US 20250267742A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2025/0267742 A1
(43) Pub. Date: Aug. 21, 2025

Dharmadhikari et al.

(54) **METHODS AND APPARATUS FOR SESSION MANAGEMENT FOR A DUALSTEER DEVICE**

(71) Applicant: **Cable Television Laboratories, Inc.**, Louisville, CO (US)

(72) Inventors: **Omkar Shripad Dharmadhikari**, Lakewood, CO (US); **Arun S. Yerra**, San Ramon, CA (US); **Rahil Gandotra**, Boulder, CO (US); **Yunjung Yi**, Vienna, VA (US)

(21) Appl. No.: **19/054,242**

(22) Filed: **Feb. 14, 2025**

Related U.S. Application Data

(60) Provisional application No. 63/554,848, filed on Feb. 16, 2024.

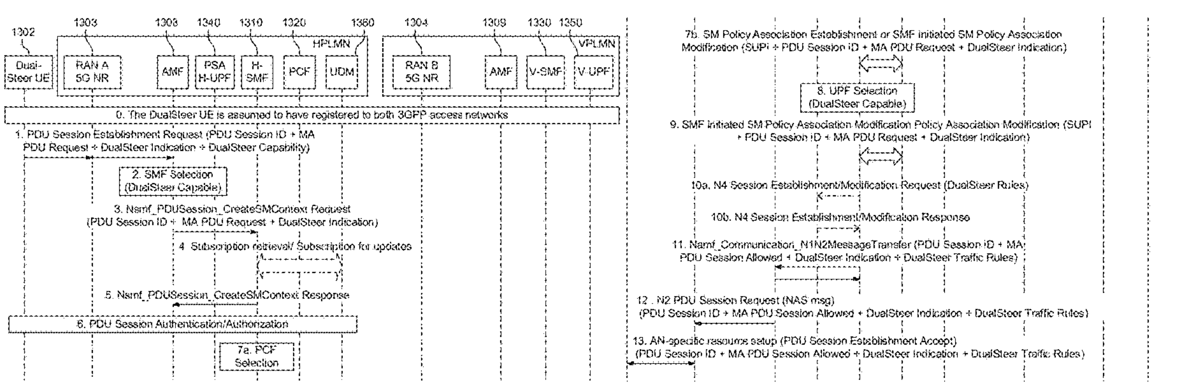
Publication Classification

(51) **Int. Cl.**
H04W 76/15 (2018.01)
H04W 84/04 (2009.01)

(52) **U.S. Cl.**
CPC *H04W 76/15* (2018.02); *H04W 84/042* (2013.01)

(57) **ABSTRACT**

Methods and apparatus for session management for a DualSteer device are provided herein. A user equipment (UE) transmits first information indicating that the UE requests access to two Third Generation Partnership Project (3GPP) access networks simultaneously and that the UE supports access to two 3GPP access networks simultaneously. Further, the UE receives second information indicating rules for accessing the two 3GPP access networks simultaneously. Moreover, the UE transmits data using a multi-access (MA) protocol data unit (PDU) session based on the rules for accessing the two 3GPP access networks simultaneously, where the MA PDU session is established on a first 3GPP access network and a second 3GPP access network. Additionally or alternatively, the first information is included in a PDU session establishment request message. Additionally or alternatively, the second information is included in a PDU session establishment accept message. Additionally or alternatively, the UE is a DualSteer UE.



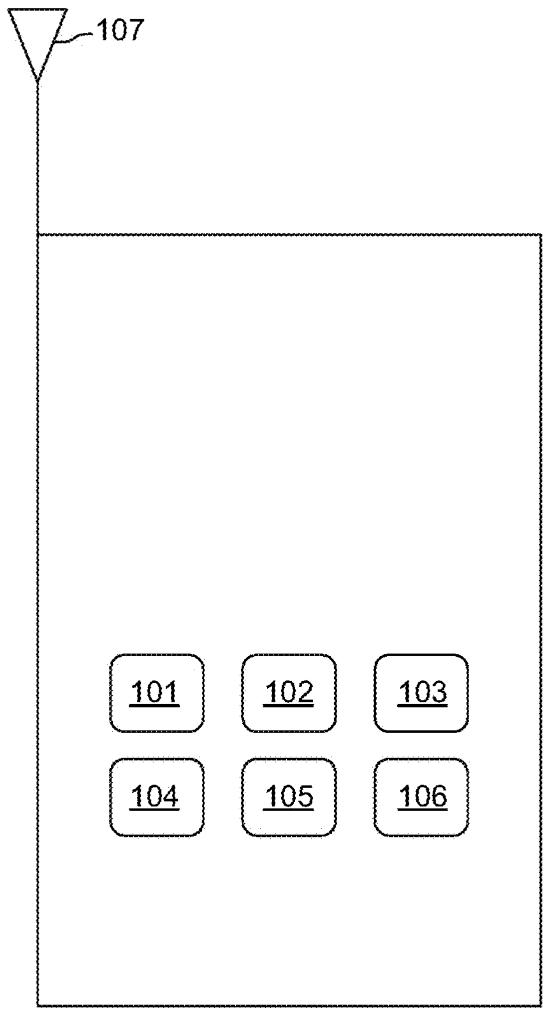


FIG. 1

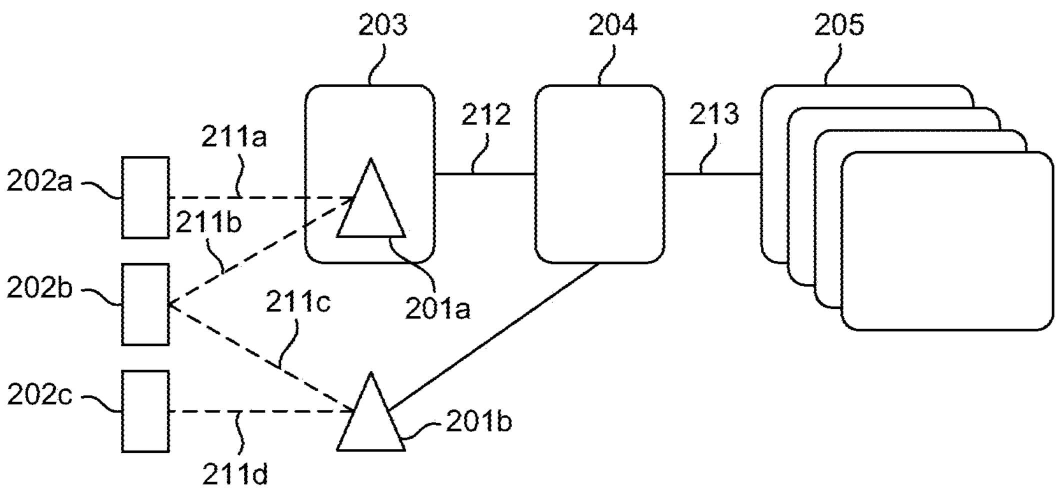

203
204
205
212
213
211a
202a
211b
202b
211c
201a
202c
201b
211d

FIG. 2

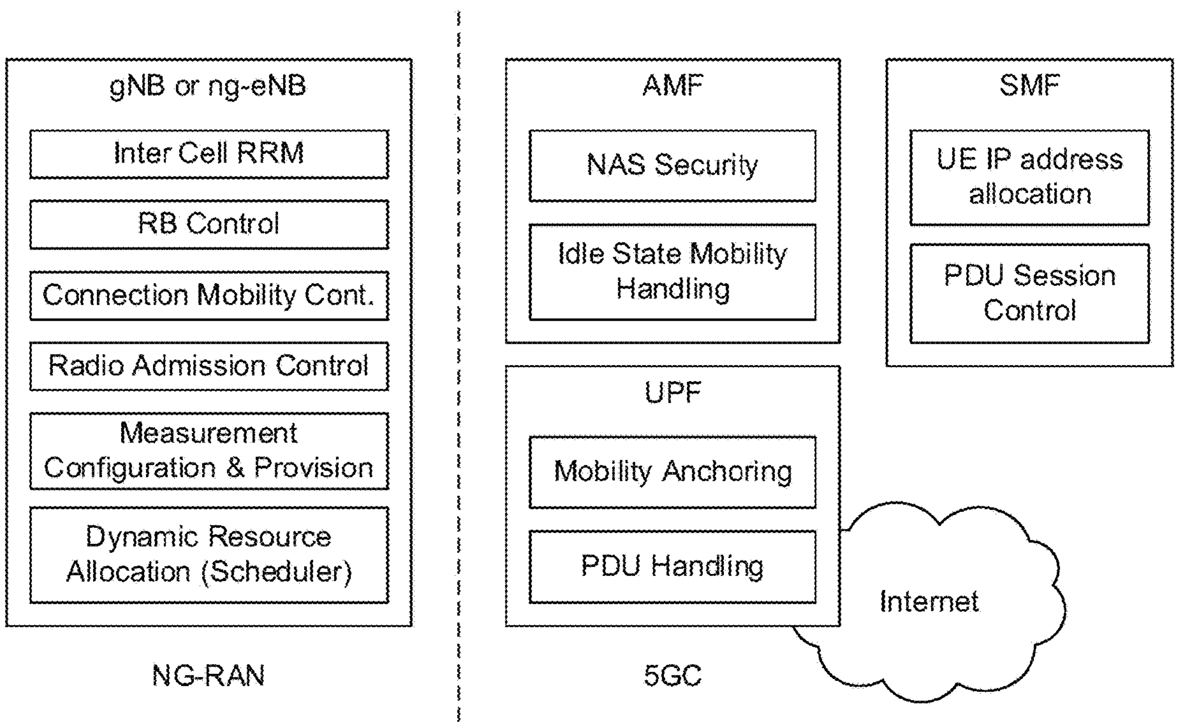

gNB or ng-eNB
Inter Cell RRM
RB Control
Connection Mobility Cont.
Radio Admission Control
Measurement Configuration & Provision
Dynamic Resource Allocation (Scheduler)
NG-RAN
AMF
NAS Security
Idle State Mobility Handling
UPF
Mobility Anchoring
PDU Handling
5GC
SMF
UE IP address allocation
PDU Session Control
Internet

FIG. 3

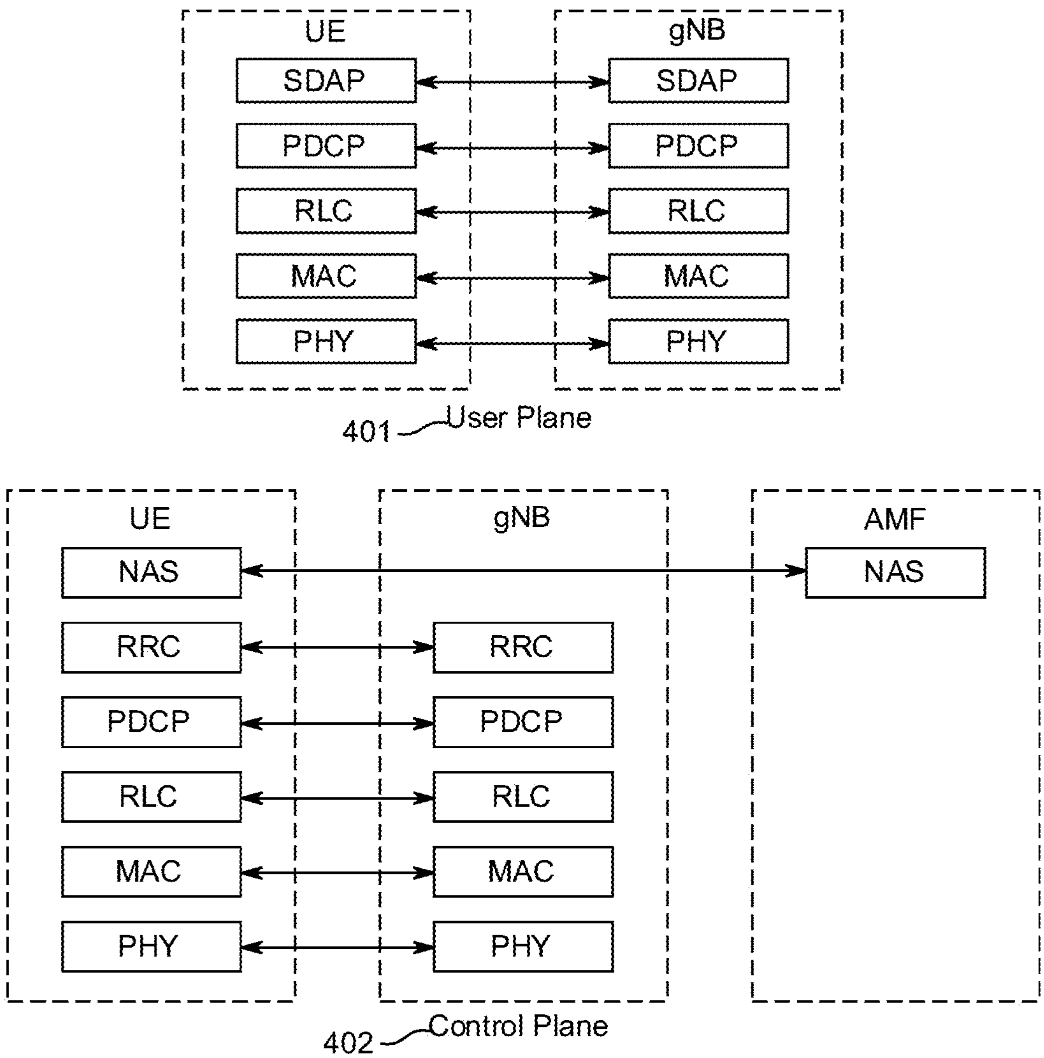

UE
gNB
SDAP
SDAP
PDCP
PDCP
RLC
RLC
MAC
MAC
PHY
PHY
401
User Plane
UE
gNB
AMF
NAS
NAS
RRC
RRC
PDCP
PDCP
RLC
RLC
MAC
MAC
PHY
PHY
402
Control Plane

FIG. 4

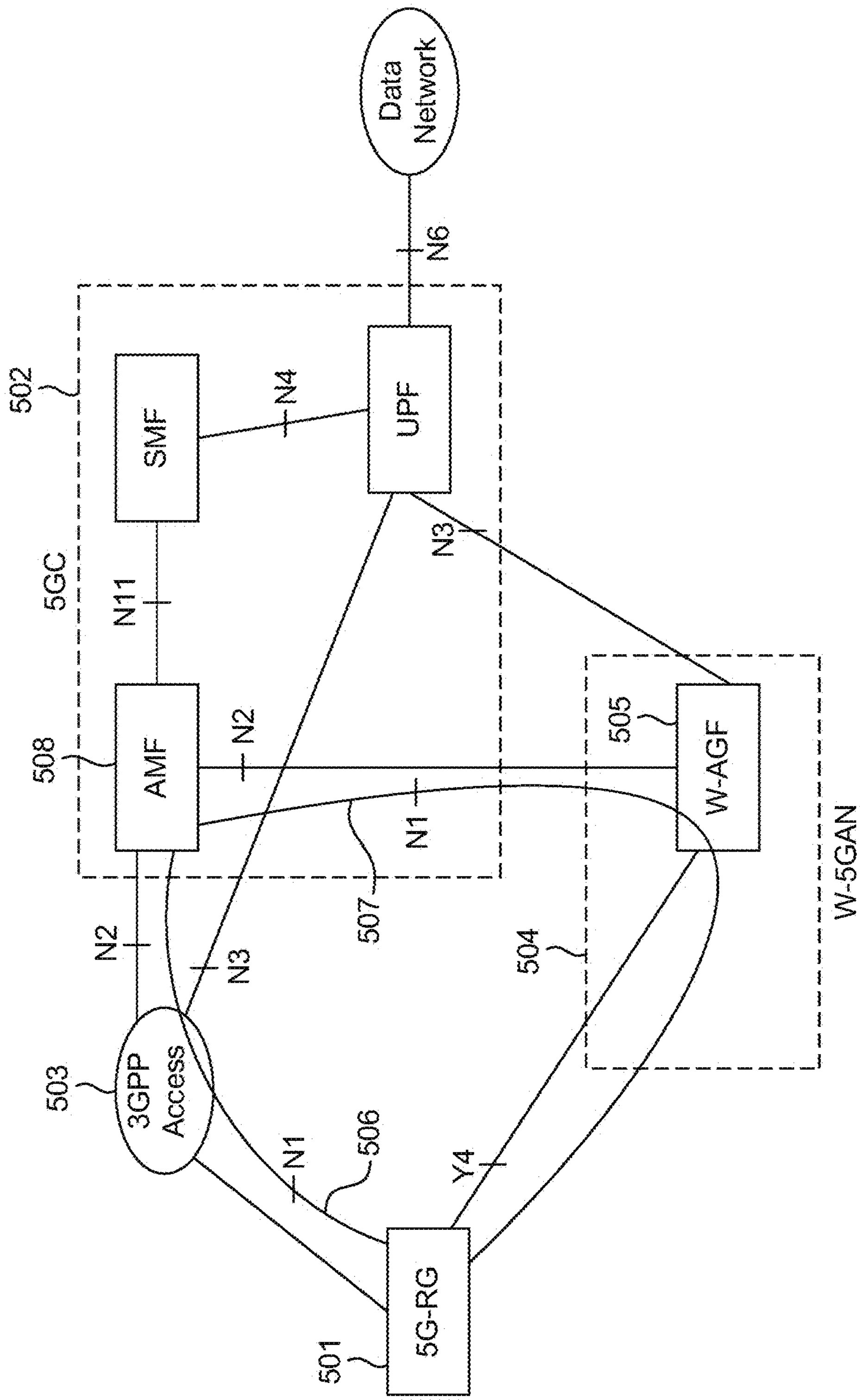
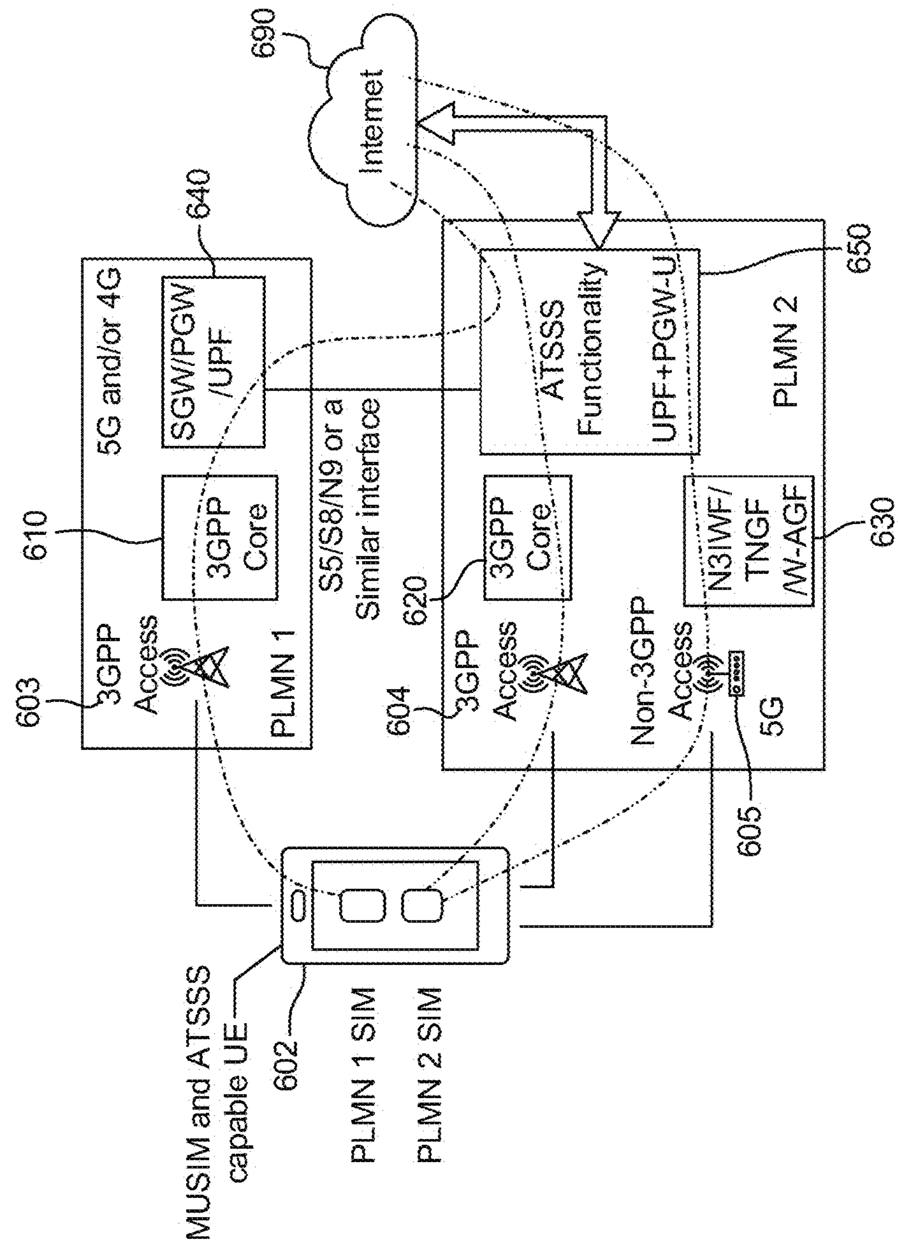
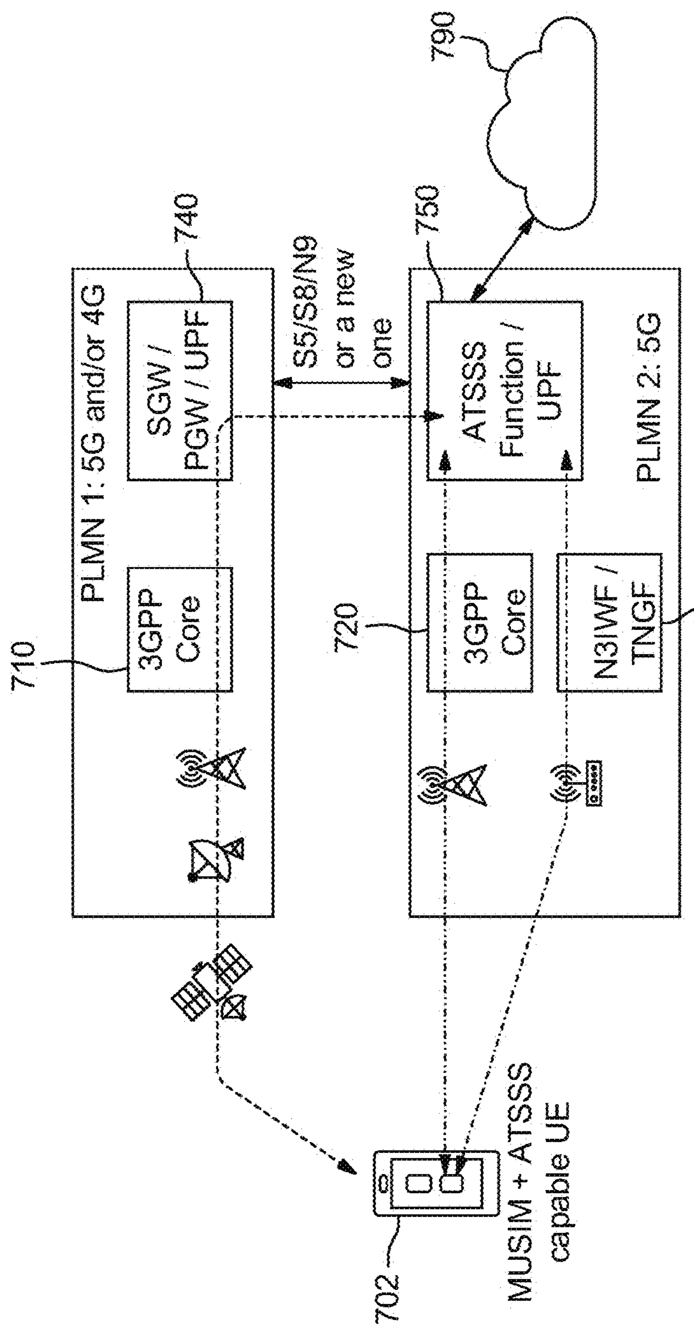

Data Network
N6
502
5GC
SMF
N4
UPF
N11
N3
508
AMF
N2
N1
505
W-AGF
W-5GAN
507
504
N2
N3
503
3GPP Access
506
N1
Y4
501
5G-RG

FIG. 5



690
Internet
640
5G and/or 4G
SGW/PGW /UPF
610
3GPP Core
603
3GPP Access
PLMN 1
S5/S8/N9 or a Similar interface
ATSSS Functionality
UPF+PGW-U
650
PLMN 2
620
3GPP Core
604
3GPP Access
Non-3GPP Access
N3IWF/ TNGF /W-AGF
630
5G
605
MUSIM and ATSSS capable UE
602
PLMN 1 SIM
PLMN 2 SIM

FIG. 6



790
740
750
PLMN 1: 5G and/or 4G
SGW / PGW / UPF
S5/S8/N9 or a new one
ATSSS Function / UPF
PLMN 2: 5G
710
3GPP Core
720
3GPP Core
N3IWF / TNGF
730
702
MUSIM + ATSSS capable UE

FIG. 7

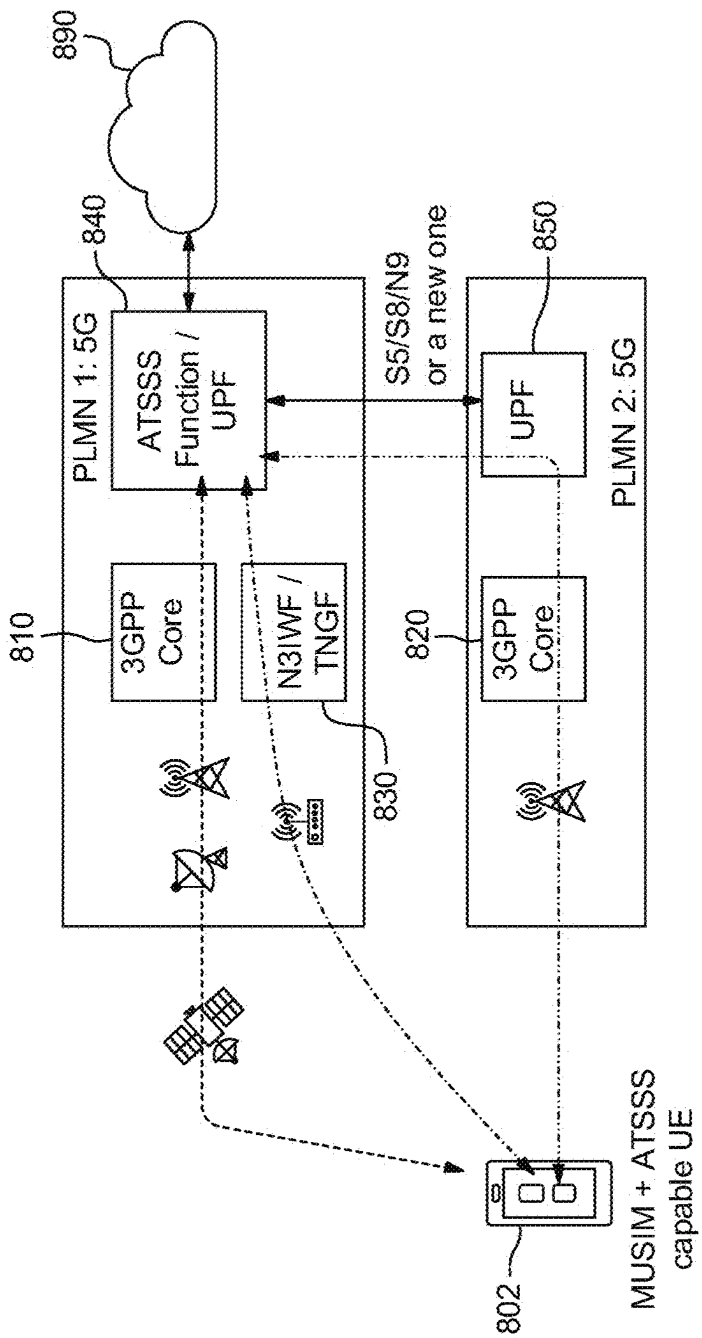

890
840
ATSSS Function / UPF
PLMN 1: 5G
S5/S8/N9 or a new one
850
UPF
PLMN 2: 5G
810
3GPP Core
N3IWF / TNGF
830
820
3GPP Core
802
MUSIM + ATSSS capable UE

FIG. 8

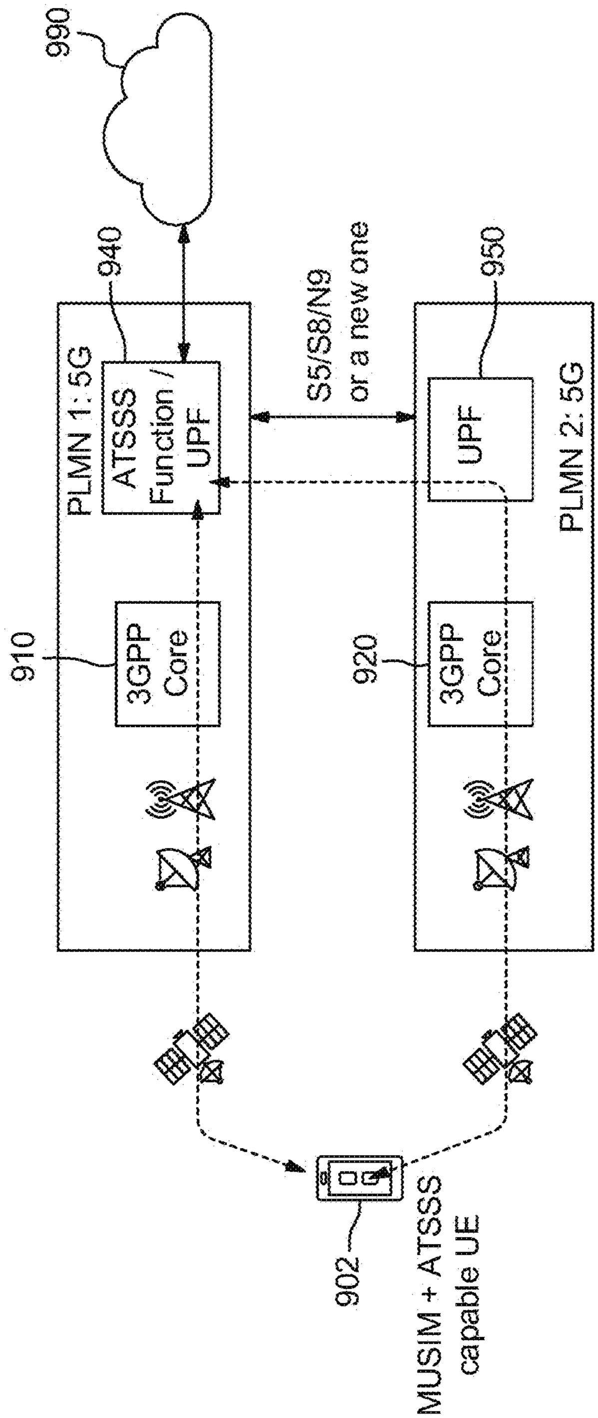

990
940
PLMN 1: 5G
ATSSS
Function /
UPF
910
3GPP
Core
S5/S8/N9
or a new one
950
UPF
PLMN 2: 5G
920
3GPP
Core
902
MUSIM + ATSSS
capable UE

FIG. 9

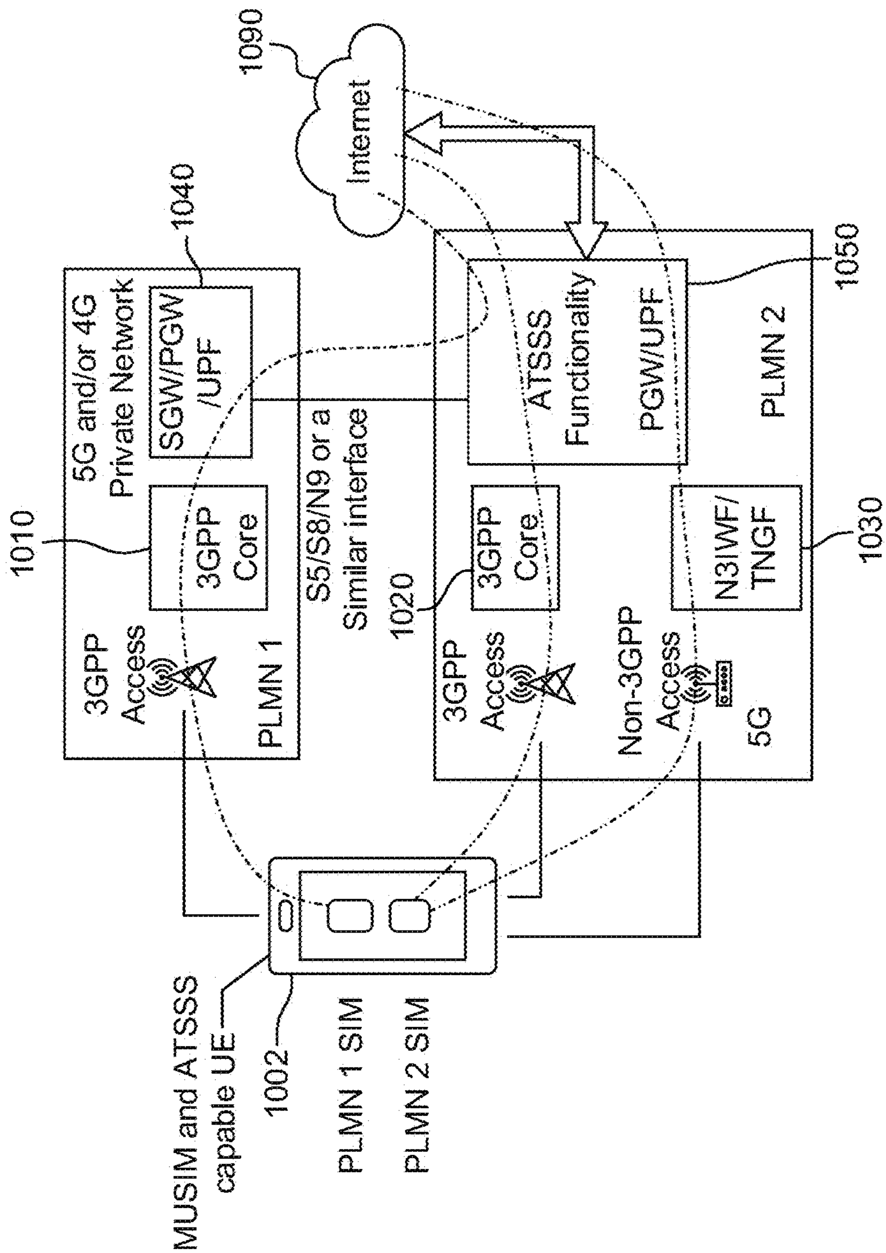

1090
Internet
1040
5G and/or 4G
Private Network
SGW/PGW
/UPF
1010
3GPP
Core
3GPP
Access
PLMN 1
S5/S8/N9 or a
Similar interface
1050
ATSSS
Functionality
PGW/UPF
PLMN 2
1020
3GPP
Core
3GPP
Access
N3IWF/
TNGF
1030
Non-3GPP
Access
5G
MUSIM and ATSSS
capable UE
1002
PLMN 1 SIM
PLMN 2 SIM

FIG. 10

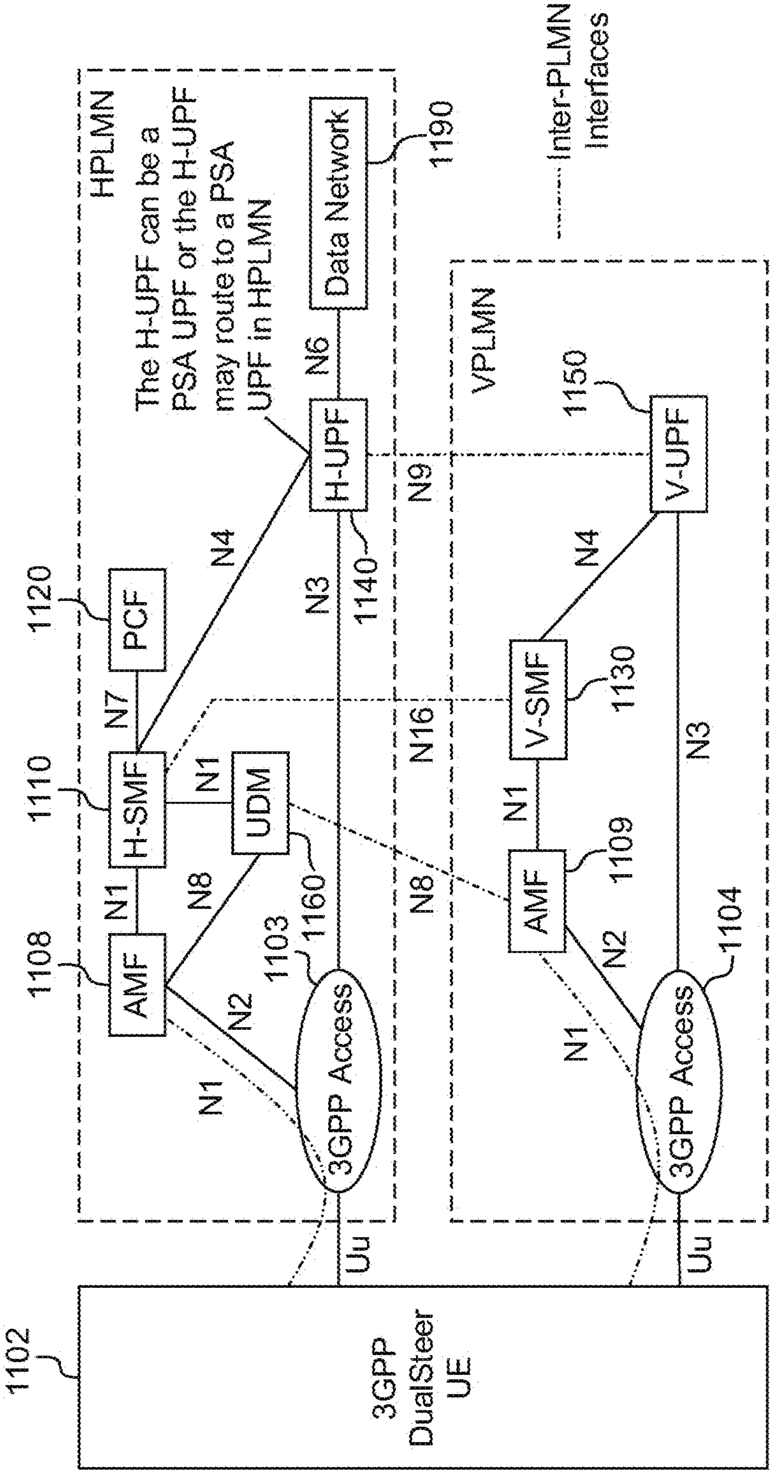
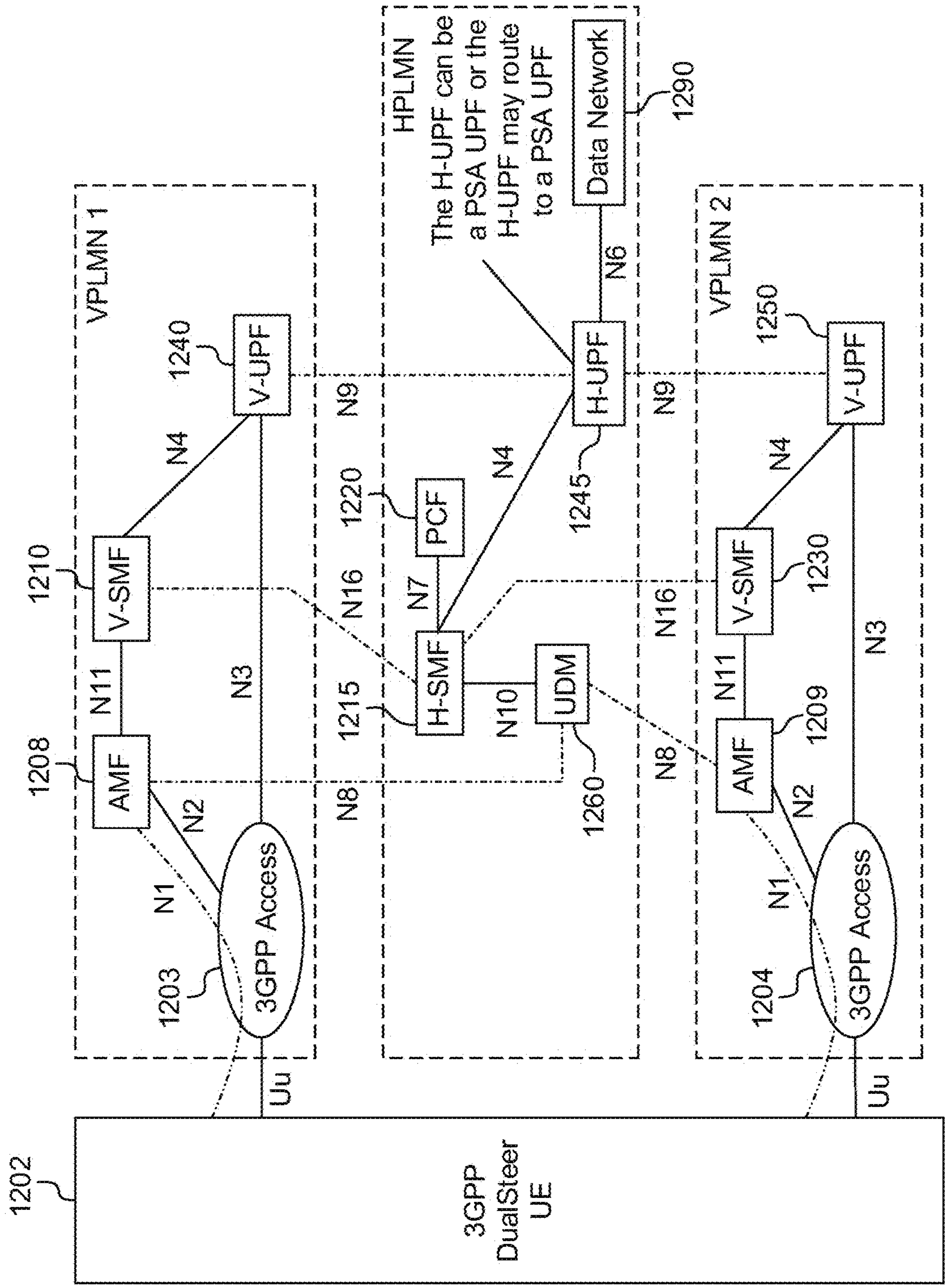

HPLMN
The H-UPF can be a PSA UPF or the H-UPF may route to a PSA UPF in HPLMN
Data Network
1190
1120
PCF
N7
N4
N6
H-UPF
N3
1140
N9
1110
H-SMF
N1
UDM
1160
N8
1108
AMF
N1
N2
1103
3GPP Access
N1
Uu
Inter-PLMN Interfaces
VPLMN
1150
V-UPF
N4
V-SMF
1130
N16
N1
AMF
1109
N8
N2
1104
N1
3GPP Access
N3
Uu
1102
3GPP DualSteer UE

FIG. 11



VPLMN 1
HPLMN
The H-UPF can be a PSA UPF or the H-UPF may route to a PSA UPF
Data Network
1290
VPLMN 2
1202
3GPP DualSteer UE
Uu
Uu
1203
3GPP Access
1204
3GPP Access
N1
N2
N1
N2
1208
AMF
1209
AMF
N11
N11
1210
V-SMF
1230
V-SMF
N3
N3
N4
N4
1240
V-UPF
1250
V-UPF
N9
N9
N8
N8
N16
N16
1215
H-SMF
N10
UDM
1260
N7
PCF
1220
N4
H-UPF
1245
N6

FIG. 12

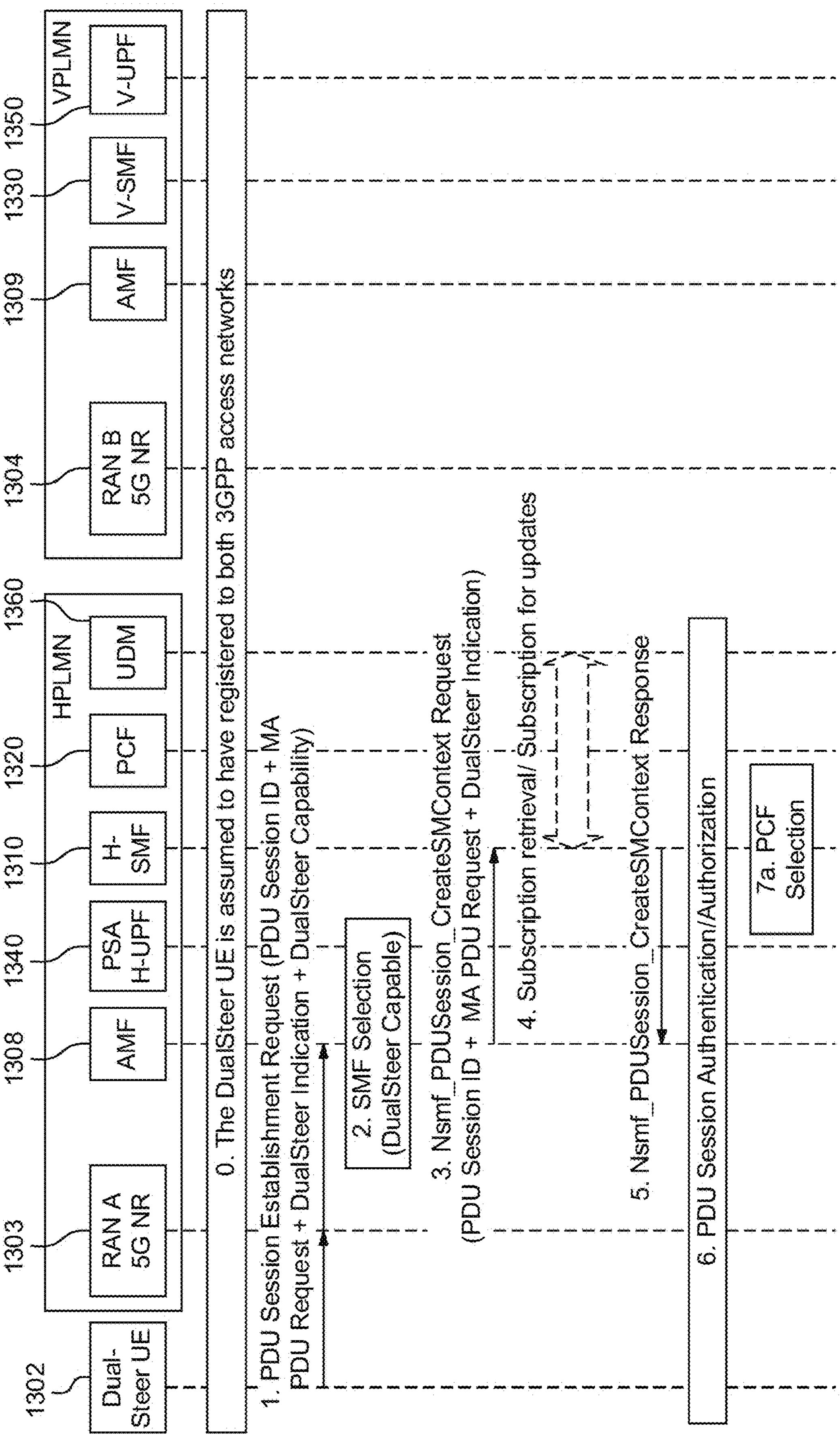

1302
Dual-Steer UE
1303
RAN A 5G NR
1308
AMF
1340
PSA H-UPF
1310
H-SMF
1320
PCF
1360
UDM
HPLMN
1304
RAN B 5G NR
1309
AMF
1330
V-SMF
1350
V-UPF
VPLMN
0. The DualSteer UE is assumed to have registered to both 3GPP access networks
1. PDU Session Establishment Request (PDU Session ID + MA PDU Request + DualSteer Indication + DualSteer Capability)
2. SMF Selection (DualSteer Capable)
3. Nsmf_PDUSession_CreateSMContext Request (PDU Session ID + MA PDU Request + DualSteer Indication)
4. Subscription retrieval/ Subscription for updates
5. Nsmf_PDUSession_CreateSMContext Response
6. PDU Session Authentication/Authorization
7a. PCF Selection

FIG. 13

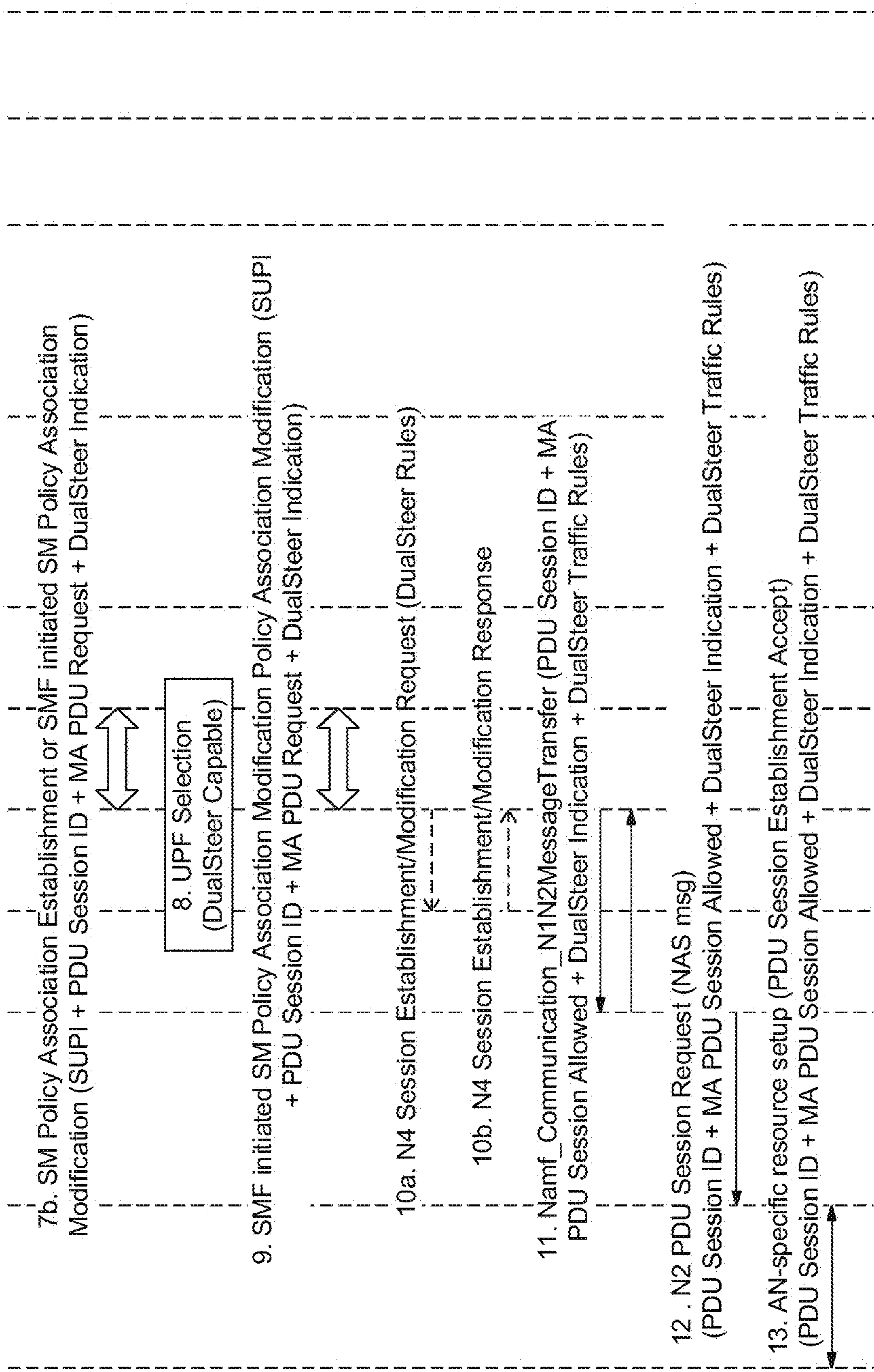

7b. SM Policy Association Establishment or SMF initiated SM Policy Association Modification (SUPI + PDU Session ID + MA PDU Request + DualSteer Indication)
8. UPF Selection (DualSteer Capable)
9. SMF initiated SM Policy Association Modification Policy Association Modification (SUPI + PDU Session ID + MA PDU Request + DualSteer Indication)
10a. N4 Session Establishment/Modification Request (DualSteer Rules)
10b. N4 Session Establishment/Modification Response
11. Namf_Communication_N1N2MessageTransfer (PDU Session ID + MA PDU Session Allowed + DualSteer Indication + DualSteer Traffic Rules)
12 . N2 PDU Session Request (NAS msg) (PDU Session ID + MA PDU Session Allowed + DualSteer Indication + DualSteer Traffic Rules)
13. AN-specific resource setup (PDU Session Establishment Accept) (PDU Session ID + MA PDU Session Allowed + DualSteer Indication + DualSteer Traffic Rules)

FIG. 13 (Cont'd)

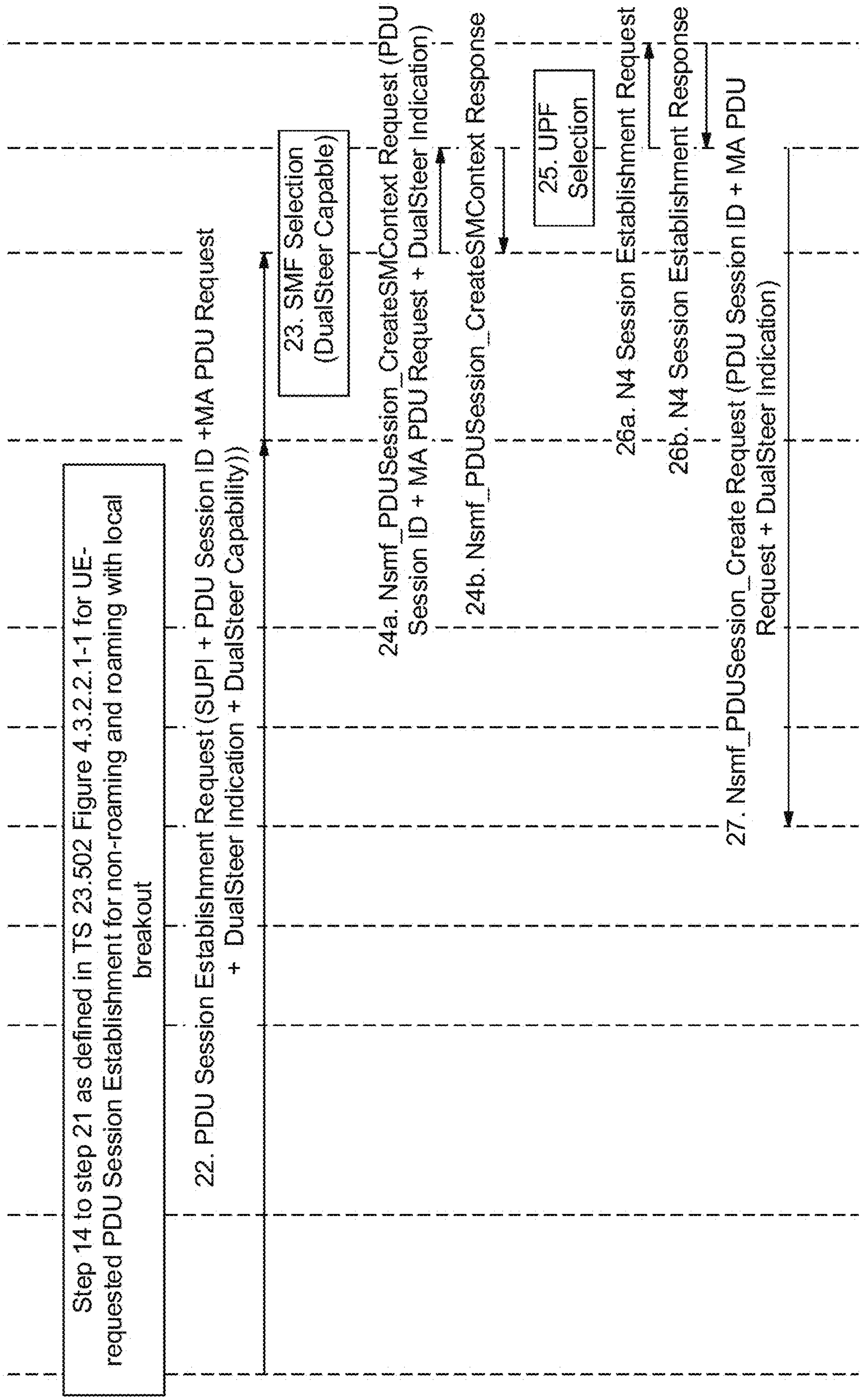

Step 14 to step 21 as defined in TS 23.502 Figure 4.3.2.2.1-1 for UE-requested PDU Session Establishment for non-roaming and roaming with local breakout
22. PDU Session Establishment Request (SUPI + PDU Session ID +MA PDU Request + DualSteer Indication + DualSteer Capability))
23. SMF Selection (DualSteer Capable)
24a. Nsmf_PDUSession_CreateSMContext Request (PDU Session ID + MA PDU Request + DualSteer Indication)
24b. Nsmf_PDUSession_CreateSMContext Response
25. UPF Selection
26a. N4 Session Establishment Request
26b. N4 Session Establishment Response
27. Nsmf_PDUSession_Create Request (PDU Session ID + MA PDU Request + DualSteer Indication)

FIG. 13 (Cont'd)

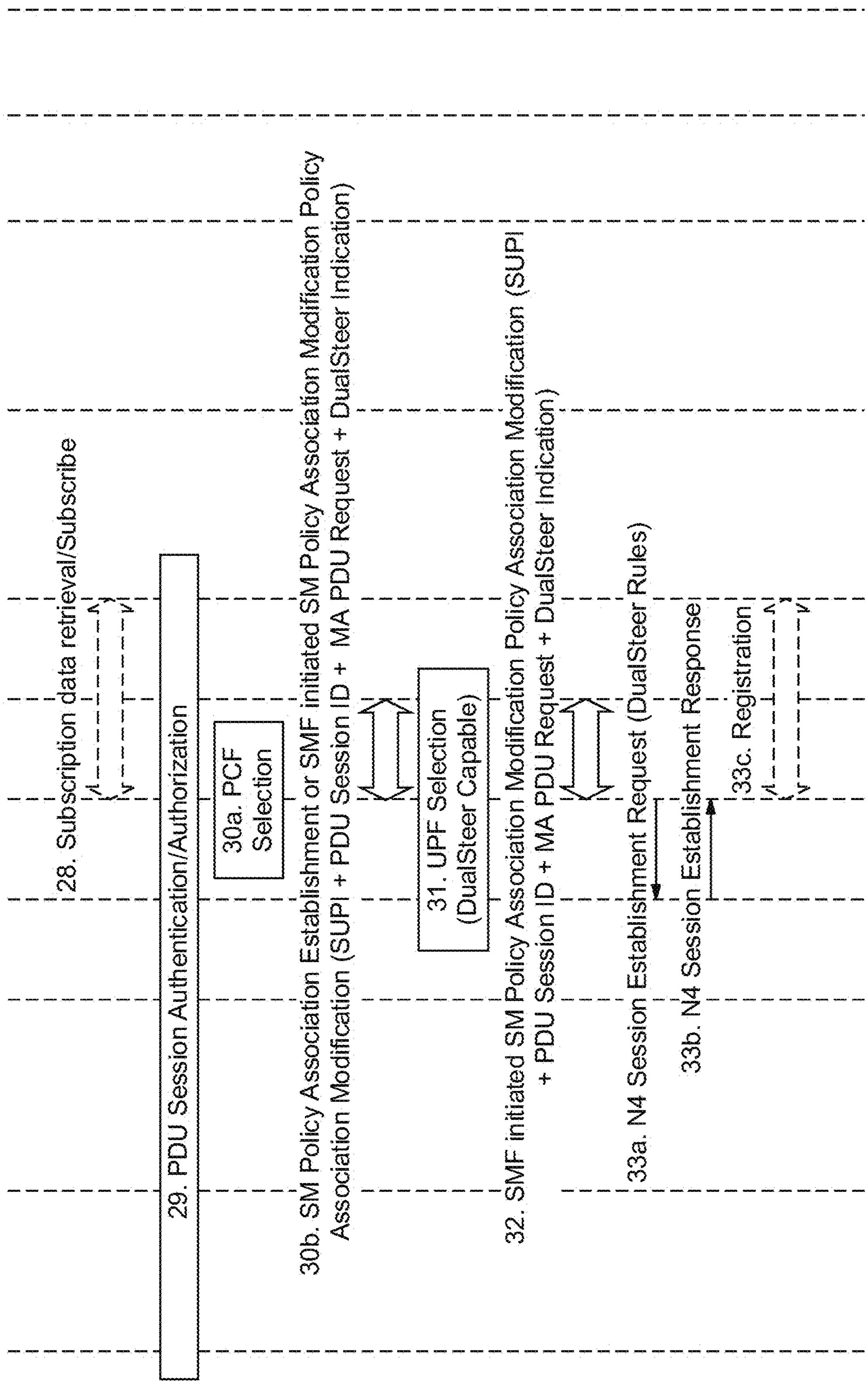

28. Subscription data retrieval/Subscribe
29. PDU Session Authentication/Authorization
30a. PCF Selection
30b. SM Policy Association Establishment or SMF initiated SM Policy Association Modification Policy Association Modification (SUPI + PDU Session ID + MA PDU Request + DualSteer Indication)
31. UPF Selection (DualSteer Capable)
32. SMF initiated SM Policy Association Modification Policy Association Modification (SUPI + PDU Session ID + MA PDU Request + DualSteer Indication)
33a. N4 Session Establishment Request (DualSteer Rules)
33b. N4 Session Establishment Response
33c. Registration

FIG. 13 (Cont'd)

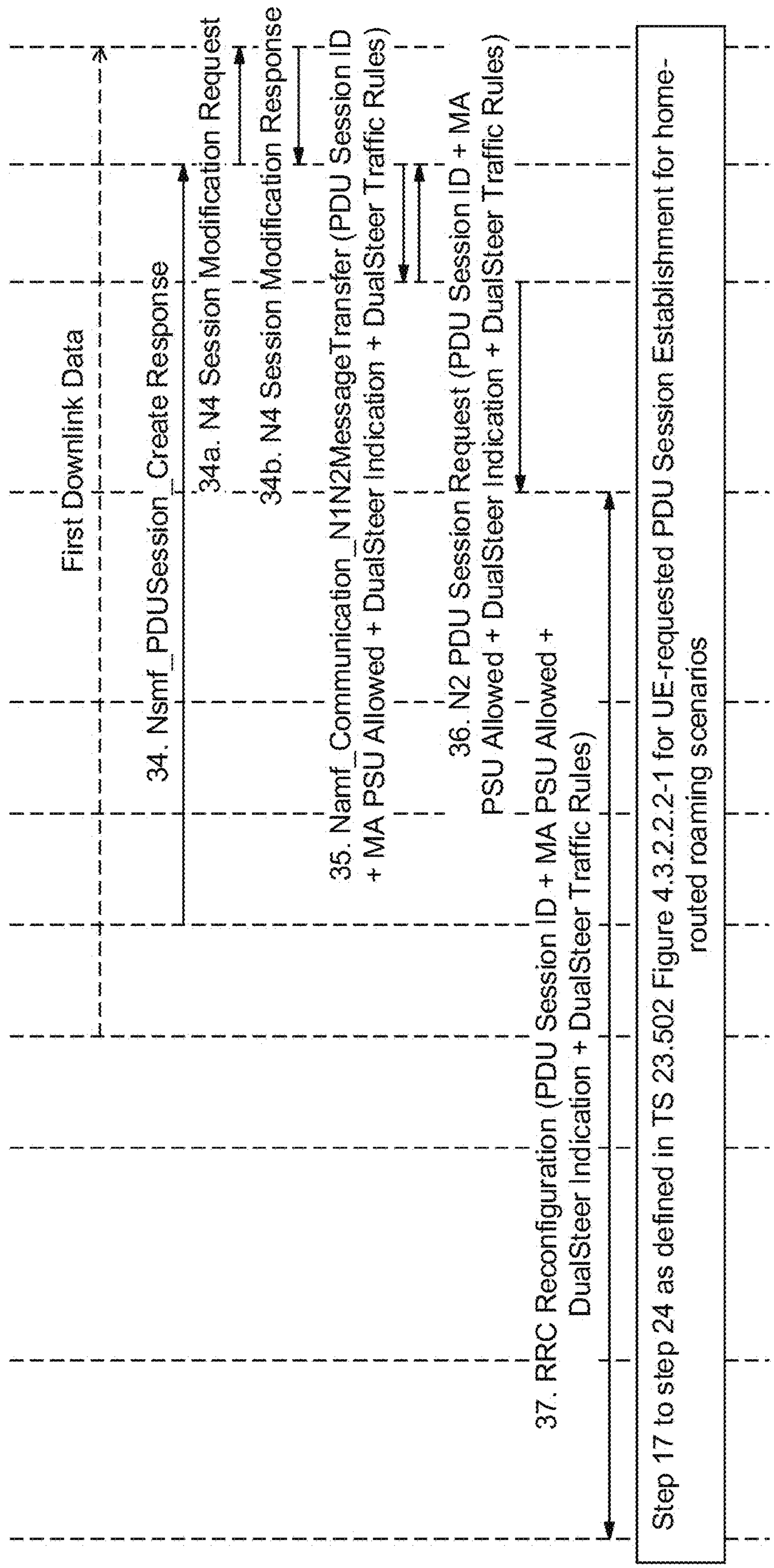

First Downlink Data
34. Nsmf_PDUSession_Create Response
34a. N4 Session Modification Request
34b. N4 Session Modification Response
35. Namf_Communication_N1N2MessageTransfer (PDU Session ID + MA PSU Allowed + DualSteer Indication + DualSteer Traffic Rules)
36. N2 PDU Session Request (PDU Session ID + MA PSU Allowed + DualSteer Indication + DualSteer Traffic Rules)
37. RRC Reconfiguration (PDU Session ID + MA PSU Allowed + DualSteer Indication + DualSteer Traffic Rules)
Step 17 to step 24 as defined in TS 23.502 Figure 4.3.2.2.2-1 for UE-requested PDU Session Establishment for home-routed roaming scenarios

FIG. 13 (Cont'd)

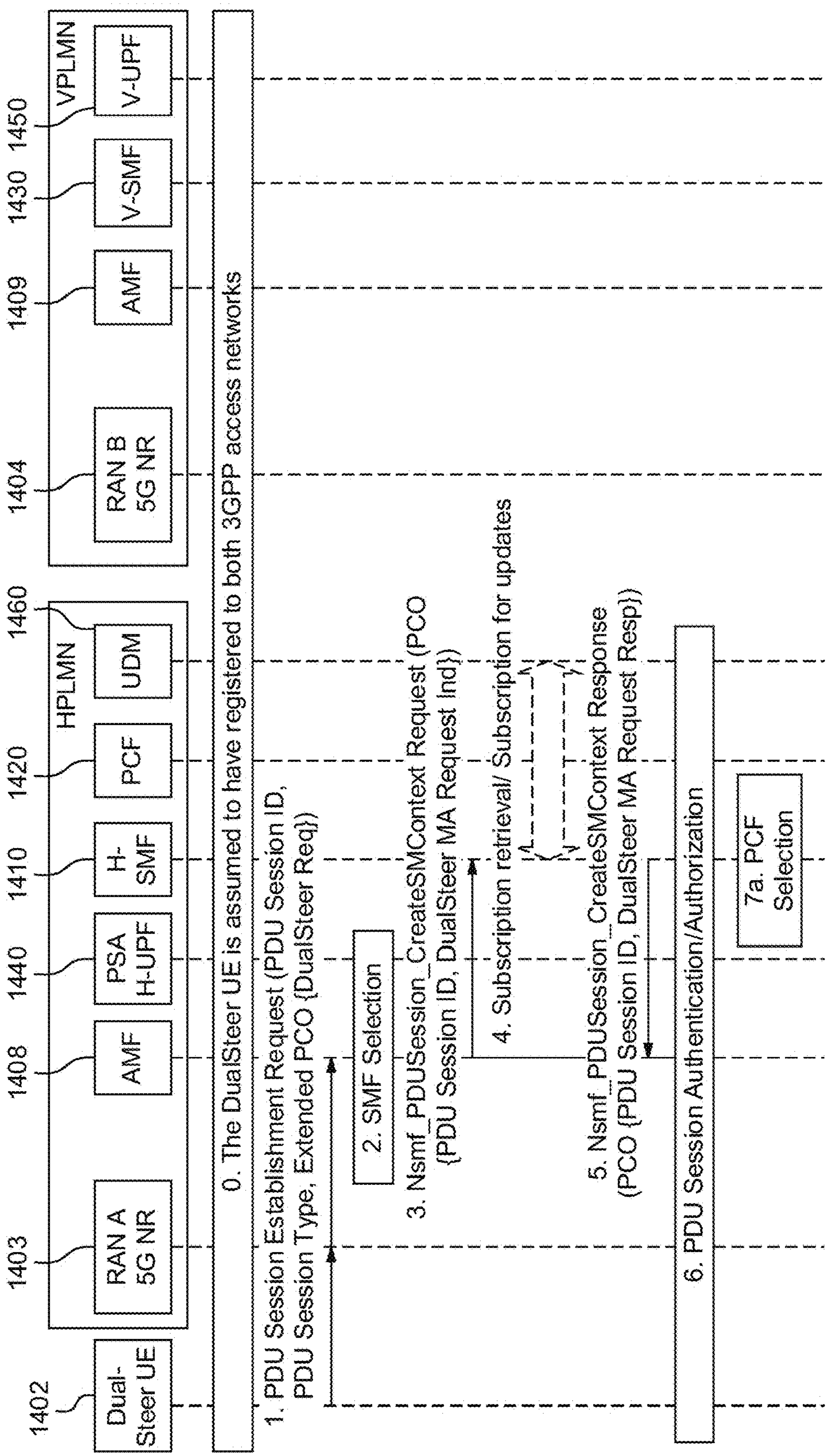

1402
Dual-Steer UE
1403
RAN A 5G NR
1408
AMF
1440
PSA H-UPF
1410
H-SMF
1420
PCF
1460
UDM
HPLMN
1404
RAN B 5G NR
1409
AMF
1430
V-SMF
1450
V-UPF
VPLMN
0. The DualSteer UE is assumed to have registered to both 3GPP access networks
1. PDU Session Establishment Request (PDU Session ID, PDU Session Type, Extended PCO {DualSteer Req})
2. SMF Selection
3. Nsmf_PDUSession_CreateSMContext Request (PCO {PDU Session ID, DualSteer MA Request Ind})
4. Subscription retrieval/ Subscription for updates
5. Nsmf_PDUSession_CreateSMContext Response (PCO {PDU Session ID, DualSteer MA Request Resp})
6. PDU Session Authentication/Authorization
7a. PCF Selection

FIG. 14

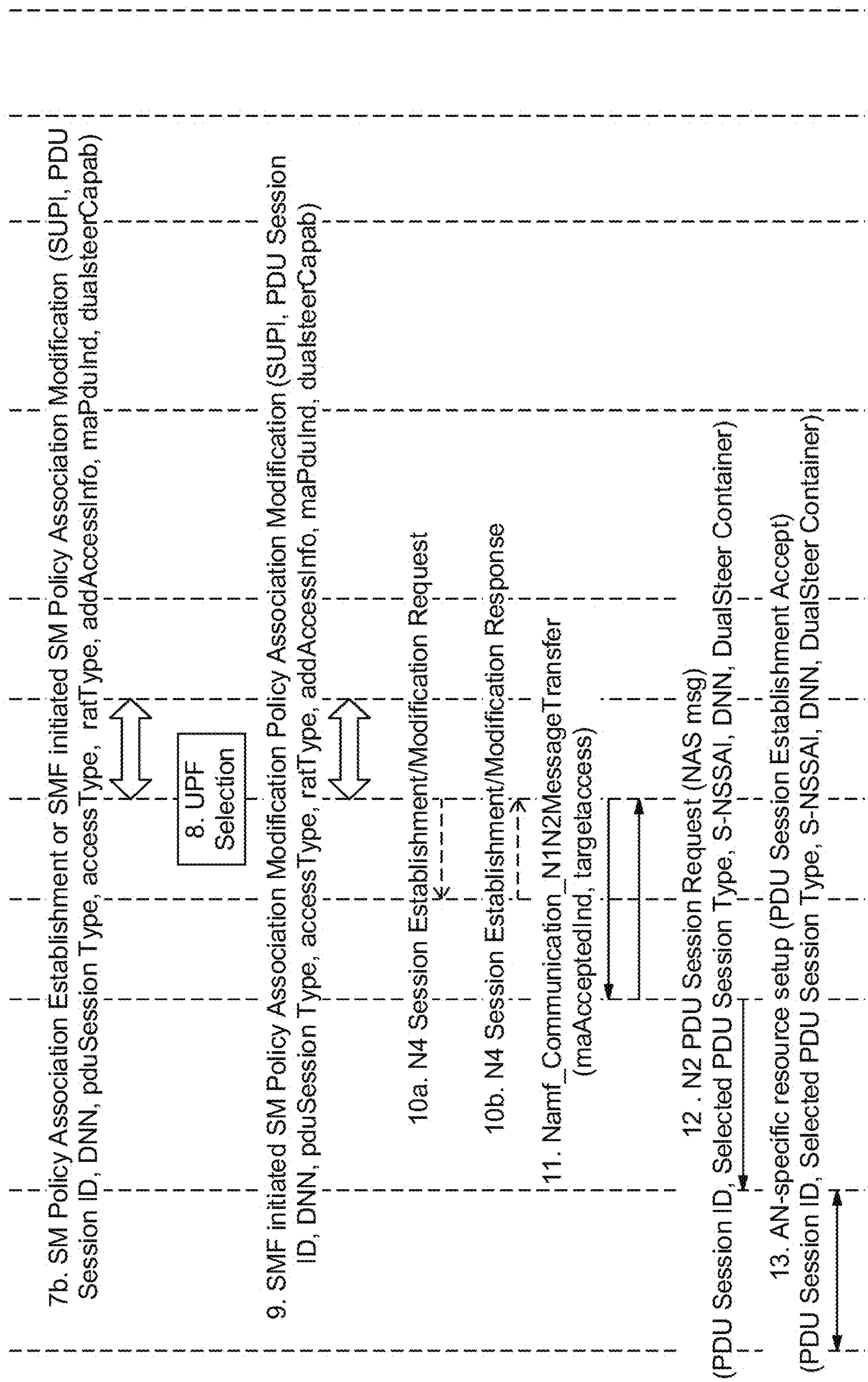

7b. SM Policy Association Establishment or SMF initiated SM Policy Association Modification (SUPI, PDU Session ID, DNN, pduSession Type, accessType, ratType, addAccessInfo, maPduInd, dualsteerCapab)
8. UPF Selection
9. SMF initiated SM Policy Association Modification (SUPI, PDU Session ID, DNN, pduSession Type, accessType, ratType, addAccessInfo, maPduInd, dualsteerCapab)
10a. N4 Session Establishment/Modification Request
10b. N4 Session Establishment/Modification Response
11. Namf_Communication_N1N2MessageTransfer (maAcceptedInd, targetaccess)
12 . N2 PDU Session Request (NAS msg) (PDU Session ID, Selected PDU Session Type, S-NSSAI, DNN, DualSteer Container)
13. AN-specific resource setup (PDU Session Establishment Accept) (PDU Session ID, Selected PDU Session Type, S-NSSAI, DNN, DualSteer Container)

FIG. 14 (Cont'd)

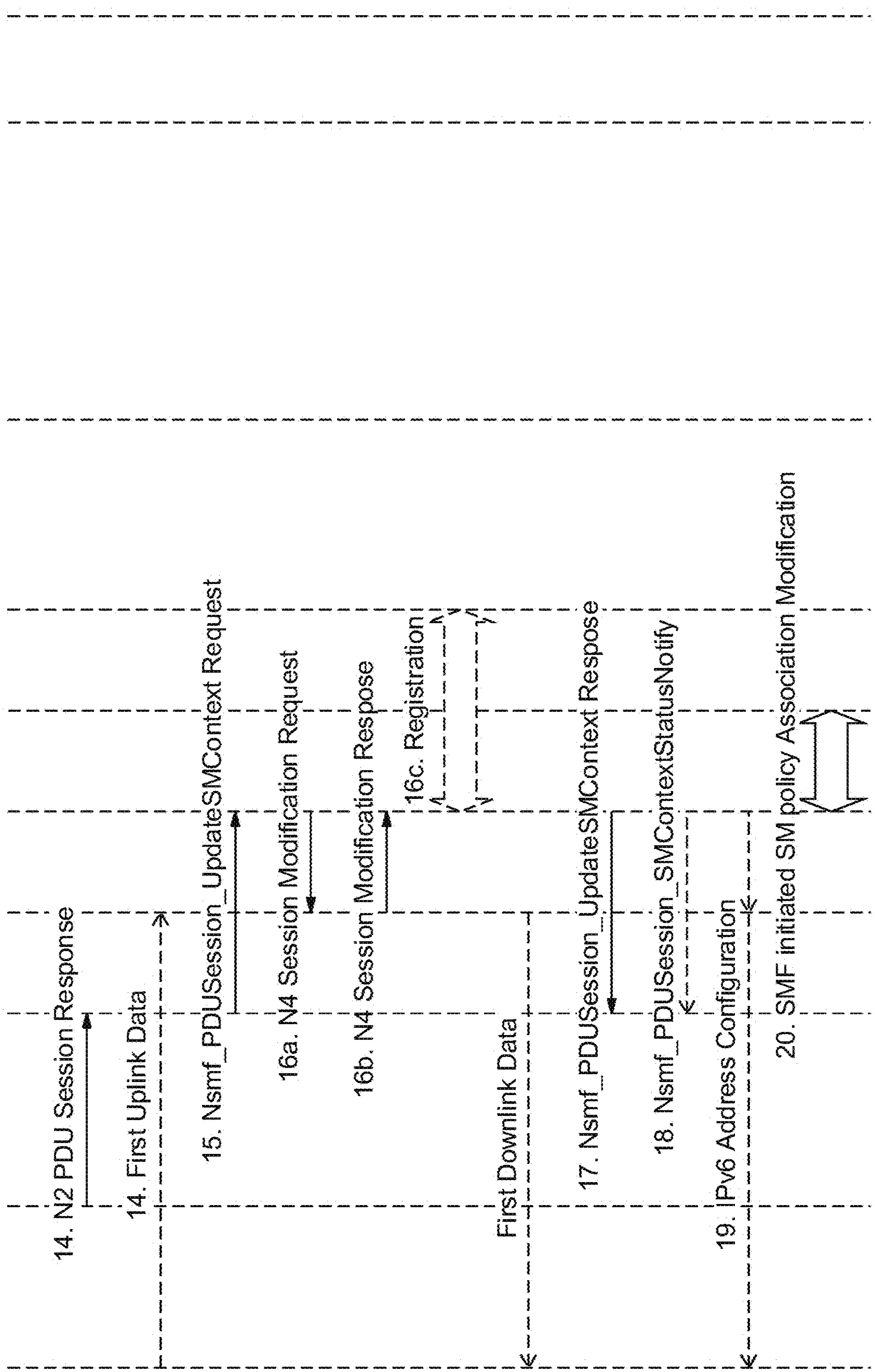

14. N2 PDU Session Response
14. First Uplink Data
15. Nsmf_PDUSession_UpdateSMContext Request
16a. N4 Session Modification Request
16b. N4 Session Modification Respose
16c. Registration
First Downlink Data
17. Nsmf_PDUSession_UpdateSMContext Respose
18. Nsmf_PDUSession_SMContextStatusNotify
19. IPv6 Address Configuration
20. SMF initiated SM policy Association Modification

FIG. 14 (Cont'd)

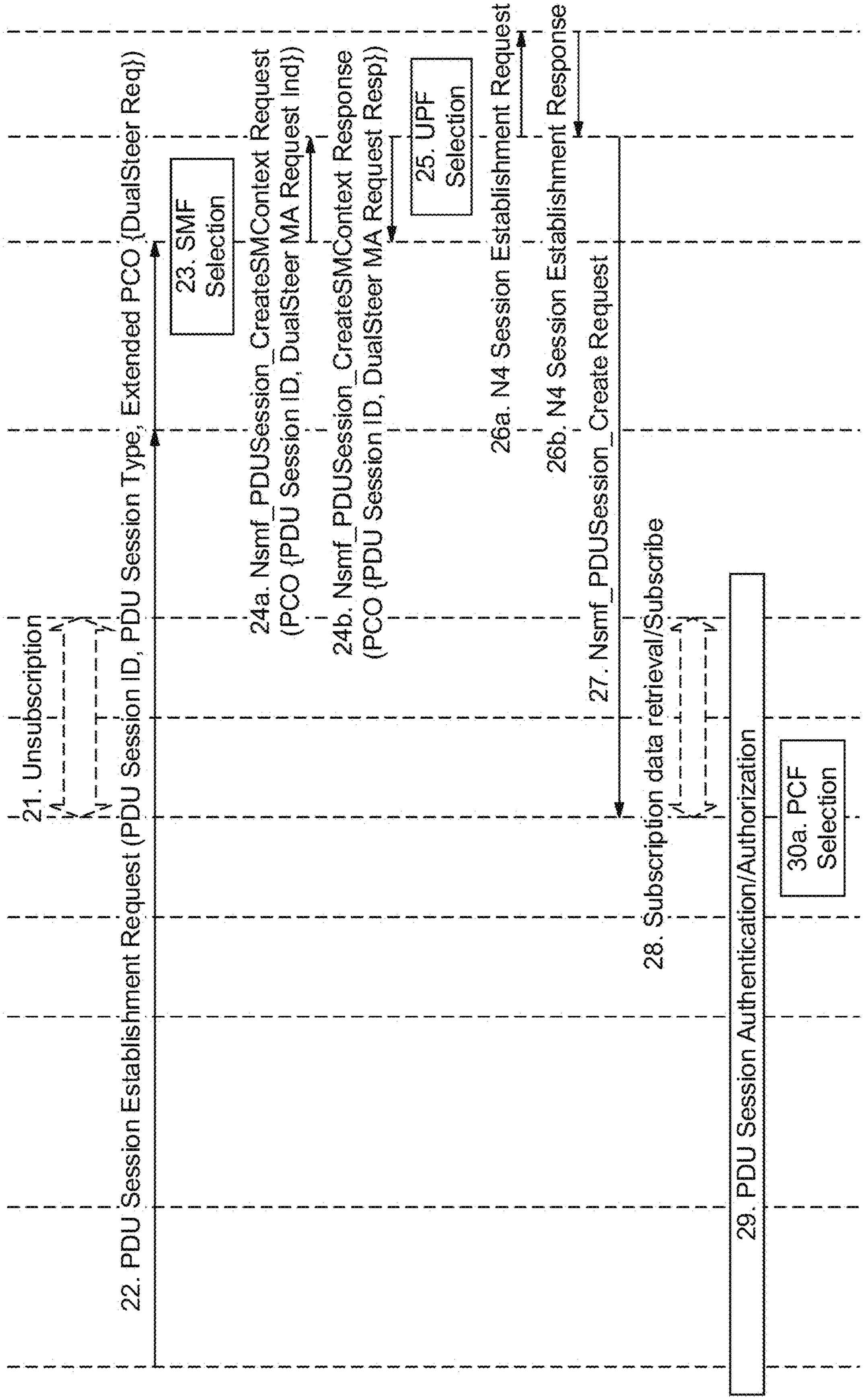

21. Unsubscription
22. PDU Session Establishment Request (PDU Session ID, PDU Session Type, Extended PCO {DualSteer Req})
23. SMF Selection
24a. Nsmf_PDUSession_CreateSMContext Request (PCO {PDU Session ID, DualSteer MA Request Ind})
24b. Nsmf_PDUSession_CreateSMContext Response (PCO {PDU Session ID, DualSteer MA Request Resp})
25. UPF Selection
26a. N4 Session Establishment Request
26b. N4 Session Establishment Response
27. Nsmf_PDUSession_Create Request
28. Subscription data retrieval/Subscribe
29. PDU Session Authentication/Authorization
30a. PCF Selection

FIG. 14 (Cont'd)

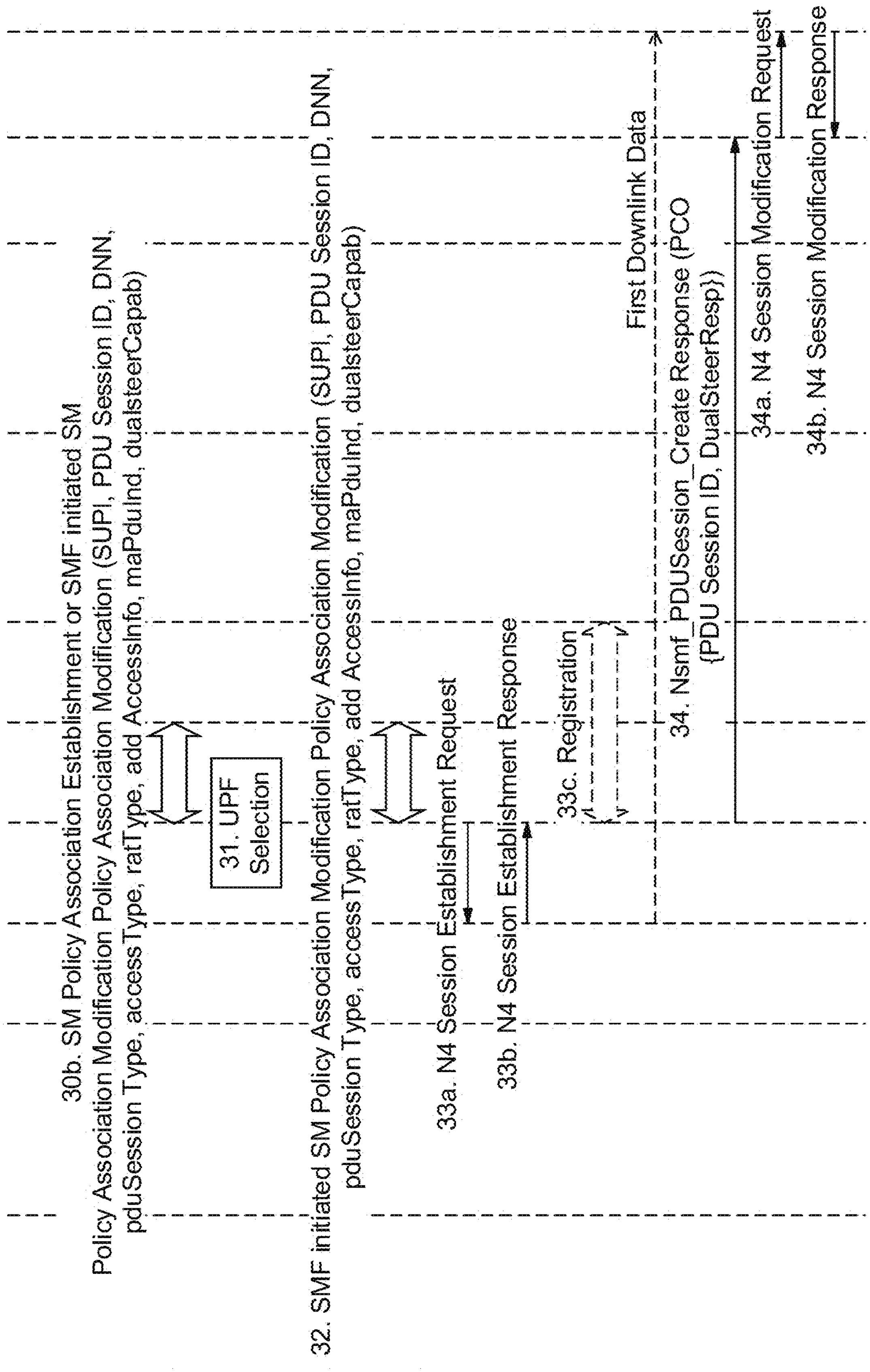

30b. SM Policy Association Establishment or SMF initiated SM
Policy Association Modification Policy Association Modification (SUPI, PDU Session ID, DNN,
pduSession Type, accessType, ratType, add AccessInfo, maPduInd, dualsteerCapab)
31. UPF
Selection
32. SMF initiated SM Policy Association Modification Policy Association Modification (SUPI, PDU Session ID, DNN,
pduSession Type, accessType, ratType, add AccessInfo, maPduInd, dualsteerCapab)
33a. N4 Session Establishment Request
33b. N4 Session Establishment Response
33c. Registration
First Downlink Data
34. Nsmf_PDUSession_Create Response (PCO
{PDU Session ID, DualSteerResp})
34a. N4 Session Modification Request
34b. N4 Session Modification Response

FIG. 14 (Cont'd)

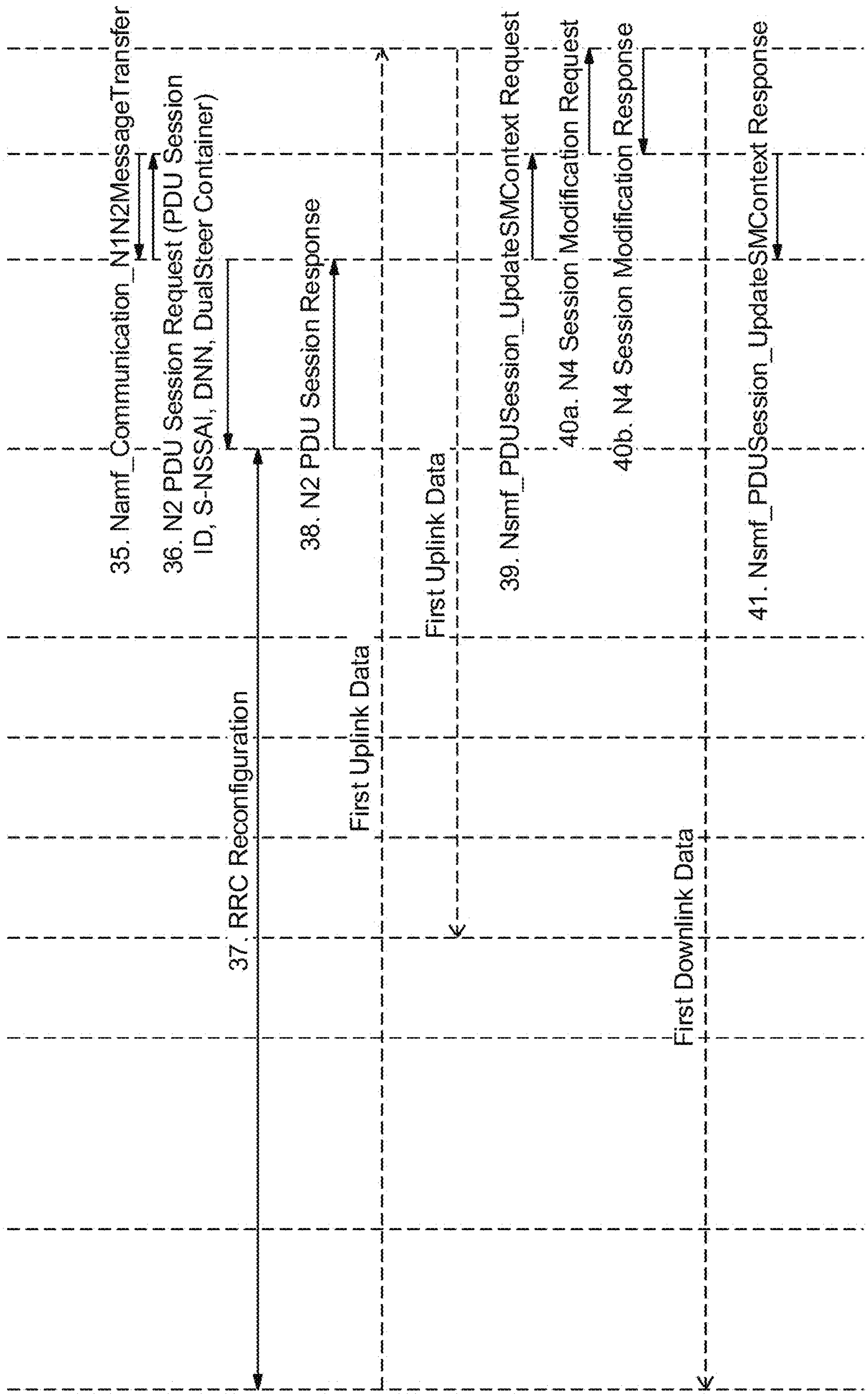

35. Namf_Communication_N1N2MessageTransfer
36. N2 PDU Session Request (PDU Session ID, S-NSSAI, DNN, DualSteer Container)
37. RRC Reconfiguration
38. N2 PDU Session Response
First Uplink Data
First Uplink Data
39. Nsmf_PDUSession_UpdateSMContext Request
40a. N4 Session Modification Request
40b. N4 Session Modification Response
First Downlink Data
41. Nsmf_PDUSession_UpdateSMContext Response

FIG. 14 (Cont'd)

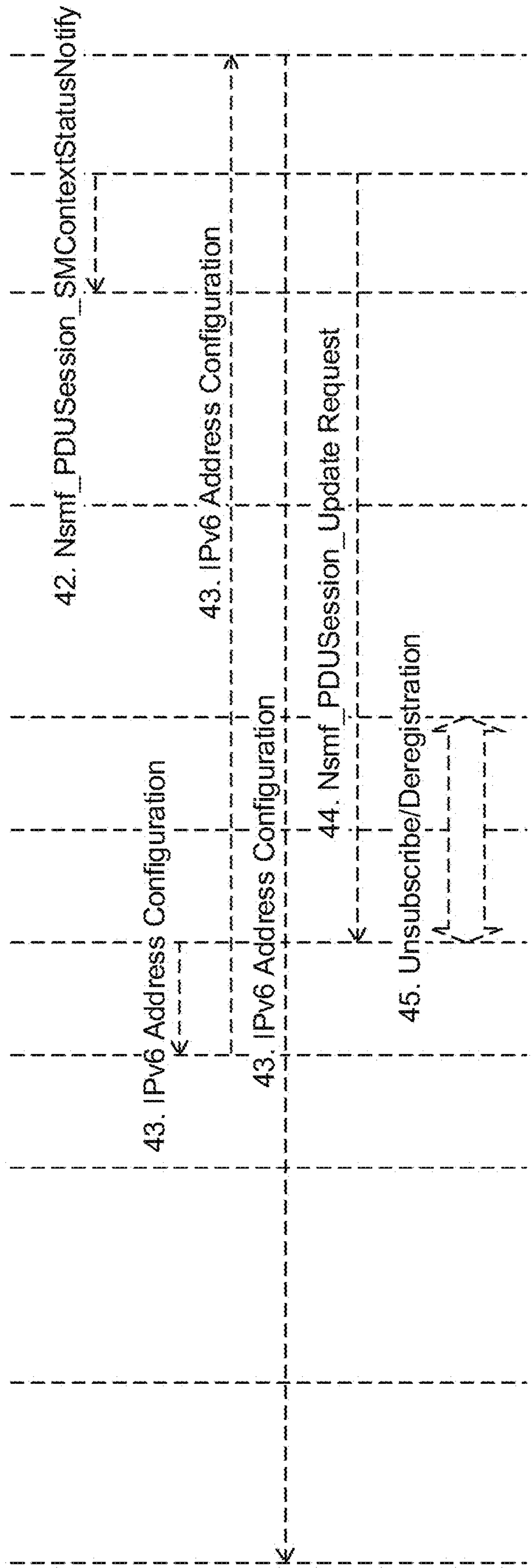

42. Nsmf_PDUSession_SMContextStatusNotify
43. IPv6 Address Configuration
43. IPv6 Address Configuration
43. IPv6 Address Configuration
44. Nsmf_PDUSession_Update Request
45. Unsubscribe/Deregistration

FIG. 14 (Cont'd)

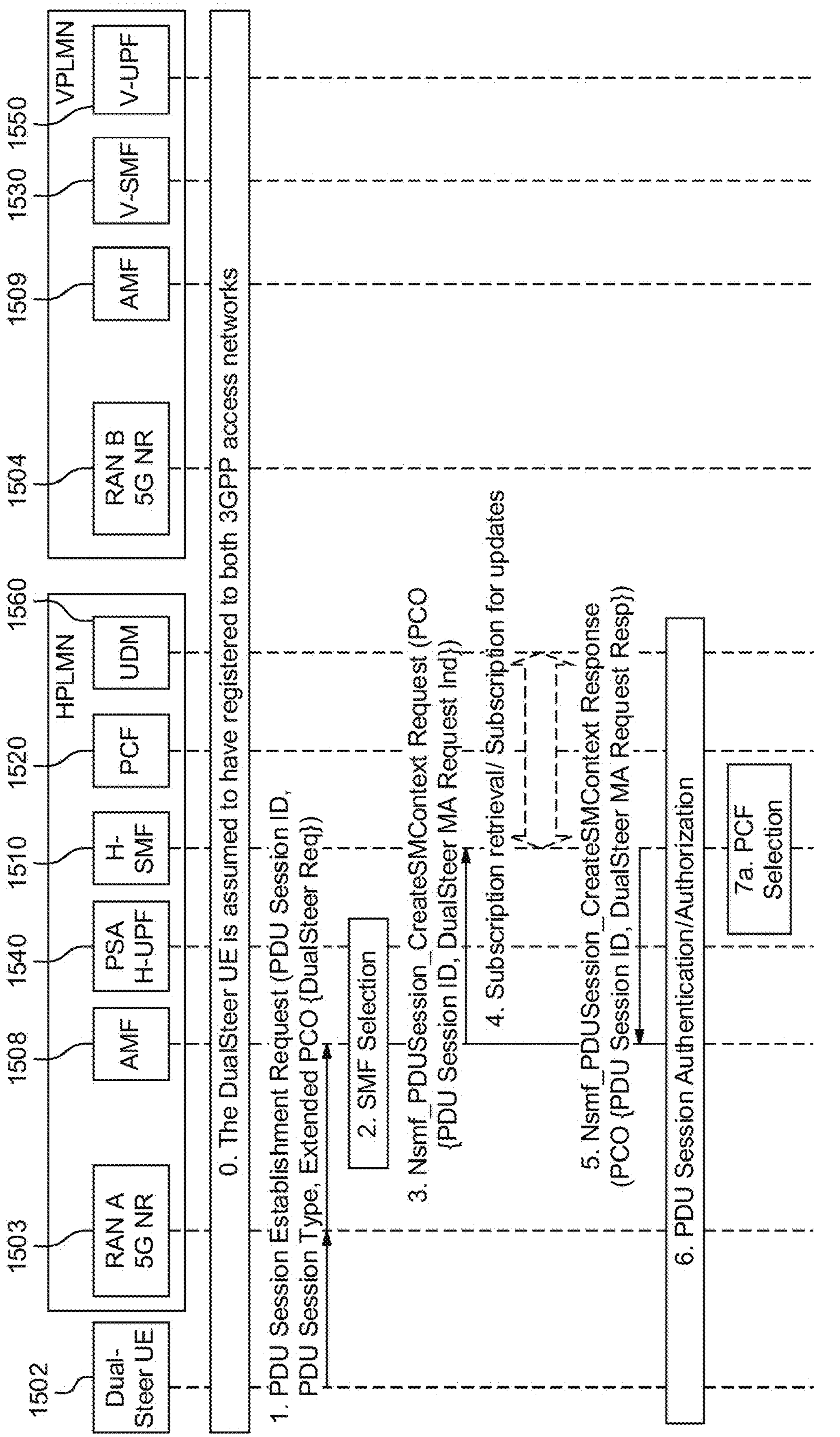

1502
Dual-Steer UE
1503
RAN A 5G NR
1508
AMF
1540
PSA H-UPF
1510
H-SMF
1520
PCF
1560
UDM
HPLMN
1504
RAN B 5G NR
1509
AMF
1530
V-SMF
1550
V-UPF
VPLMN
0. The DualSteer UE is assumed to have registered to both 3GPP access networks
1. PDU Session Establishment Request (PDU Session ID, PDU Session Type, Extended PCO {DualSteer Req})
2. SMF Selection
3. Nsmf_PDUSession_CreateSMContext Request (PCO {PDU Session ID, DualSteer MA Request Ind})
4. Subscription retrieval/ Subscription for updates
5. Nsmf_PDUSession_CreateSMContext Response (PCO {PDU Session ID, DualSteer MA Request Resp})
6. PDU Session Authentication/Authorization
7a. PCF Selection

FIG. 15

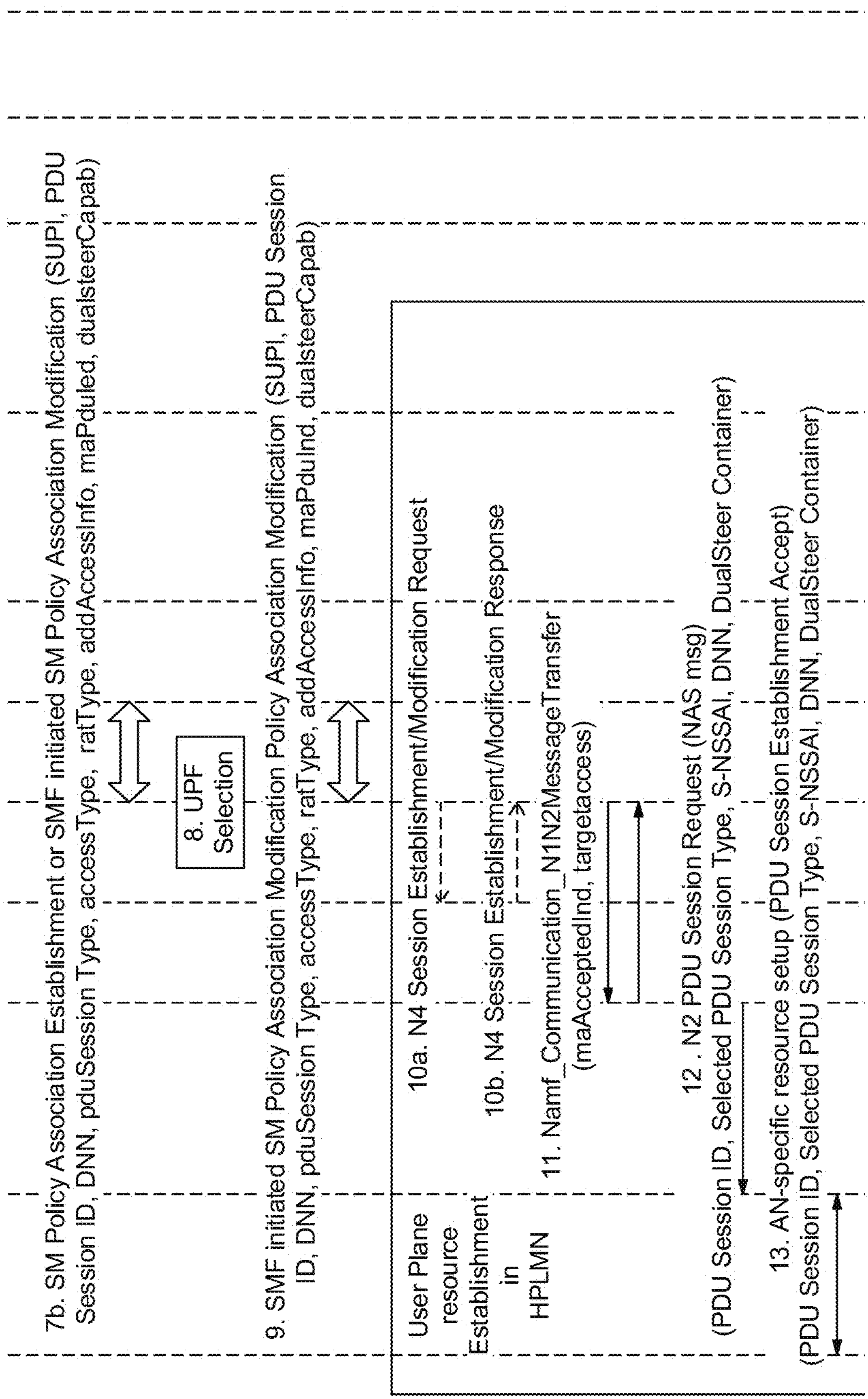

7b. SM Policy Association Establishment or SMF initiated SM Policy Association Modification (SUPI, PDU Session ID, DNN, pduSession Type, accessType, ratType, addAccessInfo, maPduIed, dualsteerCapab)
8. UPF Selection
9. SMF initiated SM Policy Association Modification Policy Association Modification (SUPI, PDU Session ID, DNN, pduSession Type, accessType, ratType, addAccessInfo, maPduInd, dualsteerCapab)
User Plane resource Establishment in HPLMN
10a. N4 Session Establishment/Modification Request
10b. N4 Session Establishment/Modification Response
11. Namf_Communication_N1N2MessageTransfer (maAcceptedInd, targetaccess)
12 . N2 PDU Session Request (NAS msg) (PDU Session ID, Selected PDU Session Type, S-NSSAI, DNN, DualSteer Container)
13. AN-specific resource setup (PDU Session Establishment Accept) (PDU Session ID, Selected PDU Session Type, S-NSSAI, DNN, DualSteer Container)

FIG. 15 (Cont'd)

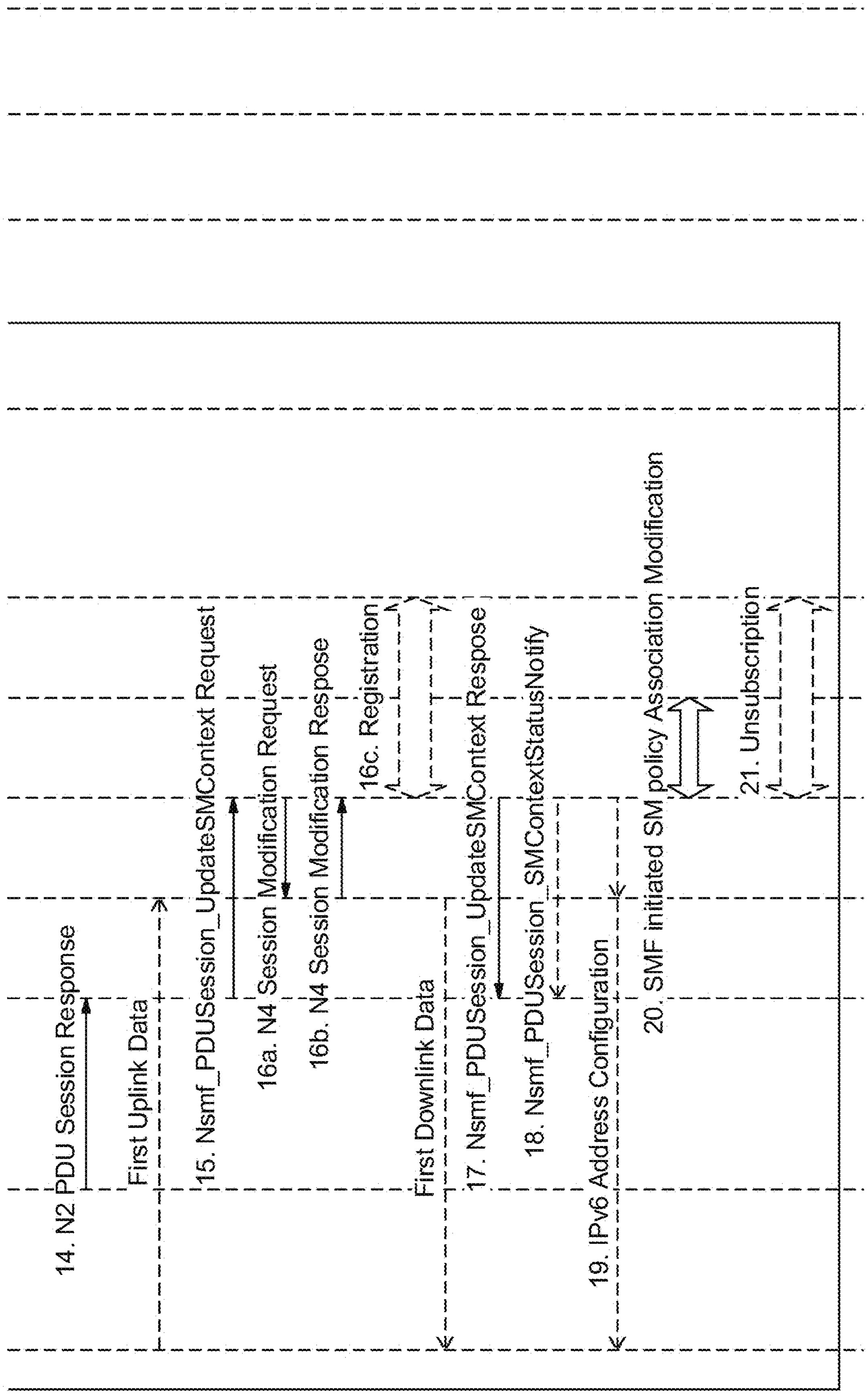

14. N2 PDU Session Response
First Uplink Data
15. Nsmf_PDUSession_UpdateSMContext Request
16a. N4 Session Modification Request
16b. N4 Session Modification Respose
16c. Registration
First Downlink Data
17. Nsmf_PDUSession_UpdateSMContext Respose
18. Nsmf_PDUSession_SMContextStatusNotify
19. IPv6 Address Configuration
20. SMF initiated SM policy Association Modification
21. Unsubscription

FIG. 15 (Cont'd)

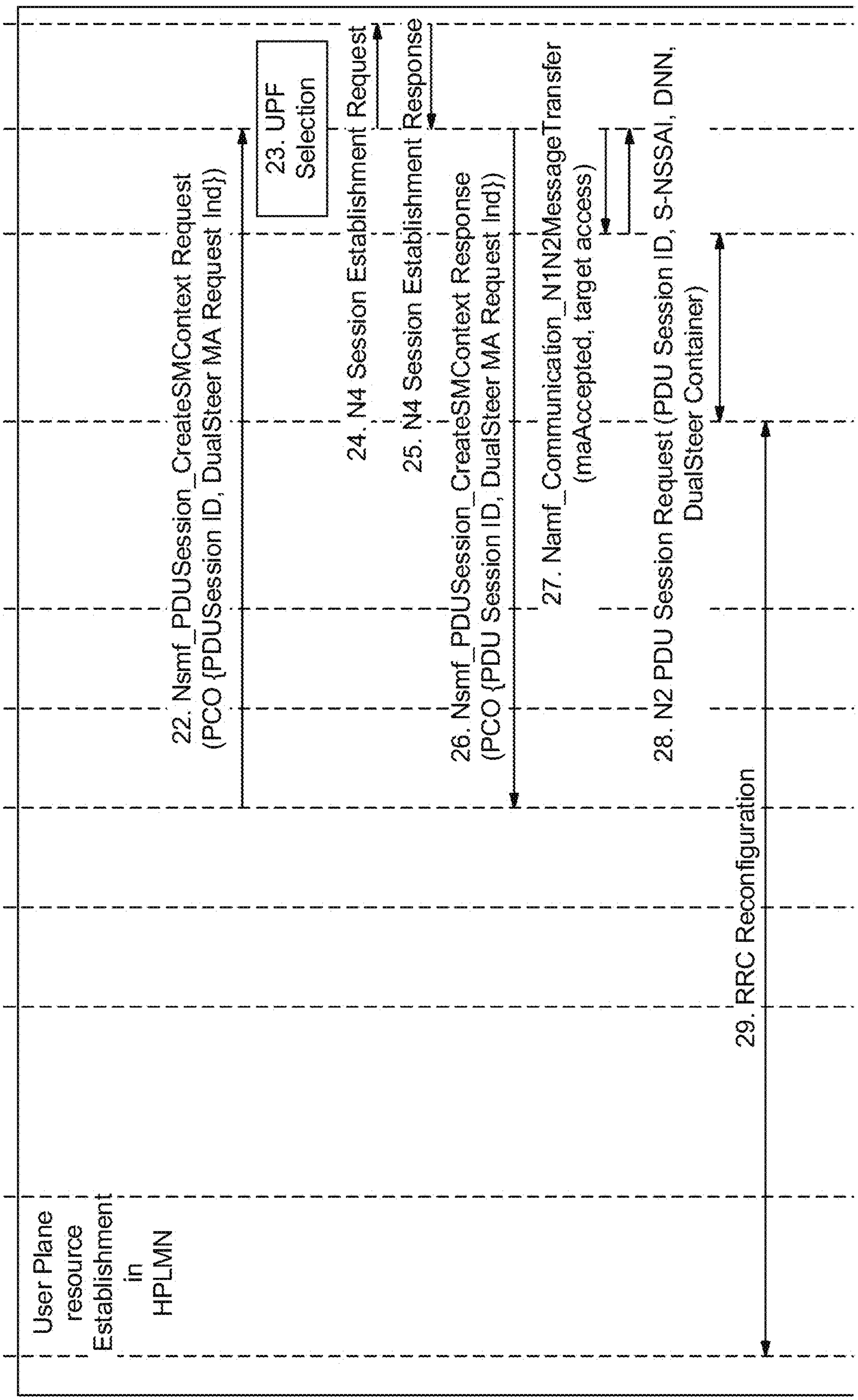

User Plane resource Establishment in HPLMN
22. Nsmf_PDUSession_CreateSMContext Request (PCO {PDUSession ID, DualSteer MA Request Ind})
23. UPF Selection
24. N4 Session Establishment Request
25. N4 Session Establishment Response
26. Nsmf_PDUSession_CreateSMContext Response (PCO {PDU Session ID, DualSteer MA Request Ind})
27. Namf_Communication_N1N2MessageTransfer (maAccepted, target access)
28. N2 PDU Session Request (PDU Session ID, S-NSSAI, DNN, DualSteer Container)
29. RRC Reconfiguration

FIG. 15 (Cont'd)

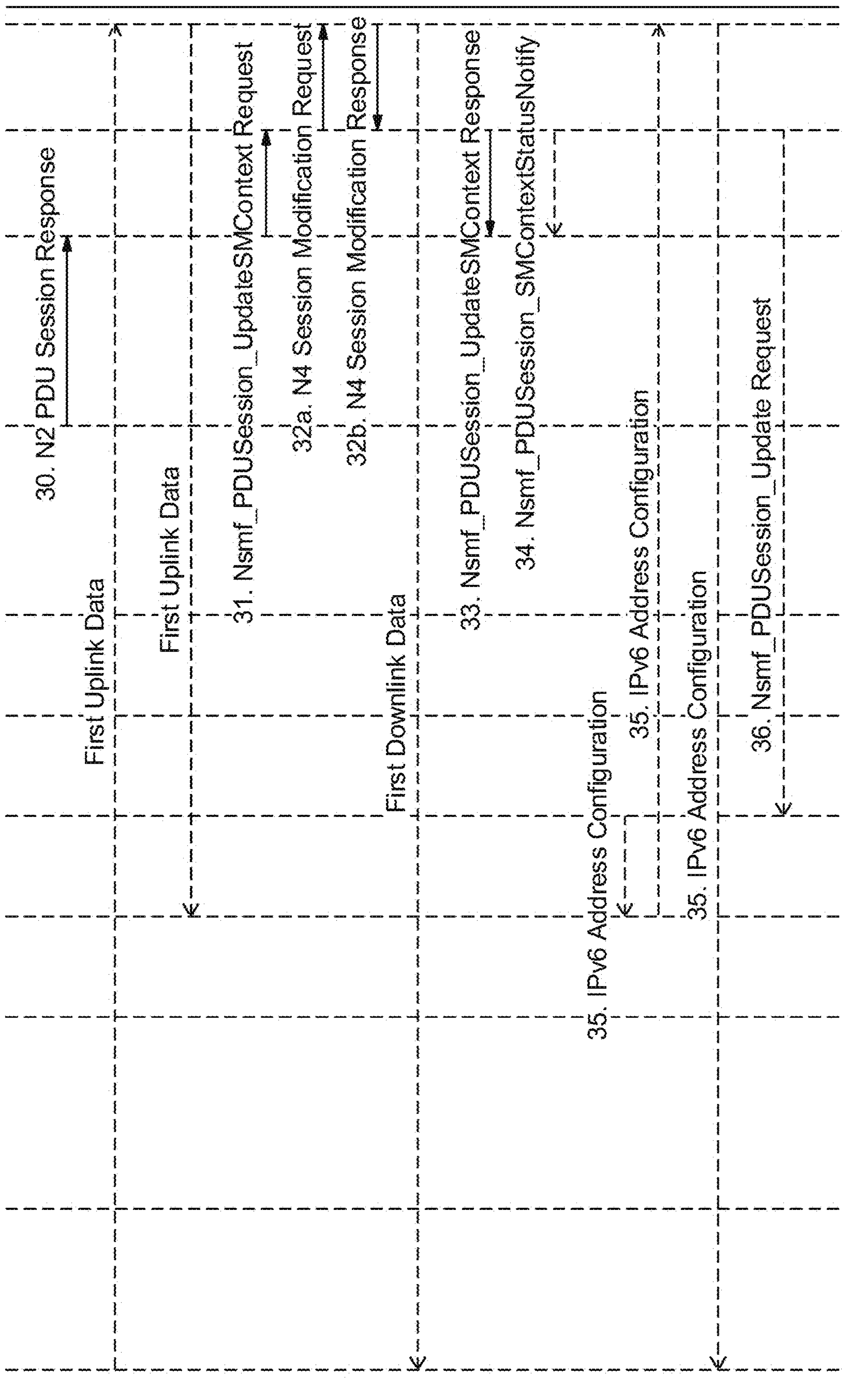

30. N2 PDU Session Response
First Uplink Data
First Uplink Data
31. Nsmf_PDUSession_UpdateSMContext Request
32a. N4 Session Modification Request
32b. N4 Session Modification Response
First Downlink Data
33. Nsmf_PDUSession_UpdateSMContext Response
34. Nsmf_PDUSession_SMContextStatusNotify
35. IPv6 Address Configuration
35. IPv6 Address Configuration
35. IPv6 Address Configuration
36. Nsmf_PDUSession_Update Request

FIG. 15 (Cont'd)

METHODS AND APPARATUS FOR SESSION MANAGEMENT FOR A DUALSTEER DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/554,848, filed Feb. 16, 2024, the contents of which are incorporated herein by reference.

BACKGROUND

[0002] A multi-access-protocol data unit (MA PDU) session is a PDU session associated with two independent tunnels between a PDU session anchor (PSA) and an access node (AN) of a radio access network (RAN), and with multiple access types. For example, the MA PDU may be associated with a Third Generation Partnership Project (3GPP) access type and a non-3GPP access type, with both access types connected to the Fifth Generation (5G) Core (5GC). The traffic of an MA PDU session may be transferred over 3GPP access, over non-3GPP access, or over both accesses.

[0003] MA PDU is a key enabler of Access Traffic Steering, Switching and Splitting (ATSSS). An ATSSS-capable user equipment (UE) may communicate over 3GPP access, over non-3GPP access, or over both accesses.

[0004] SUMMARY

[0005] Methods and apparatus for session management for a DualSteer device are provided herein. A user equipment (UE) transmits first information indicating that the UE requests access to two Third Generation Partnership Project (3GPP) access networks simultaneously and that the UE supports access to two 3GPP access networks simultaneously. Further, the UE receives second information indicating rules for accessing the two 3GPP access networks simultaneously. Moreover, the UE transmits data using a multi-access (MA) protocol data unit (PDU) session based on the rules for accessing the two 3GPP access networks simultaneously, where the MA PDU session is established on a first 3GPP access network and a second 3GPP access network.

[0006] Additionally or alternatively, the first information is included in a PDU session establishment request message. Additionally or alternatively, the second information is included in a PDU session establishment accept message. Additionally or alternatively, the UE is a DualSteer UE.

[0007] In an example, the first information includes a DualSteer request, and the second information includes a DualSteer container information element (IE). Additionally or alternatively, the DualSteer container IE includes DualSteer parameters.

[0008] Additionally or alternatively, the first information includes DualSteer indication information and DualSteer capability information. Additionally or alternatively, the second information includes the DualSteer indication information and DualSteer traffic rules information.

[0009] Additionally or alternatively, the UE is registered over the first 3GPP access network and the second 3GPP access network in the same public land mobile network (PLMN). Additionally or alternatively, the UE is registered over the first 3GPP access network and the second 3GPP access network in different PLMNs. Additionally or alternatively, the UE is registered over the first 3GPP access network or the second 3GPP access network in a PLMN.

[0010] In another example, a network node receives first information indicating that a UE requests access to two 3GPP access networks simultaneously and that the UE supports access to two 3GPP access networks simultaneously. Further, the network node sends second information indicating rules for accessing the two 3GPP access networks simultaneously. Also, the network node receives data using an MA PDU session based on the rules for accessing the two 3GPP access networks simultaneously, where the MA PDU session is established on a first 3GPP access network and a second 3GPP access network.

[0011] In an example, the network node includes an Access and Mobility Management Function (AMF). Additionally or alternatively, the network node includes a Session Management Function (SMF).

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings, wherein like reference numerals in the figures indicate like elements, and wherein:

[0013] FIG. **1** is an illustration of an example device;

[0014] FIG. **2** illustrates an example communication system;

[0015] FIG. **3** illustrates an example of a functional split between a next generation radio access network (NG-RAN) and Fifth Generation (5G) core (5GC);

[0016] FIG. **4** illustrates an example of a protocol stack for a user plane and a control plane;

[0017] FIG. **5** illustrates an example of the architecture for the case of a 5G-residential gateway (RG) connecting to the 5GC;

[0018] FIG. **6** illustrates an example of the architecture for a communication system capable of Access Traffic Steering, Switching and Splitting (ATSSS) and multi-subscriber identity module (MUSIM) communication;

[0019] FIG. **7** illustrates an example of the architecture for a communication system capable of ATSSS and MUSIM communication with a terrestrial network (TN) operator leveraging a non-TN (NTN) of a partner;

[0020] FIG. **8** illustrates an example of the architecture for a communication system capable of ATSSS and MUSIM communication with an NTN operator leveraging a TN of a partner;

[0021] FIG. **9** illustrates an example of the architecture for a communication system capable of ATSSS and MUSIM communication with an NTN operator leveraging an NTN of a partner;

[0022] FIG. **10** illustrates an example of the architecture for a communication system capable of ATSSS and MUSIM communication applicable to a non-public network (NPN);

[0023] FIG. **11** illustrates an example of the architecture for a communication system for a DualSteer multi-access-protocol data unit (MA PDU) session across a visited public land mobile network (VPLMN) and a home public land mobile network (HPLMN);

[0024] FIG. **12** illustrates an example of the architecture for a communication system for a DualSteer MA PDU session across two VPLMNs;

[0025] FIG. **13** illustrates an example of a DualSteer MA PDU session establishment procedure with an HPLMN and a VPLMN;

[0026] FIG. **14** illustrates an example of a user equipment (UE) requested PDU session establishment procedure for a DualSteer UE with simultaneous access to two Third Generation Partnership Project (3GPP) networks, using different public land mobile networks (PLMNs); and

[0027] FIG. **15** illustrates an example of a UE requested PDU session establishment procedure for a DualSteer UE with simultaneous access to two 3GPP networks, using the same PLMN.

DETAILED DESCRIPTION

[0028] The underlying principle of a communication system is to enable one or more devices to communicate with one or more other devices. At a basic level, each device may need some basic components to operate. Any device referenced herein, including the hardware (e.g., virtual or physical) to run a function, software entity, application, or the like, may be understood to have at least one or more of the following components (e.g., where there may be one or more of each component): a processor, a transceiver (e.g., which may or may not be integrated with the processor), an input (e.g., microphone, keyboard, mouse, etc.), an output (e.g., port for outputting display signals, a display, a touch screen, a printer, etc.), a power source, a positioning chip (e.g., GPS, GLONASS, etc., which may or may not be integrated with the processor and/or transceiver), button (e.g., for controlling the specific function of one or more aspects of the device). These components may be operably connected to one another, meaning that there may be a direct connection or an indirect connection to one or more of the components.

[0029] A User Equipment (UE) may be interchangeable with a station (STA), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a computer, a server, a functional entity (e.g., virtual and/or physical) a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, or the like.

[0030] FIG. **1** is an illustration of an example device. In one case, the device may be a UE suited for mobile operation. In this example, the UE may have a processor **101**, a transceiver **102**, a touchscreen **103**, a power source **104** (e.g., a battery), a GPS **105**, one or more other components **106** (e.g., as described herein), and/or an antenna **107**.

[0031] Generally, a processor may be any kind of processor, such as a processor capable of carrying out one or more of the techniques described herein. A transceiver may be configured to transmit and receive signals. In one case, there may be a separate receiver and transmitter. A transceiver may be connected to one or more antennas (e.g., MIMO technology). A transceiver may be configured to transmit RF signals. In one case, a transceiver may be configured to transmit light signals (e.g., IR, UV, laser, etc.). A transceiver may be configured to send/receive more than one type of RF signal (e.g., different radio access technologies for one transceiver, or multiple transceivers each dedicated to a specific radio access technology). A transceiver may be configured to modulate signals for transmission, and demodulate signals for reception. The UE may be capable of full duplex operation, where there is transmission and reception of some or all signals may be concurrent and/or simultaneous, for example, different timing/spacing for uplink (UL) or downlink (DL).

[0032] Different radio access technologies may be used with one or more transceivers (e.g., 802.11, WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR etc.).

[0033] FIG. **2** illustrates an example communication system. This example may be used to illustrate multiple wireless protocols. For all wireless protocols, there may be mobile or stationary devices (e.g., **202***a*, **202***b*, **202***c*, such as a UE) that connect to a base station device **201***a* and/or **201***b*. In one case, this may enable a mobile device to connect to a service (e.g., a remote server) or data network (e.g., internet).

[0034] In one case, the base stations (**201***a*, **201***b*) may be equivalent to, and/or interchangeable with, a base transceiver station (BTS), a NodeB, an eNode B (eNB), a Home Node B, a Home eNode B, a next generation NodeB, such as a gNode B (gNB), a new radio (NR) NodeB, a site controller, an access point (AP), a wireless router, transmission receive point (TRP), network (NW), RP (reception point), RRH (radio remote head), DA (distributed antenna), BS (base station), a sector (of a BS), and a cell (e.g., a geographical cell area served by a BS). Each base station may be representative of more than one base station (e.g., multiple transmission reception points).

[0035] Generally, a communication system may use a combination of wired and wireless connections at different points in the system. One or more wireless technologies may (e.g., channel access methods), may include code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail unique-word discrete Fourier transform Spread OFDM (ZT-UW-DFT-S-OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0036] A base station may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). A base station (**201***a*, **201***b*) may communicate with one or more UEs (**202***a*, **202***b*, **202***c*) over an air interface (**211***a*, **211***b*, **211***c*, **211***d*).

[0037] In one case, one or more base stations may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) approach. Therefore, the system (e.g., and perhaps one or more UEs) may implement multiple types of radio access technologies that uses more than one type of base station (e.g., an eNB and a gNB).

[0038] In one case, the communication system may include a radio access network (RAN) **203**, a core network (CN) **204**, and one or more other elements represented by **205** (e.g., public switched telephone network (PSTN), the Internet, and other networks or the like).

[0039] In one scenario using FIG. **2** as an illustration, a RAN **203** may be in communication with a CN **204**. The base station **201***a* may be an eNB, and the access technology may be based on E-UTRA (e.g., LTE, etc.). The communication system may handle data transmission from the UE **202***a*. The data may have varying quality of service (QOS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN **204** may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown, the RAN **203** and/or the CN **204** may be in direct or indirect communication with other RANs that employ the same radio access technology (RAT) as the RAN **203** or a different RAT. For example, in addition to being connected to the RAN **203**, which may be utilizing a NR radio access technology, the CN **204** may also be in communication with another RAN (not shown) employing another radio access technology (e.g., E-UTRA, WiFi, etc.). Each of the eNBs may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, and the like. Each eNB may communicate with one another over an X2 interface (not shown).

[0040] In one scenario using FIG. **2** as an illustration, the RAN **203** and the CN **204** may employ NR radio access technologies and related protocols. The base station may be a gNB **201**. The gNB(s) may implement carrier aggregation technology, where multiple component carriers may be transmitted to the UE **202***a*. A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. The UE(s) may communicate with the gNB(s) using transmissions associated with a scalable numerology (e.g., subcarrier spacing, etc.). For example, the OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The UE(s) may communicate with gNB(s) using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., containing a varying number of OFDM symbols and/or lasting varying lengths of absolute time). The gNB(s) may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, dual connectivity, interworking between NR and E-UTRA, routing of user plane data towards User Plane Function (UPF), routing of control plane information towards Access and Mobility Management Function (AMF), and the like. The gNB(s) may communicate with one another over an Xn interface.

[0041] Not shown (e.g., but still possibly part of one or more example scenarios described herein), the CN may include one or more AMFs, one or more UPFs, one or more Session Management Functions (SMFs), and/or one or more Data Networks (DNs). In one case, the aforementioned elements may be owned and/or operated by an entity other than the CN operator.

[0042] In one scenario using FIG. **2** as an illustration, an Internet **205** may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite.

[0043] FIG. **3** illustrates an example of a functional split between the next generation radio access network (NG-RAN) and Fifth Generation (5G) core (5GC). The AMF may be connected to one or more gNB the RAN via an N2 interface and may serve as a control node. For example, the AMF may be responsible for authenticating a UE's support for network slicing (e.g., handling of different protocol data unit (PDU) sessions with different requirements), selecting a particular SMF, management of the registration area, termination of non-access stratum (NAS) signaling, mobility management, and the like. Network slicing may be used by the AMF in order to customize CN support for one or more UEs based on the types of services being utilized by the respective UE. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for MTC access, and the like. The AMF may provide a control plane function for switching between the RAN and other RANs that employ other radio technologies (e.g., as described herein). The SMF may be connected to an AMF in the CN via an N11 interface. The SMF may also be connected to a UPF in the CN via an N4 interface. The SMF may select and control the UPF and configure the routing of traffic through the UPF. The SMF may perform other functions, such as managing and allocating UE IP address, managing PDU sessions, controlling policy enforcement and QoS, providing DL data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like. The UPF may be connected to one or more gNB in the RAN via an N3 interface, which may provide a UE with access to packet-switched networks, such as the Internet, to facilitate communications between one or more UEs and IP-enabled devices. The UPF may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering DL packets, providing mobility anchoring, and the like. The CN may facilitate communications with other networks. For example, the CN may provide a UE with access to the other networks **212**, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In one example, the UEs may be connected to a local DN through a UPF via an N3 interface to the UPF and an N6 interface between the UPF and the DN. As discussed herein, a NR RAN may be called an NG-RAN and a NR CN may be called a 5GC.

[0044] FIG. **4** illustrates an example of a protocol stack for the user plane and control plane. The user plane protocol stack **401** and the control plane stack **402**. A higher layer may refer to one or more layers in a protocol stack, or a specific sublayer within the protocol stack. The protocol stack may comprise of one or more layers in a UE or a network node (e.g., eNB, gNB, other functional entity, etc.), where each layer may have one or more sublayers. Each layer/sublayer may be responsible for one or more functions. Each layer/sublayer may communicate with one or more of the other layers/sublayers, directly or indirectly. In some cases, these layers may be numbered, such as Layer 1, Layer 2, and Layer 3. For example, Layer 3 may comprise of one or more of the following: NAS, Internet Protocol (IP), and/or Radio Resource Control (RRC). For example, Layer 2 may comprise of one or more of the following: Packet Data Convergence Control (PDCP), Radio Link Control (RLC), and/or Medium Access Control (MAC). For example, Layer 3 may comprise of physical (PHY) layer type operations. The greater the number of the layer, the higher it is relative to other layers (e.g., Layer 3 is higher than Layer 1). In some cases, the aforementioned examples may be called layers/sublayers themselves irrespective of layer number, and may be referred to as a higher layer as described herein. For example, from highest to lowest, a higher layer may refer to one or more of the following layers/sublayers: a NAS layer, a RRC layer, a PDCP layer, a RLC layer, a MAC layer, and/or a PHY layer. Any reference herein to a higher layer in conjunction with a process, device, or system will refer to a layer that is higher than the layer of the process, device, or system. In some cases, reference to a higher layer herein may refer to a function or operation performed by one or more layers described herein. In some cases, reference to a high layer herein may refer to information that is sent or received by one or more layers described herein. In some cases, reference to a higher layer herein may refer to a configuration that is sent and/or received by one or more layers described herein.

[0045] The examples provided herein are based on the Third Generation Partnership Project (3GPP) 5G architecture and the procedures associated with the 5GC. One with ordinary skills in the art may envision other technologies being used and the same concepts may apply. Examples of other technologies may be 4G, CBRS, cdma2000, 6G, and beyond. The examples provided herein should not limit the scope of the methods.

[0046] The 3GPP standards support the access to the 5GC via a wireline access network (AN). A wireline 5G access network (W-5GAN) is a wireline AN that may connect to a 5GC. For example, devices in a home local access network (LAN), such as a residential gateway (RG), may connect to the 5GC via a Wireline Access Gateway Function (W-AGF) in the W-5GAN. The W-AGF is a network function that may interface with the 5GC Control Plane (CP) and the 5GC User Plane (UP) functions, via N2 and N3 interfaces, respectively. In the example of a home LAN, the W-AGF may provide connectivity towards the 5GC to the home LAN devices using one or more N2 and N3 interfaces with the 5GC.

[0047] A residential gateway (RG) is a device providing, for example, voice, data, broadcast video, video on demand, etc. to other devices in specific locations referred to as customer premises. In this example, an RG may have one or more processors, such as Central Processing Units (CPUs), Graphical Process Units (GPUs), Front End Processors (FEPs), Communication Processors (CPs), Field Programmable Gate Arrays (FPGAs), Vision Processing Units (VPU), Quantum Processing Units (QPUs), Associative Processing Units (APUs), and Tensor Processing Units (TPUs); a baseband radio; one or more transceivers; one or more antennas; storage, such as HDD, SSD, NVM, RAM, ROM, memory, cache; memory controller(s), a touchscreen, and a power source. The RG may also have one or more of its functions virtualized.

[0048] An RG may contain functionality that enables devices behind it to also connect with the 5GC and obtain 5G services. The devices behind the RG may be of different types, such as 3GPP-capable devices (e.g., UEs), authenticable non-3GPP (AUN3) devices, non-authenticable non-3GPP (NAUN3) devices, or non-5G-Capable over WLAN (N5CW) devices. An RG may be 5G-capable, in which case it is referred to as a 5G-RG, or it may be non-3GPP capable, in which case it is referred to as a Fixed Network RG (FN-RG). The 5G-RG may play the role of a UE.

[0049] While reference to 5GC is mentioned to assist in explaining the concepts of this invention, the examples and techniques discussed herein are equally applicable to other generations of wireless technologies, and may interchangeable with 3G, 4G, 6G, etc.

[0050] There are benefits to both users and operators to allow RGs, and devices that are non-3GPP capable and are behind RGs, to access the 3GPP 5G 5GC. The 5GC provides several features that may be beneficial, independent of the type of access technology used by the devices accessing the network. Users may receive the benefits of the rich 5G features, and operators may have means to charge for the usage of such features.

[0051] As an example, there may be one or more procedures that enable access to the Evolved Packet Core (EPC) or the 5GC via non-3GPP RATs. One such example is a UE accessing the 5GC using WLAN.

[0052] Additionally, there may be one or more procedures for supporting access to the 5GC via a wireline AN. As an example, a home LAN may be connected to the 5GC via an RG. The RG may contain functionality that enables devices behind it to connect with the 5GC and obtain 5G services.

[0053] The 5G-RG and the W-AGF may interface with the 5GC Control Plane (CP) and the 5GC User Plane (UP) functions, via N2 and N3 interfaces, respectively. They may enable authentication, registration and packet data network (PDN) connectivity procedures associated with the devices behind the RG. They may facilitate the provisioning of differentiated services to the devices behind the RG, via the interfaces with the 5GC.

[0054] FIG. **5** illustrates an example of the architecture for the case of a 5G-RG connecting to the 5GC. As shown in an example in FIG. **5**, there may be a 5G-RG **501** connecting to the 5GC (**502**, shown in dotted line in FIG. **5**). As mentioned before, the 5G-RG **501** may be a 3GPP capable, and accordingly, it may connect to the 5GC **502** via a 3GPP access **503**. An N1 link **506** may be established, via the 3GPP access **503** between the 5G-RG **501** and the 5GC **502**.

[0055] At the same time, the 5G-RG **501** may connect to the 5GC **502** via a wireline access network W-5GAN (**504**, shown in dotted line in FIG. **5**), using the W-AGF **505** functionality to interface with the 5GC **502**. An N1 link **507** may be established between the 5GC **502** and the 5G-RG **501**, which may transverse, transparently, through the W-AGF **507**.

[0056] In the example in FIG. **5**, multiple (e.g., 2) N1 links (e.g., N1 instances, N1 interfaces, N1 connections) **506**, **507** may exist between the 5G-RG **501** and the 5GC **502**, e.g., there may be one N1 link **506** via the 3GPP access **503** and one N1 link **507** via the W-5GAN **504**. The 5G-RG **501** may be connected to a single 5GC **502**, and a single AMF **508** may be connected and servicing the 5G-RG **501**. The N1 link **507** between the 5G-RG **501** and the 5GC/AMF **502** may be an end-to-end link; e.g., the termination points are the 5G-RG **501** and the 5GC **502**. The 5G-RG **501** supports NAS procedures and may behave as a UE. The NAS messages between the 5G-RG **501** and the 5GC **502** may be sent from the 5G-RG **501** to the W-AGF **505** via the W-CP signaling connection. The W-AGF **505** may transparently forward the message to the AMF **508**. The W-AGF **505** may use an N2 Uplink NAS Transport message to forward the NAS message.

[0057] FIG. **6** illustrates an example of the architecture for a communication system capable of Access Traffic Steering, Switching and Splitting (ATSSS) and multi-subscriber identity module (MUSIM) communication. As shown in an example in FIG. **6**, a UE **602** may connect to a first public land mobile network (PLMN), such as PLMN 1, and may connect to a second PLMN, such as PLMN 2. The UE **602** may be MUSIM and ATSSS capable, and may contain a PLMN 1 subscriber identity module (SIM) and a PLMN 2 SIM. The UE **602** may be 3GPP capable, and use the PLMN 1 SIM to access the 3GPP Core **610**, via 3GPP access **603**, and the serving gateway (SGW)/PDN gateway (PGW)/UPF **640** in the PLMN 1. The PLMN 1 may be 5G capable, 4G capable, or both.

[0058] Further, the UE **602** may use the PLMN 2 SIM to access the 3GPP Core **620**, via 3GPP access **604**, and the UPF+PGW-U **650** in the PLMN **2**. The UPF+PGW-U **650** may include ATSSS functionality. The UE may further may use the PLMN **2** SIM to access the Non-3GPP Interworking Function (N3IWF)/Trust Non-3GPP (TNGF)/W-AGF **630**, via Non-3GPP access **605**, and the UPF+PGW-U **650** in the PLMN 2. The PLMN 2 may be 5G capable.

[0059] Further, data sessions across both SIMs are anchored using the UPF+PGW-U **650** in the PLMN 2, which may be the anchor network. Accordingly, the UE **602** may access the internet **690** using the PLMN 2 SIM and the UPF+PGW-U **650** in the PLMN 2, via either the 3GPP Access **604** or the non-3GPP Access **605**, or via both. Additionally or alternatively, the UE **602** may further access the internet **690** using the PLMN 1 SIM and the UPF+PGW-U **650** by way of the SGW/PGW/UPF **640**. Additionally or alternatively, the UPF+PGW-U **650** and the SGW/PGW/UPF **640** may be linked by an S5/S8/N9 or similar interface.

[0060] Steering, switching and splitting can be performed across SIMs camped on the same PLMN. Additionally or alternatively, steering, switching and splitting can be performed across SIMs camped on different PLMNs. Moreover, the different PLMNs may be deployed by the same or different operators. Additionally or alternatively, a PLMN may be a terrestrial network (TN) or a non-TN (NTN). Additionally or alternatively, a PLMN may be a public network or a private network. Moreover, if the PLMNs belong to different operators, an administrative relationship may exist between the two PLMNs, such as PLMN 1 and PLMN 2.

[0061] FIG. **7** illustrates an example of the architecture for a communication system capable of ATSSS and MUSIM communication with a TN operator leveraging an NTN of a partner.

[0062] As shown in an example in FIG. **7**, a UE **702** may connect to an NTN PLMN 1 and may connect to a TN PLMN 2. The UE **702** may be MUSIM and ATSSS capable. The UE **702** may access the 3GPP Core **710**, via 3GPP access, and the SGW/PGW/UPF **740** in the PLMN 1. The PLMN 1 may be 5G capable, 4G capable, or both.

[0063] Further, the UE **702** may access the 3GPP Core **720**, via 3GPP access, and then the ATSSS Function/UPF **750** in the PLMN 2. The UE may further may access the N3IWF/TNGF **730**, via non-3GPP access, and then the ATSSS Function/UPF **750** in the PLMN 2. The PLMN 2 may be 5G capable.

[0064] Also, the UE **702** may access the internet **790** using the ATSSS Function/UPF **750** in the PLMN **2**, via either the 3GPP Access or the non-3GPP Access, or via both. Additionally or alternatively, the UE **702** may further access the internet **790** using the PLMN 1 and the ATSSS Function/UPF **750** by way of the SGW/PGW/UPF **740**. Additionally or alternatively, the ATSSS Function/UPF **750** and the SGW/PGW/UPF **740** may be linked by an S5/S8/N9 or similar interface, or a new interface.

[0065] Moreover, steering, switching and splitting can be performed across NTNs and TNs operated by the same or different operators. Additionally or alternatively, whether PLMN 1 and PLMN 2 belong to the same or different operators may be dependent on a business agreement and enabling of an S5/S8/N9 interface.

[0066] An example shown in FIG. **7** provides flexibility to home operators in terms of switching, steering, or both splitting, between the PLMN 1 and PLMN 2. Further, this example avoids the complexity associated with seamless mobility across the two networks.

[0067] FIG. **8** illustrates an example of the architecture for a communication system capable of ATSSS and MUSIM communication with an NTN operator leveraging a TN of a partner. As shown in an example in FIG. **8**, a UE **802** may connect to an NTN PLMN 1 and may connect to a TN PLMN 2. The UE **802** may be MUSIM and ATSSS capable. The PLMN 1 may be 5G capable. The UE **802** may access the 3GPP Core **810**, via 3GPP access, and then the ATSSS Function/UPF **840** in the PLMN 1. The UE may further may access the N3IWF/TNGF **830**, via non-3GPP access, and then the ATSSS Function/UPF **840** in the PLMN 1. The PLMN 1 may be 5G capable.

[0068] Further, the UE **802** may access the 3GPP Core **820**, via 3GPP access, and the UPF **850** in the PLMN 2. The PLMN 2 may be 5G capable.

[0069] Moreover, the UE **802** may access the internet **890** using the ATSSS Function/UPF **840** in the PLMN 1, via either the 3GPP Access or the non-3GPP Access, or via both. Additionally or alternatively, the UE **802** may further access the internet **890** using the PLMN 2 and the ATSSS Function/UPF **840** by way of the UPF **850**. Additionally or alternatively, the ATSSS Function/UPF **840** and the UPF **850** may be linked by an S5/S8/N9 or similar interface, or a new interface.

[0070] FIG. **9** illustrates an example of the architecture for a communication system capable of ATSSS and MUSIM communication with an NTN operator leveraging an NTN of a partner. As shown in an example in FIG. **9**, a UE **902** may connect to an NTN PLMN 1 and may connect to an NTN PLMN 2. The UE **902** may be MUSIM and ATSSS capable. The PLMN 1 may be 5G capable and the PLMN 2 may be 5G capable. The UE **902** may access the 3GPP Core **910**, via 3GPP access, and then the ATSSS Function/UPF **940** in the PLMN 1. Further, the UE **902** may access the 3GPP Core **920**, via 3GPP access, and the UPF **950** in the PLMN 2.

[0071] Moreover, the UE **902** may access the internet **990** using the ATSSS Function/UPF **940** in the PLMN 1. Additionally or alternatively, the UE **802** may further access the internet **990** using the PLMN 2 and the ATSSS Function/UPF **940** by way of the UPF **950**. Additionally or alternatively, the ATSSS Function/UPF **940** and the UPF **950** may be linked by an S5/S8/N9 or similar interface, or a new interface.

[0072] FIG. **10** illustrates an example of the architecture for a communication system capable of ATSSS and MUSIM communication applicable to a non-public network (NPN). As shown in an example in FIG. **10**, a UE **1002** may connect to a PLMN 1 and to a PLMN 2. The UE **1002** may be MUSIM and ATSSS capable, and may contain a PLMN 1 SIM and a PLMN 2 SIM. The UE **1002** may be 3GPP capable, and use the PLMN 1 SIM to access the 3GPP Core **1010**, via 3GPP access, and the SGW/PGW/UPF **1040** in the PLMN 1. The PLMN 1 may be 5G capable, 4G capable, or both. Further, the PLMN 1 may be a private network.

[0073] Further, the UE **1002** may use the PLMN 2 SIM to access the 3GPP Core **1020**, via 3GPP access, and the PGW/UPF **1050** in the PLMN 2. The PGW/UPF **1050** may include ATSSS functionality. The UE **1002** may further may use the PLMN 2 SIM to access the N3IWF/TNGF **1030**, via Non-3GPP access, and the PGW/UPF **1050** in the PLMN 2. The PLMN 2 may be 5G capable.

[0074] Moreover, the UE **1002** may access the internet **1090** using the PLMN 2 SIM and the PGW/UPF **1050** in the PLMN 2, via either the 3GPP Access or the non-3GPP Access, or via both. Additionally or alternatively, the UE **1002** may further access the internet **1090** using the PLMN 1 SIM and the PGW/UPF **1050** by way of the SGW/PGW/UPF **1040**. Additionally or alternatively, the PGW/UPF **1050** and the SGW/PGW/UPF **1040** may be linked by an S5/S8/N9 or similar interface. Accordingly, this connectivity facilitates enhanced user experience for users of the private network.

[0075] MA PDU is a key enabler of Access Traffic Steering, Switching and Splitting (ATSSS). An ATSSS-capable user equipment (UE) may communicate over 3GPP access, over non-3GPP access, or over both accesses.

[0076] A DualSteer device is a device supporting traffic steering, switching and splitting of user data, for different services, across two 3GPP access networks. The traffic steering and switching of user data may be performed simultaneously or non-simultaneously over the two 3GPP networks. Traffic steering is a procedure that selects an access network and transfers traffic over the selected access network. DualSteer traffic steering occurs when traffic of one or multiple services/applications is sent across two 3GPP access networks, including scenarios where all services use the same network connection (no simultaneous data over the two networks) or different services are steered across different networks (with simultaneous data over the two networks). Traffic switching is a procedure that moves all traffic from one access network to another access network in a way that minimizes service interruption. DualSteer traffic switching occurs when traffic of one or multiple services/applications is moved from one 3GPP access network to another. Traffic splitting is a procedure that splits the traffic of a data flow across multiple access networks. When traffic splitting is applied to a data flow, some traffic of the data flow is transferred via one access and some other traffic of the same data flow is transferred via another access. DualSteer traffic splitting occurs when traffic of a single data flow belonging to a service/application is sent across two 3GPP access networks.

[0077] A DualSteer UE is an example of a DualSteer device. Additionally or alternatively, a DualSteer device may include two DualSteer UEs.

[0078] Embodiments and examples provided herein apply to two NR/5GC accesses in two different PLMNs (including two visited PLMNs (VPLMNs) or a VPLMN and the home PLMN (HPLMN)) with each access being NR TN or NR NTN. Further, embodiments and examples provided herein apply to both DualSteer UEs capable of non-simultaneous data transmission over the two networks, and DualSteer UEs capable of simultaneous data transmission over the two networks.

[0079] Also, embodiments and examples provided herein leverages MA PDU session procedures defined for ATSSS for DualSteer. The unmodified PDU Session Establishment Procedures follow the ones defined in 3GPP TS 23.502 clauses 4.3.2.2.1 and 4.3.2.2.2. The contents of 3GPP TS 23.502 are incorporated by reference, as if fully set forth herein. These procedures are modified in embodiments and examples provided herein by adding that the DualSteer UE sends a DualSteer capability indication to the network, and the network responds with a container information element (IE), specific for DualSteer or leveraging an ATSSS container, that includes the DualSteer parameters for the UE for traffic steering, traffic switching and traffic splitting.

[0080] Moreover, embodiments and examples provided herein has no impact to the registration procedure as defined in TS 23.502 clause 4.2.2.2.2, except for indicating the DualSteer support by the network within the Registration accept message indicating support for the DualSteer feature using the 5GS network feature support IE. Within this IE, the network should indicate whether it supports ATSSS, DualSteer or both. If the network supports both, it should also indicate what the network prefers-ATSSS or DualSteer. The individual registrations across both the 3GPP access networks are independent, and the DualSteer policies and rules are applied considering network availability. Further, the contents of TR 23.700-54 are incorporated by reference, as if fully set forth herein.

[0081] An example session management solution for DualSteer using MA PDU procedures is provided herein. The example solution leverages the MA PDU session, currently defined for ATSSS, as a PDU session that provides a PDU connectivity service, which can use one access network at a time, or simultaneously one 3GPP access network and one non-3GPP access network. The MA PDU session is extended to a PDU session that provides a PDU connectivity service, which can use one access network at a time, or simultaneously one 3GPP access network and one non-3GPP access network or simultaneously two 3GPP access networks.

[0082] In the case of DualSteer, an MA PDU session can be established when the UE is registered to the same PLMN over the two 3GPP access networks or registered to different PLMNs over the two 3GPP access networks. A UE can initiate MA PDU session establishment when the UE is registered to a PLMN over either of the 3GPP access networks. Therefore, at any given time, the MA PDU session can have user-plane resources established on both 3GPP access networks, or on a single 3GPP access only.

[0083] Activating multi-access PDU connectivity service for DualSteer refers to the establishment of user-plane resources on two 3GPP accesses. If the UE is registered over both 3GPP access networks in the same PLMN, the UE initiates the UE-requested PDU session establishment procedure over a selected access. Over which access to initiate this UE-requested PDU session establishment procedure is UE implementation specific.

[0084] If the UE is registered over both 3GPP access networks in different PLMNs, the UE initiates the UE-requested PDU session establishment procedure over each 3GPP access sequentially. Over which access to first initiate the UE-requested PDU session establishment procedure is UE implementation specific.

[0085] If the UE is registered to a PLMN over only one access, either 3GPP access, the UE initiates the UE-requested PDU session establishment procedure over this access. When the UE at a later point in time registers over the other 3GPP access, either in the same PLMN or in a different PLMN, it initiates the UE-requested PDU session establishment procedure with the same PDU session identifier (ID) over the other access in order to establish user plane resources on the other access for the MA PDU session.

[0086] FIG. **11** illustrates an example of the architecture for a communication system for a DualSteer MA PDU session across a VPLMN and an HPLMN. FIG. **11** shows the high-level architecture envisioned for a different PLMN scenario (HPLMN and VPLMN), where the two PLMN networks are operated by different service providers. The example solution leverages the current procedures defined for Home-Routed (HR) roaming. Further, the example solution assumes that a business agreement exists between the two operators (HPLMN and VPLMN) to carry out the DualSteer procedures with access to both 3GPP networks simultaneously. The example solution includes a DualSteer MA PDU session between a DualSteer UE and a PDU session anchor (PSA) UPF across different PLMNs (HPLMN and VPLMN).

[0087] As shown in an example in FIG. **11**, a DualSteer UE **1102** may connect to an HPLMN and a VPLMN. The UE DualSteer **1102** may access an AMF **1108** and the 3GPP Core, via a Uu link and 3GPP access **1103** in the HPLMN. Additionally or alternatively, the DualSteer UE **1102** may access an AMF **1109** and the 3GPP Core, via a Uu link and 3GPP access **1104** in the VPLMN.

[0088] In the HPLMN, the DualSteer UE **1102** may also access the AMF **1108** via an N1 link. Further, the AMF **1108** may connect with 3GPP access **1103** via an N2 link. Additionally, the AMF **1108** may connect with a home-SMF (H-SMF) **1110** via an N1 link. Also, the AMF **1108** may connect with a UDM **1160** via an N8 link. In addition, the H-SMF **1110** may connect with the UDM **1160** via an N1 link. Further, the H-SMF **1110** may connect with a policy control function (PCF) **1120** via an N7 link.

[0089] Moreover, the H-SMF **1110** may connect with a home-UPF (H-UPF) **1140** via an N4 link. The H-UPF **1140** can be a PSA UPF, or the H-UPF **1140** may route to a PSA UPF in HPLMN. For example, H-UPF **1140** may connect with visited-UPF (V-UPF) **1150** via an N9 link, which may be an inter-PLMN interface.

[0090] Further, the UE **1102** may access a data network **1190** using the H-UPF **1140** and an N6 link, via either the various connectivity described above to reach the H-UPF **1140**, or via 3GPP Access **1103** connected to the H-UPF **1140** via an N3 link.

[0091] Also, the UDM **1160** in the HPLMN may connect with the AMF **1109** in the VPLMN via an N8 link, which may be an inter-PLMN interface. Moreover, the H-SMF **1110** may connect with a visited-SMF (V-SMF) **1130** via an N16 link, which may be an inter-PLMN interface.

[0092] In the VPLMN, the DualSteer UE **1102** may also access the AMF **1109** via an N1 link. Further, the AMF **1109** may connect with 3GPP access **1104** via an N2 link. Additionally, the AMF **1109** may connect with the V-SMF **1130** via an N1 link. As noted above, the AMF **1109** may connect with a UDM **1160** via an N8 link. In addition, the H-SMF **1110** may connect the V-UPF **1150** via an N4 link. Moreover, the DualSteer UE **1102** may also access the V-UPF **1150** via 3GPP access **1104**, which is connected to the V-UPF **1150** by an N3 link.

[0093] As shown in the connectivity above, the HPLMN contains the PSA UPF. Accordingly, the above example shows a DualSteer MA PDU session between DualSteer UE **1102** and a PSA UPF across different PLMNs.

[0094] FIG. **12** illustrates an example of the architecture for a communication system for a DualSteer MA PDU session across two VPLMNs. FIG. **12** shows the high-level architecture envisioned for different PLMN scenario (two VPLMNs) where the HPLMN and the two VPLMN networks are operated by different service providers. The example solution leverages the current procedures defined for HR roaming. The example solution assumes that a business agreement exists between the operators (HPLMN and VPLMN(s)) to carry out the DualSteer procedures with access to both 3GPP networks simultaneously. The example solution includes a DualSteer MA PDU session between a DualSteer UE and a PSA UPF across different PLMNs (two VPLMNs).

[0095] As shown in an example in FIG. **12**, a DualSteer UE **1202** may connect to a VPLMN 1 and a VPLMN 2. The UE DualSteer **1202** may access an AMF **1208** and the 3GPP Core, via a Uu link and 3GPP access **1203** in the VPLMN 1. Additionally or alternatively, the DualSteer UE **1202** may access an AMF **1209** and the 3GPP Core, via a Uu link and 3GPP access **1204** in the VPLMN 2.

[0096] In the VPLMN 1, the DualSteer UE **1202** may also access the AMF **1208** via an N1 link. Further, the AMF **1208** may connect with 3GPP access **1203** via an N2 link. Additionally, the AMF **1208** may connect with a V-SMF **1210** via an N11 link. The V-SMF **1210** may connect with a V-UPF **1240** via an N4 link. Moreover, the DualSteer UE **1202** may also access the V-UPF **1240** via 3GPP access **1203**, which is connected to the V-UPF **1240** by an N3 link.

[0097] Similarly, in the VPLMN **2**, the DualSteer UE **1202** may also access the AMF **1209** via an N1 link. Further, the AMF **1209** may connect with 3GPP access **1204** via an N2 link. Additionally, the AMF **1209** may connect with a V-SMF **1230** via an N11 link. The V-SMF **1230** may connect with a V-UPF **1250** via an N4 link. Moreover, the DualSteer UE **1202** may also access the V-UPF **1250** via 3GPP access **1203**, which is connected to the V-UPF **1250** by an N3 link.

[0098] Further, the AMF **1208** in VPLMN 1 and the AMF **1209** in VPLMN 2 may connect with a UDM **1260** in an HPLMN via N8 links, which may be inter-PLMN interfaces. In addition, the H-SMF **1215** in the HPLMN may connect with the UDM **1260** via an N10 link. Further, the H-SMF **1215** may connect with a PCF **1220** via an N7 link. Further, the V-SMF **1210** and the V-SMF **1230** may connect with the H-SMF **1215** via N16 links, which may be inter-PLMN interfaces.

[0099] Further, the H-SMF **1215** may connect with an H-UPF **1245** via an N4 link. The H-UPF **1245** can be a PSA UPF, or the H-UPF **1140** may route to a PSA UPF. In an example, the PSA UPF may be in the HPLMN. For example, H-UPF **1245** may connect with V-UPF **1240** and with V-UPF **1250** via N9 links, which may be inter-PLMN interfaces.

[0100] Moreover, the UE **1202** may access a data network **1290** using the H-UPF **1245** and an N6 link, via the various connectivity described above to reach the H-UPF **1245**. As shown in the connectivity above, the HPLMN contains the PSA UPF, reached by way of VPLMN 1 or VPLMN 2.

Accordingly, the above example shows a DualSteer MA PDU session between DualSteer UE **1202** and a PSA UPF across different PLMNs.

[0101] Examples provided herein define the UE Requested PDU Session Establishment Procedure for DualSteer UE with access to two 3GPP networks using different PLMNs (HPLMN and VPLMN). In the case of different PLMNs (HPLMN and VPLMN), the PDU Session Establishment procedure is initiated by the DualSteer UE across both 3GPP access networks sequentially. Over which access to first initiate the UE-requested PDU session establishment procedure is UE implementation specific.

[0102] FIG. **13** illustrates an example of a DualSteer MA PDU session establishment procedure with an HPLMN and a VPLMN. As shown in an example in FIG. **13**, a DualSteer UE **1302** may access two 3GPP networks using different PLMNs, a HPLMN and a VPLMN. The HPLMN includes a RAN A 5G NR node **1303**, an AMF **1308**, a PSA H-UPF **1340**, an H-SMF **1310**, a PCF **1320** and a UDM **1360**. Also, the VPLMN includes a RAN B 5G NR node **1304**, an AMF **1309**, a V-SMF **1330** and a V-UPF **1350**.

[0103] The example procedure in FIG. **13** assumes the DualSteer UE **1302** first selects the HPLMN access to initiate the UE-requested PDU session establishment procedure. The UE-requested PDU session establishment procedure on the HPLMN is based on TS 23.502 clause 4.3.2.2.1 (steps **1** to **21**). The UE-requested PDU session establishment procedure on the VPLMN is based on TS 23.502 clause 4.3.2.2.2 (steps **22** to **45**). If the DualSteer UE **1302** first selects the VPLMN access to initiate the UE-requested PDU session establishment procedure, the overall procedure remains the same, with steps **22** to **45** being performed before step **1** to **21**. The example procedure assumes that the DualSteer UE **1302** has already registered with the AMFs **1308**, **1309** in both 3GPP networks, thus unless the DualSteer UE **1302** is Emergency Registered, the AMFs **1308**, **1309** have already retrieved the user subscription data from the UDM **1360**. This may registration may be represented by step **0** in FIG. **13**. Below are a few aspects of the example procedure that differ from the procedures in TS 23.502 clause 4.3.2.2.1 and 4.3.2.2.2.

[0104] The DualSteer UE **1302** includes the PDU Session ID and MA PDU session request within the PDU Session Establishment Request message indicating the support for DualSteer feature using the DualSteer Indication and DualSteer supported steering functionality/modes using the DualSteer Capability IEs as shown AMF in Steps **1** and **22**.

[0105] For example, in the HPLMN in Step **1**, the DualSteer UE **1302** transmits the PDU Session Establishment Request to the RAN B 5G NR node **1303**. The RAN A 5G NR node **1303** forwards the PDU Session Establishment Request to the AMF **1308**. The PDU Session Establishment Request includes not just the PDU Session ID and MA PDU Request, but also DualSteer Indication information and DualSteer Capability IEs.

[0106] Similarly, in the VPLMN in Step **22**, the DualSteer UE **1302** transmits the PDU Session Establishment Request to the RAN B 5G NR node **1304**. The RAN B 5G NR node **1304** forwards the PDU Session Establishment Request to the AMF **1309**. The PDU Session Establishment Request includes not just the subscription permanent identifier (SUPI), PDU Session ID and MA PDU Request, but also DualSteer Indication information and DualSteer Capability IEs.

[0107] Based on the indication in Steps **1** and **22**, the AMFs **1308**, **1309** in both the HPLMN and VPLMN select the same DualSteer capable H-SMF, as shown in Steps **2** and **23**. The AMFs **1308**, **1309** then forward the MA PDU Session Request with the DualSteer Indication information within the CreateSMcontext Request message to the H-SMF **1310** in Step **3** and **27** (via the V-SMF **1330** as in Step **24***a*).

[0108] The H-SMF **1310** performs a session management (SM) Policy Association Establishment procedure to establish an SM Policy Association with the PCF **1320** in the home network (HPLMN) and is provided with the default policy and charging control (PCC) Rules for the PDU Session. This association considers the DualSteer feature support and any associated polices in Steps **7***b* and **30***b*. For example, this association considers the DualSteer indication information.

[0109] Also, as shown in Steps **9** and **32**, if the H-SMF **1310** initiates an SM Policy Modification procedure for Policy Association Modification, the DualSteer feature support and any associated polices are also considered. For example, the Modification procedure considers the DualSteer indication information.

[0110] Further, at Steps **10***a* and **33***a*, the H-SMF **1310** may send an N4 session establishment/modification request to the PSA H-UPF **1340**. This N4 session establishment/modification request may include DualSteer Rules, which may be DualSteer N4 Rules, in an example.

[0111] Additionally, the H-SMF **1310** includes the PDU Session ID and the DualSteer response (indicating the support for DualSteer feature and the configured DualSteer rules) to the AMF in step **11** and step **35**. For example, in the HPLMN at Step **11**, the H-SMF **1310** sends a Namf_Communication_N1N2MessageTransfer to the AMF **1308**. The Namf_Communication_N1N2MessageTransfer includes not only the PDU Session ID and MA PDU Session Allowed information, but also DualSteer Indication information and DualSteer Traffic Rules. Similarly, in the VPLMN at Step **35**, the V-SMF **1330** sends a Namf_Communication_N1N2MessageTransfer to the AMF **1309**. The Namf_Communication_N1N2MessageTransfer includes not only the PDU Session ID and MA PSA Allowed information, but also DualSteer Indication information and DualSteer Traffic Rules.

[0112] The N2 PDU Session Request in steps **12** and **36**, the PDU Session Establishment Accept message in step **13** and the RRC Reconfiguration message in step **37** contain the DualSteer Container IE for the DualSteer UE from the SMF. This container includes the information elements associated with DualSteer.

[0113] For example, in the HPLMN in step **12** the AMF **1308** sends an N2 PDU session request NAS message to the RAN A 5G NR **1303**. This NAS message contains not just the PDU Session ID and MA PSA Allowed information, but also DualSteer Indication information and DualSteer Traffic Rules. Similarly, in the VPLMN in step **36**, the AMF **1309** sends an N2 PDU session request message to the RAN B 5G NR **1304**. This message contains not only PDU Session ID and MA PSA Allowed information, but also DualSteer Indication information and DualSteer Traffic Rules.

[0114] Further, in step **13**, the DualSteer UE **1302** and the RAN A 5G NR **1303** may engage in AN-specific resource setup, including a PDU Session Establishment Accept. This may include not just PDU Session ID and MA PDU Session

Allowed information, but also DualSteer Indication information and DualSteer Traffic Rules.

[0115] Moreover, in step **37**, the DualSteer UE **1302** and the RAN A 5G NR **1303** may engage in RRC Reconfiguration. This reconfiguration may include not just PDU Session ID and MA PSU Allowed information, but also DualSteer Indication information and DualSteer Traffic Rules.

[0116] As used herein, the DualSteer container information element is a modified information element to transfer parameters associated with DualSteer. The ATSSS container information element defined for ATSSS may be re-used for carrying the DualSteer parameters. The DualSteer and ATSSS (or a common) container information element will also include information regarding which amongst DualSteer and ATSSS is preferred, assuming both are supported by the UE and the network.

[0117] Further, in step **26***a*, an N4 Session Establishment Request message is sent by V-SMF **1330** to V-UPF **1350**. Also, in step **26***b*, an N4 Session Establishment Response is sent by V-UPF **1350** to V-SMF **1330**. In these steps, UL N9 tunnel CN information is allocated by the H-SMF **1310** or H-UPF **1340**. After this, N9 tunnels between the H-UPF **1340** and V-UPF **1350** are established. Additionally, the H-SMF **1310** selects the same DualSteer capable H-UPF **1340** and sends the DualSteer rules to the H-UPF **1340** for establishing the user plane resources in N4 session Establishment message in steps **10***a* and **33***a*, as mentioned above.

[0118] Given that both SUPIs on each of the networks (HPLMN and VPLMN) are provisioned in the UDM in HPLMN, the HPLMN may associate the two SUPIs to a common subscription profile. In case of different PLMN (two VPLMNs), the UE-requested PDU session establishment procedures are performed on both the VPLMNs as defined in TS 23.502 clause 4.3.2.2.2 (steps **22** to **45**) with the same identified differences as mentioned above (for steps **22**, **24***b*, **27**, **32**, **36** and **37**).

[0119] As noted in FIG. **13**, step **14** to step **21** may be as defined in 3GPP TS 23.502, FIG. 4.3.2.2.1-1 for a UE-requested PDU Session Establishment for non-roaming and roaming with local breakout. As further noted, step **17** to step **24** may be as defined in 3GPP TS 23.502, FIG. 4.3.2.2.1-1 for a UE-requested PDU Session Establishment for home-routed roaming scenarios.

[0120] In the examples provided herein, the AMF supports DualSteer capable SMF selection that can support session management across both 3GPP networks. Further, the SMF supports DualSteer capable PSA UPF selection that can support session management across both 3GPP accesses. Also, the SMF indicates DualSteer feature support and sends the DualSteer container IE to the UE via the AMF, including the DualSteer parameters. Additionally, the SMF maps the PCC rules into DualSteer rules which are sent to UE via the AMF.

[0121] In addition, the PCF creates PCC rules based on the specified DualSteer steering functionality. Further, the UE indicates DualSteer feature support as part of the MA PDU request to the SMF via the AMF. The UE may send information indicating that the UE supports an MA PDU session using two 3GPP access networks. For example, the UE may include DualSteer indication information and DualSteer capability information in a PDU Session Establishment Request sent by the UE to a network node.

[0122] Examples including a multi-access PDU connectivity service activation for a DualSteer UE are provided herein. As used in examples herein, activating multi-access PDU connectivity service refers to the establishment of user-plane resources on both 3GPP accesses.

[0123] If the UE is registered over both 3GPP access networks in the same PLMN, the UE shall initiate the UE-requested PDU session establishment procedure as specified in clause 6.4.1.2 of 3GPP TS 24.501 over a selected access. The contents 3GPP TS 24.501 are incorporated by reference, as if fully set forth herein. Over which access to initiate this UE-requested PDU session establishment procedure is UE implementation specific.

[0124] When the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE, the UE shall consider that the MA PDU session has been established and the user plane resources are successfully established on the selected access. When the user plane resources are established on the access other than the selected access, the UE shall consider the user plane resources are established on both.

[0125] Further, if the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE and fails to receive user plane resources established on the access other than the selected access, upon an implementation specific timer expiry the UE re-initiates the UE-requested PDU session establishment procedure over the access other than the selected access, in order to establish user plane resources on the access other than the selected access.

[0126] If the UE is registered over both 3GPP access networks in different PLMNs, the UE shall initiate the UE-requested PDU session establishment procedure as specified in clause 6.4.1.2 of 3GPP TS 24.501 over each 3GPP access sequentially. Over which access to first initiate the UE-requested PDU session establishment procedure is UE implementation specific. When the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE over the selected access, the UE shall consider that the MA PDU session has been established and the user plane resources of the MA PDU session on this access are successfully established. The UE shall then initiate the UE-requested PDU session establishment procedure with the same PDU session ID over the other access, in order to establish user plane resources on the other access for the MA PDU session. If the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message over the other access, the UE shall consider that the user plane resources of the MA PDU session have been established on both 3GPP access networks.

[0127] If the UE is registered to a PLMN over only one access, either 3GPP access, the UE shall initiate the UE-requested PDU session establishment procedure as specified in clause 6.4.1.2 of 3GPP TS 24.501 over this access. When the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE over the access, the UE shall consider that the MA PDU session has been established and the user plane resources of the MA PDU session on this access are successfully established. When the UE at a later point in time registers over the other 3GPP access, either in the same PLMN or in a different PLMN, the UE shall initiate the UE-requested PDU session establishment procedure with the same PDU session ID over the other access in order to establish user plane resources on the other access for the MA PDU session. If the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message over the other access, the UE shall consider that the user plane resources of the MA PDU session have been established over both 3GPP access networks.

[0128] Further, the DualSteer container information element is a modified information element to transfer parameters associated with DualSteer, as noted above. The ATSSS container information element defined for ATSSS may be re-used for carrying the DualSteer parameters.

[0129] Examples are provided herein of a PDU session establishment procedure with network modification to the MA PDU session. When a DualSteer UE capable of simultaneous data transmission over the two 3GPP networks establishes a new PDU session and the related UE route selection policy (URSP) or UE local configuration does not mandate the PDU session shall be established over a single access, one or more of the following may apply.

[0130] If the UE is registered over both 3GPP access networks in the same PLMN and the UE initiates the UE-requested PDU session establishment procedure over a selected access, either 3GPP access, the UE may include the MA PDU session information IE in the UL NAS TRANSPORT message and set the IE to "MA PDU session network upgrade is allowed" as defined in clause 9.11.3.31A of 3GPP TS 24.501. When the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE, the UE shall consider that the requested PDU session is established as an MA PDU session and the user plane resources are successfully established on the selected access. When the user plane resources are established on the access other than the selected access, the UE shall consider the user plane resources are successfully established on both accesses.

[0131] Further, if the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE and fails to receive user plane resources established on the access other than the selected access, upon an implementation specific timer expiry, the UE reinitiates the UE-requested PDU session establishment procedure over the access other than the selected access, in order to establish user plane resources on the access other than the selected access.

[0132] If the UE is registered over both 3GPP access networks in different PLMNs and the UE initiates the UE-requested PDU session establishment procedure over either access, the UE may include the MA PDU session information IE in the UL NAS TRANSPORT message and shall set the IE to "MA PDU session network upgrade is allowed" as defined in clause 9.11.3.31A of 3GPP TS 24.501. When the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE over the access, the UE shall consider that the requested PDU session is established as an MA PDU session and the user plane resources are established on this access. The UE shall then initiate the UE-requested PDU session establishment procedure with the same PDU session ID over the other access, in order to establish user plane resources on the other access for the MA PDU session. If the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE over the other access, the UE shall consider that the user plane resources of the MA PDU session have been established on both 3GPP access networks.

[0133] If the UE is registered to a PLMN over only one access, either 3GPP access, and the UE requests to establish a PDU session over this access, the UE may include the MA PDU session information IE in the UL NAS TRANSPORT message and shall set the IE to "MA PDU session network upgrade is allowed" as defined in clause 9.11.3.31A of 3GPP TS 24.501. When the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE over the access, the UE shall consider that the requested PDU session is established as an MA PDU session and the user plane resources are established on this access. When the UE at a later point in time registers over the other access, either in the same PLMN or in a different PLMN, the UE shall initiate the UE-requested PDU session establishment procedure with the same PDU session ID over the other access in order to establish user plane resources on the other access for the MA PDU session. If the UE receives the PDU SESSION ESTABLISHMENT ACCEPT message including the DualSteer container IE over the other access, the UE shall consider that the user plane resources of the MA PDU session have been established on both 3GPP access and non-3GPP access.

[0134] Examples are provided herein of a UE requested PDU session establishment procedure for a DualSteer UE with simultaneous access to two 3GPP networks, using different PLMNs. In the case of different PLMNs, the PDU Session Establishment procedure will be initiated by the DualSteer UE across both 3GPP access networks sequentially. Over which access to first initiate the UE-requested PDU session establishment procedure is UE implementation specific.

[0135] FIG. **14** illustrates an example of a UE requested PDU session establishment procedure for a DualSteer UE with simultaneous access to two 3GPP networks, using different PLMNs. As shown in an example in FIG. **14**, a DualSteer UE **1402** may access two 3GPP networks using different PLMNs, a HPLMN and a VPLMN. The HPLMN includes a RAN A 5G NR node **1403**, an AMF **1408**, a PSA H-UPF **1440**, an H-SMF **1410**, a PCF **1420** and a UDM **1460**. Also, the VPLMN includes a RAN B 5G NR node **1404**, an AMF **1409**, a V-SMF **1430** and a V-UPF **1450**.

[0136] The example procedure in FIG. **14** assumes the DualSteer UE **1402** first selects the HPLMN access to initiate the UE-requested PDU session establishment procedure. The UE-requested PDU session establishment procedure on the HPLMN will be as defined in 3GPP TS 23.502 clause 4.3.2.2.1. The UE-requested PDU session establishment procedure on the VPLMN will be as defined in 3GPP TS 23.502 clause 4.3.2.2.2. The procedure assumes that the DualSteer UE **1402** has already registered on the AMFs **1408**, **1409** in both 3GPP networks; thus, unless the UE is Emergency Registered, the AMFs **1408**, **1409** have already retrieved the user subscription data from the UDM **1460**. This may registration may be represented by step **0** in FIG. **14**. Below are a few example aspects that will differ from the current defined procedures in 3GPP TS 23.502 clause 4.3.2.2.1 and 4.3.2.2.2.

[0137] In an example shown in FIG. **14**, the DualSteer UE **1402** will include the PDU Session ID and the DualSteer request within the PDU Session Establishment Request and the CreateSMcontext Request message (indicating the support for DualSteer features) to the AMF **1408** and H-SMF **1410** in Steps **1** and **3**, and to the AMF **1409** and V-SMF **1430** in **22** and **24***a*.

[0138] If the H-SMF **1410** supports the DualSteer features, it will include the PDU Session ID and the DualSteer response (indicating the support for DualSteer features) in a message to the UE **1402** via AMF in Step **5**. Similarly, the V-SMF **1430** will include the PDU Session ID and the DualSteer response (indicating the support for DualSteer features) in a message to the AMF **1409** in Step **24***b*.

[0139] The H-SMF **1410** may perform an SM Policy Association Establishment procedure to establish an SM Policy Association with the PCF **1420** in the home network (HPLMN) and get the default PCC Rules for the PDU Session. This association will consider the DualSteer feature support and any associated polices in Steps **7***b* and **32**.

[0140] The N2 PDU Session Request in step **12** and **38**, the PDU Session Establishment Accept message in step **13** and the RRC Reconfiguration message in step **37** will contain the DualSteer Container IE for the DualSteer UE **1402** from the SMF for parameters associated with DualSteer.

[0141] Examples are provided herein of a UE requested PDU session establishment procedure for a DualSteer UE with simultaneous access to two 3GPP networks, using the same PLMN. In the case of the same PLMN, the PDU Session Establishment procedure will be initiated by the DualSteer UE. Over which 3GPP access to initiate the UE-requested PDU session establishment procedure is UE implementation specific.

[0142] FIG. **15** illustrates an example of a UE requested PDU session establishment procedure for a DualSteer UE with simultaneous access to two 3GPP networks, using the same PLMN. As shown in an example in FIG. **14**, the HPLMN includes a RAN A 5G NR node **1503**, an AMF **1508**, a PSA H-UPF **1540**, an H-SMF **1510**, a PCF **1520** and a UDM **1560**. Also, the VPLMN includes a RAN B 5G NR node **1504**, an AMF **1509**, a V-SMF **1530** and a V-UPF **1550**.

[0143] The example procedure in FIG. **15** assumes the DualSteer UE **1502** first selects the HPLMN access to initiate the UE-requested PDU session establishment procedure. The UE-requested PDU session establishment procedures will be as defined in 3GPP TS 23.502 clause 4.3.2.2.1 and clause 4.3.2.2.2. The procedure assumes that the UE **1502** has already registered on the AMFs in both 3GPP networks; thus, unless the UE **1502** is Emergency Registered, the AMFs have already retrieved the user subscription data from the UDM **1560**. This may registration may be represented by step **0** in FIG. **15**. Below are a few example aspects that will differ from the current defined procedures in 3GPP TS 23.502 clause 4.3.2.2.1 and 4.3.2.2.2.

[0144] The DualSteer UE **1502** will include the PDU Session ID and the DualSteer request within the PDU Session Establishment Request and the CreateSMcontext Request message (indicating the support for DualSteer features) to the AMF **1508** and H-SMF **1510** in Steps **1** and **3**.

[0145] If the H-SMF **1510** supports the DualSteer features, it will include the PDU Session ID and the DualSteer response (indicating the support for DualSteer features) to the AMF **1508** in Step **5** (and similarly to the AMF **1509**, via the V-SMF **1530** in Steps **22** and **27**).

[0146] The H-SMF **1510** may perform an SM Policy Association Establishment procedure to establish an SM Policy Association with the PCF **1520** in the home network (HPLMN) and get the default PCC Rules for the PDU Session. This association will consider the DualSteer feature support and any associated polices in Steps **7***b*.

[0147] Further, the N2 PDU Session Request in step **12** and **28**, the PDU Session Establishment Accept message in step **13** and the RRC Reconfiguration message in step **29** will contain the DualSteer Container IE for the DualSteer UE **1502** from the SMF for parameters associated with DualSteer.

[0148] In other examples, the procedures that apply to the same PLMN scenario with an HPLMN and a VPLMN apply equally to a scenario with two networks. For example, the procedure and steps shown in FIG. **15** for an HPLMN and a VPLMN apply equally to a network A and a network B in the same PLMN. Also, network A may be an anchoring network and network B may be a non-anchoring network. Further, the PLMN value may be the same for both network A and network B. More specifically, a PSA UPF A in network A may perform the same steps as the PSA H-UPF **1540** in the HPLMN of FIG. **15**. Similarly, an SMF A in network A may perform the same steps as the H-SMF **1510** in the HPLMN of FIG. **15**. Likewise, an SMF B in network B may perform the same steps as the V-SMF **1530** in the VPLMN of FIG. **15**. Moreover, a UPF B in network B may perform the same steps as the V-UPF **1550** in the VPLMN of FIG. **15**.

[0149] Further, in an example, network A and network B may use the communication system architecture as shown in the example in FIG. **11**. As noted, network A may be an anchoring network and network B may be a non-anchoring network. More specifically, a PSA UPF A in network A may perform the same steps as the H-UPF **1140**, which may be a PSA UPF, in the HPLMN of FIG. **11**. Similarly, an SMF A in network A may perform the same steps as the H-SMF **1110** in the HPLMN of FIG. **11**. Likewise, an SMF B in network B may perform the same steps as the V-SMF **1130** in the VPLMN of FIG. **11**. Moreover, a UPF B in network B may perform the same steps as the V-UPF **1150** in the VPLMN of FIG. **15**. Further, the inter-PLMN interfaces of FIG. **11** may be intra-PLMN interfaces in the example of network A and network B. For example, an N16 link between SMF A and SMF B may be an intra-PLMN interface. Similarly, an N9 link between UPF A and UPF B may be an intra-PLMN interface.

[0150] In an example, a UE transmits first information indicating that the UE requests access to two 3GPP access networks simultaneously and that the UE supports access to two 3GPP access networks simultaneously. Further, the UE receives second information indicating rules for accessing the two 3GPP access networks simultaneously.

[0151] Moreover, the UE transmits data using an MA PDU session based on the rules for accessing the two 3GPP access networks simultaneously, where the MA PDU session is established on a first 3GPP access network and a second 3GPP access network. Additionally or alternatively, the first information is included in a PDU session establishment request message. Additionally or alternatively, the second information is included in a PDU session establishment accept message. Additionally or alternatively, the UE is a DualSteer UE.

[0152] In an example, the first information includes a DualSteer request, and the second information includes a DualSteer container IE. Additionally or alternatively, the DualSteer container IE includes DualSteer parameters.

[0153] Additionally or alternatively, the first information includes DualSteer indication information and DualSteer capability information. Additionally or alternatively, the second information includes the DualSteer indication information and DualSteer traffic rules information.

[0154] Additionally or alternatively, the UE is registered over the first 3GPP access network and the second 3GPP access network in the same PLMN. Additionally or alternatively, the UE is registered over the first 3GPP access network and the second 3GPP access network in different PLMNs. Additionally or alternatively, the UE is registered over the first 3GPP access network or the second 3GPP access network in a PLMN.

[0155] In another example, a network node receives first information indicating that a UE requests access to two 3GPP access networks simultaneously and that the UE supports access to two 3GPP access networks simultaneously. Further, the network node sends second information indicating rules for accessing the two 3GPP access networks simultaneously. Also, the network node receives data using an MA PDU session based on the rules for accessing the two 3GPP access networks simultaneously, where the MA PDU session is established on a first 3GPP access network and a second 3GPP access network.

[0156] In an example, the network node includes an AMF. Additionally or alternatively, the network node includes an SMF.

[0157] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

What is claimed:

1. A method for use in a user equipment (UE), the method comprising:

transmitting first information indicating that the UE requests access to two Third Generation Partnership Project (3GPP) access networks simultaneously and that the UE supports access to two 3GPP access networks simultaneously;

receiving second information indicating rules for accessing the two 3GPP access networks simultaneously; and

transmitting data using a multi-access (MA) protocol data unit (PDU) session based on the rules for accessing the two 3GPP access networks simultaneously, wherein the MA PDU session is established on a first 3GPP access network and a second 3GPP access network.

2. The method of claim **1**, wherein the first information is included in a PDU session establishment request message, and the second information is included in a PDU session establishment accept message.

3. The method of claim **1**, wherein the UE is a Dualsteer UE.

4. The method of claim **1**, wherein the first information includes a DualSteer request, and the second information includes a DualSteer container information element (IE), wherein the DualSteer container IE includes DualSteer parameters.

5. The method of claim **1**, wherein the first information includes DualSteer indication information and DualSteer capability information, and the second information includes the DualSteer indication information and DualSteer traffic rules information.

6. The method of claim **1**, wherein the UE is registered over the first 3GPP access network and the second 3GPP access network in the same public land mobile network (PLMN).

7. The method of claim **1**, wherein the UE is registered over the first 3GPP access network and the second 3GPP access network in different PLMNs.

8. The method of claim **1**, wherein the UE is registered over the first 3GPP access network or the second 3GPP access network in a PLMN.

9. A user equipment (UE) comprising;

a transceiver; and

a processor operatively coupled to the transceiver; wherein:

the transceiver and the processor are configured to transmit first information indicating that the UE requests access to two Third Generation Partnership Project (3GPP) access networks simultaneously and that the UE supports access to two 3GPP access networks simultaneously;

the transceiver is configured to receive second information indicating rules for accessing the two 3GPP access networks simultaneously; and

the transceiver and the processor are configured to transmit data using a multi-access (MA) protocol data unit (PDU) session based on the rules for accessing the two 3GPP access networks simultaneously, wherein the MA PDU session is established on a first 3GPP access network and a second 3GPP access network.

10. The UE of claim **9**, wherein the first information is included in a PDU session establishment request message, and the second information is included in a PDU session establishment accept message.

11. The UE of claim **9**, wherein the UE is a Dualsteer UE.

12. The UE of claim **9**, wherein the first information includes a DualSteer request, and the second information includes a DualSteer container information element (IE), wherein the DualSteer container IE includes DualSteer parameters.

13. The UE of claim **9**, wherein the first information includes DualSteer indication information and DualSteer capability information, and the second information includes the DualSteer indication information and DualSteer traffic rules information.

14. The UE of claim **9**, wherein the UE is registered over the first 3GPP access network and the second 3GPP access network in the same public land mobile network (PLMN).

15. The UE of claim **9**, wherein the UE is registered over the first 3GPP access network and the second 3GPP access network in different PLMNs.

16. The UE of claim **9**, wherein the UE is registered over the first 3GPP access network or the second 3GPP access network in a PLMN.

17. A network node comprising:

a transceiver; and

a processor operatively coupled to the transceiver; wherein:

the transceiver is configured to receive first information indicating that a user equipment (UE) requests access to two Third Generation Partnership Project (3GPP) access networks simultaneously and that the UE supports access to two 3GPP access networks simultaneously;

the transceiver and the processor are configured to send second information indicating rules for accessing the two 3GPP access networks simultaneously; and

the transceiver is configured to receive data using a multi-access (MA) protocol data unit (PDU) session based on the rules for accessing the two 3GPP access networks simultaneously, wherein the MA PDU session is established on a first 3GPP access network and a second 3GPP access network.

18. The network node of claim **17**, wherein the UE is a Dualsteer UE, the first information includes a DualSteer request, and the second information includes a DualSteer container information element (IE), wherein the DualSteer container IE includes DualSteer parameters.

19. The network node of claim **17**, wherein the first information includes DualSteer indication information and DualSteer capability information, and the second information includes the DualSteer indication information and DualSteer traffic rules information.

20. The network node of claim **17**, wherein the network node includes one or more of an Access and Mobility Management Function (AMF), and a Session Management Function (SMF).

* * * * *