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(54) PROVIDING FEEDER-LINK SWITCHOVER EVENT INFORMATION

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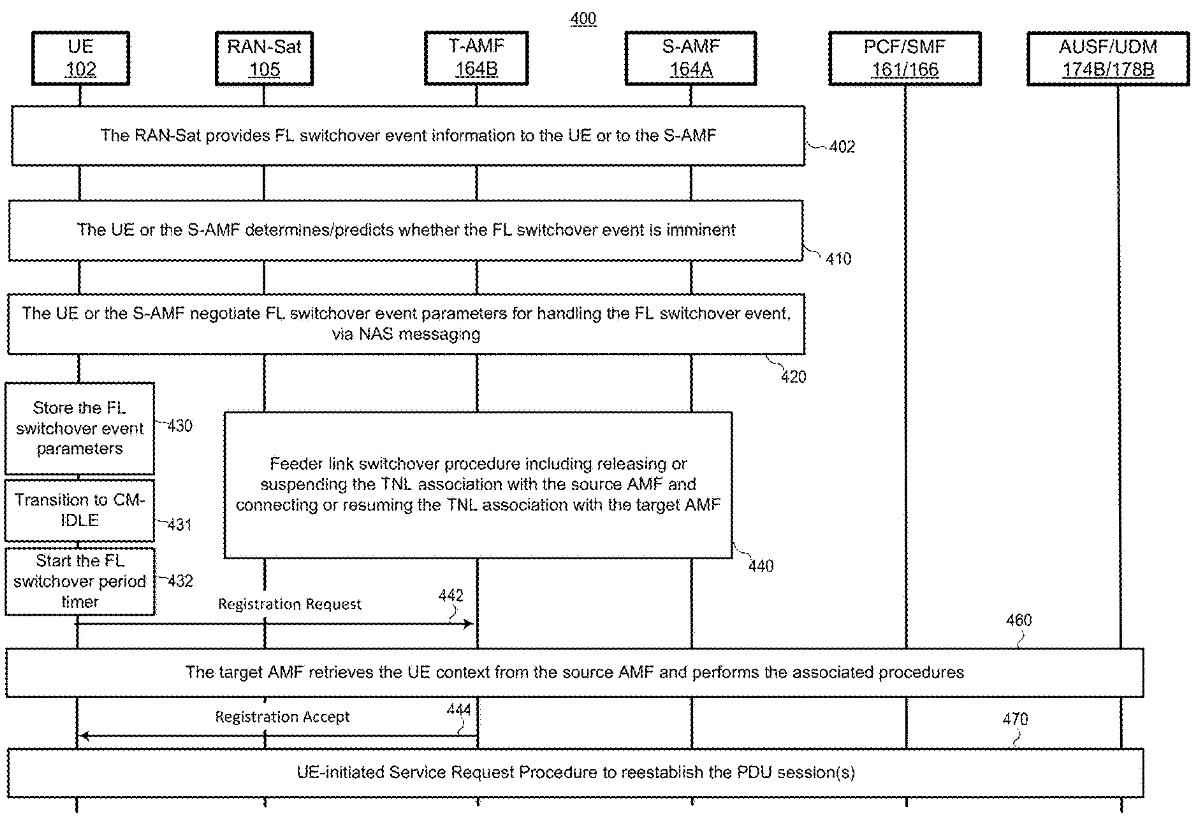
(57) ABSTRACT

A method implemented in a node of a non-terrestrial radio access network (RAN) comprises transmitting (**502**), to a core network (CN), information related to a switchover of the node from a first feeder link (FL), via which the node communicates with the CN, to a second FL; and forwarding (**524**), from the CN to a user equipment (UE), switchover event parameters related to the switchover.



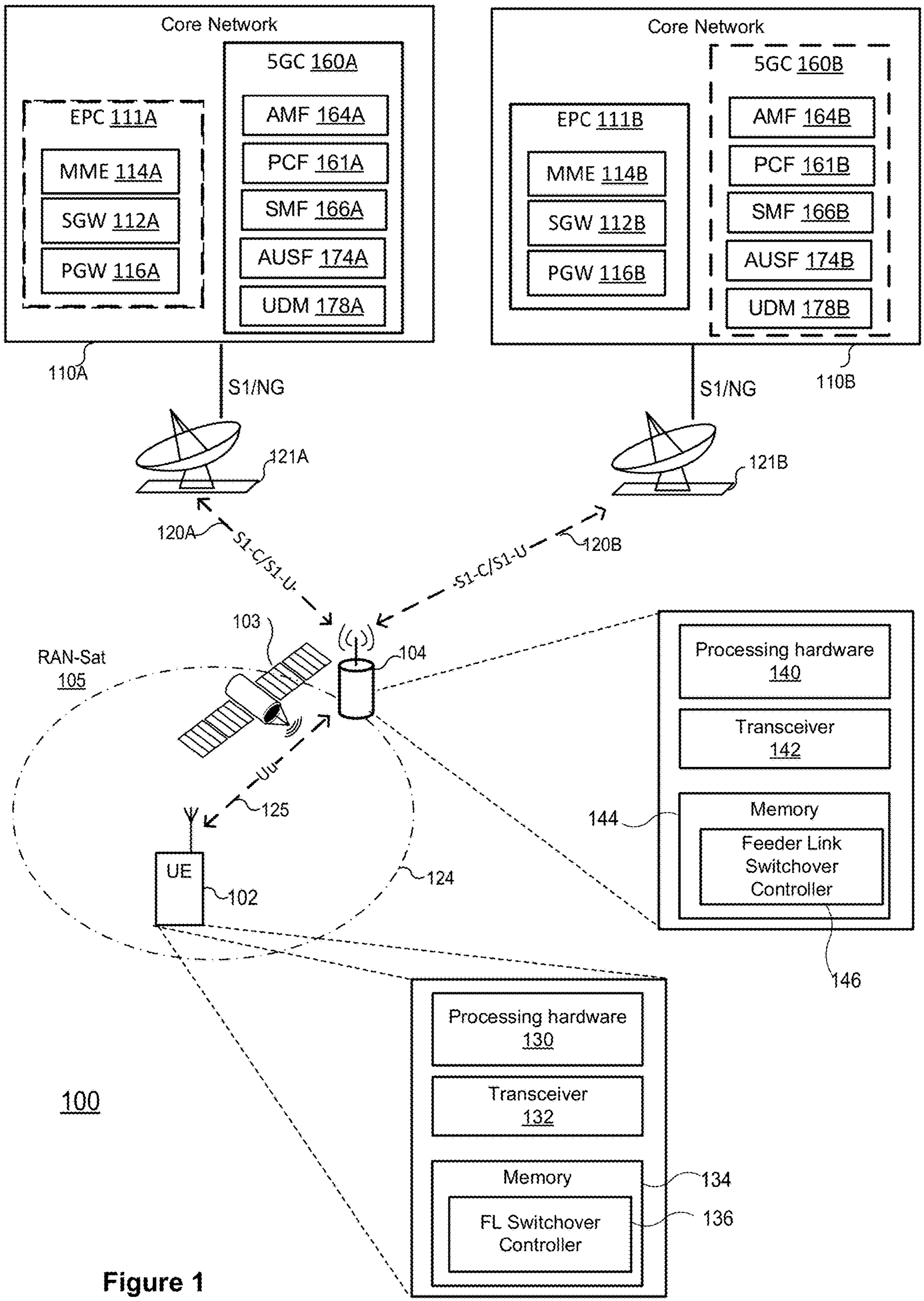

Core Network
5GC 160A
AMF 164A
PCF 161A
SMF 166A
AUSF 174A
UDM 178A
EPC 111A
MME 114A
SGW 112A
PGW 116A
110A
S1/NG
121A
120A
S1-C/S1-U
Core Network
5GC 160B
AMF 164B
PCF 161B
SMF 166B
AUSF 174B
UDM 178B
EPC 111B
MME 114B
SGW 112B
PGW 116B
110B
S1/NG
121B
120B
S1-C/S1-U
RAN-Sat
105
103
104
Uu
125
124
UE
102
Processing hardware
140
Transceiver
142
Memory
Feeder Link Switchover Controller
144
146
Processing hardware
130
Transceiver
132
Memory
FL Switchover Controller
134
136
100

Figure 1

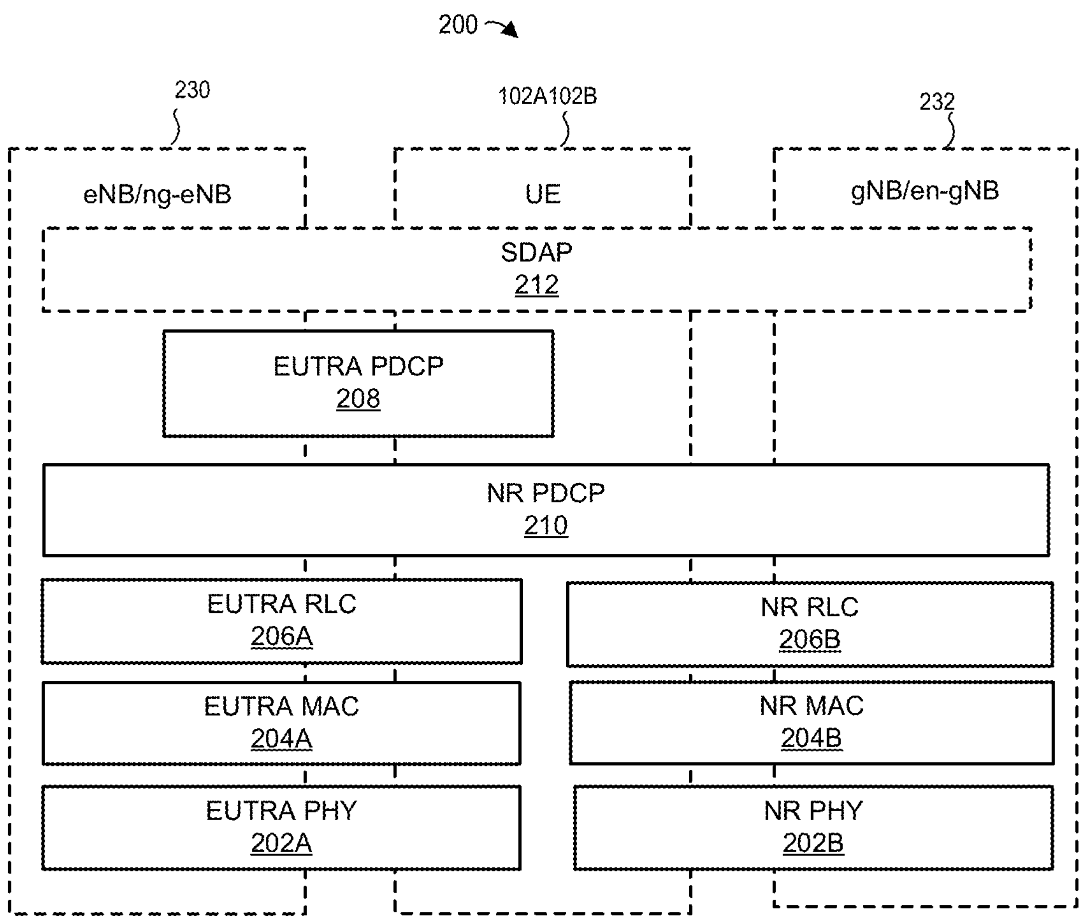

200
230
102A102B
232
eNB/ng-eNB
UE
gNB/en-gNB
SDAP
212
EUTRA PDCP
208
NR PDCP
210
EUTRA RLC
206A
NR RLC
206B
EUTRA MAC
204A
NR MAC
204B
EUTRA PHY
202A
NR PHY
202B

Figure 2

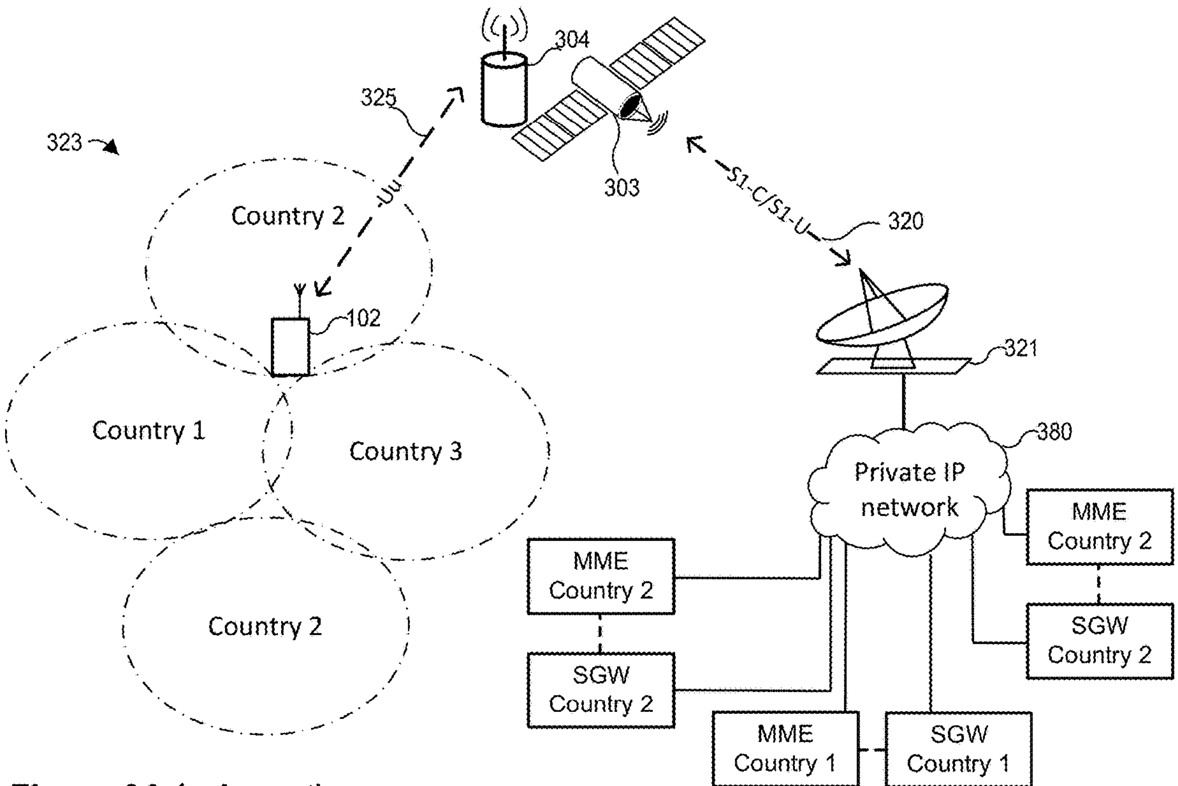


Figure 3A (prior art)

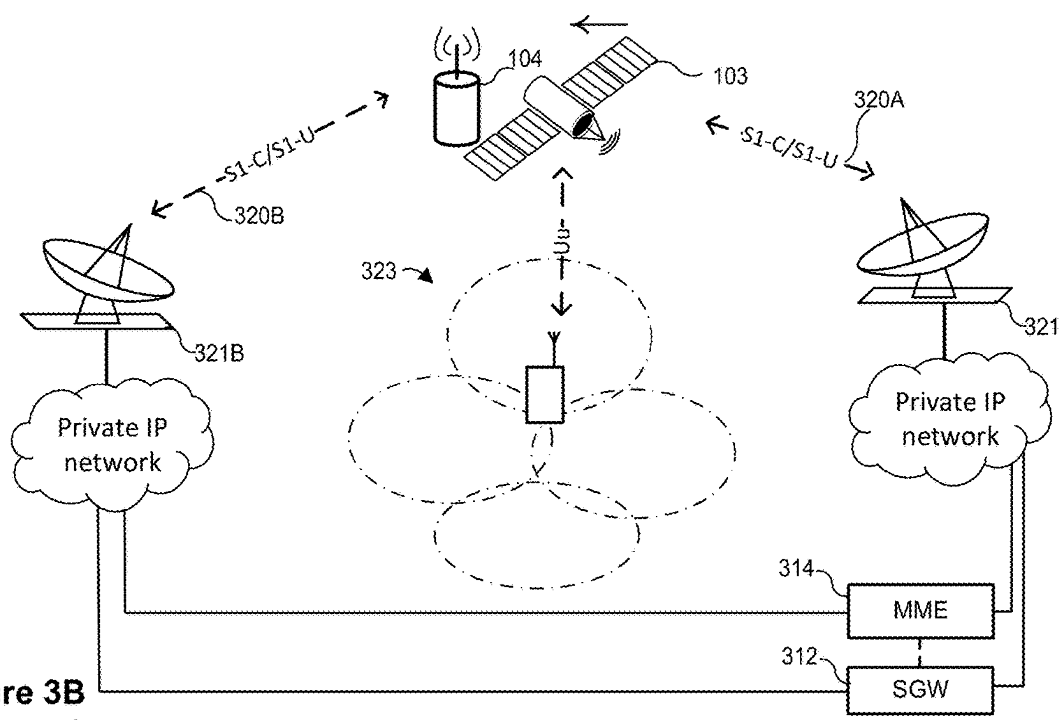


Figure 3B (prior art)

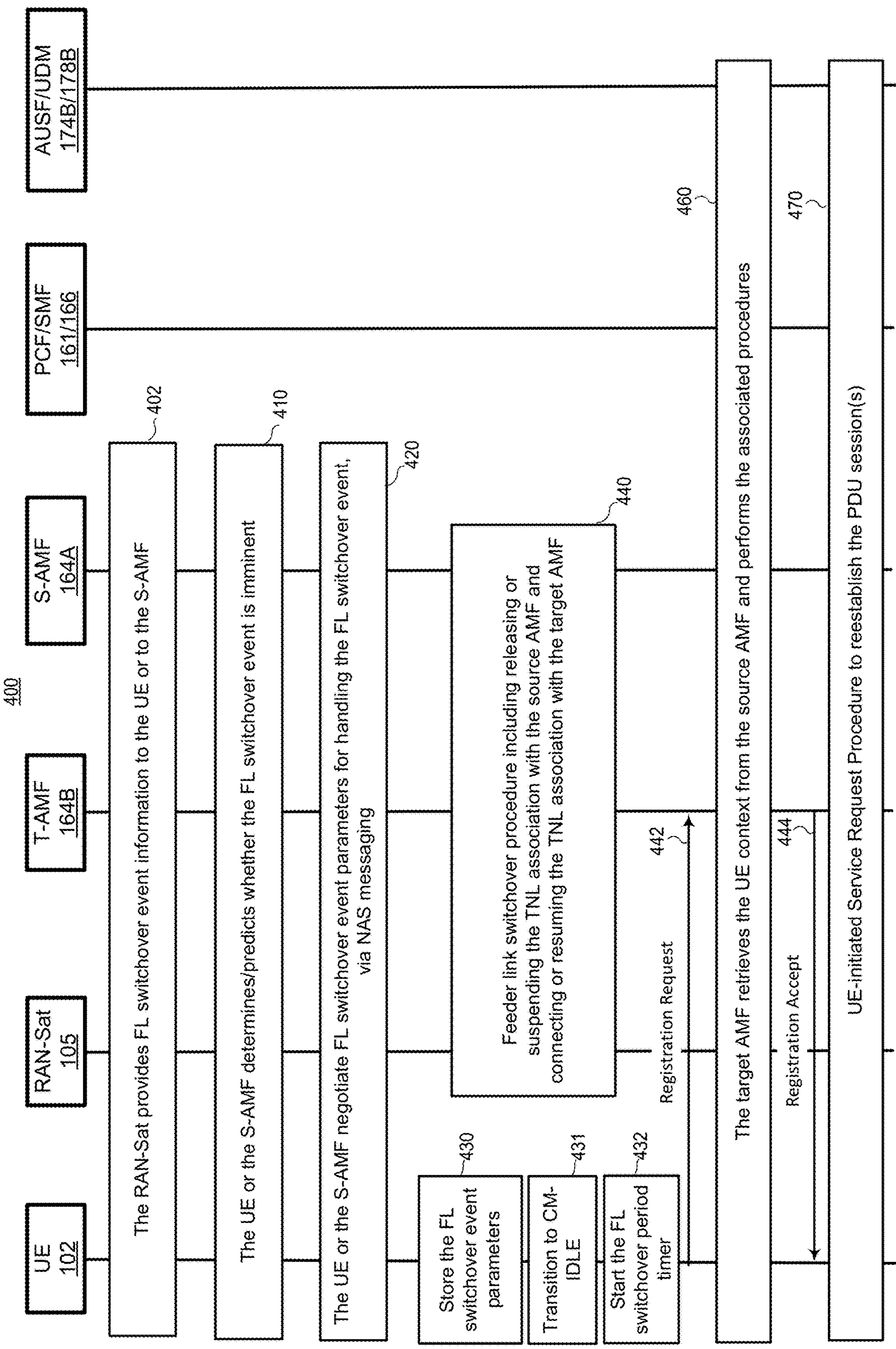

400
UE
102
RAN-Sat
105
T-AMF
164B
S-AMF
164A
PCF/SMF
161/166
AUSF/UDM
174B/178B
The RAN-Sat provides FL switchover event information to the UE or to the S-AMF
402
The UE or the S-AMF determines/predicts whether the FL switchover event is imminent
410
The UE or the S-AMF negotiate FL switchover event parameters for handling the FL switchover event, via NAS messaging
420
Store the FL switchover event parameters
430
Transition to CM-IDLE
431
Start the FL switchover period timer
432
Feeder link switchover procedure including releasing or suspending the TNL association with the source AMF and connecting or resuming the TNL association with the target AMF
440
Registration Request
442
Registration Accept
444
The target AMF retrieves the UE context from the source AMF and performs the associated procedures
460
UE-initiated Service Request Procedure to reestablish the PDU session(s)
470

Figure 4

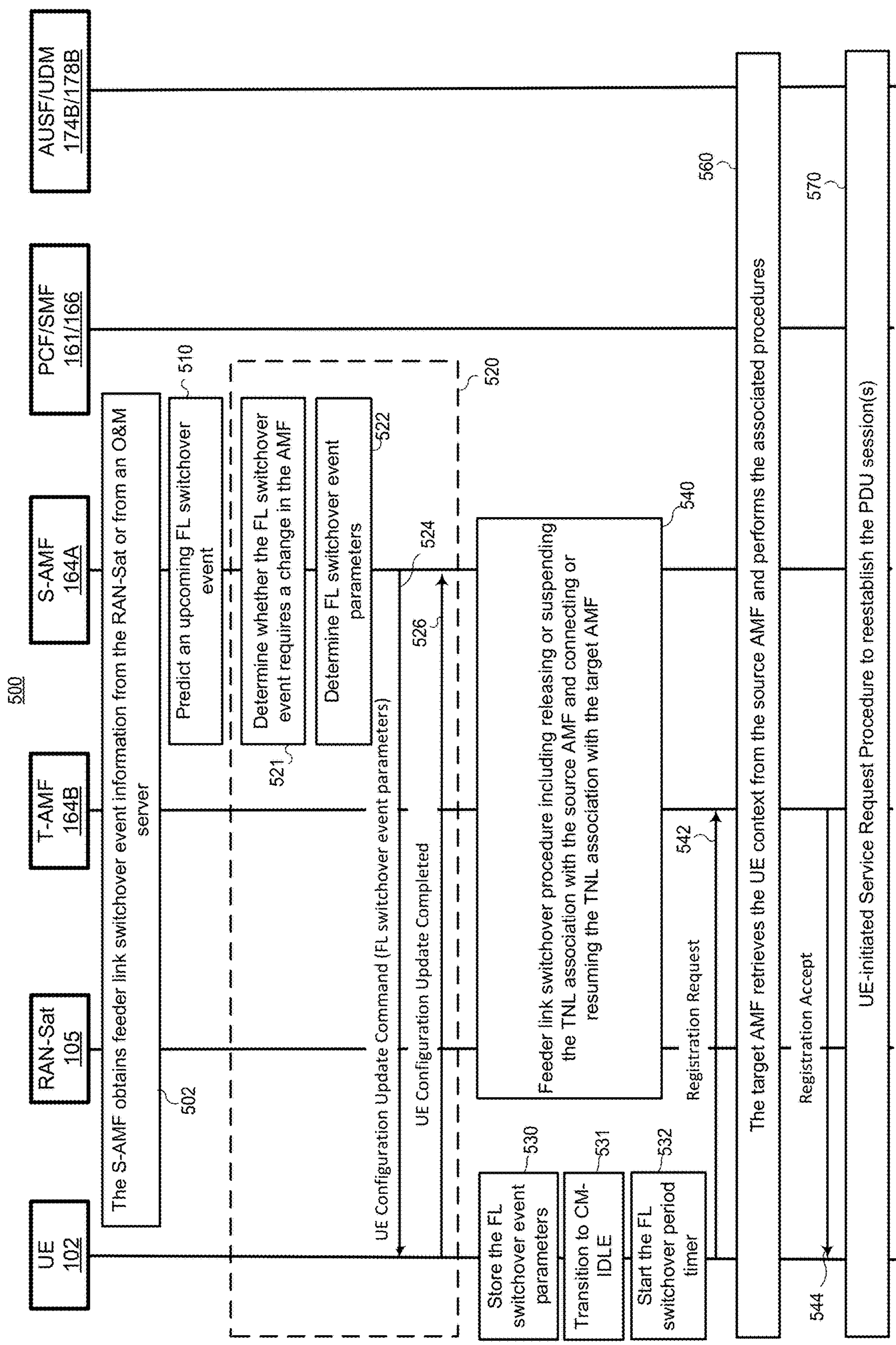

500
UE 102
RAN-Sat 105
T-AMF 164B
S-AMF 164A
PCF/SMF 161/166
AUSF/UDM 174B/178B
The S-AMF obtains feeder link switchover event information from the RAN-Sat or from an O&M server
502
Predict an upcoming FL switchover event
510
Determine whether the FL switchover event requires a change in the AMF
521
Determine FL switchover event parameters
522
520
UE Configuration Update Command (FL switchover event parameters)
524
UE Configuration Update Completed
526
Store the FL switchover event parameters
530
Transition to CM-IDLE
531
Start the FL switchover period timer
532
Feeder link switchover procedure including releasing or suspending the TNL association with the source AMF and connecting or resuming the TNL association with the target AMF
540
Registration Request
542
The target AMF retrieves the UE context from the source AMF and performs the associated procedures
560
Registration Accept
544
UE-initiated Service Request Procedure to reestablish the PDU session(s)
570

Figure 5

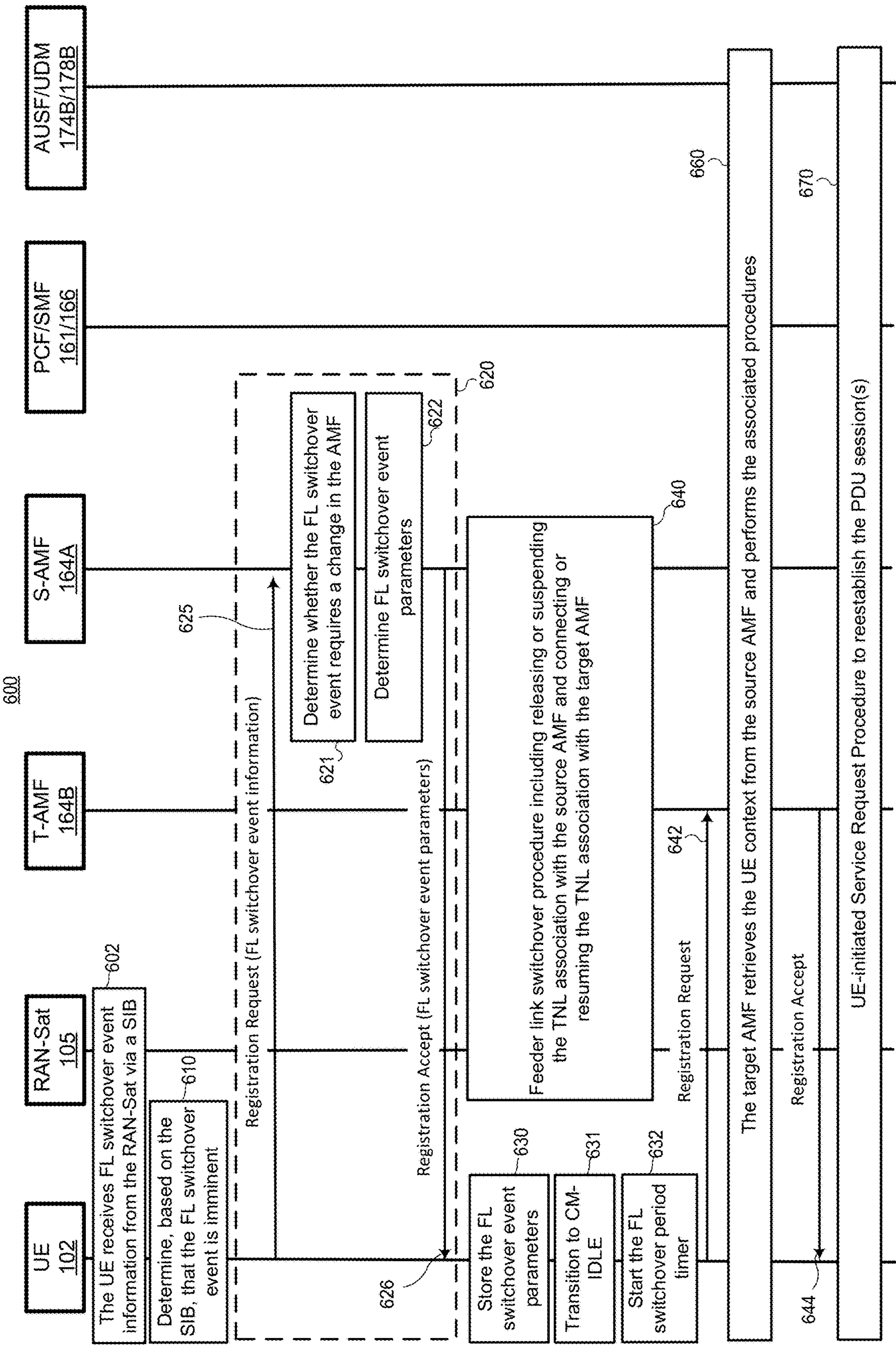

600
UE 102
RAN-Sat 105
T-AMF 164B
S-AMF 164A
PCF/SMF 161/166
AUSF/UDM 174B/178B
The UE receives FL switchover event information from the RAN-Sat via a SIB
602
Determine, based on the SIB, that the FL switchover event is imminent
610
Registration Request (FL switchover event information)
625
Determine whether the FL switchover event requires a change in the AMF
621
Determine FL switchover event parameters
622
620
Registration Accept (FL switchover event parameters)
626
Store the FL switchover event parameters
630
Transition to CM-IDLE
631
Start the FL switchover period timer
632
Feeder link switchover procedure including releasing or suspending the TNL association with the source AMF and connecting or resuming the TNL association with the target AMF
640
Registration Request
642
The target AMF retrieves the UE context from the source AMF and performs the associated procedures
660
Registration Accept
644
UE-initiated Service Request Procedure to reestablish the PDU session(s)
670

Figure 6

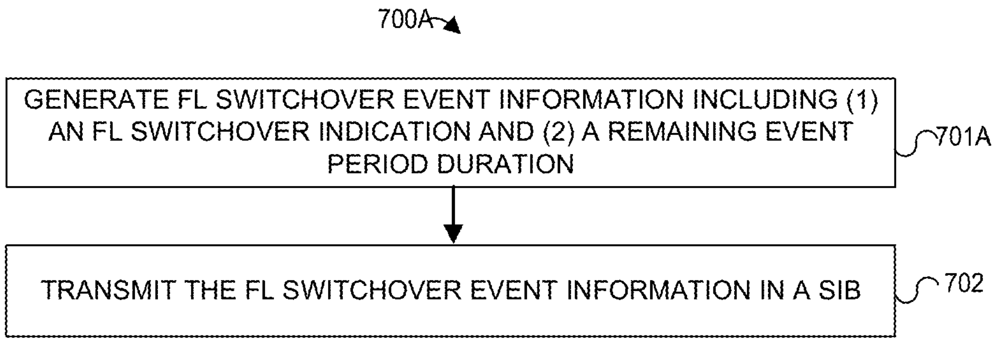


Figure 7A

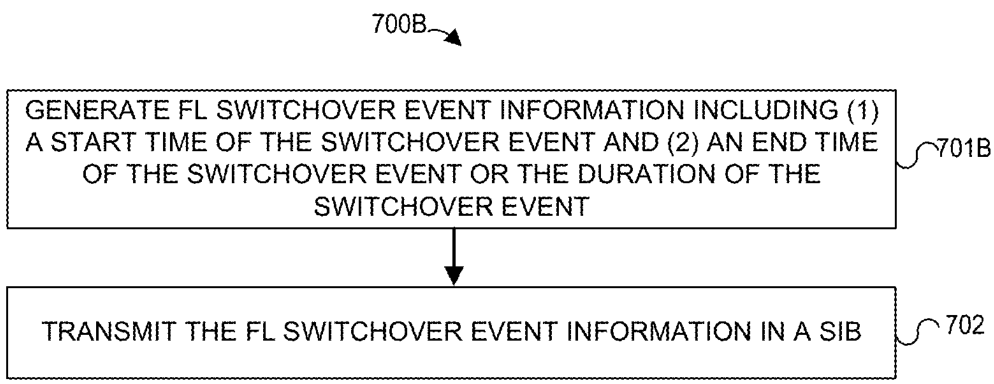


Figure 7B

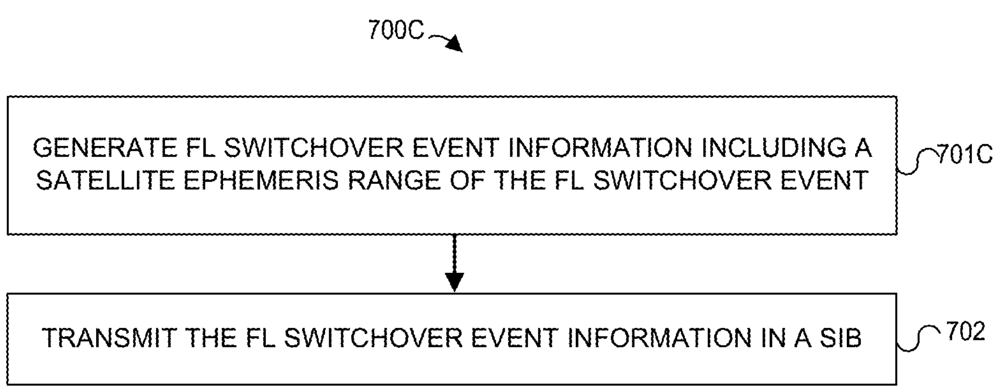


Figure 7C

PROVIDING FEEDER-LINK SWITCHOVER EVENT INFORMATION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of the filing date of provisional U.S. Patent Application No. 63/554,827 entitled "Method and System for Handling UE Accessing Regenerative-Based Satellite for Feeder Link Switchover," filed on Feb. 16, 2024 and provisional U.S. Patent Application No. 63/554,893 entitled "Method and System for Providing Feeder Link Switchover Event Information for a UE Accessing Regenerative-Based Satellite," filed on Feb. 16, 2024. The entire content of the provisional applications is hereby expressly incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] This disclosure relates generally to wireless communications and, more particularly, to a user equipment (UE) accessing a non-terrestrial network (NTN) when a feeder link between a terrestrial station and a satellite changes.

BACKGROUND

[0003] This background description is provided for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0004] Although the fifth generation (5G) communication technology relies primarily on terrestrial networks, the 3rd Generation Partnership Project (3GPP) organization has proposed to extend 5G communications to non-terrestrial networks (NTNs) with 5G new radio (NR) access techniques or with Long-Term-Evolution (LTE) access techniques. In an NTN, a radio frequency (RF) transceiver can reside on a satellite, an uncrewed aircraft system (UAS) also referred to as a drone, a balloon, an airplane, or another suitable apparatus. For simplicity, the discussion below refers to all such apparatus as satellites.

[0005] In addition to satellites, an NTN can include sat-gateways that connect the NTN to a public data network, feeder links between sat-gateways and satellites, service links to UEs, and inter-satellite links (ISL) when satellites form constellations. A satellite can belong to one of several types based on altitude, orbit, and beam footprint size. The types include a Low-Earth Orbit (LEO) satellite, a Medium-Earth Orbit (MEO) satellite, a Geostationary Earth Orbit (GEO) satellite, a UAS platform (including High Altitude Platform Station, HAPS), and a High Elliptical Orbit (HEO) satellite. GEO satellites are also known as Geosynchronous Orbit (GSO) satellites, and LEO/MEO satellites are also known as non-GSO (NGSO) satellites.

[0006] A GSO satellite can communicate with one or several sat-gateways deployed over a satellite targeted coverage area (e.g. a region or even a continent). A non-GSO satellite at different times can communicate with one serving sat-gateways via one feeder link or with several serving sat-gateways via respective feeder links. One of the objectives of NTN design is service and feeder link continuity between successive serving sat-gateways, with sufficient time duration to proceed with mobility anchoring and handover.

[0007] A satellite can support a transparent payload, to essentially operate as a radio repeater and extend the Uu interface for a terrestrial base station, or a regenerative payload that provides on-board processing to implement base station functionality, e.g., at least a portion of the functionality of a Next Generation Node B (gNB). A satellite typically generates several beams for a given service area bounded by the field of view of the satellite. The footprints of the beams typically have an elliptic shape and depend on the on-board antenna configuration and the elevation angle of the satellite. For a transparent payload implementation, a satellite can apply RF filtering and frequency conversion and amplification, and not change the waveform signal. For a regenerative payload implementation, a satellite can apply RF filtering, frequency conversion and amplification, demodulation and decoding, routing, and/or coding/modulation.

[0008] The regenerative-payload approach presents several challenges related to feeder link switchover. In particular, a user equipment (UE) can access, via a service link, a base station mounted on a satellite defining a node of a satellite-based radio access network (RAN-Sat), while remaining substantially stationary relative to the satellite. The satellite can move relative to the terrestrial network elements and, at some point, switch from a feeder link connecting the satellite to a first terrestrial station (or an "earth station" (ES) **1**) to a feeder link connecting the satellite to a second terrestrial station, ES**2**. The switchover results in a change in Transport Network Layer (TNL) association between the RAN-Sat node and the core network (CN), particularly at the Access and Mobility Management Function (AMF) in a 5G core (5GC) or Mobility Management Entity (MME) in an evolved packet core (EPC) in case of the 4G implementation. The UE meanwhile can continue to communicate with the RAN-Sat node via the same service link.

[0009] When the ES**1** and ES**2** belong to different service areas, the serving AMF or MME can change after a feeder link switchover. The UE accordingly should perform a mobility registration update. However, because the feeder link switchover changes the TNL association between the RAN-Sat and the CN, it is unclear how the RAN-Sat can provide feeder link switchover event information to the UE before the feeder link switchover event begins to impact the UE. Further, it is not clear how the UE can determine that the UE should trigger a registration request procedure for a mobility registration after the feeder link switchover event ends.

SUMMARY

[0010] An example embodiment of the techniques of this disclosure is a method implemented in a node of a non-terrestrial radio access network (RAN). The method comprises transmitting, to a core network (CN), information related to a switchover of the node from a first feeder link (FL), via which the node communicates with the CN, to a second FL; and forwarding, from the CN to a user equipment (UE), switchover event parameters related to the switchover.

[0011] Another example embodiment of these techniques is a method implemented in a node of a non-terrestrial RAN.

The method comprises transmitting, to a UE, an indication of a start time of an FL switchover event including a switchover of the node from a first FL, via which the node communicates with a first CN, to a second FL for communicating with a second CN; and receiving, from the UE after the switchover completes, a registration request for the second CN.

[0012] Another example embodiment of these techniques is a node of a non-terrestrial RAN comprising a transceiver; and processing hardware. The node is configured to: transmit, to a CN, information related to a switchover of the node from a first FL, via which the node communicates with the CN, to a second FL. The node is further configured to forward, from the CN to a UE, switchover event parameters related to the switchover.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** is a block diagram of an example wireless communication system in which a user equipment (UE) and/or a base station efficiently manage feeder link (FL) switchover events;

[0014] FIG. **2** is a block diagram of an example protocol stack according to which the UE of FIG. **1**A communicates with base stations;

[0015] FIGS. **3**A and **3**B illustrate known regenerative-based satellite access configurations;

[0016] FIG. **4** is a messaging diagram of an example scenario in which a RAN-Sat provides FL switchover event information to a UE directly or via the core network (CN), and the UE subsequently initiates a registration request after the FL switchover event completes;

[0017] FIG. **5** is a messaging diagram of an example scenario generally similar to that of FIG. **4**, but in which the source AMF obtains FL switchover event information from the RAN-Sat or from a stored pre-configuration, and generates FL switchover event parameters based on the FL switchover event information;

[0018] FIG. **6** is a messaging diagram of an example scenario generally similar to that of FIG. **4**, but in which the UE obtains FL switchover event information from the RAN-Sat and provides the FL switchover event information to source AMF, which then generates FL switchover event parameters based on the FL switchover event information; and

[0019] FIGS. **7**A-C illustrate several example methods for providing FL switchover event information to the UE, which can be implemented in the RAN-Sat of FIG. **1**.

DETAILED DESCRIPTION OF THE DRAWINGS

[0020] As discussed in more detail below, a network provides FL switchover assistance information to a UE. When the UE detects an upcoming FL switchover event, the UE determines whether a registration update is necessary based on the FL switchover assistance information. In particular, when the UE determines that the FL switchover event involves a core network, the UE can determine that a registration update is necessary. In some cases, the UE further determines the timing of the registration update based on the FL switchover assistance information. In some implementations, the UE receives FL switchover assistance information in a broadcast message in a currently serving cell, and in other implementations the UE receives the FL switchover assistance information in a message addressed specifically to the UE.

[0021] The UE and/or the network can also implement overload control to prevent a large number of UEs from requesting registration updates at the same time. To this end, the UE and/or a base station can select timer values within a certain range, which the core network can specify, or which can be pre-configured for the FL switchover procedure.

[0022] Referring first to FIG. **1**, an example wireless communication system **100** includes a UE **102**, a base station **104** operating on a satellite **103** according to the regenerative payload architecture, as a part of a satellite radio access network (RAN-Sat) **105**, and core networks (CN) **110**A and **110**B. Although the RAN **105** in this and the subsequent examples is a RAN-Sat, in general the techniques of this disclosure can apply to any suitable NTN RAN or a non-terrestrial node of a RAN. In general, the RAN-Sat **105** can include any number of base stations, and each of the base stations can cover one, two, three, or any other suitable number of cells. The base station **104** connects to the CN **110**A via a feeder link **120**A and a terrestrial network element **121**A, and to the CN **110**B via a feeder link **120**B and a terrestrial network element **121**B. The feeder links feeder link **120**A and **120**B can support the S**1**-C and SC-U interfaces. The base station **103** can be an Evolved Node B (eNB) or a Next Generation Node B (gNB), for example.

[0023] The CN **110**A can be implemented as an evolved packet core (EPC) **111**A or a fifth generation (5G) core (5GC) **160**A, for example. The CN **110**A can also be implemented as a sixth generation (6G) core in another example.

[0024] The EPC **111**A can include a Serving Gateway (SGW) **112**, a Mobility Management Entity (MME) **114**, and a Packet Data Network Gateway (PGW) **116**. The SGW **112** in general is configured to transfer user-plane packets related to audio calls, video calls, Internet traffic, etc., and the MME **114** is configured to manage authentication, registration, paging, and other related functions. The PGW **116** provides connectivity from the UE to one or more external packet data networks, e.g., an Internet network and/or an Internet Protocol (IP) Multimedia Subsystem (IMS) network.

[0025] The 5GC **160**A can include an Access and Mobility Management Function (AMF) **164**A, a Policy Control Function (PCF) **161**A, a Session Management Function (SMF) **166**A, an

[0026] Authentication Server Function (AUSF) **174**A, and a Unified Data Management Function (UDM) **178**A. The AMF **164**A is generally configured to manage registration, connection, and mobility of a UE (such as the UE **102**) and provide transport for session management (SM) messages between the UE **102** and the SMF **366**. The SMF **366** is generally configured to manage packet data unit (PDU) sessions, allocate Internet Protocol (IP) addresses for UEs, and provide downlink (DL) notifications. The PCF **161**A manages policies such as quality of service (QoS) and authentication policies, for example. The UDM **178**A is generally configured to handle user identification, access authorization based on subscription data, and subscription management.

[0027] The CN **110**B can include components **111**B-**116**B similar to the components **111**A-**116**A, and **161**B-**178**B similar to the components **161**A-**178**A. In some configurations of the system **100**, the CNs **110**A and **110**B implement different generations of technology, e.g., the CN **110**A implements the 5GC **160**A functionality, and the CN **110**B implements the EPC **111**B functionality. In other configurations, the CN **110**A and the CN **110**B implement the same generation of technology.

[0028] The UE **102** is equipped with processing hardware **130** that can include one or more general-purpose processors such as CPUs and non-transitory computer-readable memory storing machine-readable instructions executable on the one or more general-purpose processors, and/or special-purpose processing units. The UE **102** further includes a transceiver **132** configured to transmit data in the uplink direction and receive data transmitted in the downlink direction. A memory **134** can include an FL switchover controller **136** configured to efficiently detect and manage FL switchover events and manage the related overload, as discussed in further detail below.

[0029] The base station **104** similarly is equipped with processing hardware **140** that can include one or more general-purpose processors such as CPUs and non-transitory computer-readable memory storing machine-readable instructions executable on the one or more general-purpose processors, and/or special-purpose processing units. The base station **104** further includes a transceiver **142** configured to transmit data in the downlink direction and receive data transmitted in the uplink direction. A memory **144** can include an FL switchover controller **146** configured to generate FL switchover assistance information, manage overload related to FL switchover assistance information, etc.

[0030] FIG. **2** illustrates, in a simplified manner, an example protocol stack **200** according to which the UE **102** can communicate with an eNB/ng-eNB or a gNB (e.g., one or more of the base stations **104**, **106**).

[0031] In the example stack **200**, a physical layer (PHY) **202**A of EUTRA provides transport channels to the EUTRA MAC sublayer **204**A, which in turn provides logical channels to the EUTRA RLC sublayer **206**A. The EUTRA RLC sublayer **206**A in turn provides RLC channels to an EUTRA PDCP sublayer **208** and, in some cases, to an NR PDCP sublayer **210**. Similarly, the NR PHY **202**B provides transport channels to the NR MAC sublayer **204**B, which in turn provides logical channels to the NR RLC sublayer **206**B. The NR RLC sublayer **206**B in turn provides data transfer services to the NR PDCP sublayer **210**. The NR PDCP sublayer **210** in turn can provide data transfer services to Service Data Adaptation Protocol (SDAP) **212** or a radio resource control (RRC) sublayer (not shown in FIG. **2**A). The UE **102**, in some implementations, supports both the EUTRA and the NR stack as shown in FIG. **2**A, to support handover between EUTRA and NR base stations and/or to support DC over EUTRA and NR interfaces. Further, as illustrated in FIG. **2**A, the UE **102** can support layering of NR PDCP **210** over EUTRA RLC **206**A, and SDAP sublayer **212** over the NR PDCP sublayer **210**.

[0032] The EUTRA PDCP sublayer **208** and the NR PDCP sublayer **210** receive packets (e.g., from an Internet Protocol (IP) layer, layered directly or indirectly over the PDCP layer **208** or **210**) that can be referred to as service data units (SDUs), and output packets (e.g., to the RLC layer **206**A or **206**B) that can be referred to as protocol data units (PDUs). Except where the difference between SDUs and PDUs is relevant, this disclosure for simplicity refers to both SDUs and PDUs as "packets."

[0033] On a control plane, the EUTRA PDCP sublayer **208** and the NR PDCP sublayer **210** can provide signaling radio bearers (SRBs) or RRC sublayer (not shown in FIG. **2**A) to exchange RRC messages or non-access-stratum (NAS) messages, for example. On a user plane, the EUTRA PDCP sublayer **208** and the NR PDCP sublayer **210** can provide Data Radio Bearers (DRBs) to support data exchange. Data exchanged on the NR PDCP sublayer **210** can be SDAP PDUs, Internet Protocol (IP) packets or Ethernet packets.

[0034] For clarity, FIGS. **3**A and **3**B illustrates known scenarios associated with regenerative-based satellite access. Referring first to FIG. **3**A, a base station **304**, which can be implemented as an eNB-Y, operates on a LEO satellite **303**. Earth stationary cells **323** cover countries **1**, **2**, **3** in this scenario, and the UE **102** in this scenario is in a cell of country **2** and accesses the base station **304** via a Uu service link **325**. The base station **304** connects, via a feeder link **320**, to an earth station(ES) **321**, which in turn connects, via a private IP network **380**, to three MME pools corresponding to countries **1**, **2**, and **3**, respectively.

[0035] FIG. **3**B illustrates a switchover from a feeder link **320**A to a feeder link **320**B. The LEO satellite **303** moves in the direction of the arrow in FIG. **3**B. The UE **102** is substantially stationary in a certain earth stationary cell, while the base station **304** mounted on the LEO satellite **303** moves out of the range of an ES **321**A and moves into the range of an ES **321**B. According to this configuration, the ES **321**A and the ES **321**B access the same MME **314** and SGW **312**.

[0036] However, the switchover from the feeder link **320**A to the feeder link **320**B in some scenarios also necessitates a change in core networks. The UE **102** in this case should transmit a registration request for a mobility registration update procedure.

[0037] Next, FIGS. **4**-**6** illustrate several scenarios in which a RAT provides FL switchover event information to a UE. Generally speaking, similar events in these drawings are labeled with similar reference numbers that share two least significant digits, with differences discussed below where appropriate. For example, event **430** is similar to event **530**, and event **440** is similar to event **540**.

[0038] Referring first to a scenario **400** illustrated in FIG. **4**, a node of the RAN-Sat **105**, such as the base station **104**, performs an FL switchover that requires a change from the source (or "old") AMF **164**A to the target (or "new") AMF **164**B. For convenience, the discussion below refers to a node of the RAN-Sat **105** simply as "the RAN-Sat **105**."

[0039] The RAN-Sat **105** provides **402**, to the UE **102** or the S-AMF **164**A, FL switchover event information. The UE **102** or the S-AMF **164**A determines or predicts **410** whether the FL switchover event is imminent (i.e., will happen in the near future). The UE **102** and the S-AMF **164**A negotiate **420** FL switchover event parameters, e.g., the duration of an FL switchover period and/or the start time of the FL switchover event. The UE **102** and the S-AMF **164**A can negotiate **420** the FL switchover event parameters using NAS messages for example. The UE **102** and the S-AMF **164**A perform **420** the negotiation to manage the Connection Management (CM) state of the UE and maintain the registration of the UE during the FL switchover event.

[0040] The UE **102** stores **430** the FL switchover event parameters. The **102** can transition **431** to the CM-idle state, in which the UE **102** has no active connection to a core network, based on the local configuration or in response to the RAN-Sat **105** disconnecting the RRC, for example. The UE **102** starts **432** an FL switchover timer with an expiration period based on (e.g., equal to) the duration of the FL switchover period, so that the FL switchover timer runs during the FL switchover event.

[0041] The S-AMF **164**A, the T-AMF **164**B, and the RAN-Sat **105** perform **440** an FL switchover procedure or event. During this procedure, the RAN-Sat **105** and the S-AMF **164**A release or suspend the N2 connection with the first TNL association, and the RAN-Sat **105** can connect or resume the N2 connection with the second TNL association, with the S-AMF **164**A (i.e., the same AMF) or the T-AMF **164**B (i.e., a different AMF).

[0042] When the UE **102** determines that the FL switchover timer has expired (which means that the FL switchover event **440** should have completed), the UE **102** sends **442** a registration request message to the T-AMF **164**B. The UE **102** can send **442** the registration request message based on an implicit indication in the FL switchover parameters. In another implementation or scenario, the FL switchover parameters include an explicit indication that the UE **102** is to perform a registration request procedure after the FL switchover event completes (e.g., a registration indication).

[0043] The T-AMF **164**B retrieves **460** a UE context from the S-AFM **164**A by sending an Namf_Communication_UEContextTransfer message and receiving an Namf_Communication_UEContextTransfer response message in response. The procedure **460** can include additional messaging related to retrieving a UE identify, authentication, AUSF selection, UDM selection, etc. specified in TS 23.502 V18.4.0 (2023-12) FIG. **4.2.2.2.2-1**, steps **4-19**. The T-AMF **164**B sends **444**, to the UE **102**, a Registration Accept message. Finally, the UE **102** initiates **470** a service request procedure (e.g., in accordance with TS 23.501) to re-establish one or more PDU session(s) if the UE **102** transitions from the CM-idle to the CM-connected state. Alternatively, if the UE **102** performed **442** an initial registration, the UE **102** initiates **470** a PDU Session establishment request procedure to request a new service.

[0044] Now referring to FIG. **5**, a scenario **500** is generally similar to the scenario **400**, with the differences considered below. Here, the RAN-Sat **105** can provide FL switchover event information to the S-AMF **164**A, which then configures the UE **102** to initiate a registration request after the FL switchover event completes, if the FL switchover event requires a change in the AMF.

[0045] In particular, the S-AMF **164**A obtains **502** the FL switchover event information from the RAN-Sat **105** via an N2 message or from an O&M repository (not shown) based on the local pre-configuration. The S-AMF **164**A predicts **510** an upcoming FL switchover event. The S-AMF **164**A determines **521**, based for example on the target service area and associated Tracking Area Identity (TAI) list, whether the FL switchover event will require a change of the core networks, particularly a change from the S-AMF **164**A to the T-SMF **164**B. The S-AMF **164**A determines **522** FL event parameters based on the FL switchover event information obtained **502** earlier from the RAN-Sat **105** or the O&M server. The S-AMF **164**A then sends **524**, to the UE **102** via the RAN-Sat **105**, a UE Configuration Update Command including FL switchover event parameters. The UE **102** then sends **526**, to the S-AMF **164**A and in response to the UE Configuration Update Command, a UE Configuration Update Completed message. The events **521**, **522**, **524**, and **526** collectively can be understood as an FL switchover event parameter negotiation procedure **520**.

[0046] Events **530**, **531**, **532**, **540**, **542**, **544**, **560**, and **570** are similar to the events **430**, **431**, **432**, **440**, **442**, **444**, **460**, and **470** discussed above.

[0047] Next, FIG. **6** illustrates a scenario **600** that is generally similar to the scenario **400**, but in this scenario the RAN-Sat **105** provides, to the UE **102** and via a broadcast message such as a system information block (SIB), FL switchover event information. Example techniques using **602** a SIB for conveying the FL switchover event information are discussed in more detail with reference to FIG. **7**. After the UE determines **610**, based on the SIB, that the FL switchover event is imminent, the UE **102** and the S-AMF **164**A negotiate **620** FL switchover event parameters. During this negotiation, the S-AMF **164**A configures the UE **102** to initiate a registration request after the FL switchover event completes, if the FL switchover event requires a change in the AMF.

[0048] More specifically, the UE **102** receives **602**, in a SIB or other suitable broadcast message from the RAN-Sat **105**, FL switchover event information. Using this information, the UE **102** then detects **610** an upcoming FL switchover event (i.e., determines that the FL switchover event is imminent). The UE **102** sends **625**, to the S-AMF **164**A, a Registration Request message including the FL switchover event information. The events **621** and **622** are similar to the events **521** and **522** discussed above. The S-AMF **164**A sends **626**, to the UE **102** and responsive to the Registration Request message, a Registration Accept message including FL switchover event parameters.

[0049] Events **630**, **631**, **632**, **640**, **642**, **644**, **660**, and **670** are similar to the events **430/530**, **431/531**, **432/532**, **440/540**, **442/542**, **444/544**, **460/560**, and **470/570** discussed above.

[0050] FIGS. **7**A-C illustrate several example methods a RAN-Sat, such as the RAN-Sat **105** for example, can implement to generate and transmit FL switchover information. At block **701**A of a method **700**A illustrated in FIG. **7**A, the RAN-Sat generates FL switchover event information that includes an FL switchover event indication, to indicate for example that the FL switchover event is ongoing, as well as the remaining duration of the switchover event, in the currently serving cell and/or one or more neighboring cells. More generally, the FL switchover event indication can indicate the status of the FL switchover event, and the value "active" for example can indicate that the FL switchover event is ongoing (e.g., has started or will start imminently and can be considered to be ongoing).

[0051] Alternatively, at block **701**B of a method **700**B illustrated in FIG. **7**B, the RAN-Sat generates FL switchover event information that indicates the start time of the FL switchover event and the duration of the FL switchover event. If the FL switchover event is already ongoing, the RAN-Sat can set the start time to zero.

[0052] As another alternative, at block **701**C of a method **700**C illustrated in FIG. **7**C, the RAN-Sat generates FL switchover event information that indicates the location of the FL switchover event, and particularly the satellite ephemeris range for the FL switchover event. The RAN-Sat can generate this information based on the satellite ephemeris information available to the RAN-Sat, for example. When the FL switchover event is already ongoing, the satellite ephemeris range can remain the same or can change based on the current ephemeris information.

[0053] It is also possible for the RAN-Sat to include the information from more than one of the blocks **701**A-C. For example, the RAN-Sat can include both the timing information (e.g., the start time of the FL switchover event) and the location (e.g., the satellite ephemeris information) in the FL switchover event information.

[0054] At block **702** of the method **700**A, **700**B, or **700**C, the RAN-Sat transmits the FL switchover even information via a broadcast message, for example (see, e.g., event **402** or **602**). The broadcast message can be a certain SIB. The UE **102** can use the FL switchover even information to determine whether the FL switchover event is ongoing or upcoming at a time and/or location (e.g., the serving cell and/or a neighboring cell) the UE can determine.

[0055] In some implementations, at block **702** the RAN-Sat transmits is a SIB of a type dedicated specifically to conveying FL switchover event information (e.g., the timing and/or the location) or an existing SIB such as SIB**19** for example. In some implementations, changes to the FL switchover event information do not result in system information change notifications or in changes of the valueTag in SIB**1**.

[0056] One example definition of the special-purpose SIB dedicated to conveying FL switchover event information is as follows:

```
SIB ::= SEQUENCE {
FL-switchover-info          FL-switchover-info    OPTIONAL,
                                                  -- NEED R
lateNonCriticalExtension    OCTET STRING          OPTIONAL,
...
}
```

[0057] In another implementation, a SIB**19** includes the FL switchover event information in an ntn-Config information element (IE):

```
SIB19 ::= SEQUENCE {
FL-switchover-info              FL-switchover-info              OPTIONAL,   -- NEED R
ntn-Config-r17                  NTN-Config-r17                  OPTIONAL,   -- NEED R
ntn-NeighCellConfigList-r17     ntn-NeighCellConfigList-r17     OPTIONAL,   -- NEED R
...
}
```

[0058] In another implementation, a SIB**19** includes the FL switchover as a part of NTN-Config at a serving cell and/or NTN-NeighCellConfigList at the neighboring cells:

```
  SIB 19 ::= SEQUENCE {
  ntn-Config-(new)                NTN-Config-(new)                OPTIONAL,   -- NEED R
  ntn-Config-r17                  NTN-Config-r17                  OPTIONAL,   -- NEED R
  ntn-NeighCellConfigList-(new)   NTN-NeighCellConfigList-(new)   OPTIONAL,   -- NEED R
  ...
  }
NTN-NeighCellConfigList-(new) ::= SEQUENCE (SIZE(1..maxCellNTN-r17)) OF NTN-
NeighCellConfig-(new)
  NTN-NeighCellConfig-(new) ::=    SEQUENCE {
  ntn-Config-(new)                  NTN-Config-(new)              OPTIONAL,   -- NEED R
  carrierFreq-r17                   ARFCN-ValueNR                 OPTIONAL,   -- NEED R
  physCellId-r17                    PhysCellId                    OPTIONAL,   -- NEED R
  }
  NTN-Config-(new) ::=            SEQUENCE {
  (new) fl-switchover-info        FL-switchover-info                OPTIONAL,   -- NEED R
  epochTime-r17                   EpochTime-r17                     OPTIONAL,   -- NEED R
  ntn-UlSyncValidityDuration-r17  ENUMERATED{ s5, s10, s15,         OPTIONAL,   -- NEED R
                                  s20, s25, s30, s35, s40, s45, s50,
                                  s55, s60, s120, s180, s240, s900}
  cellSpecificKoffset-r17         INTEGER(1..1023)                  OPTIONAL,   -- NEED R
  kmac-r17                        INTEGER(1..512)                   OPTIONAL,   -- NEED R
  ta-Info-r17                     TA-Info-r17                       OPTIONAL,   -- NEED R
  ntn-PolarizationDL-r17          ENUMERATED {rhcp,1hcp,linear}     OPTIONAL,   -- NEED R
  ntn-PolarizationUL-r17          ENUMERATED {rhcp,1hcp,linear}     OPTIONAL,   -- NEED R
  ephemerisInfo-r17               EphemerisInfo-r17                 OPTIONAL,   -- NEED R
  ta-Report-r17                   ENUMERATED {enabled}              OPTIONAL,   -- NEED R
  ...
}
```

[0059] In other implementations, at block **702** the RAN-Sat transmits a SIB including an NTN-Config **1**E with an in EphemerisInfo IE, which in turn includes FL switchover event information. According to this approach, the FL switchover event information indicates, to the UEs in the cell, that FL switchover event is ongoing, or will start at a specific time and/or a specific location (as indicated in the satellite ephemeris information), at the relevant satellite.

[0060] In one example implementation, the FL switchover event information includes an FL switchover indication, to explicitly indicate that the satellite is going though an FL switchover.

[0061] In another example implementation, the FL switchover event information includes an FL switchover indication as well as the duration of the remaining FL switchover event. As indicated above, this information indicates, to a UE, that the FL switchover event is ongoing and will continue for the indicated remainder of the FL switchover event.

[0062] In yet another example implementation, the FL switchover event information includes an indication of the start time of the FL switchover event and an indication of either the end time of the FL switchover event or of the duration of the FL switchover event. In this case, the FL switchover information indicates that the satellite will start the FL switchover event at the start time, and that the FL switchover event will last until the indicated end time or through the indicated duration.

[0063] In yet another example implementation, the FL switchover event information indicates the location of the FL switchover event, based on the satellite ephemeris info. In particular, the FL switchover event information in this case can include a satellite ephemeris range of the FL switchover event. For the ongoing FL switchover event, the satellite ephemeris can remains the same or can change based on the current ephemeris information.

[0064] In the examples above, the start time, the end time, and the duration of the FL switchover period are estimates or predictions the RAN-Sat generates based on the available information.

[0065] An example definition of the ephemeris information the RAN-Sat **105** can broadcast at block **702** is provided below:

```
EphemerisInfo-(new) ::=          Choice {
(new) fl-swithover-info          FL-switchover-info          OPTIONAL,
                                                             -- NEED R
positionVelocity-r17             PositionVelocity-r17,
orbital-r17                      Orbital-r17
...
}
```

[0066] The following description may be applied to the description above.

[0067] Generally speaking, description for one of the above figures can apply to another of the above figures. Any event or block described above can be optional. For example, an event or block with dashed lines can be optional. In some implementations, "message" is used and can be replaced by "information element (IE)", and vice versa. In some implementations, "IE" is used and can be replaced by "field", and vice versa. In some implementations, "configuration" can be replaced by "configurations" or "configuration parameters", and vice versa. The "eNB" can be replaced by "base station", "gNB", "6G base station", "evolved gNB" or 6G gNB.

[0068] A user device in which the techniques of this disclosure can be implemented (e.g., the UE **102**) can be any suitable device capable of wireless communications such as a smartphone, a tablet computer, a laptop computer, a mobile gaming console, a point-of-sale (POS) terminal, a health monitoring device, a drone, a camera, a media-streaming dongle or another personal media device, a wearable device such as a smartwatch, a wireless hotspot, a femtocell, or a broadband router. Further, the user device in some cases may be embedded in an electronic system such as the head unit of a vehicle or an advanced driver assistance system (ADAS). Still further, the user device can operate as an internet-of-things (IoT) device or a mobile-internet device (MID). Depending on the type, the user device can include one or more general-purpose processors, a computer-readable memory, a user interface, one or more network interfaces, one or more sensors, etc.

[0069] Certain embodiments are described in this disclosure as including logic or a number of components or modules. Modules may can be software modules (e.g., code, or machine-readable instructions stored on non-transitory machine-readable medium) or hardware modules. A hardware module is a tangible unit capable of performing certain operations and may be configured or arranged in a certain manner. A hardware module can comprise dedicated circuitry or logic that is permanently configured (e.g., as a special-purpose processor, such as a field programmable gate array (FPGA) or an application-specific integrated circuit (ASIC), a digital signal processor (DSP), etc.) to perform certain operations. A hardware module may also comprise programmable logic or circuitry (e.g., as encompassed within a general-purpose processor or other programmable processor) that is temporarily configured by software to perform certain operations. The decision to implement a hardware module in dedicated and permanently configured circuitry, or in temporarily configured circuitry (e.g., configured by software) may be driven by cost and time considerations.

[0070] When implemented in software, the techniques can be provided as part of the operating system, a library used by multiple applications, a particular software application, etc. The software can be executed by one or more general-purpose processors or one or more special-purpose processors.

What is claimed is:

1. A method implemented in a node of a non-terrestrial radio access network (RAN), the method comprising:

transmitting, to a core network (CN), information related to a switchover of the node from a first feeder link (FL), via which the node communicates with the CN, to a second FL; and

forwarding, from the CN to a user equipment (UE), switchover event parameters related to the switchover.

2. The method of claim **1**, wherein the information related to the switchover includes a duration of a switchover event including the switchover.

3. The method of claim **1**, wherein the information related to the switchover includes a start time of the switchover.

4. The method of claim **1**, wherein the information related to the switchover includes an end time of the switchover.

5. The method of claim 1, wherein the information related to the switchover includes an indication that the switchover is ongoing at a cell served by the node.

6. The method of claim 1, wherein:
the CN is a first CN; and
after the switchover, the node communicates with the second CN via the second FL.

7. The method of claim 6, further comprising:
suspending or releasing, during the switchover, a first N2 connection with a first Transport Network Layer (TNL) association between the node and the first CN; and
connecting, after the switchover, to the second C2, via a second N2 connection with a second TNL association between the node and the second CN.

8. A method implemented in a node of a non-terrestrial radio access network (RAN), the method comprising:
transmitting, to a user equipment (UE), an indication of a start time of a feeder link (FL) switchover event including a switchover of the node from a first FL, via which the node communicates with a first CN, to a second FL for communicating with a second CN; and
receiving, from the UE and after the switchover event completes, a registration request for the second CN.

9. The method of claim 8, further comprising:
transmitting an indication of a duration of the FL switchover event.

10. The method of claim 8, further comprising:
transmitting an indication of an end time of the FL switchover event.

11. The method of claim 8, wherein the transmitting of the indication includes transmitting a system information block (SIB).

12. The method of claim 11, wherein the SIB is a special-purpose dedicated to conveying FL switchover event parameters.

13. The method of claim 11, wherein the SIB includes a special-purpose information element (IE) dedicated to conveying FL switchover event parameters.

14. A node of a non-terrestrial radio access network (RAN) comprising:
a transceiver; and
processing hardware; the node configured to:
transmit, to a core network (CN), information related to a switchover of the node from a first feeder link (FL), via which the node communicates with the CN, to a second FL, and
forward, from the CN to a user equipment (UE), switchover event parameters related to the switchover.

15. The node of claim 14, wherein the information related to the switchover includes a duration of a switchover event including the switchover.

16. The node of claim 14, wherein the information related to the switchover includes a start time of the switchover.

17. The node of claim 14, wherein the information related to the switchover includes an end time of the switchover.

18. The node of claim 14, wherein the information related to the switchover includes an indication that the switchover is ongoing at a cell served by the node.

19. The node of claim 14, wherein:
the CN is a first CN; and
after the switchover, the node communicates with the second CN via the second FL.

20. The node of claim 19, further configured to:
suspend or release, during the switchover, a first N2 connection with a first Transport Network Layer (TNL) association between the node and the first CN; and
connect, after the switchover, to the second C2, via a second N2 connection with a second TNL association between the node and the second CN.

* * * * *