly allowed slices mode.

**[0279]** For example, based on the determined partly slice mode indicator, the AMF may determine to apply/use the partly allowed slices (and/or the partly allowed slice TAs) and/or the partly rejected slices (and/or the partly rejected slice TAs) for the UE. For example, to apply/use the partly allowed slices and/or the partly allowed slice TAs for the UE may be that the AMF constructs the registration response message comprising information related to partly allowed slices. For example, to apply/use the partly rejected slices and/or the partly rejected slice TAs for the UE may be that the AMF constructs the registration response message comprising information related to partly rejected slices.

**[0280]** For example, the registration response may comprise at least one of:

- **[0281]** The registration area (RA).
- **[0282]** The partly slice mode indicator.
- **[0283]** The allowed slices.
- **[0284]** The rejected slices.
- **[0285]** The partly slice list. This may comprise at least one of the partly allowed slices and/or the partly rejected slices.
- **[0286]** The partly TA list. This may comprise at least one of the partly allowed TA list and/or the partly rejected TA list.

**[0287]** In an example, based on receiving the registration request from the UE, the AMF may send the Nudm service request message to a UDM. In response to the Nudm service request, the UDM may respond to the AMF, with the Nudm service response. The Nudm service response may comprise subscription information for partly allowed slices, subscription information for partly rejected slices, the partly slice mode indicator, and/or the like. For example, the subscription information for partly rejected slices may indicate whether the UE has a subscription for the feature of partly rejected slices, and/or whether the UE can be configured with information related to the partly rejected slices. The AMF may receive the Nudm service response. Based on the subscription information for partly allowed slices, the AMF may determine the partly slice mode indicator. For example, if the subscription information indicates that the UE has a subscription for the partly rejected slices, the AMF may determine to set the partly slice mode indicator to partly rejected slice mode.

**[0288]** In an example, based on receiving the registration request from the UE, the AMF may send the Npcf service request message to the PCF. In response to the Npcf service request, the PCF may respond to the AMF, with Npcf service response. The Npcf service response may comprise the partly slice mode indicator. The AMF may receive the Npcf service response. Based on the Npcf service response, the AMF may determine the partly slice mode indicator. For example, if the partly slice mode indicator of the Npcf service response is set to partly allowed slice mode, the AMF may determine to use partly allowed slice mode.

**[0289]** In an example, the AMF may send the Nnssf service request message to the NSSF. In response to the Nnssf service request, the NSSF may respond to the AMF, with Nnssf service response. The Nnssf service response may comprise the partly slice mode indicator. The AMF may receive the Nnssf service response. Based on the Nnssf service response, the AMF may determine the partly slice mode indicator. For example, if the partly slice mode indicator of the Nnssf service response is set to partly allowed slice mode, the AMF may determine to use partly allowed slice mode

**[0290]** FIG. **23** may depict one example embodiment of the present disclosure. Similar to the previous figure (e.g., FIG. **21**), a UE may send a registration request message and may receive a registration response message. By informing whether the UE supports a feature of partly allowed slices, whether the UE supports a feature of partly rejected slices and/or a preferred network behavior, a network node (e.g., AMF) supporting the feature of partly allowed network slices may be able to send to the UE, a relevant configuration for one or more network slices, reducing unnecessary signaling. For brevity, redundant details will be omitted.

**[0291]** In an example, a first AMF (e.g., AMF 1) may send a first Nnrf service request (e.g., NF registration request) to an NRF, for registration of the first AMF. For example, the first AMF may register the first AMF to the NRF, to provide one or more AMF services to one or more network nodes. For example, the first Nnrf service request may be a Nnrf_NFManagement_NFRegister request. For example, the first Nnrf service request message may comprise at least one of a type of network node, an instance ID, an IP address, one or more supported services, and so on. For example, the type of network node may indicate a type of AMF. For example, the instance ID may indicate an identifier of the AMF (e.g., AMF ID 1). For example, the one or more supported services may indicate one or more services provided by the first AMF and/or one or more capabilities of the first AMF. For example, the one or more capabilities may indicate whether the first AMF supports the feature of partly rejected slices, the feature of the partly allowed slices, and/or the feature of the partly slices. For example, the feature of the partly slices may be at least one of the feature of partly rejected slices, and/or the feature of partly allowed slices. For example, that the feature of partly slices is supported may be that the feature of partly allowed slices and the feature of partly rejected slices are supported, and/or that a node (e.g., an AMF, a NG-RAN, a UE) supports processing/receiving/handling/sending a list of network slices that are supported in one part (e.g., first-type TAs) of the RA and/or not supported in other part (second-type TAs) of the RA. Based on that the first AMF supports the feature of partly allowed slices, the feature of partly rejected slices, and/or the feature of partly slices, the one or more supported services may indicate that the first AMF supports the feature of partly allowed slices, the feature of partly rejected slices, the feature of partly slices, and/or one or more services associated with the partly slices. The NRF may receive the first Nnrf service request, and/or may store the information delivered by the first Nnrf service request. In response to the received first Nnrf service request, the NRF may send to the first AMF, a first Nnrf service response, indicating successful registration of the first AMF. The first AMF may receive the first Nnrf service response.

**[0292]** In an example, a second AMF (e.g., AMF 2) may send a second Nnrf service request (e.g., NF registration request) to an NRF, for registration of the second AMF. For example, the second AMF may register the second AMF to the NRF, to provide one or more AMF services to one or more network nodes. For example, the second Nnrf service request may be a Nnrf_NFManagement_NFRegister request. For example, the second Nnrf service request message may comprise at least one of a type of network node, an instance ID, an IP address, one or more supported services, and so on. For example, the type of network node may indicate the type of AMF. For example, the instance ID may indicate AMF ID 2. For example, the one or more supported services may indicate the one or more services provided by the second AMF and/or one or more capabilities of the second AMF. For example, based on that the second AMF does not support the feature of partly rejected slices, that the second AMF does not support the feature of the partly allowed slices, and/or that the second AMF does not support the feature of the partly slices, the one or more supported services may not indicate that the second AMF supports the feature of the partly allowed slices, the feature of the partly rejected slices, and/or the feature of the partly slices. The NRF may receive the second Nnrf service request, and/or may store the information delivered by the second Nnrf service request. In response to the received second Nnrf service request, the NRF may send to the second AMF, a second Nnrf service response, indicating successful registration of the second AMF. The second AMF may receive the second Nnrf service response.

**[0293]** In an example, the UE may send the registration request. In an example, the UE may send a registration request message to the second AMF via a NG-RAN. The registration request message may comprise at least one of:

- **[0294]** The identifier of the UE.
- **[0295]** The requested slices.
- **[0296]** Capability indicator for the partly allowed slices.
- **[0297]** Capability indicator for the partly rejected slices.
- **[0298]** A preferred network behavior. This may indicate one or more services that the UE expects from a network. For example, if the UE supports/wants a service associated with the feature of partly allowed network slices, the feature of partly rejected network slices, and/or the like, the UE may indicate that the preferred network behavior is the feature of partly allowed slices, the feature of partly rejected slices, and/or the like.

[0299] For example, the UE may construct the registration request message, may set capability indicator for the partly allowed slices to supported, may set capability indicator for the partly rejected slices to supported, and/or may indicate that the preferred network behavior is the feature of partly allowed slices.

[0300] In an example, the second AMF may receive the registration request message. Based on that the preferred network behavior of the registration request message indicates the feature of partly allowed slices (and/or the feature of partly rejected slices), and/or based on that the second AMF does not support to the feature of partly allowed slices (and/or the feature of partly rejected slices), the second AMF may determine that the second AMF may not be able to process the request of the UE. Based on the determination, the second AMF may send a third Nnrf service request to the NRF. In an example, the third Nnrf service request may be a Nnrf_NFDiscovery Request message. For example, the third Nnrf service request may request information of one or more AMFs which supports the feature of partly allowed slices, the feature of partly rejected slices, and/or the like. Based on the third Nnrf service request, the NRF may construct a third Nnrf service response. Based on that third Nnrf service request indicates the type of AMF, the capability of partly allowed slices, and/or the capability of the partly rejected slices, the NRF may construct the third Nnrf service response comprising information of one or more AMFs (e.g., the first AMF) supporting the feature of partly allowed slices and/or the feature of the partly rejected slices. Based on the third Nnrf service request, the second AMF may receive the third Nnrf service response. For example, the third Nnrf service response may be a Nnrf_NFDiscovery Response. The third Nnrf service response may comprise information of one or more AMFs supporting the feature of partly allowed slices, the feature of partly rejected slices, and/or the like. Based on the information of the third Nnrf service response, the second AMF may select the first AMF. Based on the selecting the first AMF, the second AMF may forward the registration request message to the first AMF.

[0301] In an example, the first AMF may receive the registration request message forwarded by the second AMF. For example, in response to the registration request message, the second AMF may send the registration response message to the UE. For example, based on the capability indicator for the partly allowed slices of the registration request message, based on whether the first AMF supports the partly allowed slices, based on the capability indicator for the partly rejected slices of the registration request message, and/or based on whether the first AMF supports the partly rejected slices, the first AMF may determine whether to apply/use the partly allowed slices, whether to apply/use the partly allowed slice TAs, whether to apply/use the partly rejected slices, and/or whether to apply/use the partly rejected slice TAs. For example, if the capability indicator for the partly allowed slices of the registration request message is set to supported, the first AMF may determine to use the feature of partly accepted slices. Based on the determination, the first AMF may send the registration accept message to the UE. For example, the registration accept message may indicate that the network supports the feature of the partly allowed slices, the feature of the partly rejected slices, and/or the like.

[0302] FIG. 24 may depict one example embodiment of the present disclosure. In an example, a UE may send a session management request (e.g., PDU session registration request, PDU session modification request, and/or the like) message for a PDU session and may receive a session management response message. By determining whether the PDU session is associated with one or more partly allowed (accepted) network slices and/or the one or more allowed (accepted) network slices, a first network node (e.g., an AMF) may select a second network node (e.g., a SMF) supporting the feature of partly slices (e.g., partly allowed slices and/or partly rejected slices). For brevity, redundant details will be omitted.

[0303] In an example, a first SMF (e.g., SMF 1) may send a first Nnrf service request (e.g., NF registration request) to an NRF, for registration of the first SMF. For example, the first SMF may register the first SMF to the NRF, to provide one or more SMF services to one or more network nodes. For example, the first Nnrf service request may be a Nnrf_NFManagement_NFRegister request. For example, the first Nnrf service request message may comprise at least one of a type of network node, an instance ID, an IP address, one or more supported services, and so on. For example, the type of network node may indicate a type of SMF. For example, the instance ID may indicate SMF ID 1. For example, the one or more supported services may indicate one or more services provided by the first SMF and/or one or more capabilities of the first SMF. For example, the one or more capabilities may indicate whether the first SMF supports the feature of partly rejected slices, the feature of the partly allowed slices, and/or the feature of the partly slices. For example, the feature of the partly slices may be at least one of the feature of the partly rejected slices, and/or the feature of the partly allowed slices. For example, that the feature of the partly slices is supported may be that the feature of the partly allowed slices and/or the feature of the partly rejected slices are supported, and/or that a node (e.g., an SMF, a NG-RAN, a UE) supports processing/receiving/handling/sending a list of network slices that are supported in one part (e.g., first-type TAs) of the RA and/or not supported in other part (e.g., second-type TAs) of the RA. Based on that the first SMF supports the feature of the partly allowed slices, the feature of the partly rejected slices, and/or the feature of the partly slices, the one or more supported services may indicate that the first SMF supports the feature of the partly allowed slices, the feature of the partly rejected slices, and/or the feature of the partly slices. The NRF may receive the first Nnrf service request, and/or may store the information delivered by the first Nnrf service request. In response to the received first Nnrf service request, the NRF may send to the first SMF, a first Nnrf service response, indicating successful registration of the first SMF. The first SMF may receive the first Nnrf service response.

[0304] In an example, a second SMF (e.g., SMF 2) may send a second Nnrf service request (e.g., NF registration request) to an NRF, for registration of the second SMF. For example, the second SMF may register the second SMF to the NRF, to provide one or more SMF services to one or more network nodes. For example, the second Nnrf service request may be a Nnrf_NFManagement_NFRegister request. For example, the second Nnrf service request message may comprise at least one of a type of network node, an instance ID, an IP address, one or more supported services, and so on. For example, the type of network node may indicate SMF. For example, the instance ID may indicate an identifier of the second SMF (e.g., SMF ID 2).

For example, the one or more supported services may indicate the one or more services provided by the second SMF and/or one or more capabilities of the second SMF. For example, based on that the second SMF does not support the feature of partly rejected slices, that the second SMF does not support the feature of the partly allowed slices, and/or that the second SMF does not support the feature of the partly slices, the one or more supported services may not indicate that the second SMF supports the feature of the partly allowed slices, the feature of the partly rejected slices, and/or the feature of the partly slices. The NRF may receive the second Nnrf service request, and/or may store the information delivered by the second Nnrf service request. In response to the received second Nnrf service request, the NRF may send to the second SMF, a second Nnrf service response, indicating successful registration of the second SMF. The second SMF may receive the second Nnrf service response.

**[0305]** In an example, the UE may send a NAS request message to an AMF. For example, the NAS request message may comprise at least one of an identifier of the UE, the session management request message (e.g., PDU session establishment request message) for the PDU session, an identifier of a network slice associated with the session management request message, and/or information of partly slices. For example, the information of partly slices may comprise an indication of whether the UE supports the feature of the partly allowed slice, an indication of whether the UE supports the feature of the partly rejected slice, an indication of whether the network slice (associated with the session management request message) is one of one or more partly allowed network slices, an indication of whether the network slice (associated with the session management request message) is one of one or more partly rejected network slices, and/or the like. For example, the session management request message may comprise at least one of the identifier of the network slice associated with the session management request message, an identifier of a network name (e.g., Data Network Name), a type (e.g., IP, ethernet) of the PDU session, the information of partly slices.

**[0306]** In an example, the AMF may receive the NAS request message. The AMF may determine whether the session management request message is associated with one or more partly allowed network slices and/or one or more partly rejected network slices. If the AMF determines that the session management request message is associated with one or more partly allowed network slices and/or one or more partly rejected network slices, the AMF may determine to send the session management request message to a SMF supporting the feature of partly allowed slices and/or the feature of partly rejected slice. Alternatively, and/or additionally, the AMF may determine whether the NAS request message comprises the information of partly slices. If the AMF determines that the NAS request message comprises the information of partly slices, the AMF may determine to send the session management request message to a SMF supporting the feature of partly allowed slices and/or the feature of partly rejected slice.

**[0307]** In an example, based on determining to send the session management request message to the SMF supporting the feature of partly allowed slices and/or the feature of partly rejected slice, the AMF may send a third Nnrf service request to the NRF. In an example, the third Nnrf service request may be a Nnrf_NFDiscovery Request message. For example, the third Nnrf service request may request information of one or more SMFs which supports the feature of partly allowed network slices, the feature of partly rejected network slices, and/or the like. Based on the third Nnrf service request, the NRF may construct a third Nnrf service response. Based on that third Nnrf service request indicates the type of SMF, the capability of partly allowed slices, and/or the capability of the partly rejected slices, the NRF may construct the third Nnrf service response comprising information of one or more SMFs (e.g., the first SMF) supporting the feature of partly allowed slices and/or the feature of the partly rejected slices. Based on the third Nnrf service request, the AMF may receive the third Nnrf service response. For example, the third Nnrf service response may be a Nnrf_NFDiscovery Response. The third Nnrf service response may comprise information of one or more SMFs supporting the feature of partly allowed network slices, the feature of partly rejected network slices, and/or the like. Based on the information of the third Nnrf service response, the AMF may select the first SMF. Based on the selecting the first SMF, the AMF may send the session management request message to the selected SMF (e.g., first SMF).

**[0308]** FIG. **25** may depict one example embodiment of the present disclosure. In an example, a UE may send a NAS message. By informing whether UE supports the feature of partly network slices (e.g., partly allowed slices and/or partly rejected slices), a network node supporting the feature is selected. For brevity, redundant details will be omitted.

**[0309]** In an example, a first NSSF (e.g., NSSF 1) may send a first Nnrf service request (e.g., NF registration request) to an NRF, for registration of the first NSSF. For example, the first NSSF may register the first NSSF to the NRF, to provide one or more NSSF services to one or more network nodes. For example, the first Nnrf service request may be a Nnrf_NFManagement NFRegister request. For example, the first Nnrf service request message may comprise at least one of a type of network node, an instance ID, an IP address, one or more supported services, and so on. For example, the type of network node may indicate NSSF. For example, the instance ID may indicate NSSF ID 1. For example, the one or more supported services may indicate one or more services provided by the first NSSF and/or one or more capabilities of the first NSSF. For example, the one or more capabilities may indicate whether the first NSSF supports the feature of partly rejected slices, the feature of partly allowed slices, and/or the feature of partly slices. For example, the feature of partly slices may be at least one of the feature of partly rejected slices, and/or the feature of partly allowed slices. For example, that the feature of partly slices is supported may be that the feature of partly allowed slices and/or the feature of partly rejected slices are supported, and/or that a node (e.g., a NSSF, a NG-RAN, a UE) supports processing/receiving/handling/sending a list of network slices that are supported in one part of the RA and/or not supported in other part of the RA. Based on that the first NSSF supports the feature of partly allowed slices, the feature of partly rejected slices, and/or the feature of partly slices, the one or more supported services may indicate that the first NSSF supports the feature of partly allowed slices, the feature of partly rejected slices, and/or the feature of partly slices. The NRF may receive the first Nnrf service request, and/or may store the information delivered by the first Nnf service request. In response to the received first Nnrf service request, the NRF may send to the first NSSF, a first Nnrf service response, indicating successful registration of the first NSSF. The first NSSF may receive the first Nnrf service response.

**[0310]** In an example, a second NSSF (e.g., NSSF 2) may send a second Nnrf service request (e.g., NF registration request) to an NRF, for registration of the second NSSF. For example, the second NSSF may register the second NSSF to the NRF, to provide one or more NSSF services to one or more network nodes. For example, the second Nnrf service request may be a Nnrf_NFManagement_NFRegister request. For example, the second Nnrf service request message may comprise at least one of a type of network node, an instance ID, an IP address, one or more supported services, and so on. For example, the type of network node may indicate NSSF. For example, the instance ID may indicate NSSF ID **2**. For example, the one or more supported services may indicate the one or more services provided by the second NSSF and/or one or more capabilities of the second NSSF. For example, based on that the second NSSF does not support the feature of partly rejected slices, that the second NSSF does not support the feature of the partly allowed slices, and/or that the second NSSF does not support the feature of partly slices, the one or more supported services may not indicate that the second NSSF supports the feature of partly allowed slices, the feature of partly rejected slices, and/or the feature of partly slices. The NRF may receive the second Nnrf service request, and/or may store the information delivered by the second Nnrf service request. In response to the received second Nnrf service request, the NRF may send to the second NSSF, a second Nnrf service response, indicating successful registration of the second NSSF. The second NSSF may receive the second Nnrf service response.

**[0311]** In an example, the UE may send the NAS request message to an AMF. For example, the NAS request message may comprise at least one of an identifier of the UE, a session management request message, a registration request message, and/or the information of partly slice.

**[0312]** In an example, the AMF may receive the NAS request message. The AMF may determine whether the NAS request message is associated with one or more partly allowed network slices and/or one or more partly rejected network slices. For example, if the UE indicates support of the feature of partly allowed slices, the AMF may determine that the NAS request message is associated with partly allowed slices. If the AMF determines that the NAS request message is associated with one or more partly allowed network slices and/or one or more partly rejected network slices, the AMF may determine to send a Nnssf service request message to a NSSF supporting the feature of partly allowed slices and/or the feature of partly rejected slice.

**[0313]** In an example, based on determining to send the Nnssf service request message to the NSSF supporting the feature of partly allowed slices and/or the feature of partly rejected slice, the AMF may send a third Nnrf service request to the NRF. In an example, the third Nnrf service request may be a Nnrf_NFDiscovery Request message. For example, the third Nnrf service request may request information of one or more NSSFs which supports the feature of partly allowed network slices, the feature of partly rejected network slices, and/or the like. Based on the third Nnrf service request, the NRF may construct a third Nnrf service response. Based on that third Nnrf service request indicates the type of NSSF, the capability of partly allowed slices, and/or the capability of the partly rejected slices, the NRF may construct the third Nnrf service response comprising information of one or more NSSFs (e.g., the first NSSF) supporting the feature of partly allowed slices and/or the feature of the partly rejected slices. Based on the third Nnrf service request, the AMF may receive the third Nnrf service response. For example, the third Nnrf service response may be a Nnrf_NFDiscovery Response. The third Nnrf service response may comprise information of one or more NSSFs supporting the feature of partly allowed network slices, the feature of partly rejected network slices, and/or the like. Based on the information of the third Nnrf service response, the AMF may select the first NSSF. Based on the selecting the first NSSF, the AMF may send the Nnssf service request message (e.g., Nnssf_NSselection_Get) to the selected NSSF (e.g., first NSSF).

**[0314]** FIG. **26** may depict one example embodiment of the present disclosure. Similar to the previous figure (e.g., FIG. **21**), a UE may send a registration request message and may receive a registration response message. By delivering information of partly allowed slices and/or partly rejected slices in a message, a network can reduce a signaling load. For brevity, redundant details will be omitted.

**[0315]** In an example, the UE may send a registration request message to an AMF via a NG-RAN. The registration request message may comprise at least one of:

**[0316]** The identifier of the UE.

**[0317]** The requested slices.

**[0318]** Capability indicator for the partly allowed slices.

**[0319]** Capability indicator for the partly rejected slices.

**[0320]** In an example, the AMF may receive the registration request message. Based on the registration request message, the AMF may send the registration response message to the UE.

**[0321]** For example, the registration response may comprise at least one of:

**[0322]** The registration area (RA).

**[0323]** The allowed slices.

**[0324]** The rejected slices.

**[0325]** The partly allowed slices.

**[0326]** The partly rejected slices.

**[0327]** For example, the RA may comprise TA1 and/or TA2. For example, the accepted slices may indicate a slice A1 and/or a slice A2. For example, the rejected slices may indicate a slice R1 and/or a slice R2.

**[0328]** For example, the partly allowed slice may indicate that

**[0329]** A slice PA1 may be one of one or more partly allowed network slices. The slice PA1 (partly) area may indicate one or more areas (e.g., TAs, Cells) where the slice PA1 is allowed and/or one or more areas where the slice PA1 is not allowed. The slice PA1 area may indicate one or more areas of the RA.

**[0330]** A slice PA2 may be one of one or more partly allowed network slices. The slice PA2 (partly) area may indicate one or more areas where the slice PA2 is allowed and/or one or more areas where the slice PA2 is not allowed. The slice PA2 area may indicate one or more areas of the RA.

**[0331]** For example, the partly rejected slice may indicate that

**[0332]** A slice PR1 may be one of one or more partly rejected network slices. The slice PR1 (partly) area may indicate one or more areas where the slice PR1 is rejected and/or one or more areas where the slice PR1 is not rejected. The slice PA1 area may indicate one or more areas of the RA.

**[0333]** A slice PR2 may be one of one or more partly rejected network slices. The slice PR2 area may indicate one or more areas where the slice PR2 is allowed and/or one or more areas where the slice PR2 is not allowed. The slice PA2 area may indicate one or more areas of the RA.

**[0334]** FIG. **27** may depict one example embodiment of the present disclosure. For brevity, redundant details will be omitted.

**[0335]** In an example, a UE in a first TA, send to an AMF, a first registration request message. For example, the first registration request message may comprise at least one of:

**[0336]** an identifier of the UE.

**[0337]** a list of one or more requested network slices,

**[0338]** a capability indicator indicating whether the UE supports the feature of partly slices (e.g., the feature of partly allowed slices, and/or the feature of partly rejected slices).

**[0339]** In an example, the UE in a first TA, receives from the AMF, a registration response (e.g., registration accept, registration reject) message. The registration response message may comprise at least one of:

**[0340]** information of one or more partly slices (e.g., partly allowed slices). This may be a list of one or more identifiers of one or more network slices. This may indicate one or more network slices that are partly supported in a RA. For example, the one or more partly slices (e.g., slice N, slice M) may be partly allowed slices.

**[0341]** a list of one or more identifiers for one or more TAs (e.g., TA B1, TA B2) supporting the one or more partly slices.

**[0342]** In an example, the UE may determine whether the UE enters to a second TA from the first TA. For example, when the UE camps on (enters) a new cell, the UE may determine a TA of the new cell. For example, the UE determines a TA of a cell, based on information received from a SIB. In an example, if the UE enters to the second TA, and/or if the UE has information of the partly slices (e.g., the partly allowed slices, the partly rejected slices), the UE may determine whether the second TA is one of TAs supporting a network slice of the one or more partly slices.

**[0343]** For example, based on that the second TA is TA B1 and/or based on that the TA B1 is one of one or more TAs (e.g., TA B1, TA B2) supporting the one or more partly slices (e.g., Slice N, slice M), the UE may determine that the second TA support the one or more partly slices. Based on the determination, the UE may determine to send a NAS request message. For example, the NAS request message may be a service request message, a PDU session establishment request message. For example, the NAS request message may request a service associated with one or more partly allowed (accepted) network slices (e.g., Slice N, Slice M).

**[0344]** For example, alternatively and/or additionally, based on that the second TA is TA B3 and/or based on that the TA B3 is not one of one or more TAs (e.g., TA B1, TA B2) supporting the one or more partly slices (e.g., Slice N, slice M), the UE may determine that the second TA does not support the one or more partly slices. Based on the determination, the UE may determine not to send a NAS request message. For example, the NAS request message may be a service request message, a PDU session establishment request message. For example, the NAS request message may request a service associated with one or more partly allowed (accepted) network slices (e.g., Slice N, Slice M).

**[0345]** FIG. **28** may depict one example embodiment of the present disclosure. For brevity, redundant details will be omitted.

**[0346]** In an example, a UE may send to an AMF, a registration request message. For example, the registration request message may comprise at least one of:

**[0347]** A identifier of the UE. This may identify the UE. This may be a SUPI, a SUCI, a GUTI, a TMSI and/or the like.

**[0348]** A requested slices. This may indicate one or more network slices that the UE requests service from a network. This may be a list of one or more identifiers of the one or more network slices.

**[0349]** A capability indicator indicating whether the UE supports the feature of partly slices (e.g., the feature of partly allowed slices, and/or the feature of partly rejected slices).

**[0350]** In an example, the UE may receive from the AMF, a registration response (e.g., registration accept, registration reject, UE configuration update and/or the like) message. The registration response message may comprise at least one of:

**[0351]** A allowed slices. This may indicate one or more network slices allowed for the UE. The one or more network slices may be allowed in all TAs of a RA for the UE. For example, the RA for the UE comprises TA1, TA2 and TA3, and the allowed slices may comprise slice Z1 and slice Z2. The UE may be allowed to use the slice Z1 and the slice Z2, in TA1, TA2 and TA3.

**[0352]** A partly slices. This may indicate a partly (partially) allowed slices, a partly rejected slices, and/or the like. This may be one or more identifiers of one or more partly allowed network slices and/or one or more identifiers of one or more partly rejected network slices. The one or more network slices of the partly slices may not be allowed in all TAs of a RA for the UE. For example, the RA for the UE may comprise TA1, TA2 and TA3, the partly allowed slices may comprise slice Z3, the slice Z3 may be allowed in TA1 and/or the slice Z3 may not be allowed in TA2 and TA3.

**[0353]** In an example, the UE may determine whether the registration response message comprises the allowed slices. If the registration response comprises the allowed slices, the UE determines that the UE is registered to a network and/or the UE may stay in (or transit to) a RM-registered state. For example, in the RM-registered, the UE may request a PDU session.

**[0354]** In an example, the UE may determine whether the registration response message comprises the allowed slices. If the registration response does not comprise the allowed slices, the UE may determine whether the registration response message comprises the partly allowed slices. If the registration response comprises the partly allowed slices, the UE determines that the UE is registered to a network and/or the UE may stay in (or transit to) RM-registered state. By determining registration status based on the partly allowed slices and/or the allowed slices, signaling transactions between the AMF and the UE can be reduced. For example, when the UE moves to an area where the partly allowed slices are supported, because the UE is in RM-registered state, the UE can skip a registration procedure.

**[0355]** In an example, the UE may determine whether the registration response message comprises the allowed slices. If the registration response does not comprise the allowed slices, the UE may determine whether the registration response message comprises the partly allowed slices. If the registration response does not comprise the partly allowed slices, the UE determines that the UE is not registered to a network and/or the UE may stay in (or transit to) RM-deregistered state. For example, in the RM-deregistered, the UE may not request a PDU session.

**[0356]** FIG. **29** may depict one example embodiment of the present disclosure. For brevity, redundant details will be omitted.

**[0357]** In an example, a UE sends to an AMF, a registration request message. For example, the registration request message may comprise at least one of:

- **[0358]** A identifier of the UE. This may identify the UE. This may be a SUPI, a SUCI, a GUTI, a TMSI and/or the like.
- **[0359]** A requested slices. This may indicate one or more network slices that the UE requests service from a network. This may be a list of one or more identifiers of the one or more network slices.
- **[0360]** A capability indicator indicating whether the UE supports the feature of partly slices (e.g., the feature of partly allowed slices, and/or the feature of partly rejected slices).

**[0361]** In an example, the UE may receive from the AMF, a registration response (e.g., registration accept, registration reject, UE configuration update and/or the like) message. The registration response message may comprise at least one of:

- **[0362]** A allowed slices. This may indicate one or more network slices allowed for the UE. The one or more network slices may be allowed in all TAs of a RA for the UE. For example, the RA for the UE comprises TA1, TA2 and TA3, and the allowed slices may comprise slice Z1 and slice Z2. For example, the UE may be allowed to use the slice Z1 and the slice Z2, in TA1, TA2 and TA3.
- **[0363]** A partly slices. This may indicate a partly allowed slices, a partly rejected slices, and/or the like. This may be one or more identifiers of one or more partly allowed network slices and/or one or more identifiers of one or more partly rejected network slices. The one or more network slices of the partly slices may not be allowed in all TAs of a RA for the UE. For example, the RA for the UE comprises TA1, TA2 and TA3, the partly rejected slices may comprise slice Z3. For example, the slice Z3 may be allowed in TA1 and/or the slice Z3 may not be allowed in TA2 and TA3.

**[0364]** In an example, the UE may determine whether the registration response message comprises the allowed slices. If the registration response comprises the allowed slices, the UE determines that the UE is registered to a network and/or the UE may stay in (or transit to) a RM-registered state. For example, in the RM-registered, the UE may request a PDU session for a network slice of the allowed slices.

**[0365]** In an example, the UE may determine whether the registration response message comprises the allowed slices. If the registration response does not comprise the allowed slices, the UE may determine whether the registration response message comprises the partly rejected slices. If the registration response does not comprise the partly rejected slices, the UE determines that the UE is not registered to a network and/or the UE may stay in (or transit to) RM-deregistered state. For example, in the RM-deregistered, the UE may not request a PDU session.

**[0366]** In an example, the UE may determine whether the registration response message comprises the allowed slices. If the registration response does not comprise the allowed slices, the UE may determine whether the registration response message comprises the partly rejected slices. If the registration response comprises the partly rejected slices and if the UE enters a new TA, the UE determines whether the new TA is one of TAs supporting the partly rejected slices. If the new TA is one of TAs supporting the partly rejected slices, the UE may stay in (or transit to) RM-registered state. If the new TA is not one of TAs supporting the partly rejected slices, the UE may stay in (or transit to) RM-deregistered state.

**[0367]** In an example, a UE may be in a first TA and may send to an AMF of a network, a first message. The first message may be a request message requesting one or more requested network slices. For example, the one or more requested network slices may be a requested slices, and/or a list of one or more identifiers of the one or more requested network slices. For example, the first message may be a registration request message, a service request message, a UL NAS transport message, and/or the like.

**[0368]** In an example, the first message may comprise at least one of:

- **[0369]** A capability indicator indicating that the UE supports partly allowed network slices feature. Partly (partially) allowed network slices feature may be a feature associated with partly allowed network slices. For example, that the UE supports partly allowed network slices feature may be at least one of that the UE is capable at least one of handling, processing, sending, receiving, parsing, or interpreting on the information associated with one or more partly allowed network slices and/or that the UE is capable of at least one of acting, behaving, determining, based on the information associated with one or more partly allowed network slices.
- **[0370]** Information indicating the one or more requested network slices. For example, the information may be one or more S-NSSAIs and/or a NSSAI.

**[0371]** In an example, the first message may further comprise at least one of:

- **[0372]** An identifier of the UE. This may indicate a SUPI, a SUCI, a GUTI, a IMEI, and/or the like.
- **[0373]** A registration type. This may indicate a type/purpose of registration. For example, this may indicate an initial registration, a periodic registration, an emergency registration, a normal registration, and/or the like.

**[0374]** In an example, the UE may receive from the network, a response message, based on sending the first message. For example, the response message may be a registration response message. For example, the registration response may be a registration accept message and/or the registration reject message. The response message may indicate at least one of:

- **[0375]** A registration area (RA). The RA may comprise one or more TAs where the UE is registered. For example, the RA comprises the one or more TAs (e.g., first-type TAs) for the one or more partly allowed network slices, and one or more other TAs (e.g., second-type TAs) than the one or more TAs (e.g., first-type TAs) for the partly allowed network slices. In the one or more TAs (e.g., first-type TAs) for the one or more partly allowed network slices, the UE may be allowed to request/use the one or more partly allowed network slices. In the one or more other TAs (e.g., second-type TAs) than the one or more TAs for the one or more partly allowed network slices, the UE may not be allowed to request/use the one or more partly allowed network slices. The one or more TAs (e.g., first-type TAs) for the one or more partly allowed network slices may comprise at least one TA. The one or more other TAs (e.g., second-type TAs) than the one or more TAs for the one or more partly allowed network slices may comprise at least one TA. For example, the RA may be a list of TAs, and/or may indicate one or more TAs.

**[0376]** One or more partly allowed network slices. The one or more partly allowed network slices may be one or more network slices from the one or more requested network slices. The one or more partly allowed network slices may be allowed in a portion (e.g., first-type TAs) of the RA, may not be allowed in all portions of the RA, may be allowed in one or more TAs of the RA, may not be allowed in all TAs of the RA. This may comprise one or more identifiers of the one or more partly allowed network slices. An identifier of the one or more identifiers may be a NSSAI and/or a S-NSSAI.

**[0377]** One or more TAs for the one or more partly allowed network slices. This may indicate one or more TAs (e.g., first-type TAs) of the RA, where the one or more partly allowed network slices are allowed. This may indicate one or more TAs (e.g., second-type TAs) of the RA, where the one or more partly allowed network slices are rejected (not allowed). A first network slice of the one or more partly allowed network slices may be allowed in a third TAs of the RA. A second network slice of the one or more partly allowed network slices may be allowed in a fourth TAs of the RA. In one example, the one or more TAs for the one or more partly allowed network slices may indicate same TAs for different partly allowed network slices. For example, the third TAs (e.g., TA X1, TA X2) may be same as the fourth TAs (e.g., TA X1, TA X2). In another example, the one or more TAs for the one or more partly allowed network slices may indicate different TAs for different partly allowed network slices. For example, the third TAs (e.g., TA X1, TA X2) may not be same as the fourth TAs (e.g., TA X3, TA X4).

**[0378]** For example, the RA may comprise a first TA and a second TA. For example, the one or more partly allowed network slices may comprise a slice A. For example, the one or more TAs (allowed) for one (e.g., the slice A) of the one or more partly allowed network slices may indicate the second TA (of the RA) and may not indicate the first TA (of the RA). For example, the UE may be allowed to use the slice A in the second TA, and/or may not be allowed to use the slice A in the first TA.

**[0379]** In an example, the response message may further comprise at least one of:

**[0380]** a temporary identifier of the UE. This may indicate a new temporary identifier allocated by the network to the UE.

**[0381]** information of one or more allowed network slices. This may indicate one or more network slices that the UE is allowed in any TAs of the RA.

**[0382]** In an example, the UE may measure one or more neighboring cells and/or may re-select a cell of the one or more neighboring cells. If the UE reselects the cell, the UE may receive a SIB from the cell and may determine a TA supported by the cell. For example, the UE may determine that the cell supports the second TA and/or that the second TA comprises the cell. For example, the UE may select the cell of the second TA. For example, the first type TAs may comprise the second TA. For example, the second type TAs may comprise the first TA.

**[0383]** In an example, the UE may determine whether the TA of the cell and/or the second TA is one of the one or more TAs (supporting) for the partly allowed network slices. If the TA (e.g., the second TA) of the cell is one of the TAs of the one or more TAs for the partly allowed network slices, the UE may send a second message to the network via the cell. For example, the second message may request a service of one or more network slices from the one or more partly allowed network slices.

**[0384]** For example, the second message may be at least one of:

**[0385]** a registration request message.

**[0386]** a service request message.

**[0387]** a UL NAS transport message.

**[0388]** For example, the second message may comprise at least one of:

**[0389]** the identifier of the UE.

**[0390]** a PDU session identifier.

**[0391]** a payload container.

**[0392]** one or more identifiers of the one or more network slices from the one or more of partly allowed network slices. This may indicate one or more network slice for which the UE requests service.

**[0393]** For example, the payload container may be at least one of:

**[0394]** a protocol data unit (PDU) session establishment request message.

**[0395]** a PDU session modification request message.

**[0396]** For example, the payload container comprises at least one of:

**[0397]** a identifier of a PDU session.

**[0398]** a PDU session type. This may indicate a type of the session. For example, this may indicate whether ethernet session is requested and/or an IP session is requested.

**[0399]** For example, the payload container may be sent to a SMF.

**[0400]** In an example, if the UE stays in the first TA and/or a cell of a TA of the first-type TAs, the UE may not send a second message to the network via the cell. For example, the UE may not request a service of one or more network slices from the one or more partly allowed network slices while in the first TA and/or a cell of the first-type TAs.

**[0401]** For example, a TA may be identified by a TA identifier (TAI) and/or a TA code (TAC).

**[0402]** In an example, a UE may send to a network, a first message requesting one or more requested network slices. The first message may comprise a capability indication indicating that the UE supports partly allowed network slices feature. In response to sending the first message, the UE may receive a response message comprising at least one of a registration area (RA) and one or more partly allowed network slices from the one or more requested network slices.

**[0403]** In an example, a network node may receive a first request message comprising at least one of information of one or more requested network slices and a capability indication that the wireless device supports partly allowed network slices feature. The network node may send a response message comprising one or more partly allowed network slices from the one or more requested network slices.

**[0404]** In an example, a UE may send a first request message comprising at least one of one or more identifiers for one or more requested network slices and a capability indication that the wireless device supports a feature of partial network slices. The UE may receive a response message indicating at least one of one or more partially supported network slices from the one or more requested network slices and a partial network slice mode indicator indicating whether partly allowed network slice mode or partly rejected network slice mode is used.

**[0405]** In an example, a first network node may send a network function registration request message comprising an identifier of the first network node and an indication that the first network node supports the feature of partial support of network slice. The first network node may receive from a second network node, a network function registration accept message.

**[0406]** In an example, a first network node (AMF) may receive from a UE, a protocol data unit (PDU) session establishment request for a network slice. The first network node may send to a second network node (SMF), a request message comprising the PDU session establishment request, an identifier of the network slice, an indication that the network slice is partially allowed.

**[0407]** In an example, a second network node (NRF) may receive from a first network node (e.g., SMF, AMF), a network function discovery request message comprising a type of a network function and a capability indicator indicating support of a feature of partial support of network slice. The second network node may send to the first network node, a network function discovery response message comprising an identifier of the network function supporting the feature of partial support of network slice.

**[0408]** In an example, a UE may send, a registration request message comprising one or more identifiers of one or more network slices. The UE may receive, a registration accept message comprising at least one of a first information indicating one or more partly allowed network slices and one or more TAs for the one or more partly allowed network slices and a second information indicating one or more partly rejected network slices and one or more TAs for the one or more partly rejected network slices.

**[0409]** In the specification, some examples are described with partly allowed slices. The examples may be also applicable with partly rejected slices.

**[0410]** In some aspects, the techniques described herein relate to a method including: receiving, by a second network node (NRF) from a first network node, a network function discovery request message including:—a type of a network function; and—a capability indicator indicating support of a feature of partial support of network slice; sending, by the first network node to the second network node, a network function discovery response message including an identifier of the network function supporting the feature of partial support of network slice.

**[0411]** In some aspects, the techniques described herein relate to a method including: sending, by a wireless device, a registration request message including:—one or more identifiers of one or more requested network slices; receiving, by the wireless device, a registration accept message including:—a first information indicating one or more partly allowed network slices and one or more TAs for the one or more partly allowed network slices; and—a third information indicating one or more allowed network slices.

**[0412]** In some aspects, the techniques described herein relate to a method including: sending, by a wireless device, a registration request message including:—one or more identifiers of one or more requested network slices; and—an indication indicating that the wireless device supports a feature of partial network slice. receiving, by the wireless device, a registration accept message including:—a first information indicating a partly allowed network slice, wherein the partly allowed network slice is allowed in a first tracking area (TA) of a registration area (RA); and—a second information indicating a partly rejected network slice, wherein the partly rejected network slice is rejected in a second TA of the RA.

**[0413]** In some aspects, the techniques described herein relate to a method including: sending, by a wireless device, a registration request message including:—one or more identifiers of one or more requested network slices; and—an indication indicating that the wireless device supports a feature of partial network slice; receiving, by the wireless device, a registration accept message including:—a first information indicating one or more partly allowed network slices and one or more TAs for the one or more partly allowed network slices; and—a second information indicating one or more partly rejected network slices and one or more TAs for the one or more partly rejected network slices.

**[0414]** In some aspects, the techniques described herein relate to a method including: sending, by a wireless device in registered mode (RM) registered state, a registration request message including:—one or more identifiers of one or more requested network slices; and—an indication indicating that the wireless device supports a feature of partial network slices; receiving, by a wireless device, a registration accept message not including information of an allowed network slice, wherein the registration accept message includes a partially allowed network slice; transitioning, by the wireless device and based on the registration accept message, to registered mode (RM) registered state; and sending, by the wireless device in RM registered state, a PDU session request for the partially allowed network slice.

**[0415]** In some aspects, the techniques described herein relate to a method including: sending, by a wireless device in registered mode (RM) registered state, a registration request message including:—one or more identifiers of one or more requested network slices; and—an indication indicating that the wireless device supports a feature of partial; receiving, by a wireless device, a registration accept message including includes a partially allowed network slice and one or more tracking areas (TAs) supporting the partially allowed network slice; determining, by the wireless device in a first TA, that the one or more Tas does not include the first TA; and transitioning, by the wireless device and based on the determination, to registered mode (RM) deregistered state.

**[0416]** In some aspects, the techniques described herein relate to a method including: receiving, by a wireless device, a registration accept message not including information of an allowed network slice, wherein the registration accept message includes a partially allowed network slice; transitioning, by the wireless and based on the registration accept message, to RM registered state; and sending a PDU session request for the partially allowed network slice.

**1**. A method comprising:
- sending, by a wireless device, a request message comprising:
  - one or more identifiers for one or more requested network slices; and
  - a capability indication that the wireless device supports a feature of partial network slices; and
- receiving, by the wireless device, a response message comprising a partial network slice mode indicator set to indicate:
  - whether partially allowed network slices apply to the wireless device; and
  - whether partially rejected network slices apply to the wireless device;
- wherein, based on a setting of the partial network slice mode indicator; the response message further comprises one or more second identifiers of at least one of:
  - one or more partially supported network slices among the one or more requested network slices; and
  - one or more partially rejected network slices among the one or more requested network slices.

**2**. The method of claim **1**, wherein the wireless device sends the first request message to a mobility management node.

**3**. The method of claim **2**, wherein the mobility management node comprises an access and mobility management function (AMF).

**4**. The method of claim **1**, wherein the wireless device receives the response message from the mobility management node.

**5**. The method of claim **1**, wherein the mobility management node determines the setting of the partial network slice mode indicator.

**6**. The method of claim **1**, wherein the response message indicates one or more first tracking areas (TAs) associated with the one or more partially allowed network slices.

**7**. The method of claim **1**, wherein the response message indicates one or more second tracking areas (TAs) associated with the one or more partially rejected network slices.

**8**. A wireless device comprising one or more processors and memory storing instructions that, when executed by the one or more processors, cause the wireless device to:
- send a request message comprising:
  - one or more identifiers for one or more requested network slices; and
  - a capability indication that the wireless device supports a feature of partial network slices; and
- receive a response message comprising a partial network slice mode indicator set to indicate:
  - whether partially allowed network slices apply to the wireless device; and
  - whether partially rejected network slices apply to the wireless device;
- wherein, based on a setting of the partial network slice mode indicator; the response message further comprises one or more second identifiers of at least one of:
  - one or more partially supported network slices among the one or more requested network slices; and
  - one or more partially rejected network slices among the one or more requested network slices.

**9**. The wireless device of claim **8**, wherein the wireless device sends the first request message to a mobility management node.

**10**. The wireless device of claim **9**, wherein the mobility management node comprises an access and mobility management function (AMF).

**11**. The wireless device of claim **8**, wherein the wireless device receives the response message from the mobility management node.

**12**. The wireless device of claim **8**, wherein the mobility management node determines the setting of the partial network slice mode indicator.

**13**. The wireless device of claim **8**, wherein the response message indicates one or more first tracking areas (TAs) associated with the one or more partially allowed network slices.

**14**. The wireless device of claim **8**, wherein the response message indicates one or more second tracking areas (TAs) associated with the one or more partially rejected network slices.

**15**. A non-transitory computer-readable medium comprising instructions that, when executed by one or more processors of a wireless device, cause the wireless device to:
- send a request message comprising:
  - one or more identifiers for one or more requested network slices; and
  - a capability indication that the wireless device supports a feature of partial network slices; and
- receive a response message comprising a partial network slice mode indicator set to indicate:
  - whether partially allowed network slices apply to the wireless device; and
  - whether partially rejected network slices apply to the wireless device;
- wherein, based on a setting of the partial network slice mode indicator; the response message further comprises one or more second identifiers of at least one of:
  - one or more partially supported network slices among the one or more requested network slices; and
  - one or more partially rejected network slices among the one or more requested network slices.

**16**. The non-transitory computer-readable medium of claim **15**, wherein the wireless device sends the first request message to a mobility management node.

**17**. The non-transitory computer-readable medium of claim **16**, wherein the mobility management node comprises an access and mobility management function (AMF).

**18**. The non-transitory computer-readable medium of claim **15**, wherein the wireless device receives the response message from the mobility management node.

**19**. The non-transitory computer-readable medium of claim **15**, wherein the mobility management node determines the setting of the partial network slice mode indicator.

**20**. The non-transitory computer-readable medium of claim **15**, wherein the response message indicates one or more first tracking areas (TAs) associated with the one or more partially allowed network slices.

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