下世代Network Slicing模組設計

課程單元：3GPP Network Slicing Standard

國立中山大學 資訊工程系
授課教師：李宗南教授
教材編撰：中正大學李詩偉教授、陳君儀

Outline

- Objective
- 5G System Architecture
- Network Slicing Registration
- Network Slicing PDU session
- Network Slicing Handover
- Network Slicing QoS

Objective

- The objective of this course is to learn the definition, registration, PDU session, handover, security, and enhancement of network slicing in 5G 3GGP specification.

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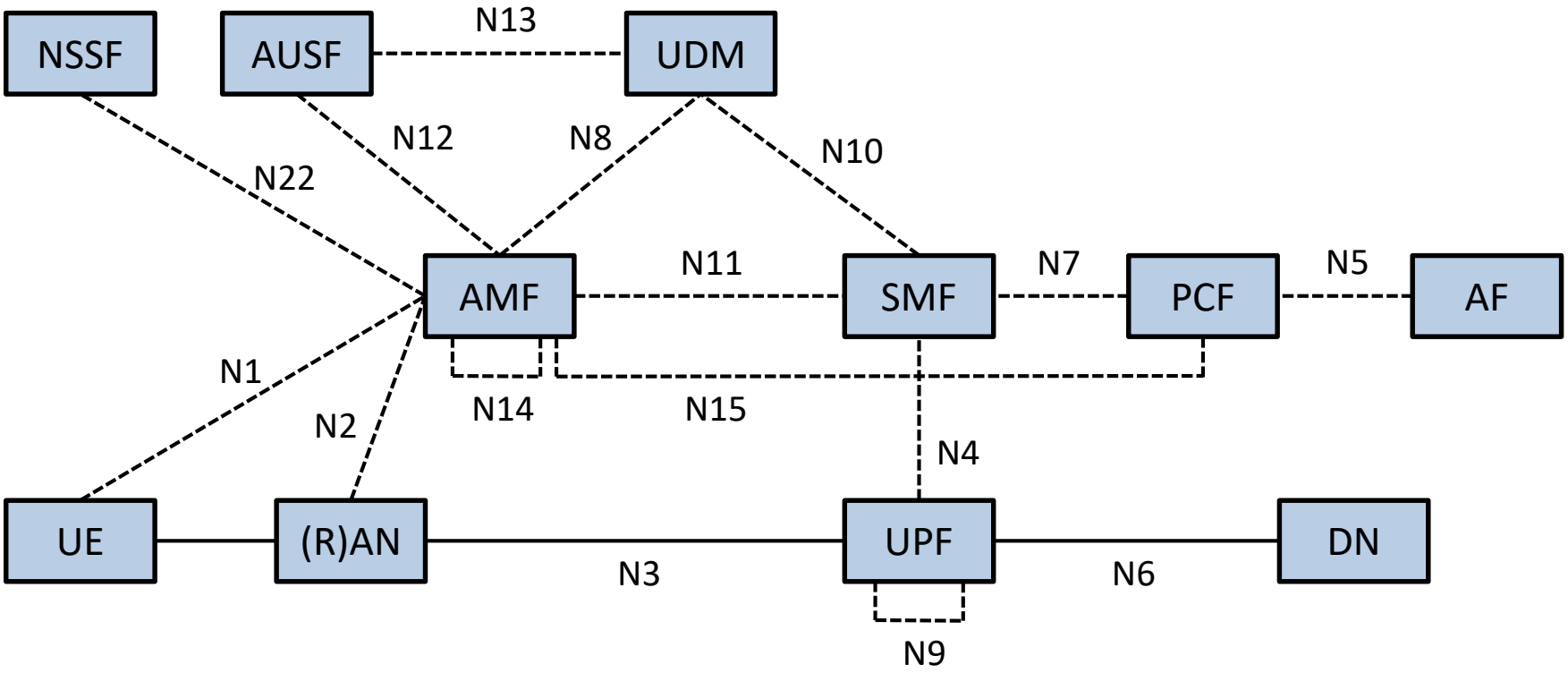
Network Slicing

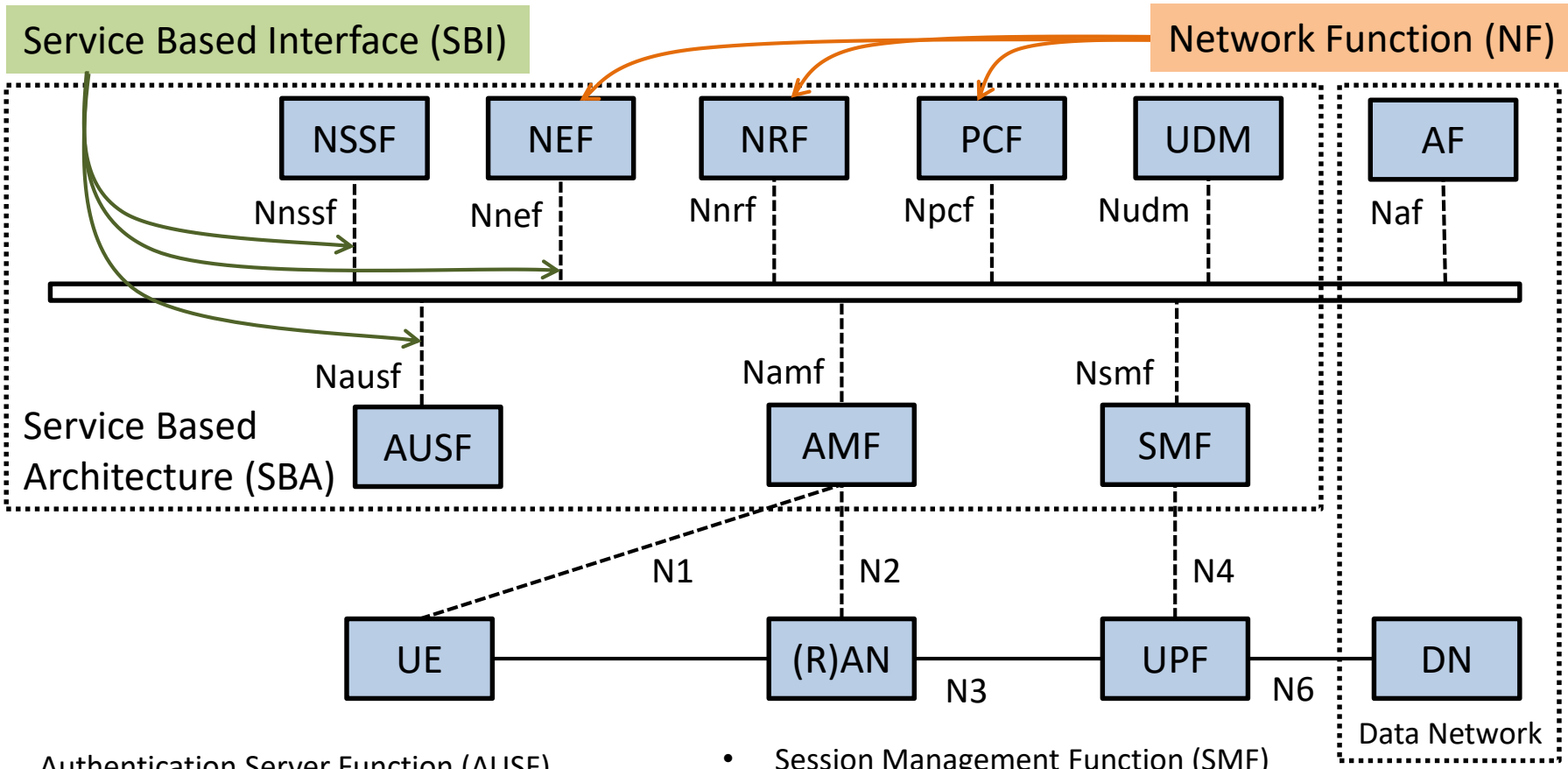
5G System Architecture

Non-Roaming 5G System Architecture Reference Point Representation



• Authentication Server Function (AUSF) • Access and Mobility Management Function (AMF) • Data Network (DN) • Network Slice Selection Function (NSSF) • Policy Control Function (PCF) • Session Management Function (SMF)	• Unified Data Management (UDM) • Unified Data Repository (UDR) • User Plane Function (UPF) • Application Function (AF) • User Equipment (UE) • (Radio) Access Network ((R)AN)

5G System Architecture - Non-Roaming Service-Based Interface Representation



- Authentication Server Function (AUSF)
- Access and Mobility Management Function (AMF)
- Network Exposure Function (NEF)
- Network Repository Function (NRF)
- Network Slice Selection Function (NSSF)
- Policy Control Function (PCF)
- Session Management Function (SMF)
- Unified Data Management (UDM)
- Unified Data Repository (UDR)
- User Plane Function (UPF)
- Application Function (AF)
- User Equipment (UE)
- (Radio) Access Network ((R)AN)

PLMN Introduction

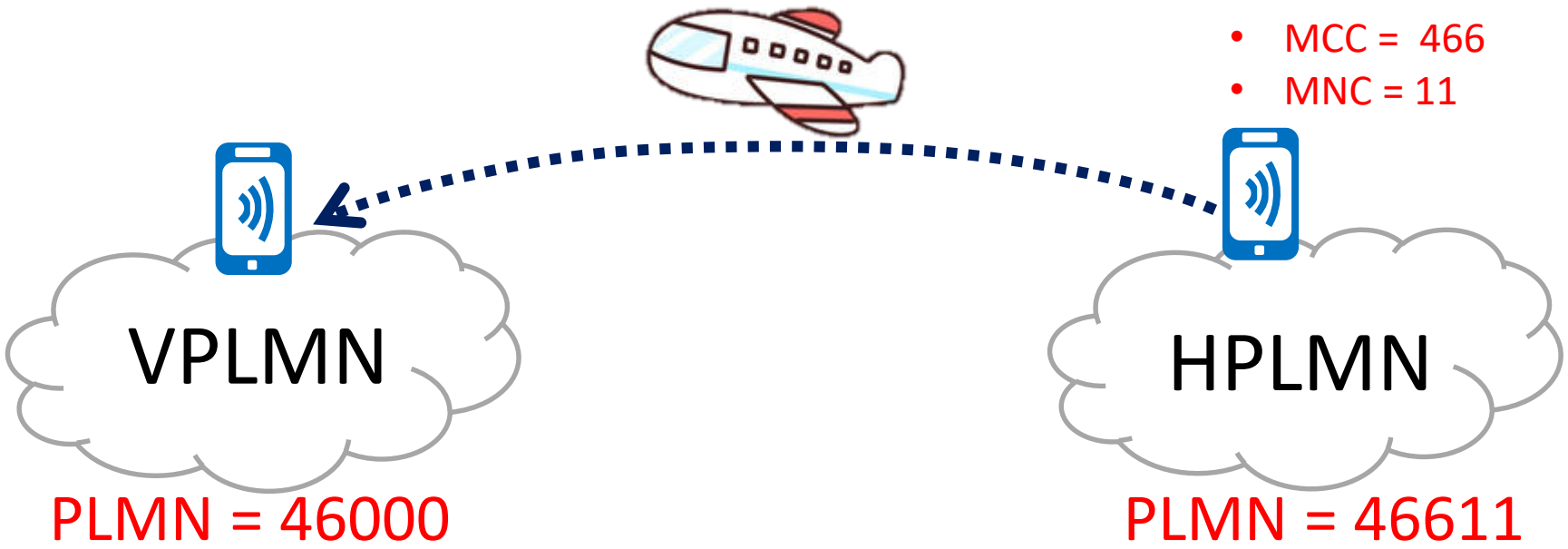
IMSI stored in UE SIM card
- Include MCC and MNC

PLMN
- MCC + MNC

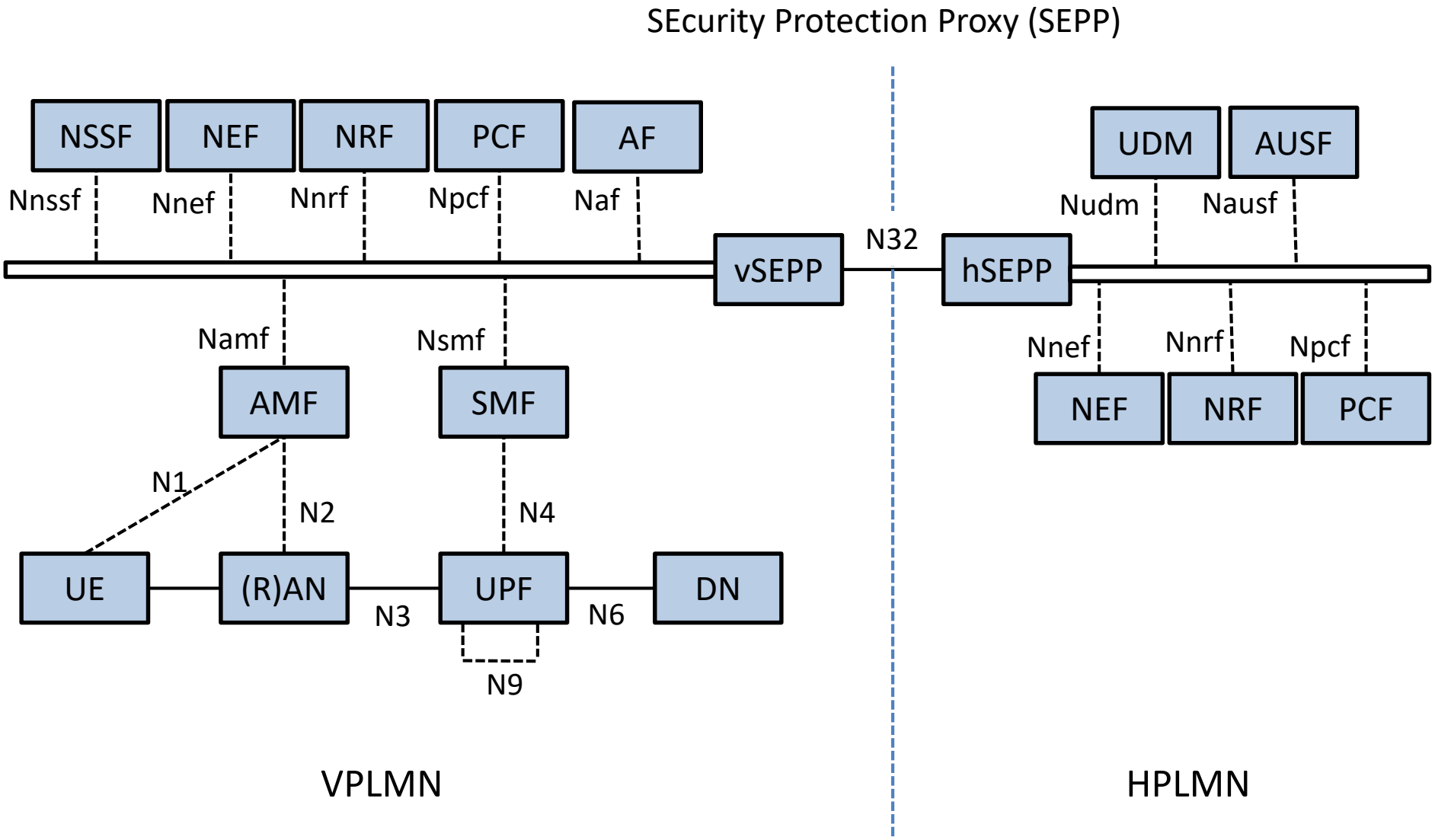
HPLMN
- PLMN same as UE MCC and MNC

VPLME
- UE visited PLMN with difference MCC and MNC from UE

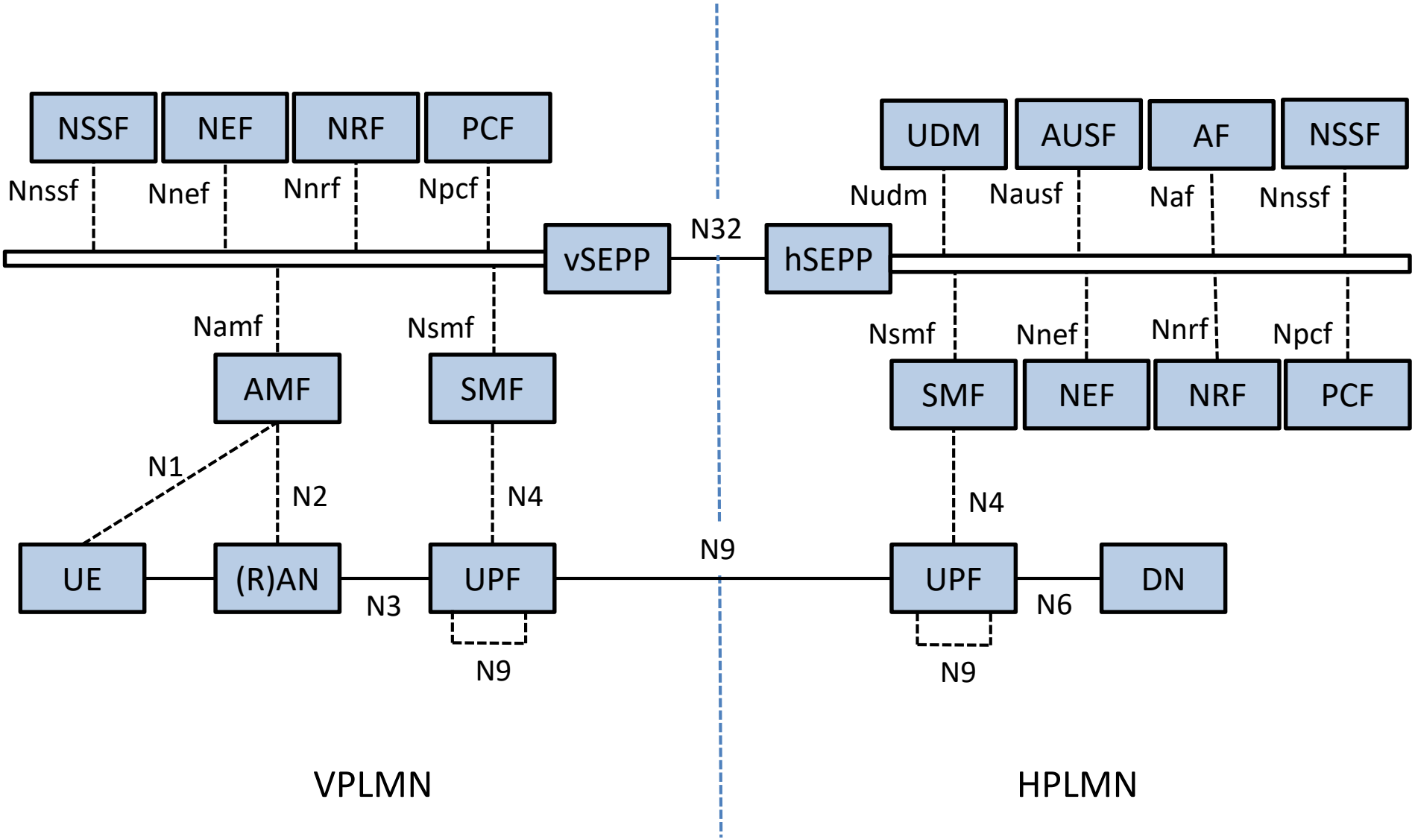
MCC : Mobile Country Code
MNC : Mobile Network Code
PLMN : Public Land Mobile Network
HPLMN : Home PLMN
VPLMN : Visited PLMN



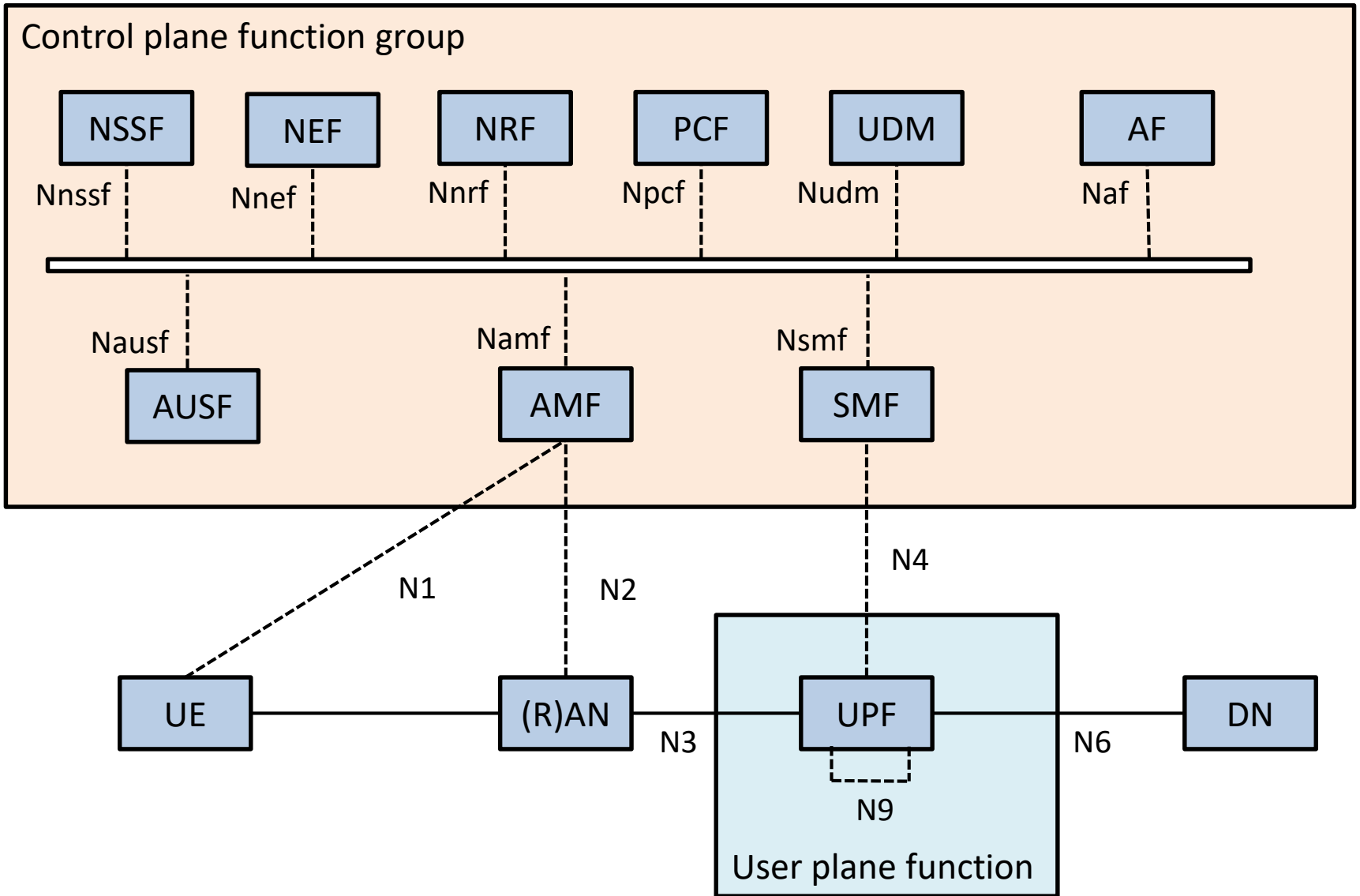
5G System Architecture - Local Breakout Scenario Service-Based Interface Representation



5G System Architecture - Home Routed scenario Service-Based Interface Representation

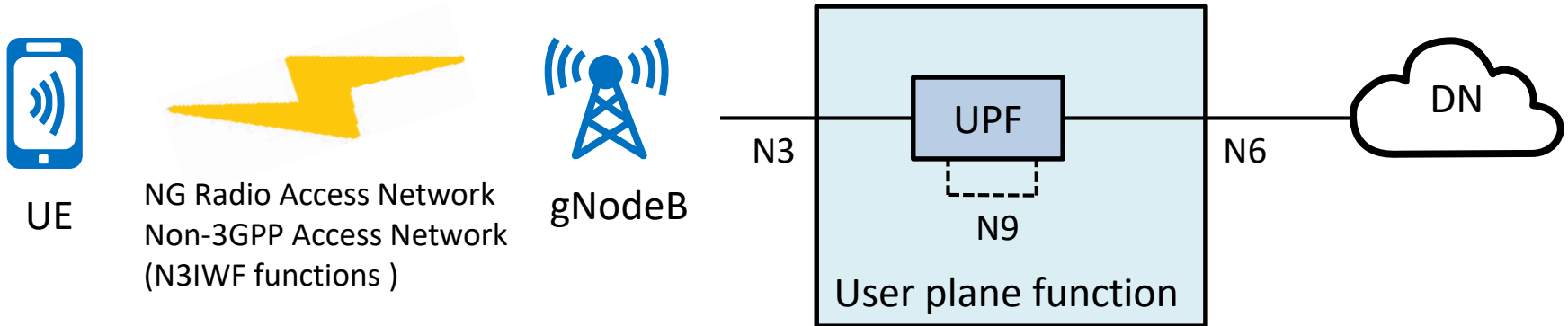


5G Service Based Architecture



5G Service Based Architecture
User Plane Function (UPF)

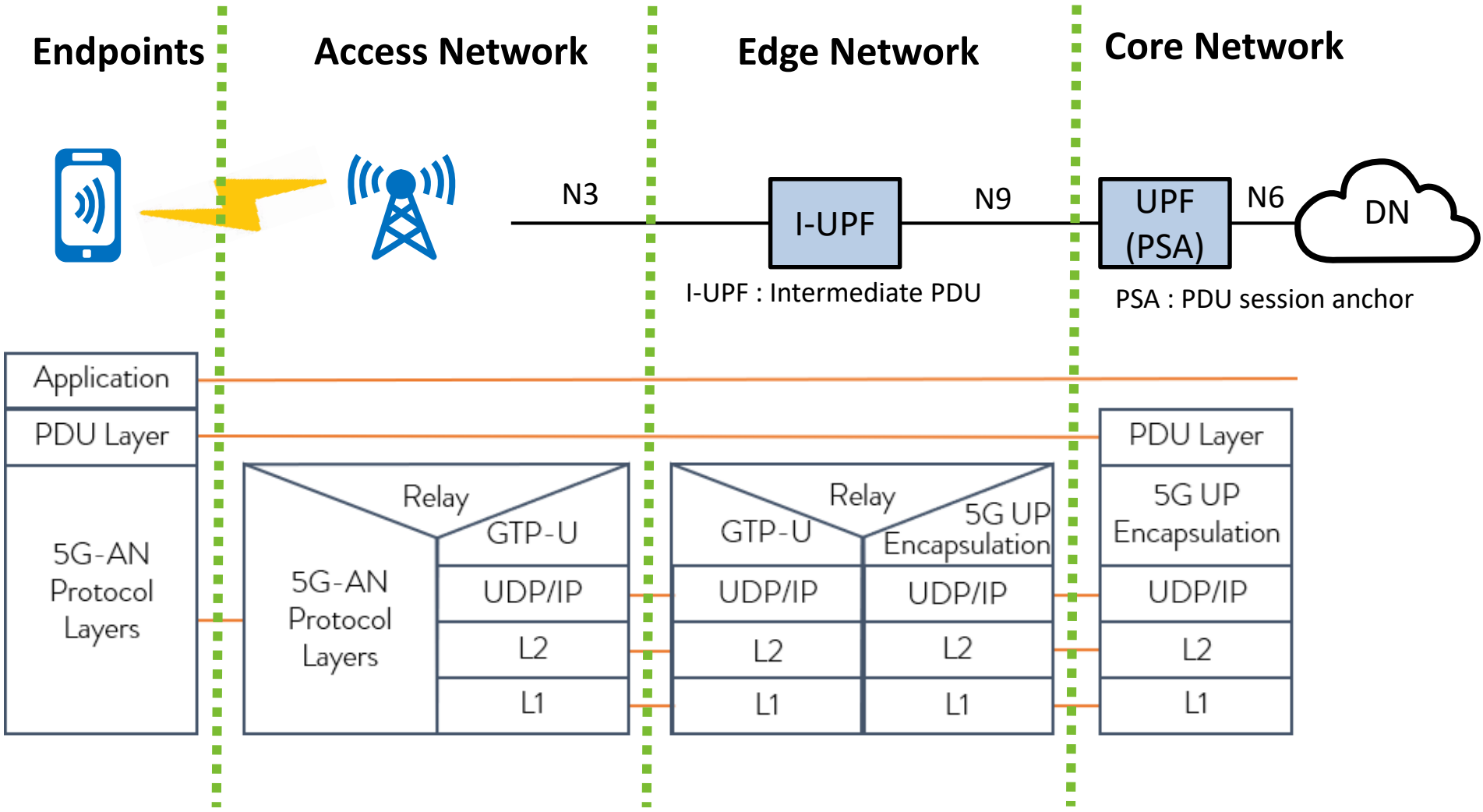
Control plane function group



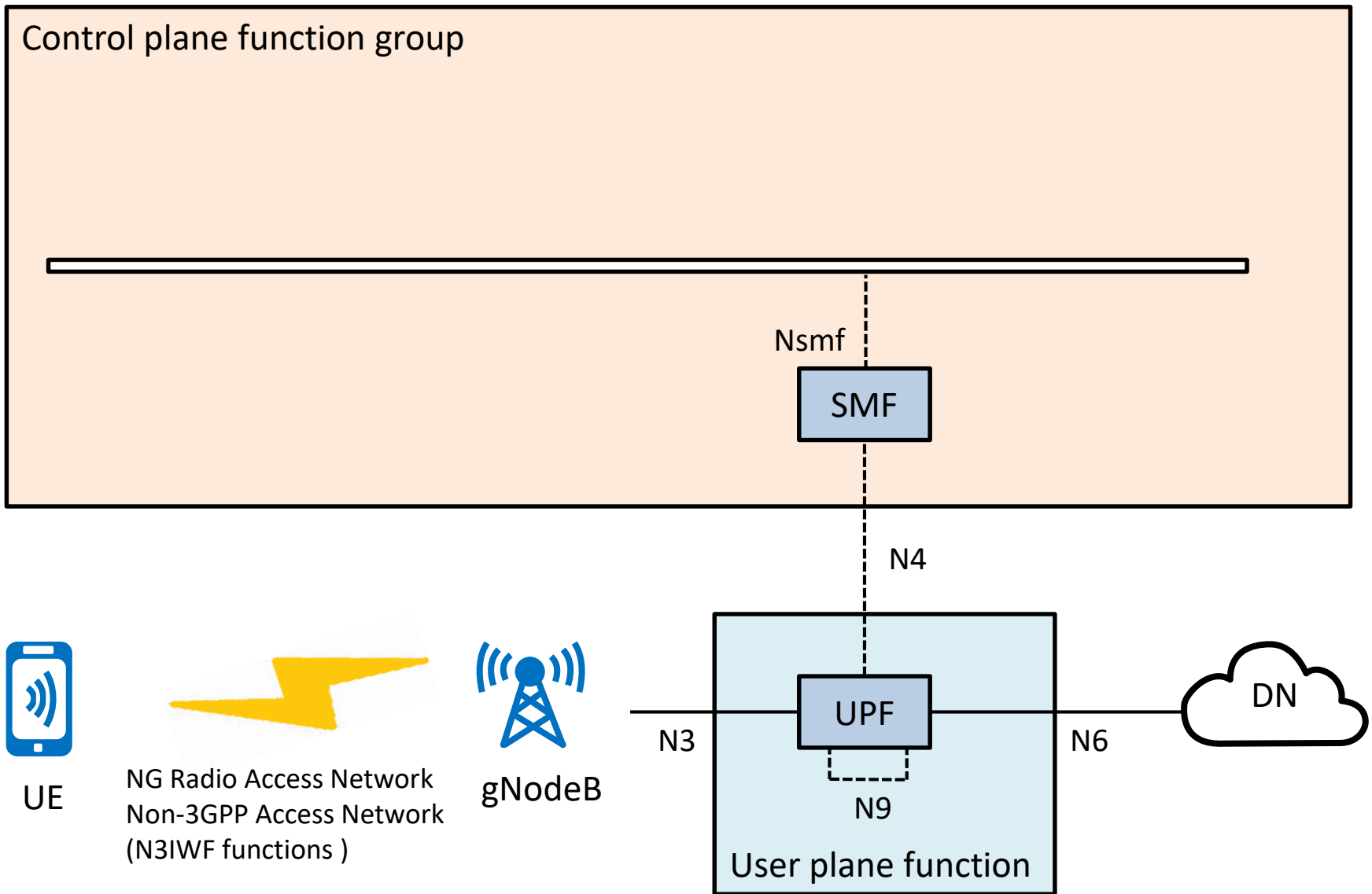
User Plane Function (UPF) Functionalities

- Anchor point for Intra-/Inter-RAT mobility
  - When applicable
- External PDU Session point of interconnect to Data Network
- Packet routing & forwarding
  - support of Uplink classifier to route traffic flows to an instance of a data network, support of Branching point to support multi-homed PDU Session
- Packet inspection
  - Application detection based on service data flow template and the optional PFDs received from the SMF in addition
- User Plane part of policy rule enforcement
  - Gating, Redirection, Traffic steering
- Lawful intercept
  - UP collection
- Traffic usage reporting
- QoS handling for user plane
  - UL/DL rate enforcement, Reflective QoS marking in DL
- Uplink Traffic verification
  - SDF to QoS Flow mapping
- Transport level packet marking in the uplink and downlink
- Downlink packet buffering and downlink data notification triggering
- Sending and forwarding of one or more "end marker" to the source NG-RAN node
- ARP proxying and / or IPv6 Neighbour Solicitation Proxying functionality for the Ethernet PDUs
  - The UPF responds to the ARP and / or the IPv6 Neighbour Solicitation Request by providing the MAC address corresponding to the IP address sent in the request

User Plane Function (UPF)



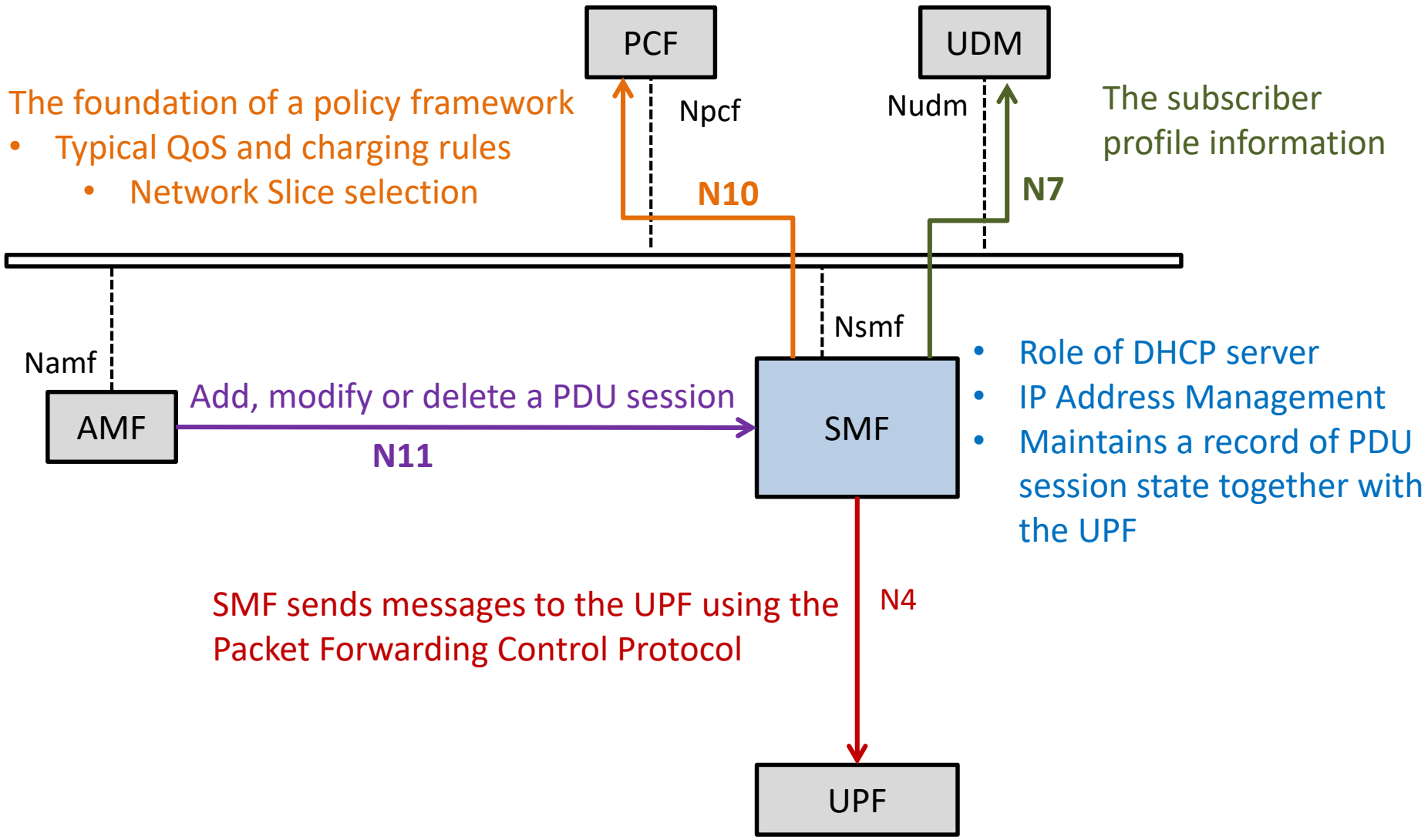
5G Service Based Architecture
Session Management Function (SMF)



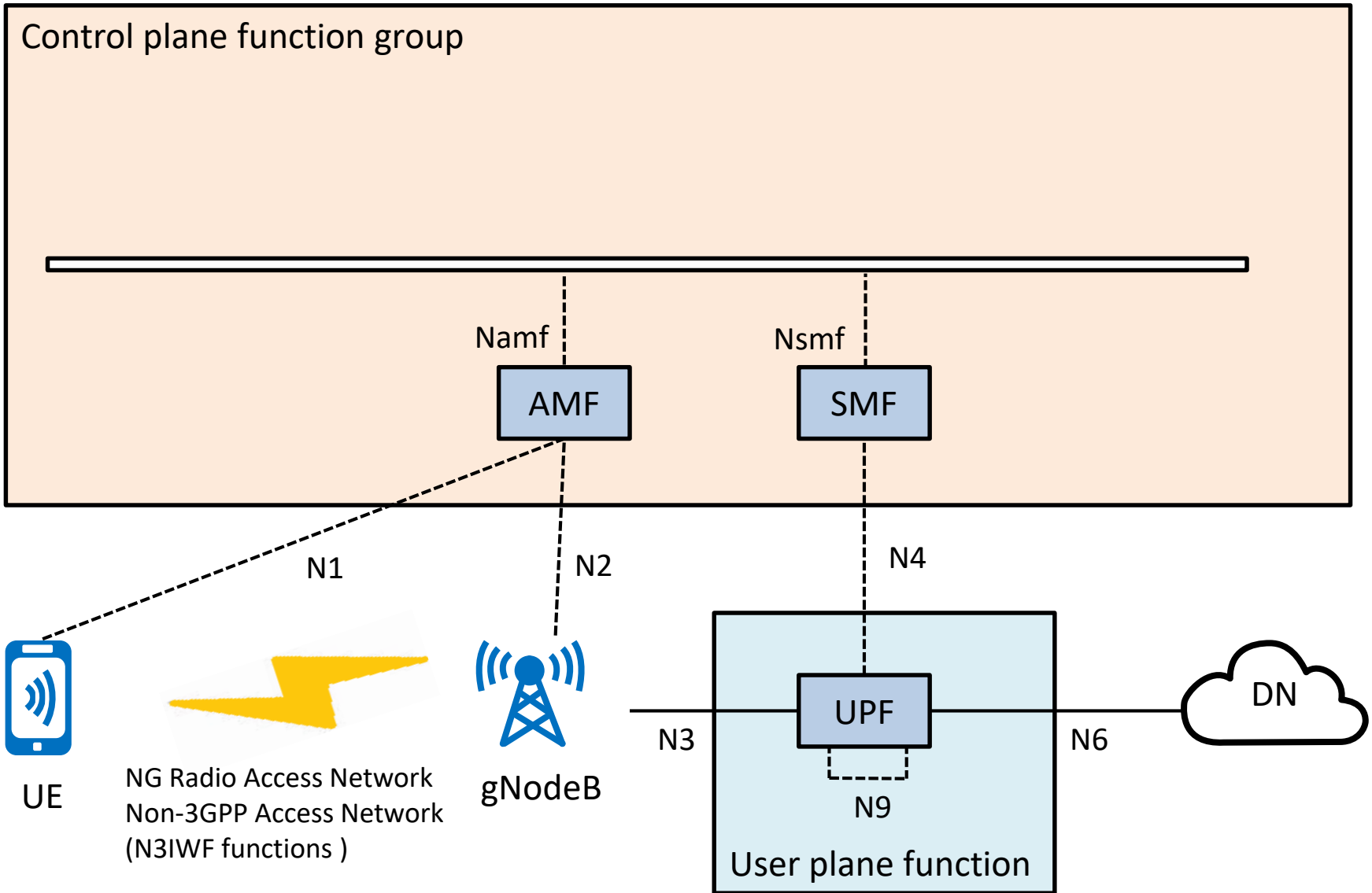
Session Management Function (SMF) Functionalities

- Session Management
  - Session Establishment, modify and release, including tunnel maintain between UPF and AN node
- UE IP address allocation & management
  - Including optional Authorization
- DHCPv4 and DHCPv6 functions
  - Server and client
- ARP proxying and / or IPv6 Neighbour Solicitation Proxying functionality for the Ethernet PDUs
  - The SMF responds to the ARP and / or the IPv6 Neighbour Solicitation Request by providing the MAC address corresponding to the IP address sent in the request
- Selection and control of UP function,
  - Including controlling the UPF to proxy ARP or IPv6 Neighbour Discovery, or to forward all ARP/IPv6 Neighbour Solicitation traffic to the SMF, for Ethernet PDU Sessions
- Configures traffic steering at UPF to route traffic to proper destination
- Termination of interfaces towards Policy control functions
- Lawful intercept
  - For SM events and interface to LI System
- Charging data collection and support of charging interfaces
- Control and coordination of charging data collection at UPF
- Termination of SM parts of NAS messages.
- Downlink Data Notification
- Initiator of AN specific SM information, sent via AMF over N2 to AN
- Determine SSC mode of a session.
- Roaming functionality:
  - Handle local enforcement to apply QoS SLAs (VPLMN).
  - Charging data collection and charging interface (VPLMN).
  - Lawful intercept (in VPLMN for SM events and interface to LI System).
  - Support for interaction with external DN for transport of signalling for PDU Session authorization/authentication by external DN.

Session Management Function (SMF)



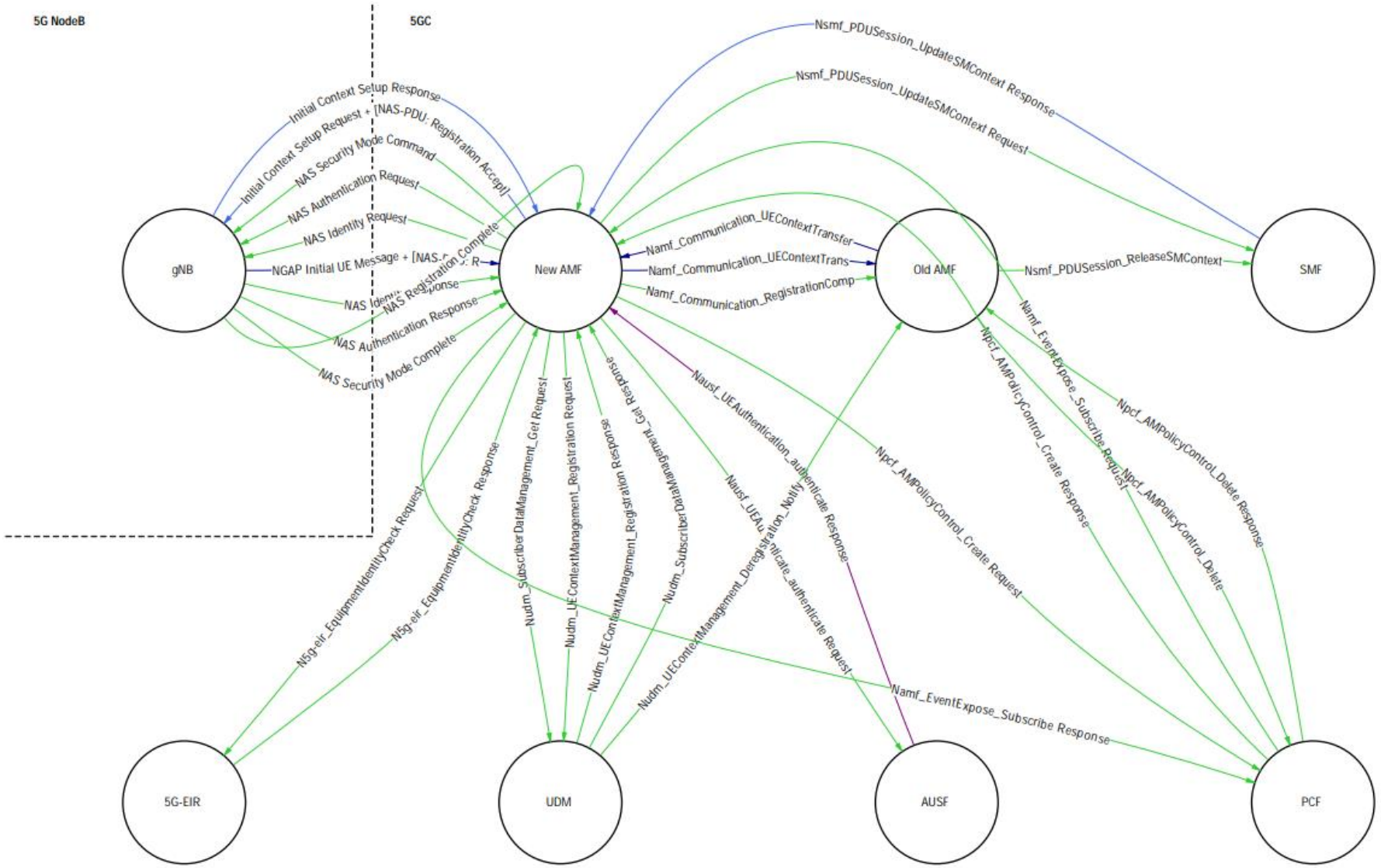
5G Service Based Architecture
Access and Mobility Management Function (AMF)



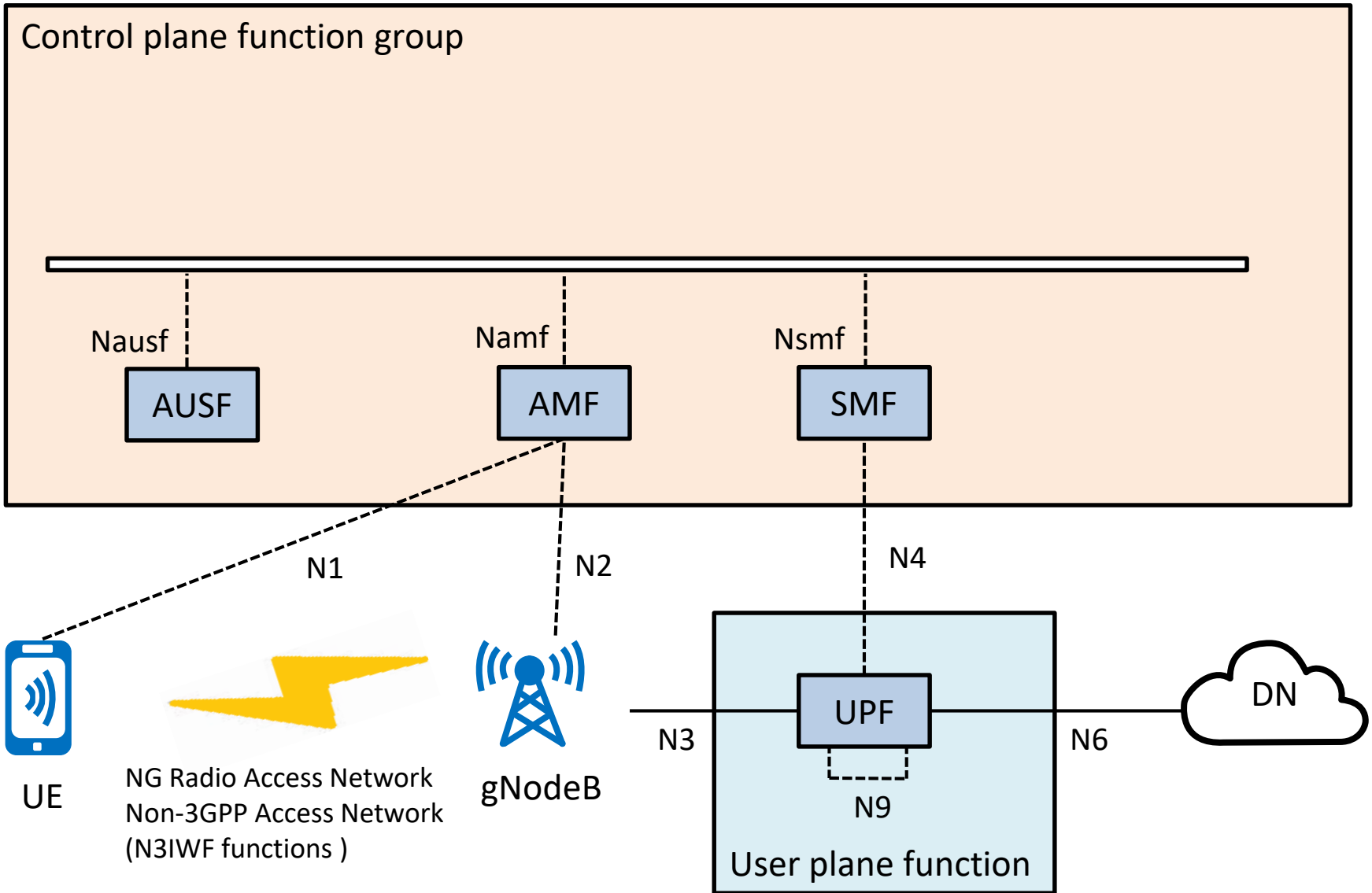
Access and Mobility Management Function (AMF) Functionalities

- Termination of RAN CP interface (N2)
- Termination of NAS (N1) , NAS ciphering and integrity protection
- Registration management
- Connection management
- Reachability management
- Mobility Management
- Lawful intercept
  - For AMF events and interface to LI System
- Provide transport for SM messages between UE and SMF
- Transparent proxy for routing SM messages
- Access Authentication
- Access Authorization
- Provide transport for SMS messages between UE and SMSF
- Security Anchor Functionality (SEAF)
- Location Services management for regulatory services
- Provide transport for Location Services messages between UE and LMF as well as between RAN and LMF
- EPS Bearer ID allocation for interworking with EPS
- UE mobility event notification

Access and Mobility Function (AMF) Context Diagram



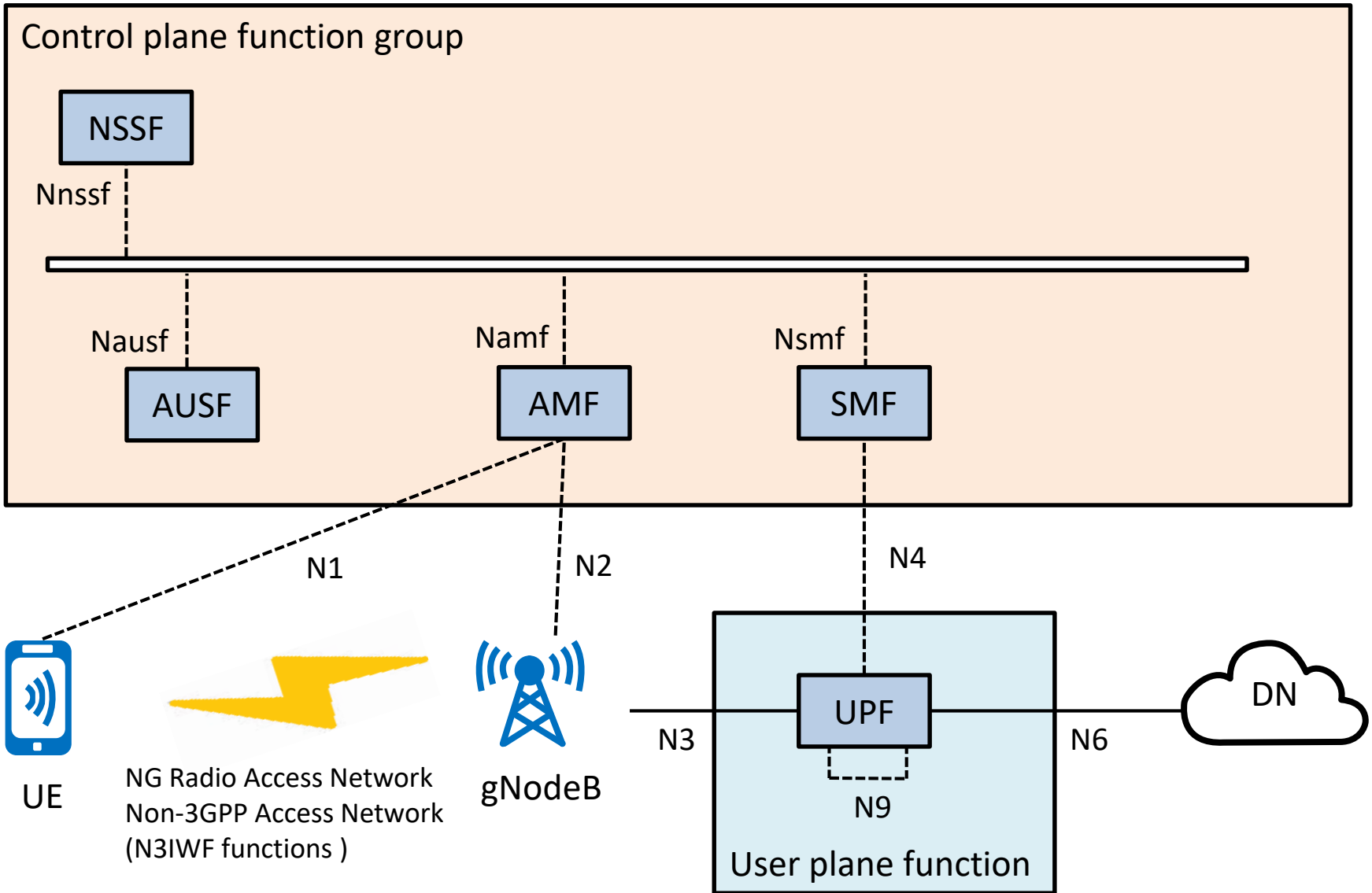
5G Service Based Architecture
Authentication Server Function (AUSF)



Authentication Server Function (AUSF) Functionalities

- Supports authentication for 3GPP access and untrusted non-3GPP access

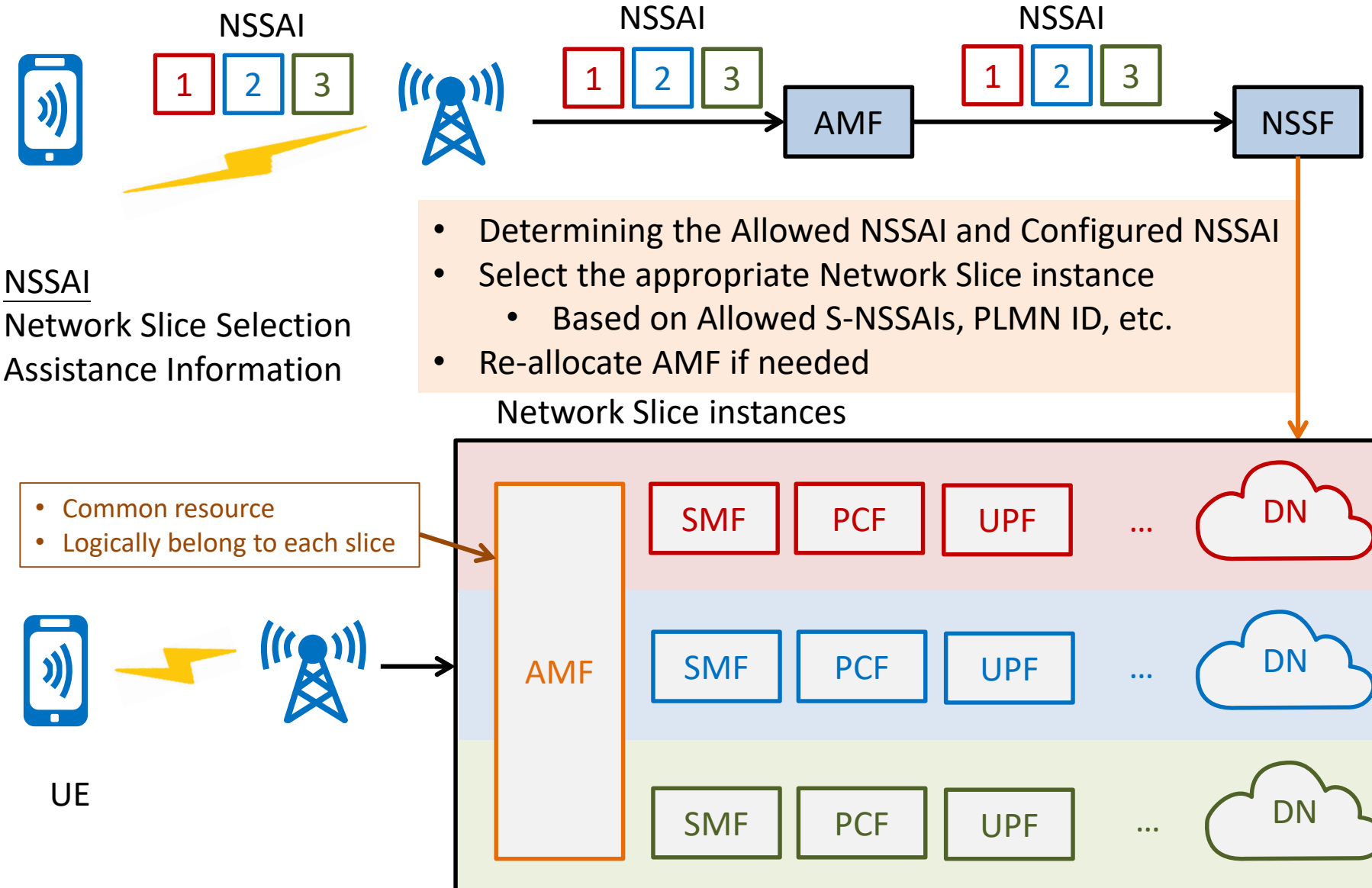
5G Service Based Architecture
Network Slice Selection Function (NSSF)



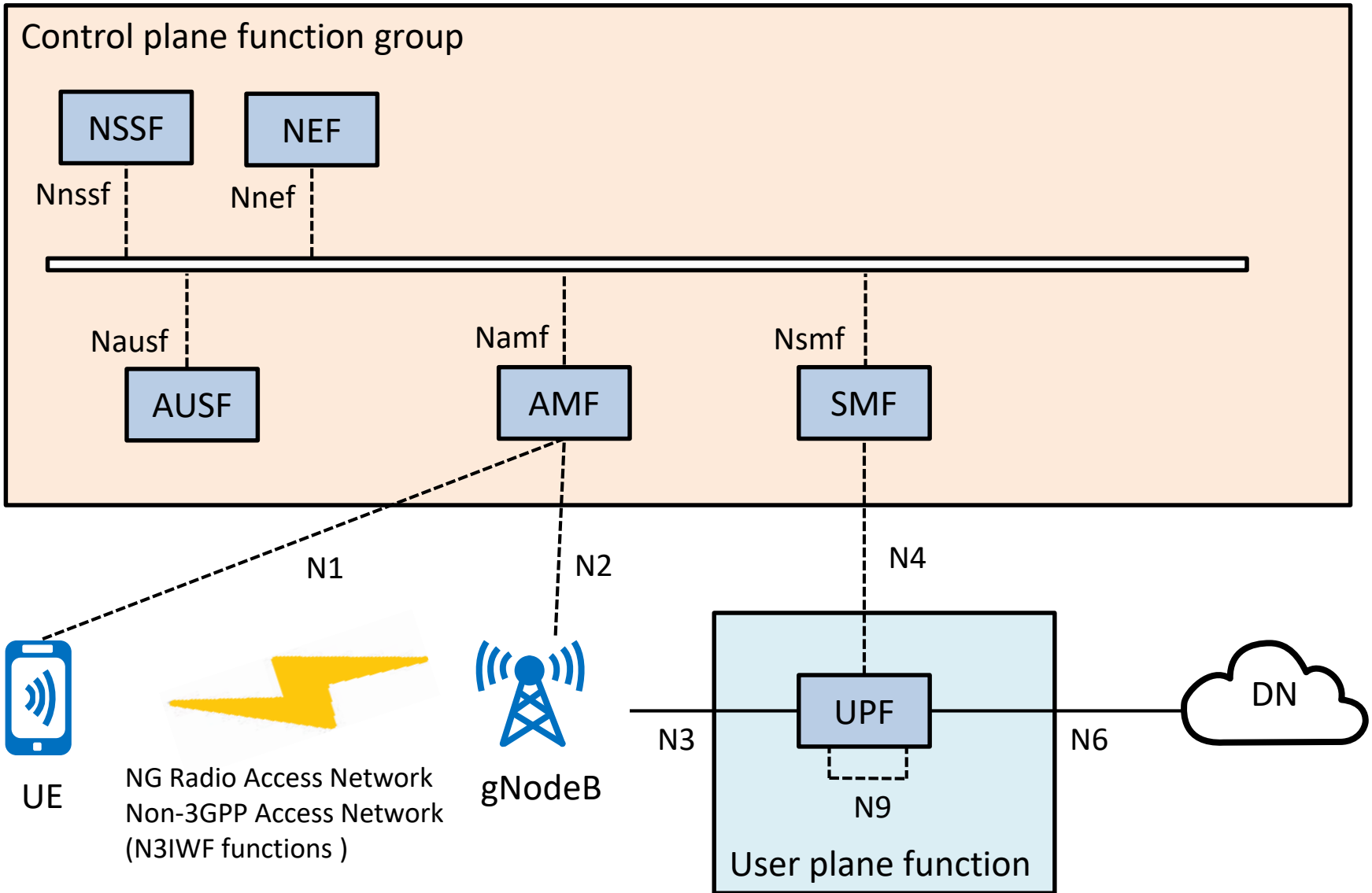
Network Slice Selection Function (NSSF) Functionalities

- Selecting the set of Network Slice instances serving the UE
- Determining the Allowed NSSAI and, if needed, the mapping to the Subscribed S-NSSAIs
- Determining the Configured NSSAI and, if needed, the mapping to the Subscribed S-NSSAIs
- Determining the AMF Set to be used to serve the UE, or, based on configuration, a list of candidate AMF(s), possibly by querying the NRF

Network Slice Selection Function (NSSF)



5G Service Based Architecture
Network Exposure Function (NEF)



Network Exposure Function (NEF) Functionalities

- Exposes capabilities and events
- Secure provision of information from an external application to 3GPP network
- Translation of internal/external information
- Control plane parameter provisioning
- Packet Flow Description (PFD) management
  - A PFD is a tuple of protocol, server-side IP and port number

Network Exposure Function (NEF)

N33
- Reference point between NEF and AF

SBI between NF and NEF
- N29 interface between NEF and SMF
- N30 interface between NEF and PCF
- N37 interface between NEF and UDR

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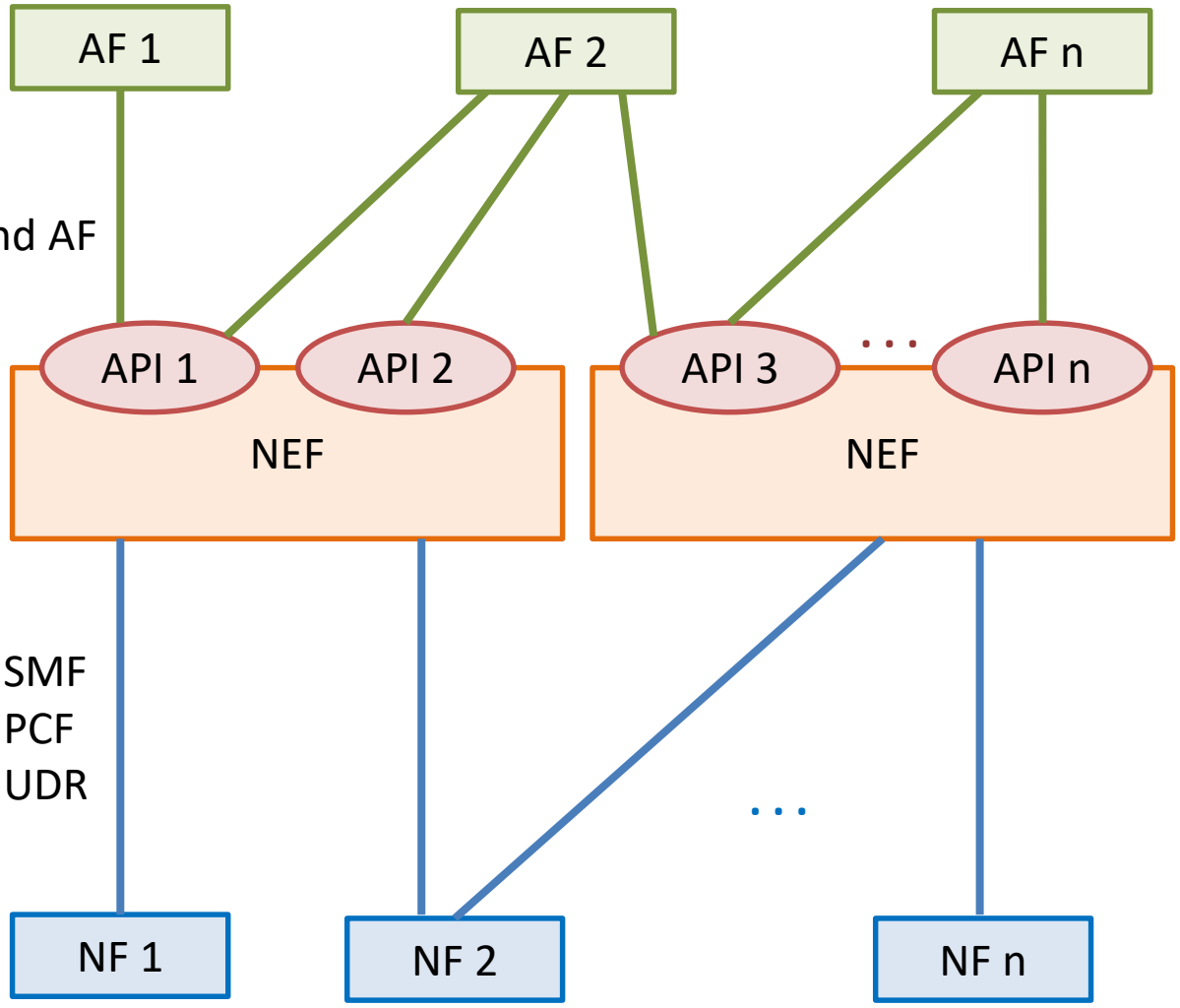
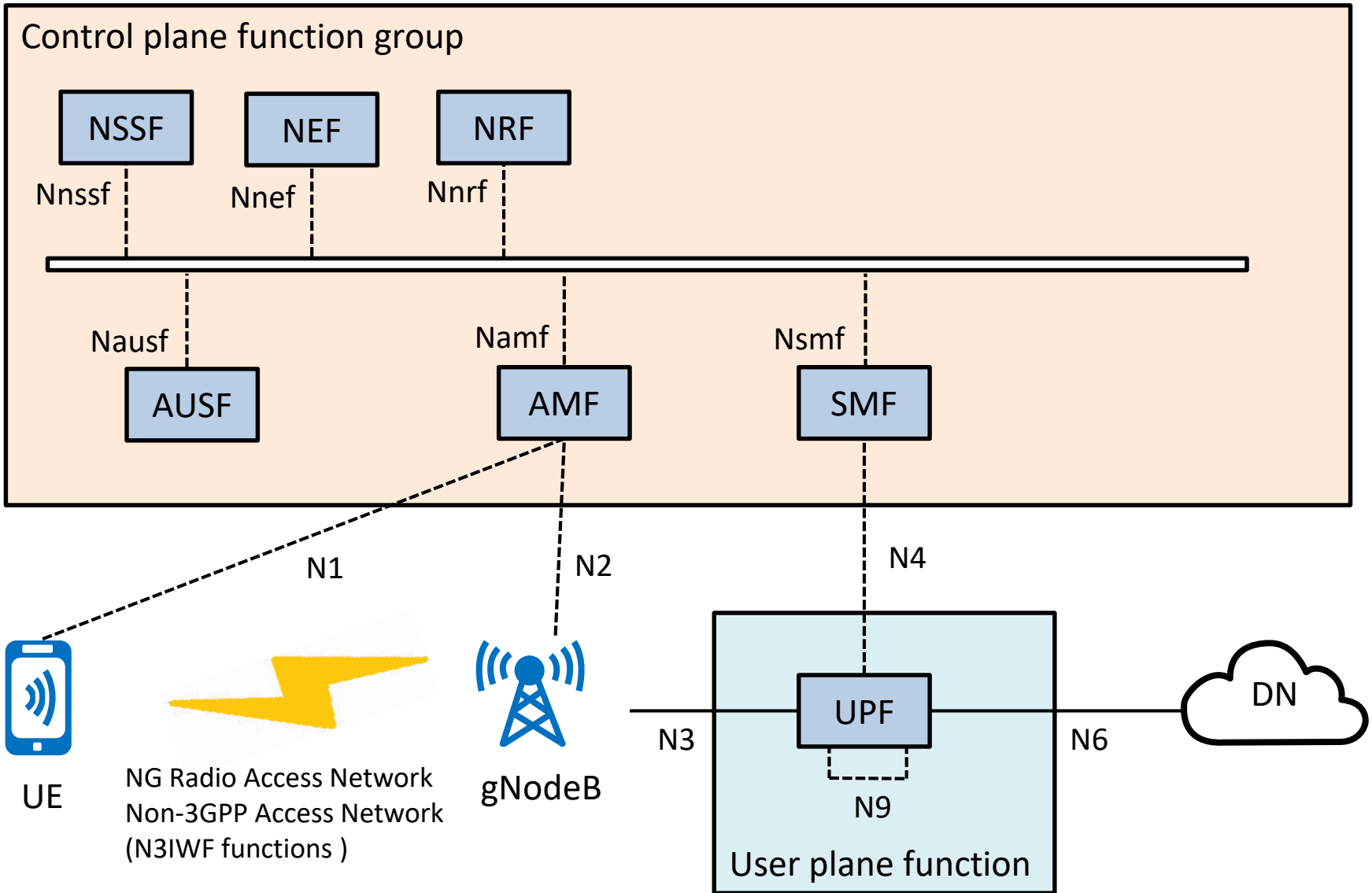


5G Service Based Architecture
Network Repository Function (NRF)

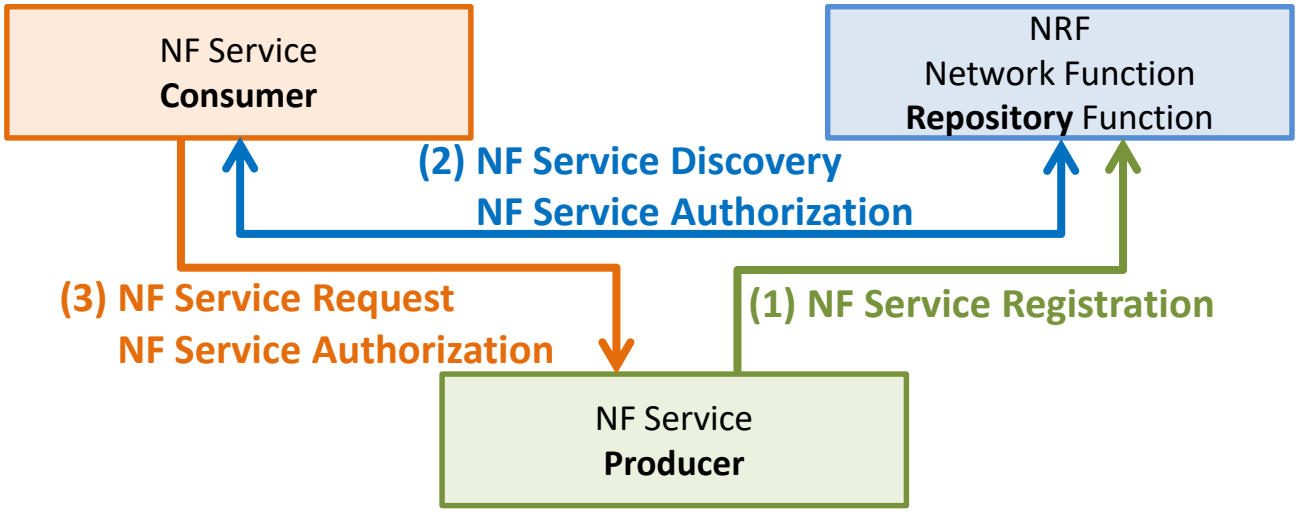


Network Repository Function (NRF) Functionalities

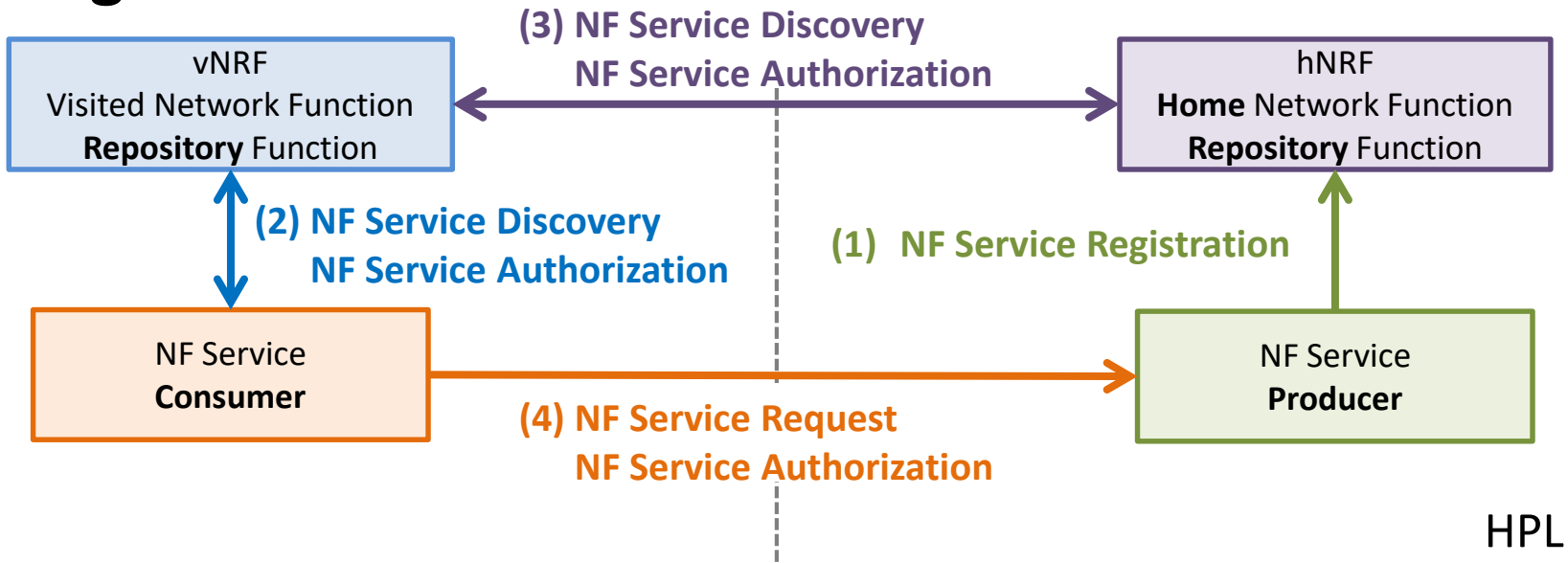
- Supports service discovery function
- Receive NF Discovery Request from NF instance, and provides the information of the discovered NF instances (be discovered) to the NF instance
- Maintains the NF profile of available NF instances and their supported services

Network Repository Function (NRF)

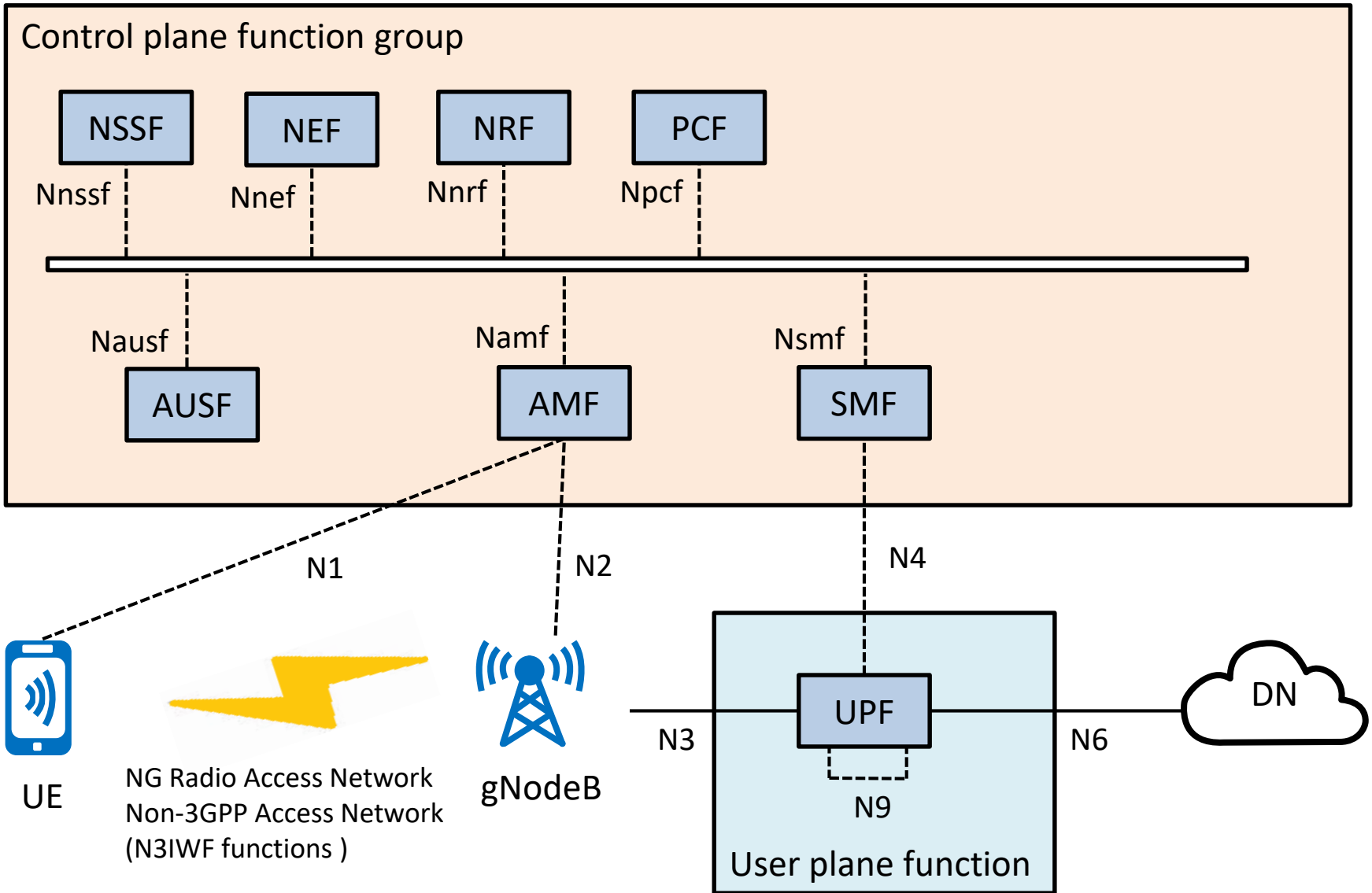
Non-Roaming



Roaming



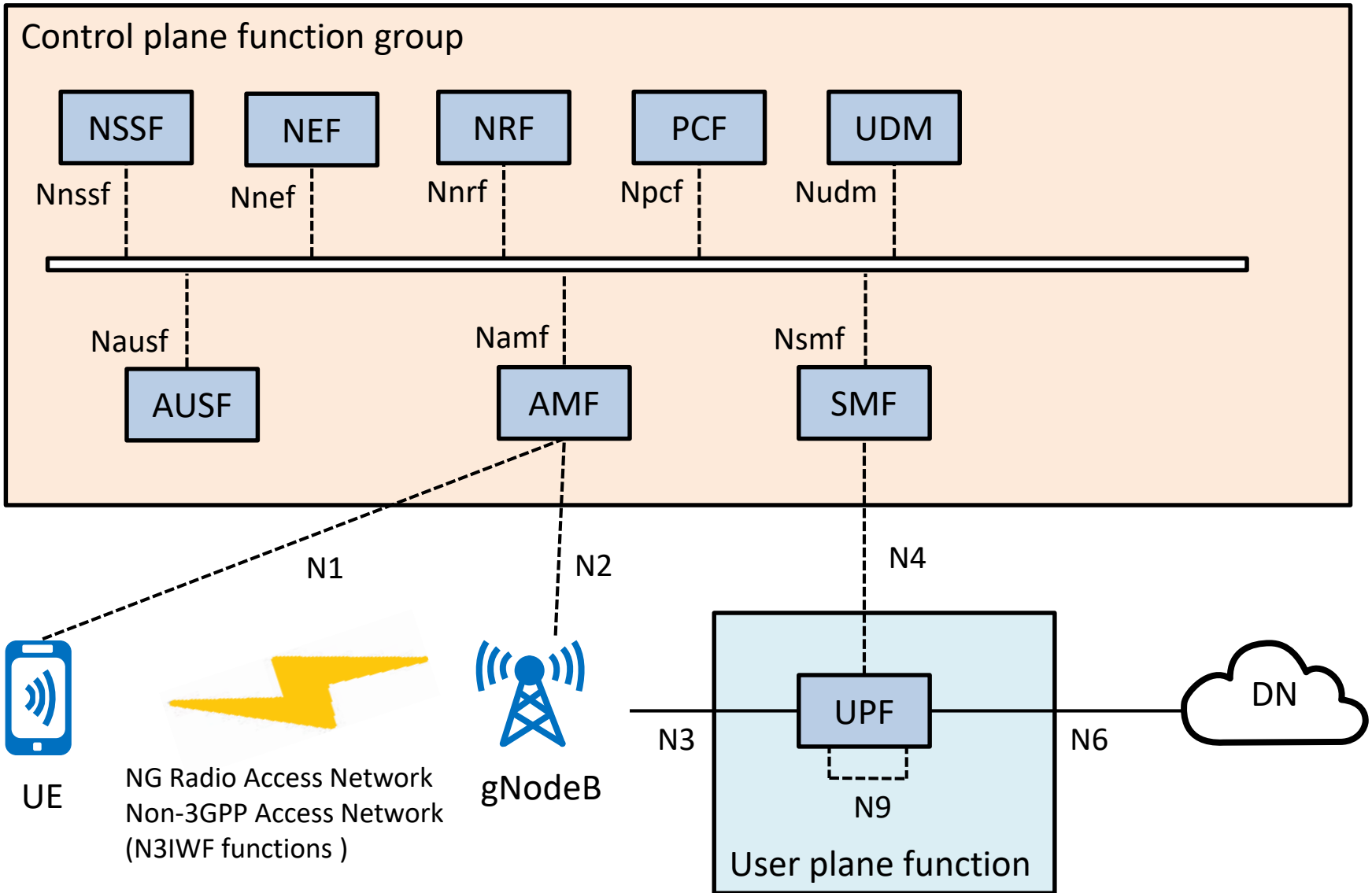
5G Service Based Architecture
Policy Control Function (PCF)



Policy Control Function (PCF)

- Supports unified policy framework to govern network behaviour
- Provides policy rules to Control Plane function(s) to enforce them
- Accesses subscription information relevant for policy decisions in a Unified Data Repository (UDR)

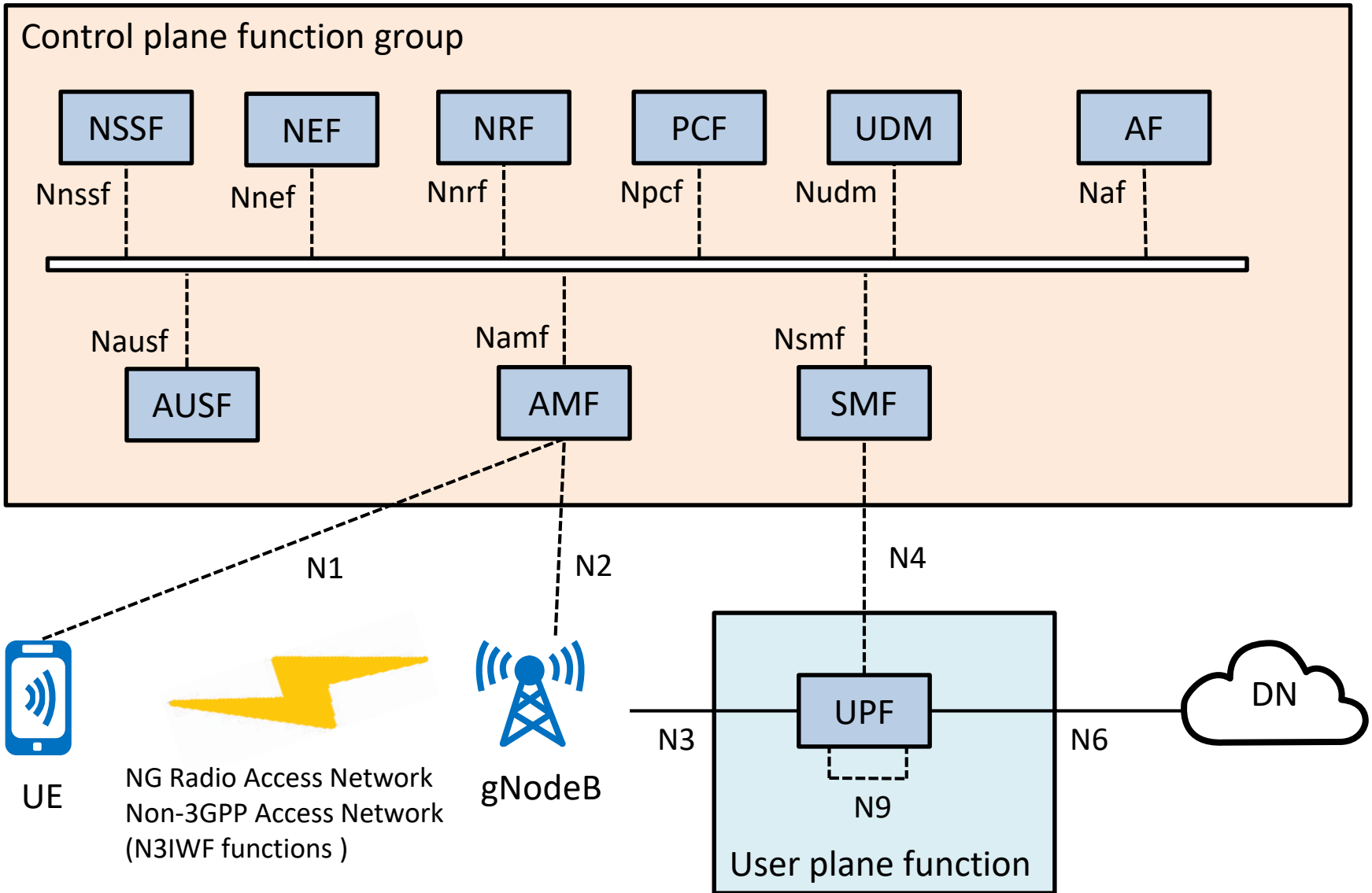
5G Service Based Architecture
Unified Data Management (UDM)



Unified Data Management (UDM) Functionalities

- Generation of 3GPP AKA Authentication Credentials
- User Identification Handling
  - Storage and management of SUPI for each subscriber in the 5G system
- Support of de-concealment of privacy-protected subscription identifier (SUCI)
- Access authorization based on subscription data
  - Roaming restrictions
- UE's Serving NF Registration Management
  - Storing serving AMF for UE, storing serving SMF for UE's PDU Session
- Support to service/session continuity
  - By keeping SMF/DNN assignment of ongoing sessions
- MT-SMS delivery support.
- Lawful Intercept Functionality
  - especially in outbound roaming case where UDM is the only point of contact for LI
- Subscription management
- SMS management

5G Service Based Architecture
Application Function (AF)



Application Function (AF) Functionalities

- Application influence on traffic routing
- Accessing Network Exposure Function
- Interacting with the Policy framework for policy control

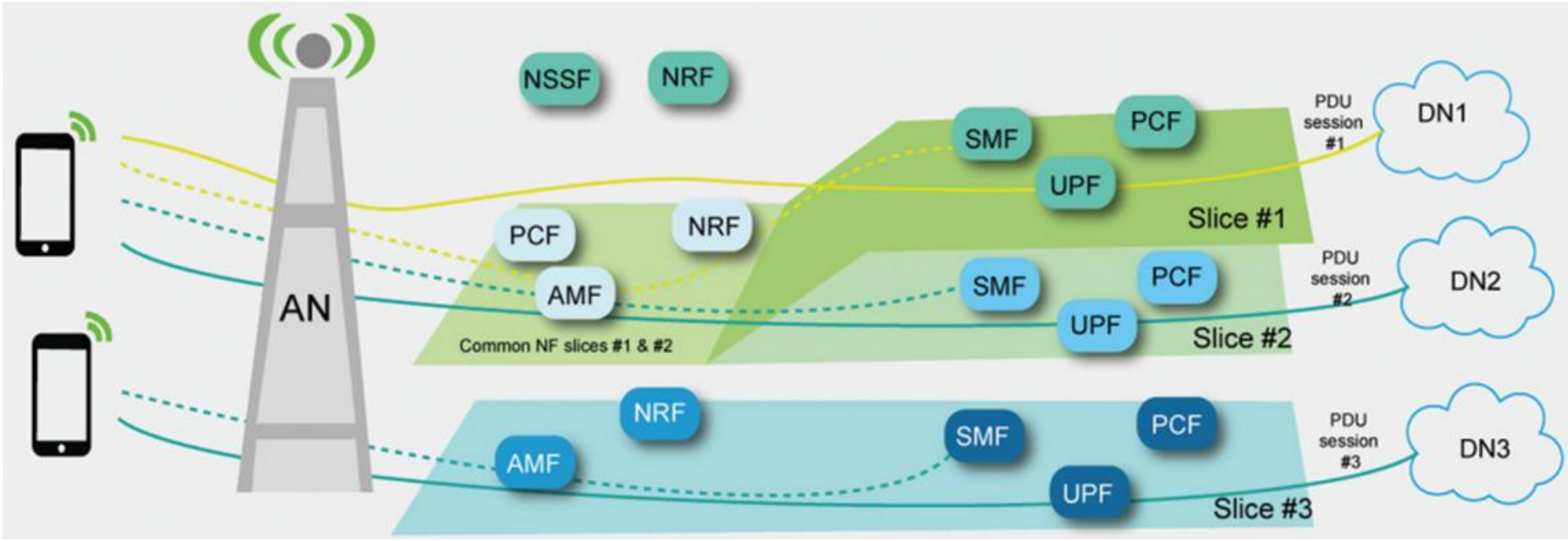
- Application Functions not allowed by the operator to access directly the Network Functions shall use the external exposure framework via the NEF to interact with relevant Network Functions

- The functionality and purpose of Application Functions are only defined in this specification with respect to their interaction with the 3GPP Core Network.

Network Slicing

NG Radio Access Network
Non-3GPP Access Network
(N3IWF functions)

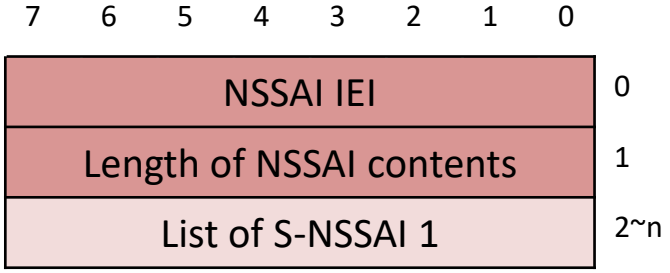
Core Network Control Plane
User Plane Network Functions



Public Land Mobile Network (PLMN)

Network Slice Selection Assistance Information (NSSAI)

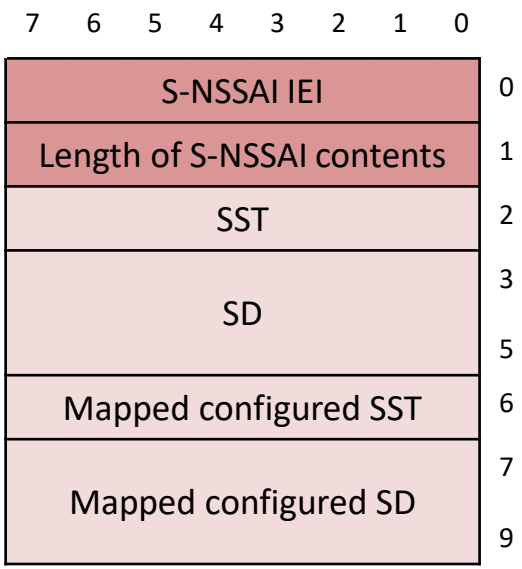
- A set of one or more S-NSSAIs is called the NSSAI



- Default Configured NSSAI
  - Default NSSAI setting by HPLMN
- Configured NSSAI
  - Configure by current PLMN
  - With PLMN identity
  - Stored in the UE is a set composed of at most 16 S-NSSAIs
- Requested NSSAI
  - NSSAI provided by the UE to the Serving PLMN during registration
- Allowed NSSAI
  - NSSAI provided by the Serving PLMN during
    - A Registration procedure, indicating the S-NSSAIs values the UE could use in the Serving PLMN for the current registration area
  - Stored in the UE is a set composed of at most 8 S-NSSAIs
- Rejected NSSAI
  - NSSAI reject by the Serving PLMN during
  - With PLMN identity

Single Network Slice Selection Assistance Information (S-NSSAI)

- Identifies a Network Slice
- Subscribed S-NSSAIs
  - S-NSSAI based on subscriber information, which a UE is subscribed to use in a PLMN
- Mapped S-NSSAI
  - In roaming scenarios, a mapping S-NSSAI values between HPLMN and Serving PLMN



- A Slice/Service type (SST)
  - The expected Network Slice behavior in terms of features and services
- A Slice Differentiator (SD)
  - Optional information that complements the Slice/Service type(s) to differentiate amongst multiple Network Slices of the same Slice/Service type

- Network may at any one time serve the UE with only one Network Slice instance associated with this S-NSSAI

S-NSSAI values

- Standard SST

Slice/Service type	SST value	Characteristics.
eMBB	1	Slice suitable for the handling of 5G enhanced Mobile Broadband.
URLLC	2	Slice suitable for the handling of ultra- reliable low latency communications.
MIoT	3	Slice suitable for the handling of massive IoT.

- Standard SST values and no SD
- Standardised SST and an SD
- Standardised SST value and no SD

- S-NSSAI with a non-standard value
  - Identifies a single Network Slice within the PLMN with which it is associated
  - Shall not be used by the UE in access stratum procedures in any PLMN other than the one to which the S-NSSAI is associated

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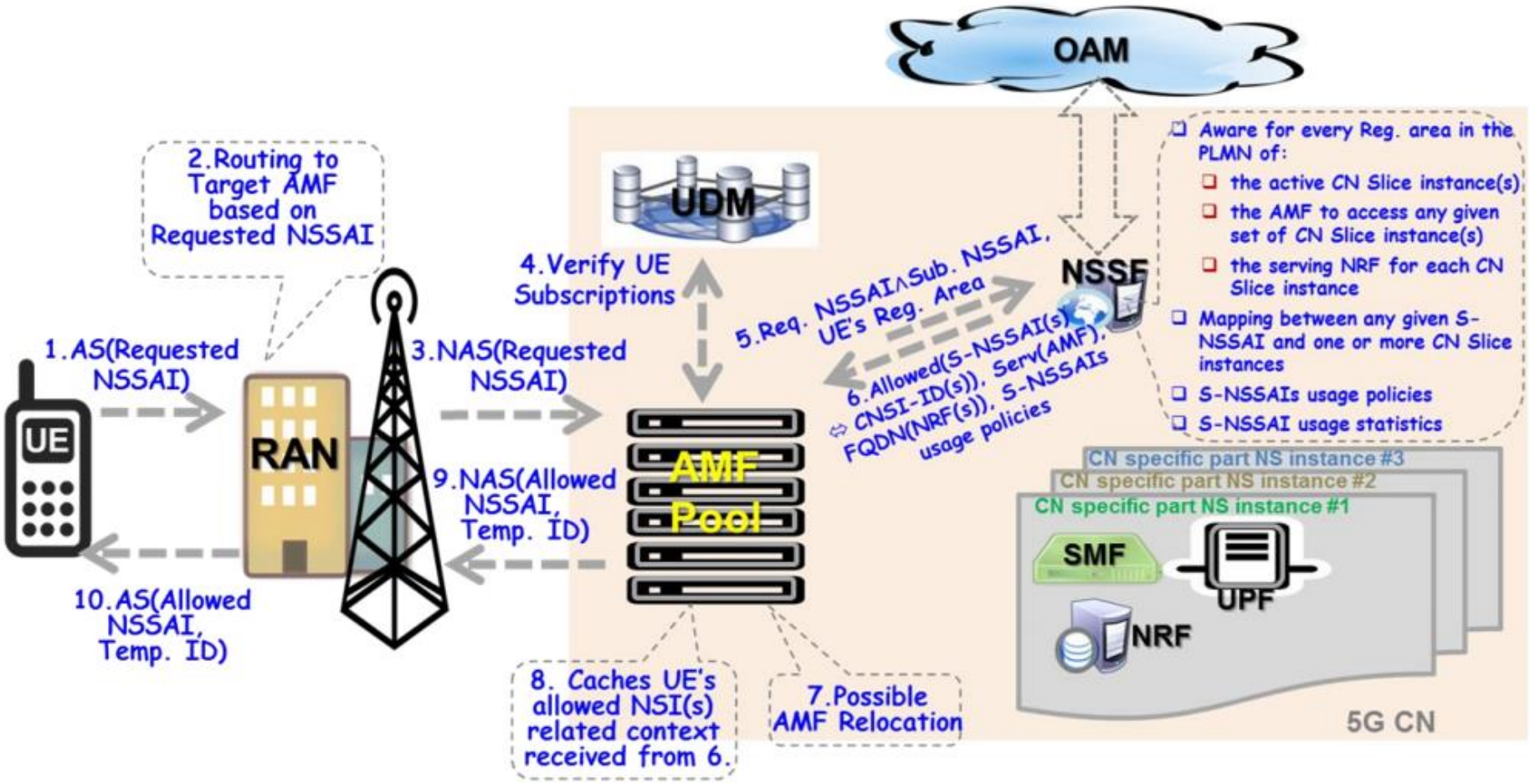
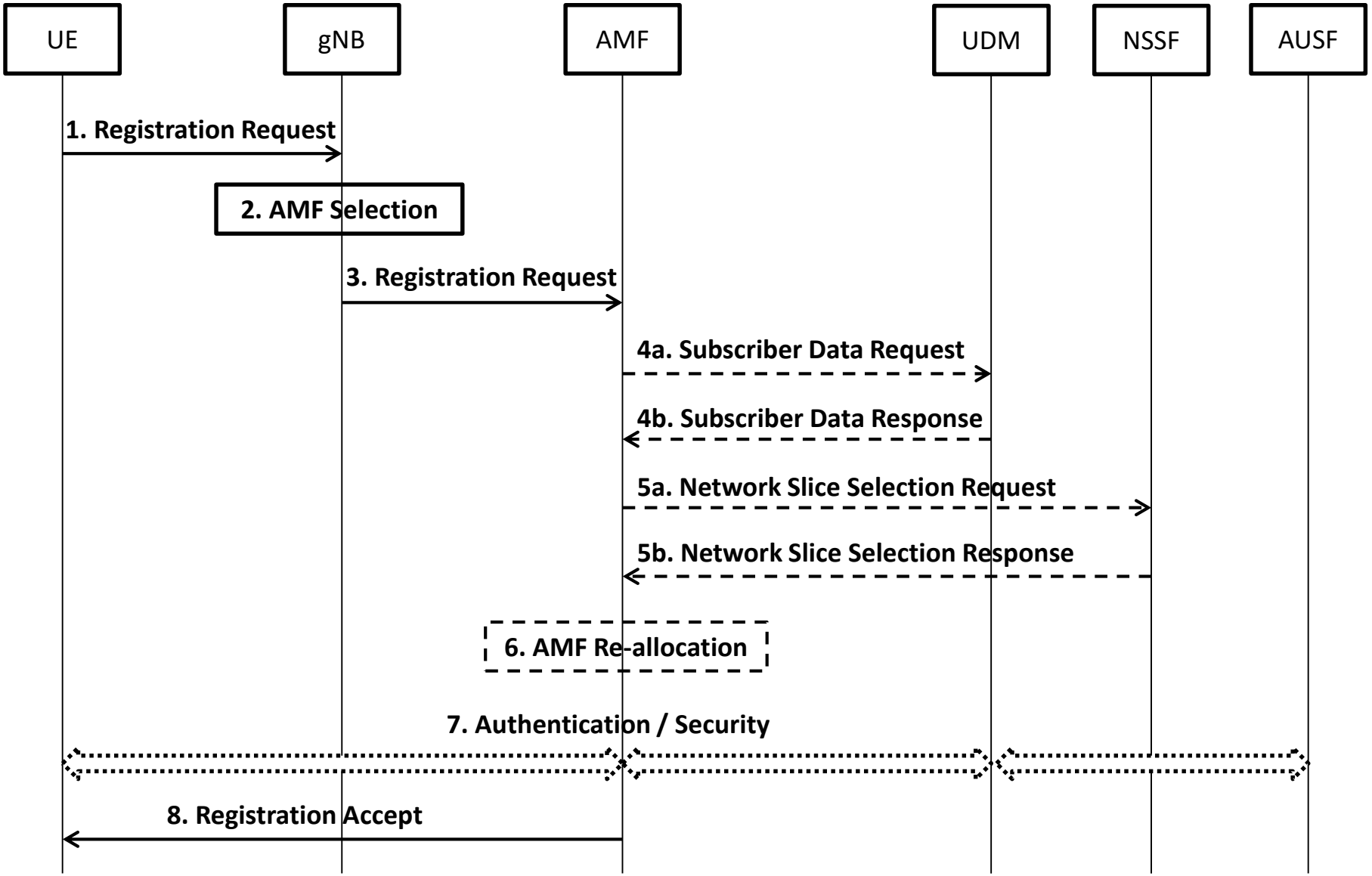
Network Slicing

Network Slicing Registration

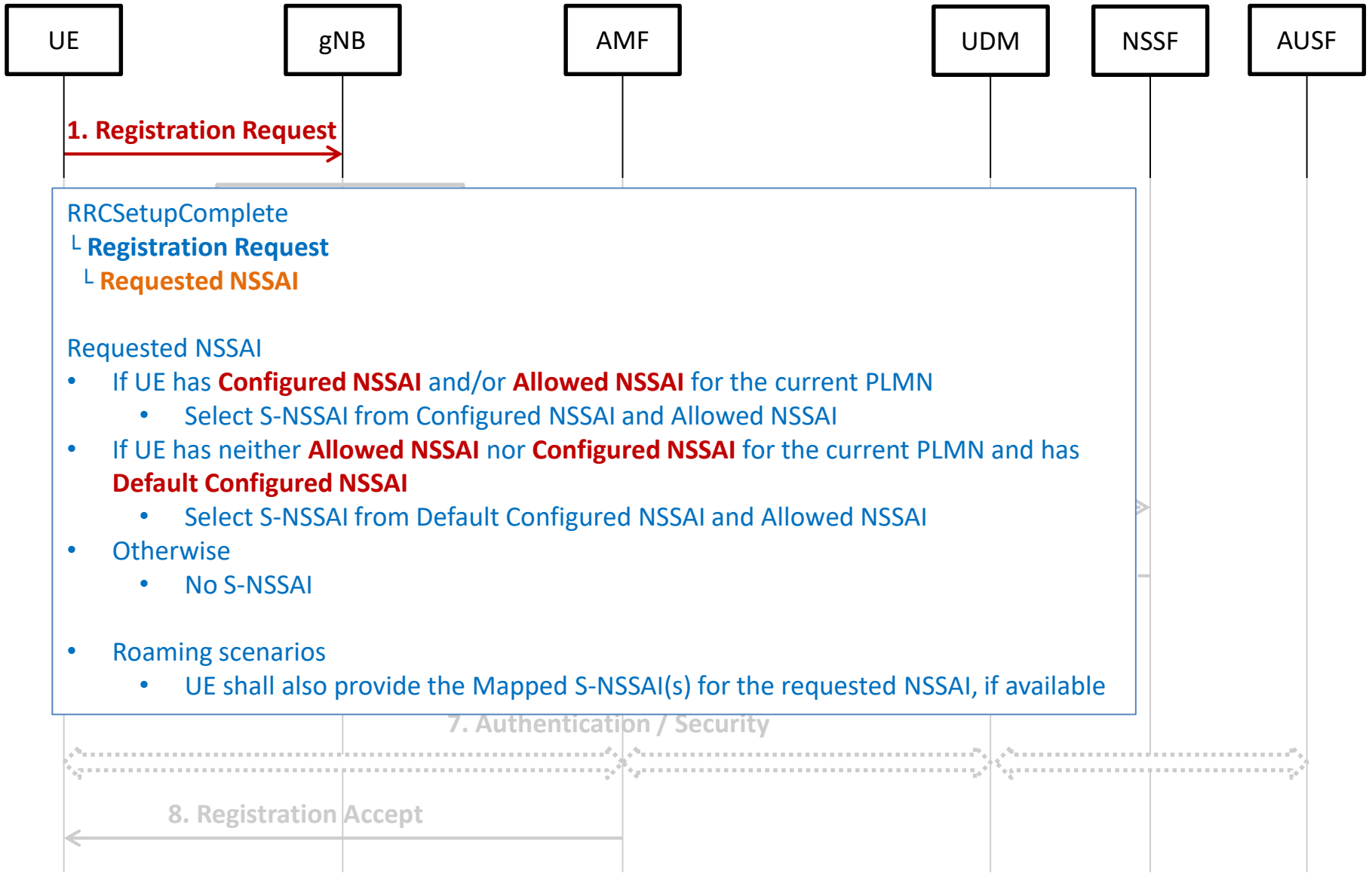
UE select the slice of the requirement



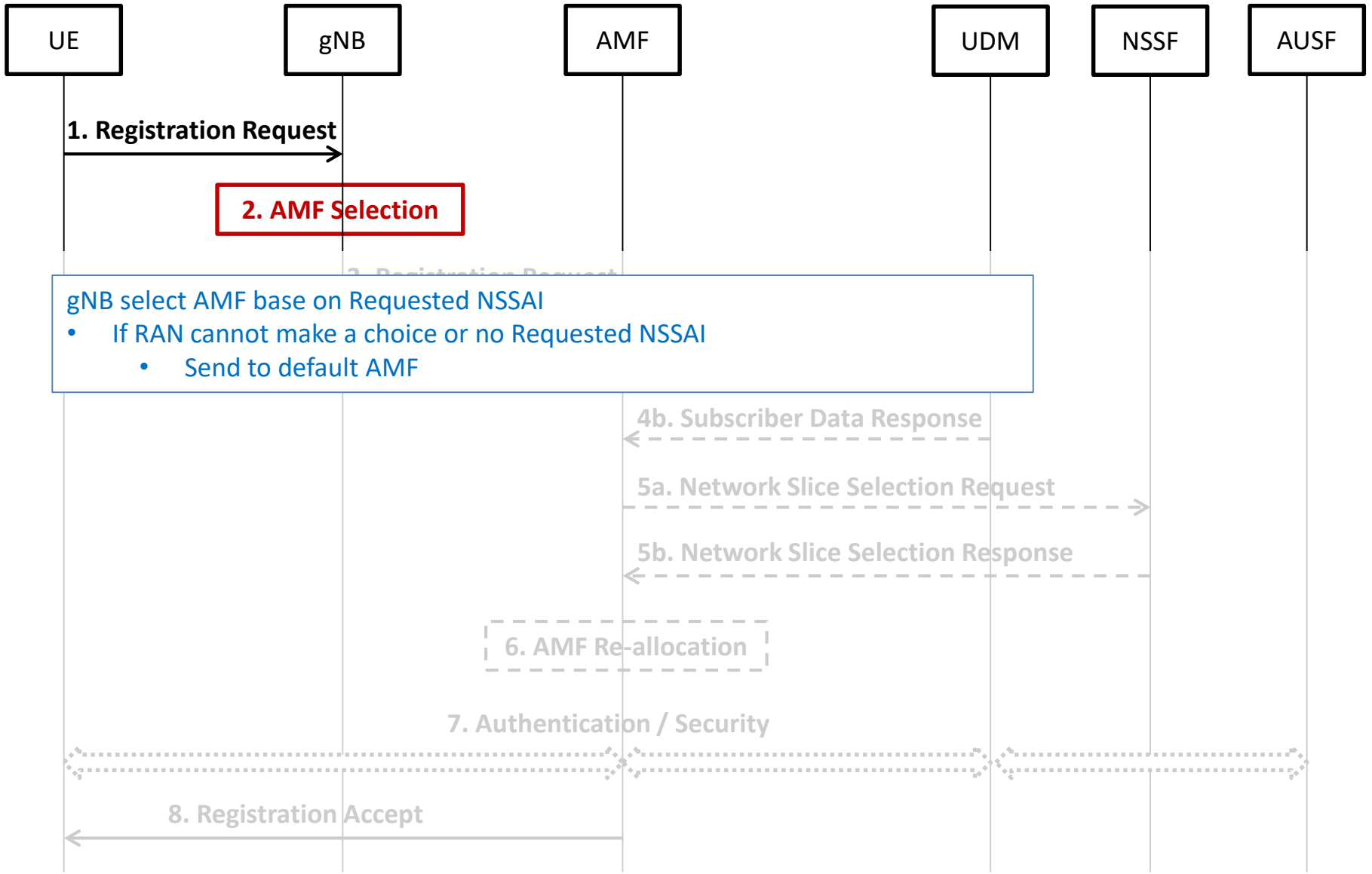
Network Slice Registration



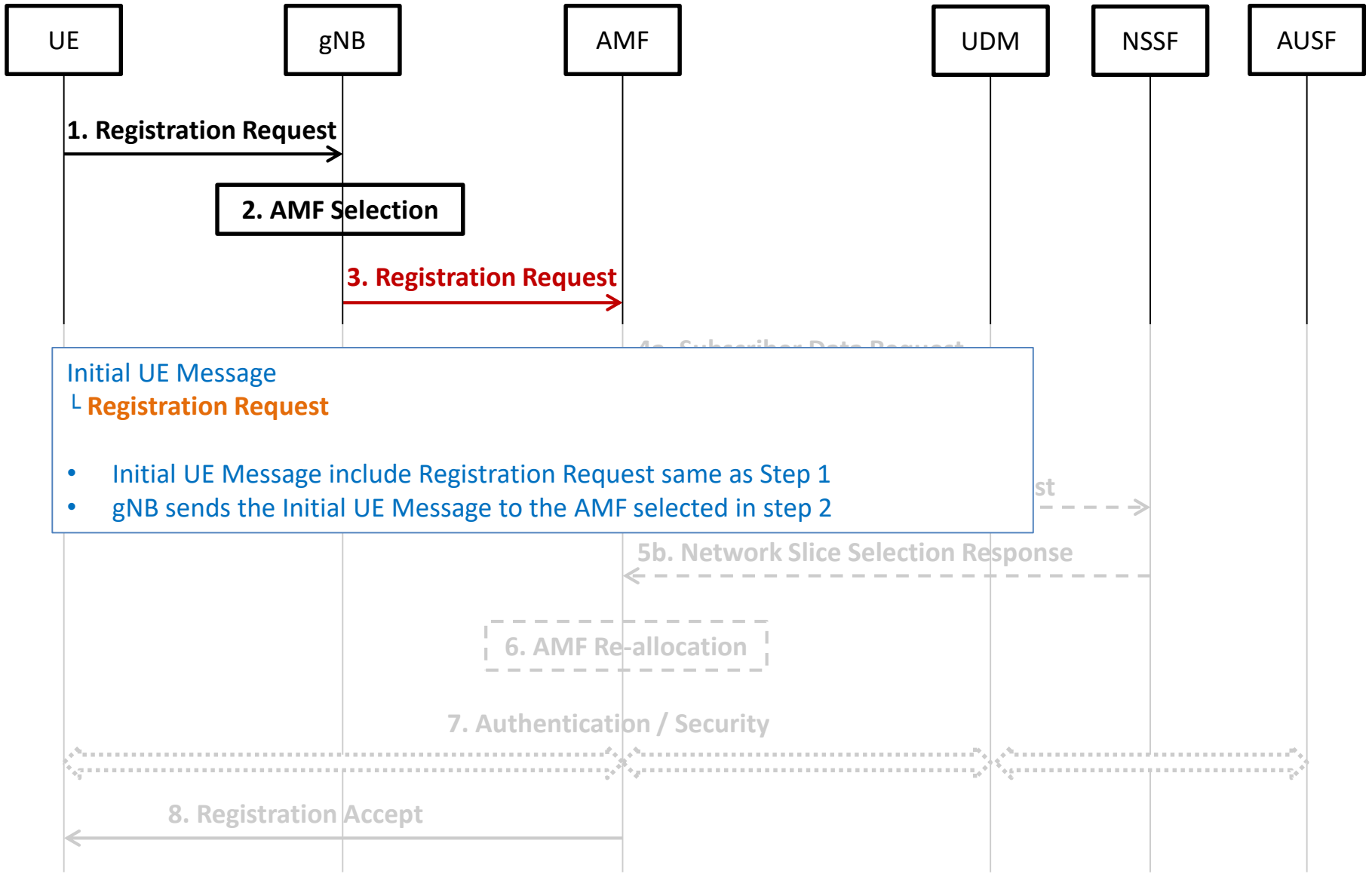
Network Slice Registration (Step 1)



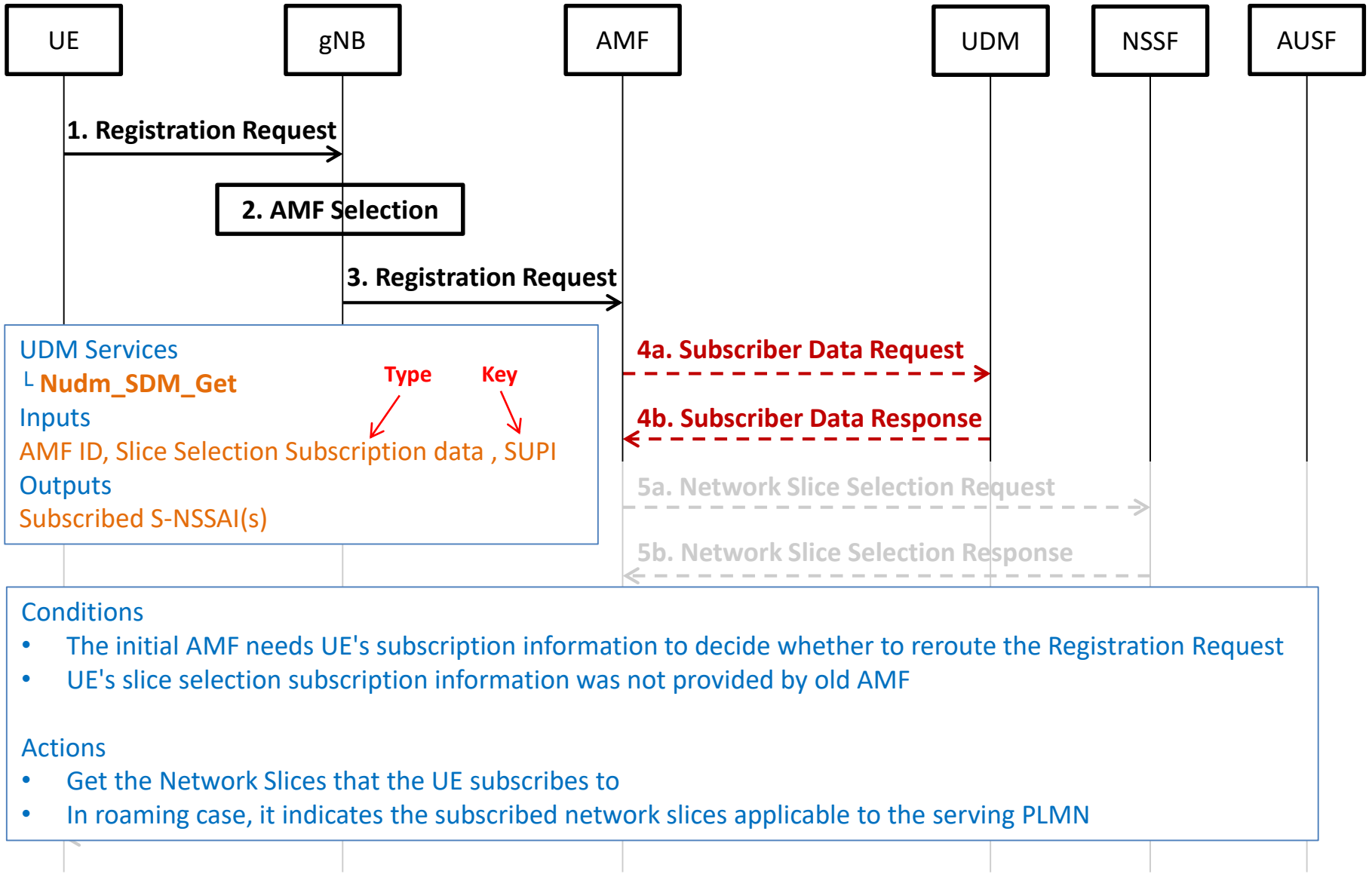
Network Slice Registration (Step 2)



Network Slice Registration (Step 3)



Network Slice Registration (Step 4)



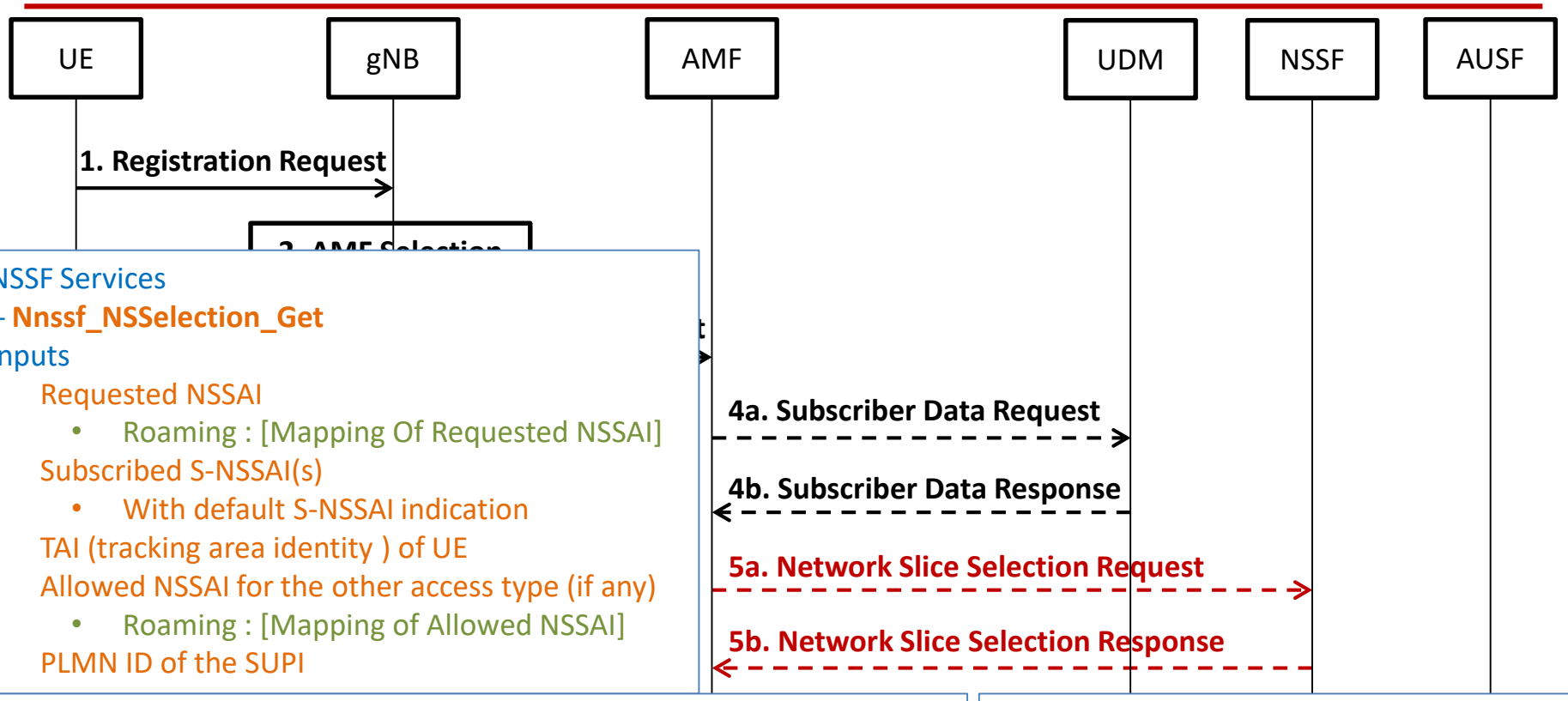
Conditions

- The initial AMF needs UE's subscription information to decide whether to reroute the Registration Request
- UE's slice selection subscription information was not provided by old AMF

Actions

- Get the Network Slices that the UE subscribes to
- In roaming case, it indicates the subscribed network slices applicable to the serving PLMN

Network Slice Registration (Step 5)



NSSF Services

└ **Nnssf_NSSelection_Get**

Inputs

- Requested NSSAI
  - Roaming : [Mapping Of Requested NSSAI]
- Subscribed S-NSSAI(s)
  - With default S-NSSAI indication
- TAI (tracking area identity) of UE
- Allowed NSSAI for the other access type (if any)
  - Roaming : [Mapping of Allowed NSSAI]
- PLMN ID of the SUPI

Outputs

- AMF Set or list of AMF addresses,
- Allowed NSSAI per access type (may be more than one allowed NSSAI)
  - Roaming : [Mapping Of Allowed NSSAI]
- [NSI ID(s)], [NRF(s)],
- [List of rejected (S-NSSAI(s), cause value(s))],
- [Configured NSSAI for the Serving PLMN]
  - Roaming : [Mapping Of Configured NSSAI]

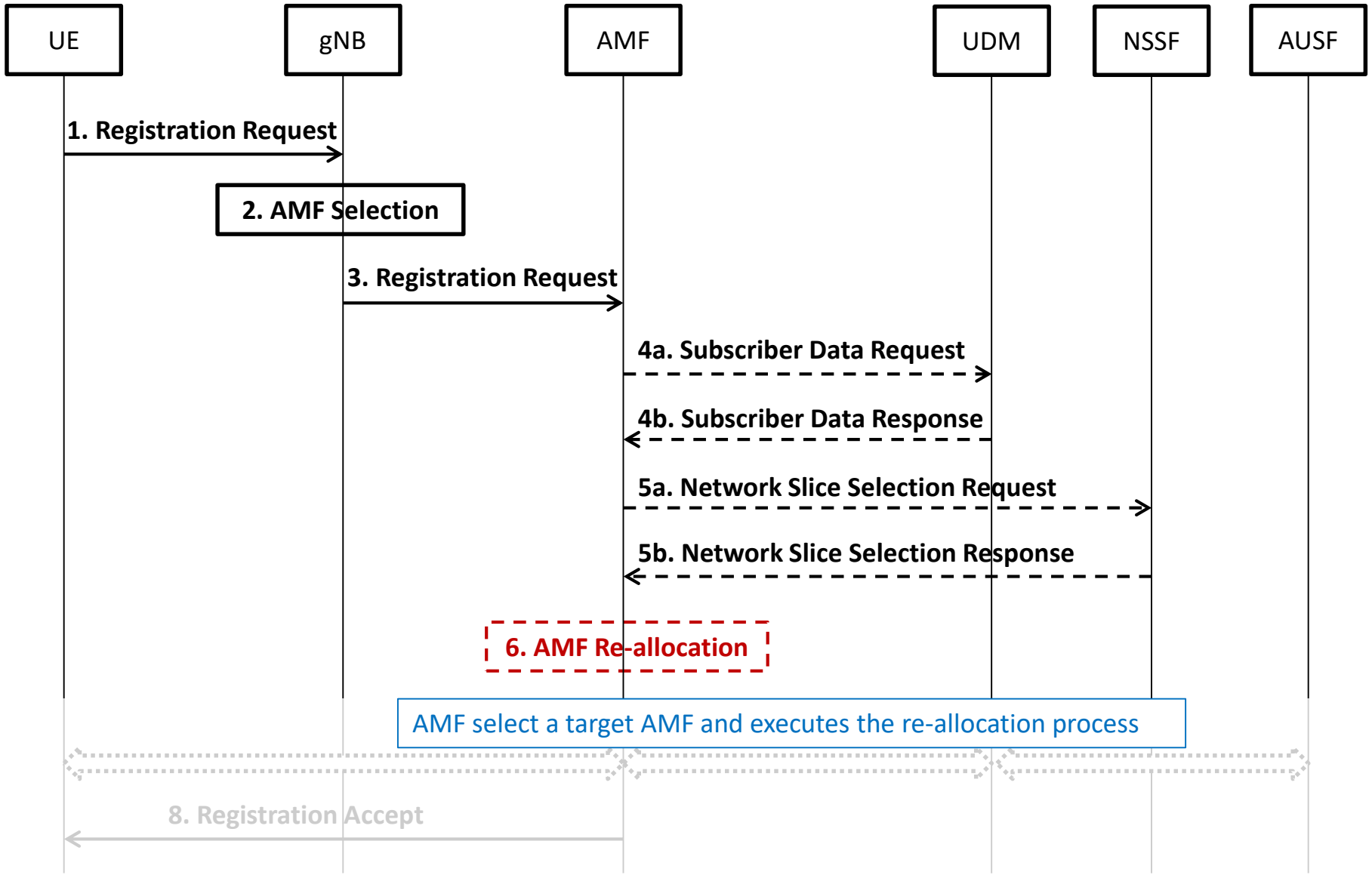
Conditions

- AMF cannot serve all the S-NSSAI(s) from the Requested NSSAI permitted by the subscription information

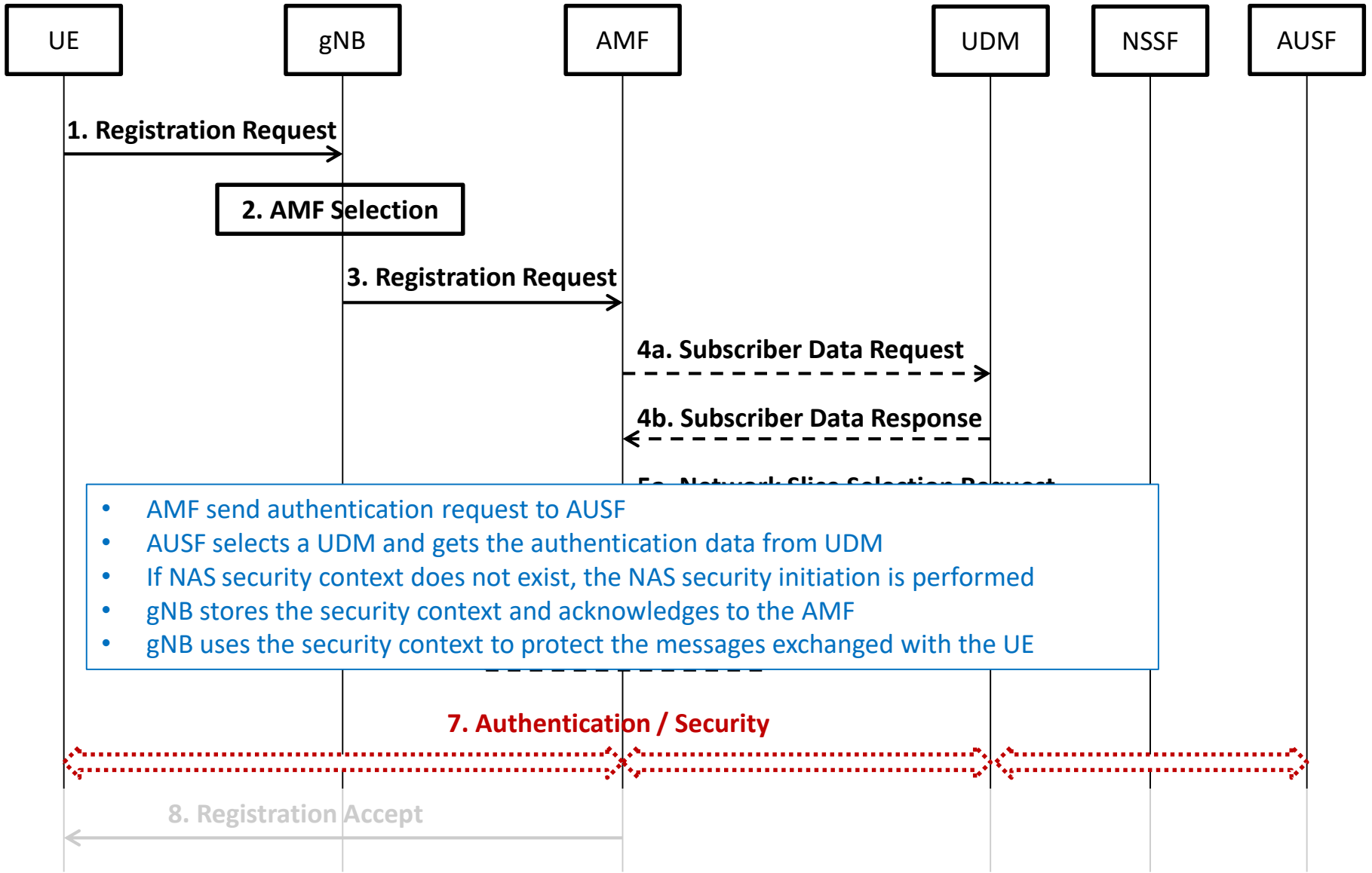
Actions

- NSSF provide the relevant Network Slice information to AMF

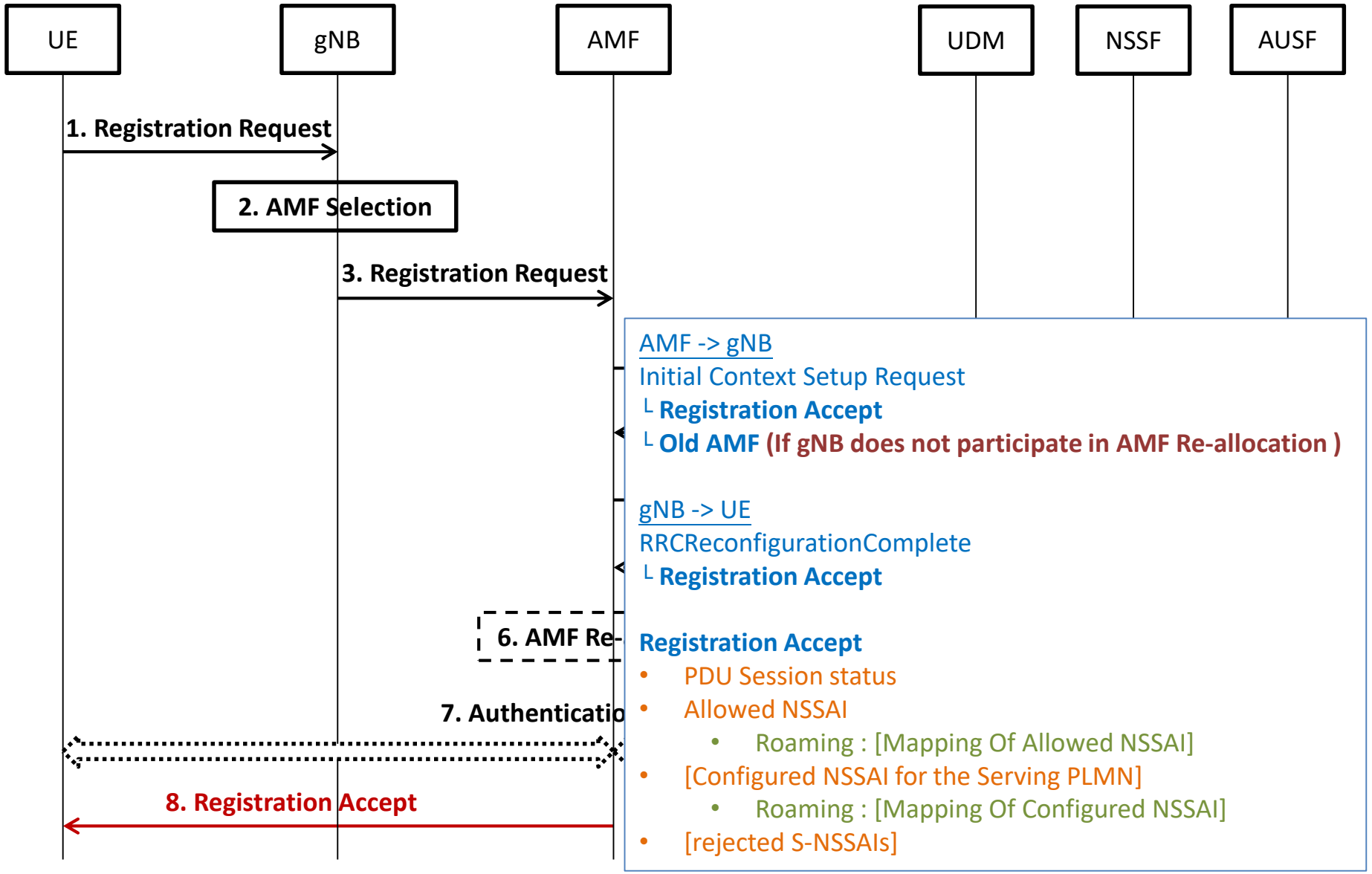
Network Slice Registration (Step 6)



Network Slice Registration (Step 7)

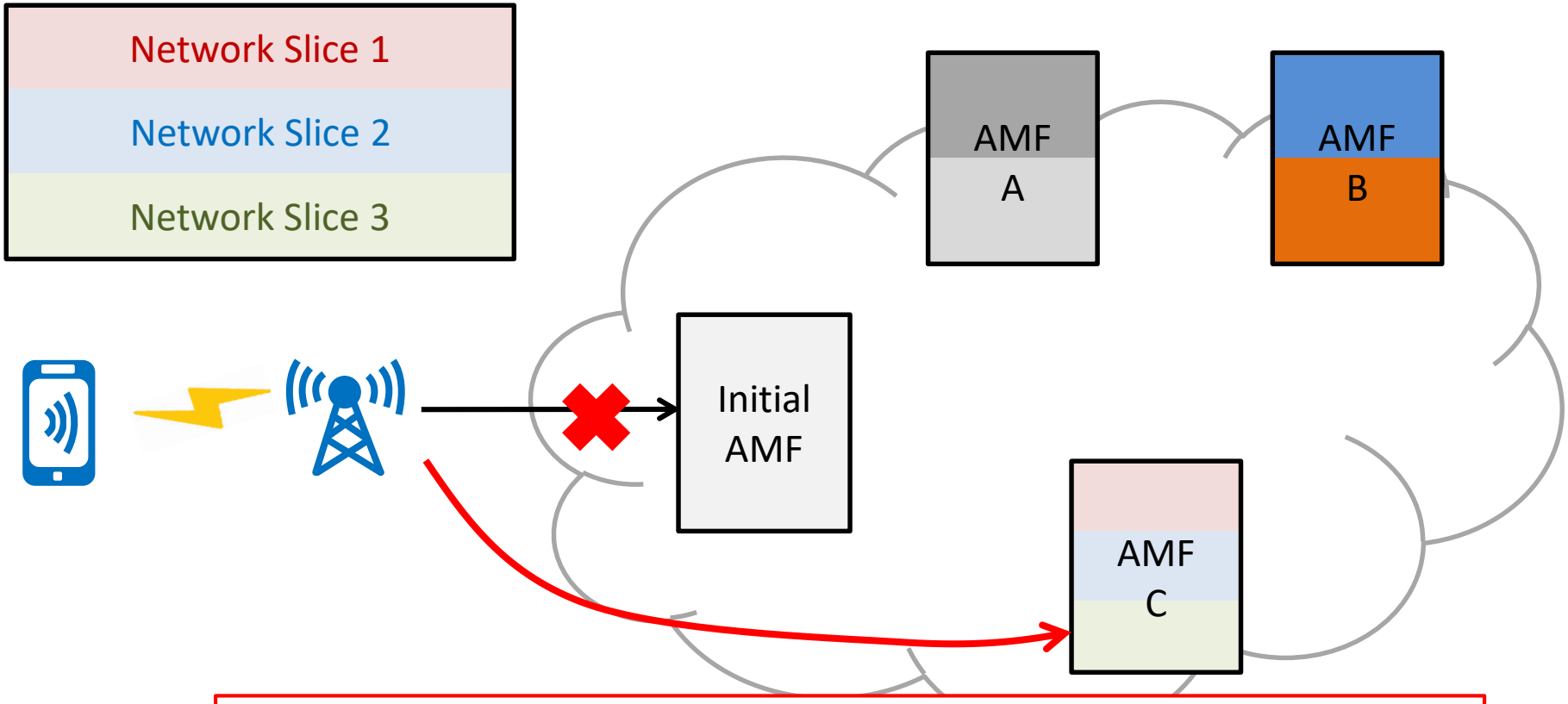


Network Slice Registration (Step 8)



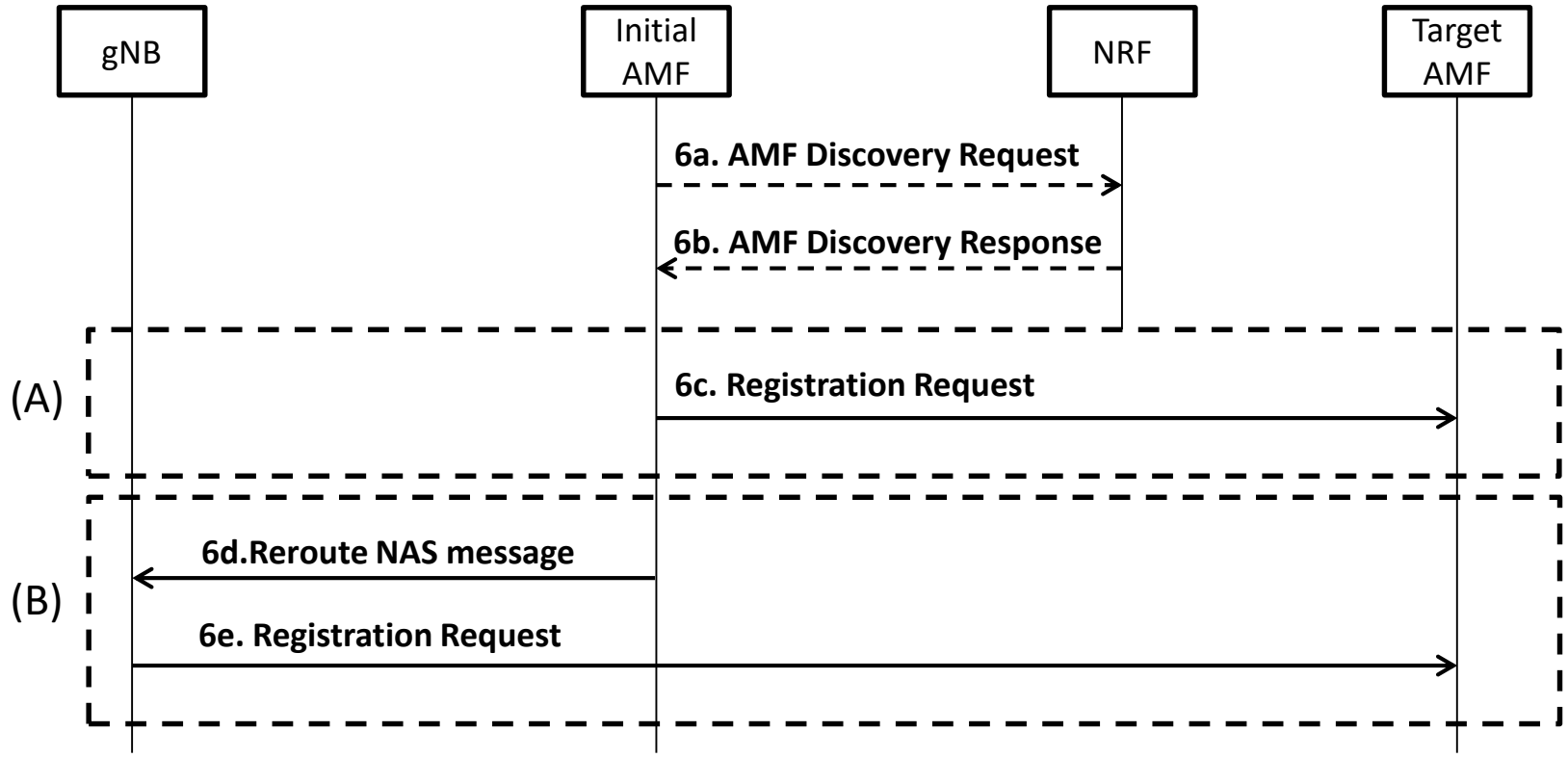
AMF Re-allocation

UE have 3 Network Slice (S-NSSAI)
Find a AMF to service Network Slice 1,2,and 3

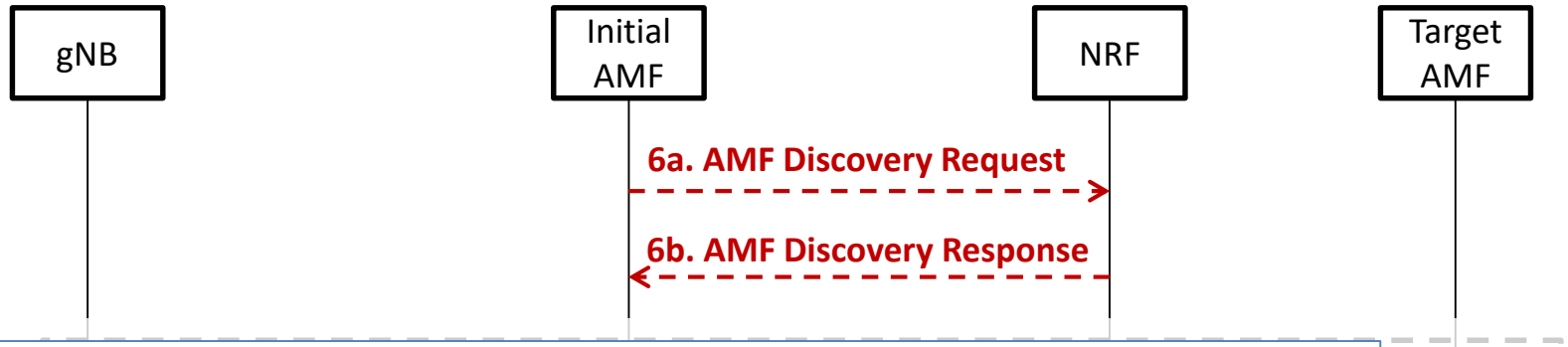


Select AMF C as Target AMF to service all Network Slice
Re-allocate initial AMF to AMF C

AMF Re-allocation - Step 6 at Registration



AMF Re-allocation - Step 6 at Registration (Step a,b)



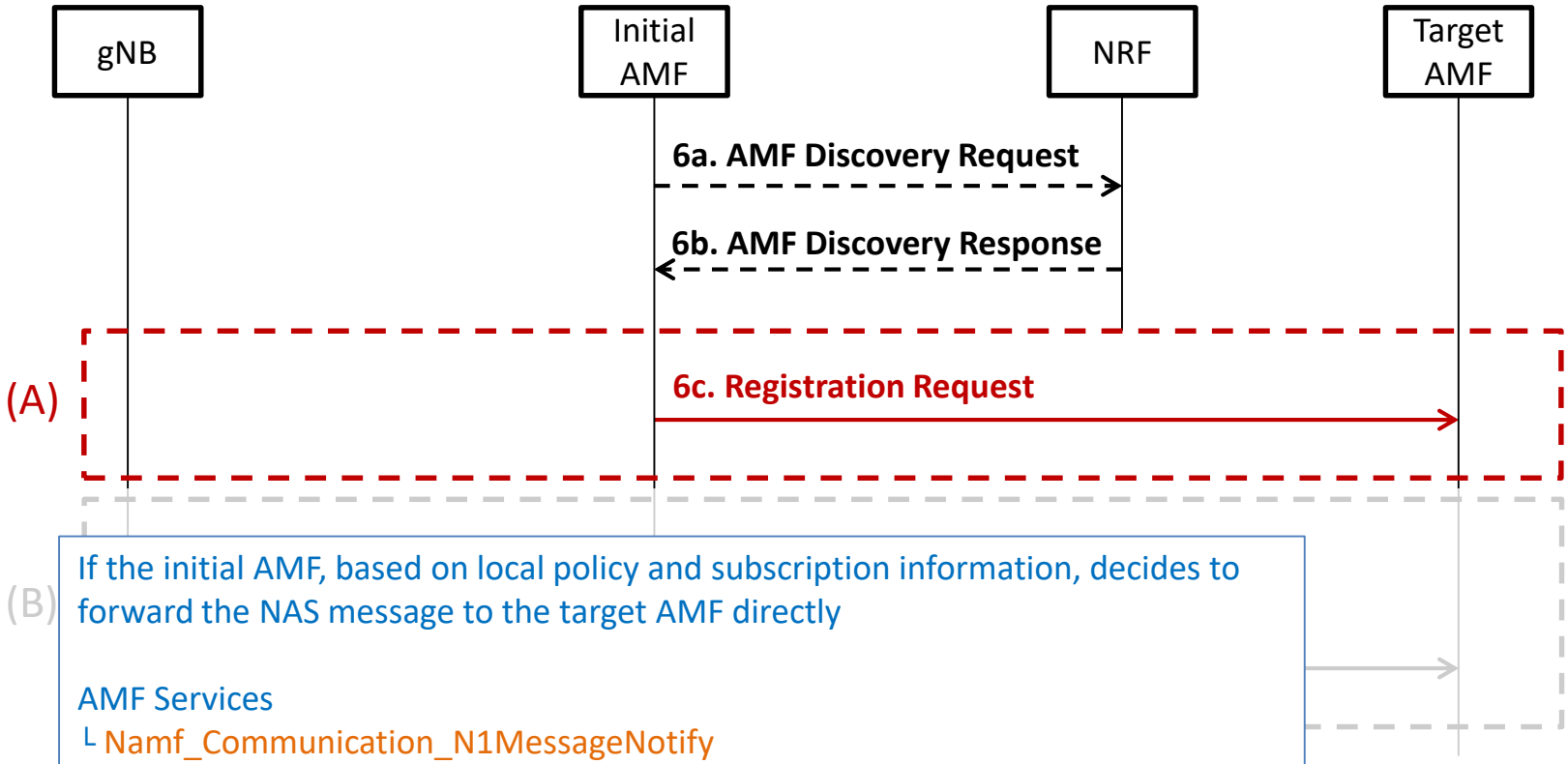
NRF Services
└ Nnrf_NFDiscovery
Inputs
- NF type=AMF
- AMF Set

Outputs
- list of (
  - AMF pointer,
  - AMF address
  - plus additional selection rules and NF capabilities
-)

Conditions
- If initial AMF does not locally store the target AMF address that use at AMF Re-allocation

Actions
- Get the AMF information

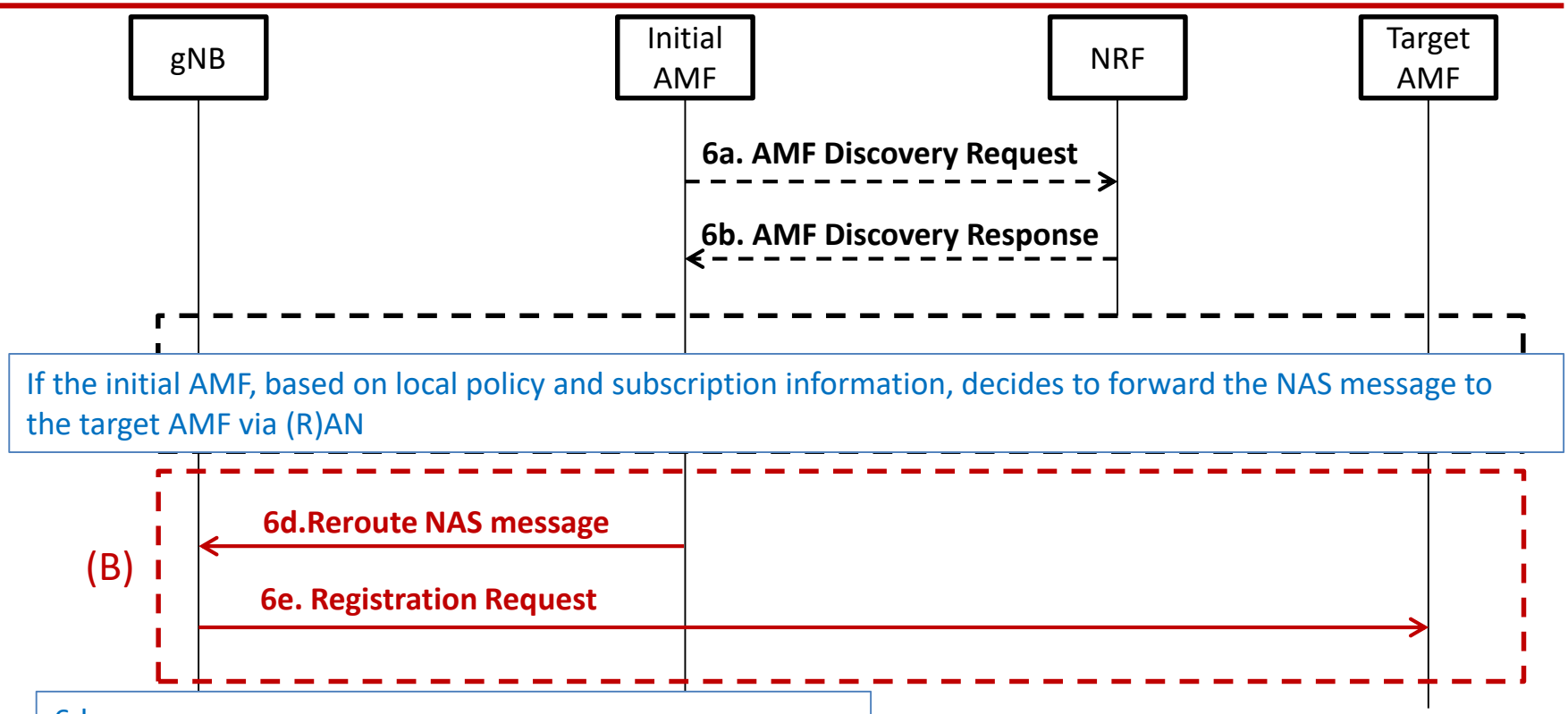
AMF Re-allocation - Step 6 at Registration (Step c)



If the initial AMF, based on local policy and subscription information, decides to forward the NAS message to the target AMF directly

AMF Services
└ Namf_Communication_N1MessageNotify
Inputs
- Initial AMF ID
- SUPI
- N2 terminating point
- Registration Request
- information from the NSSF

AMF Re-allocation - Step 6 at Registration (Step d,e)



6d.
Reroute NAS message
- Information about the target AMF
- Information about the Registration Request message
- Information from the NSSF

6e.
Initial UE Message
└ **Registration Request**

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Network Slicing

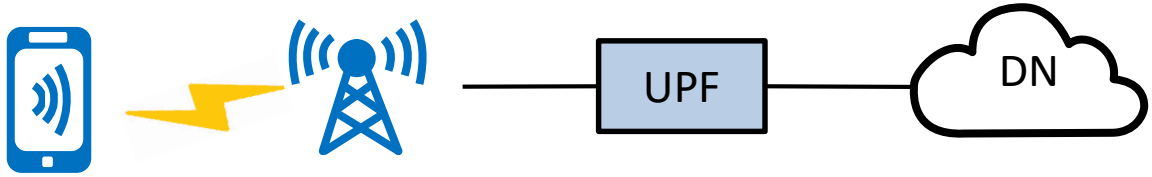
Network Slicing PDU session

PDU session (1)

UE has 3 **Allows S-NSSAI**

Network Slice 1 (S-NSSAI = 1)
Network Slice 2 (S-NSSAI = 2)
Network Slice 3 (S-NSSAI = 3)

UE can only setup PDU session for **Allows S-NSSAI**



PDU session ID : 10 — S-NSSAI = 1

PDU session ID : 11 — S-NSSAI = 1

PDU session ID : 12 — S-NSSAI = 3

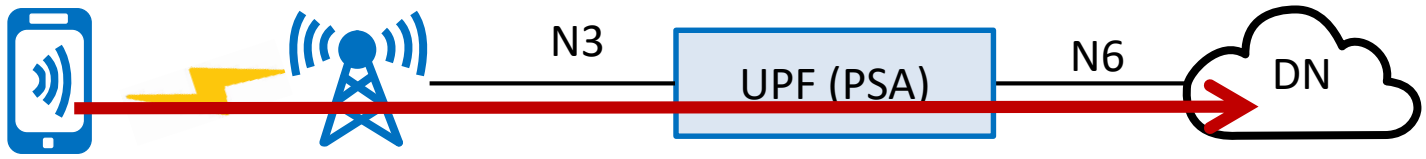
PDU session ID : 13 — S-NSSAI = 2

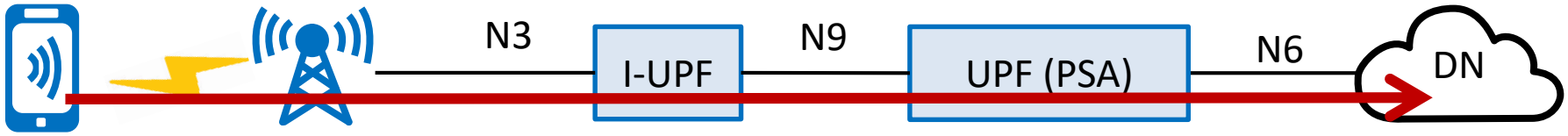
PDU session ID : 14 — S-NSSAI = 1

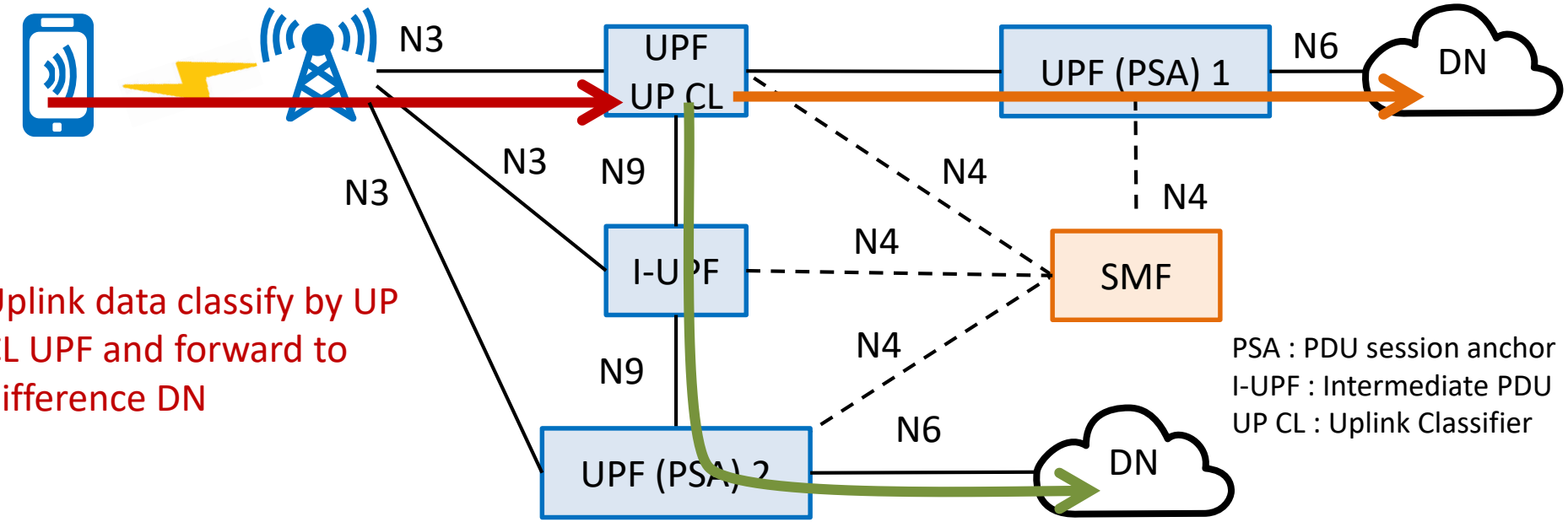
PDU session ID : 15 — S-NSSAI = 2

PDU session ID must be **unique**

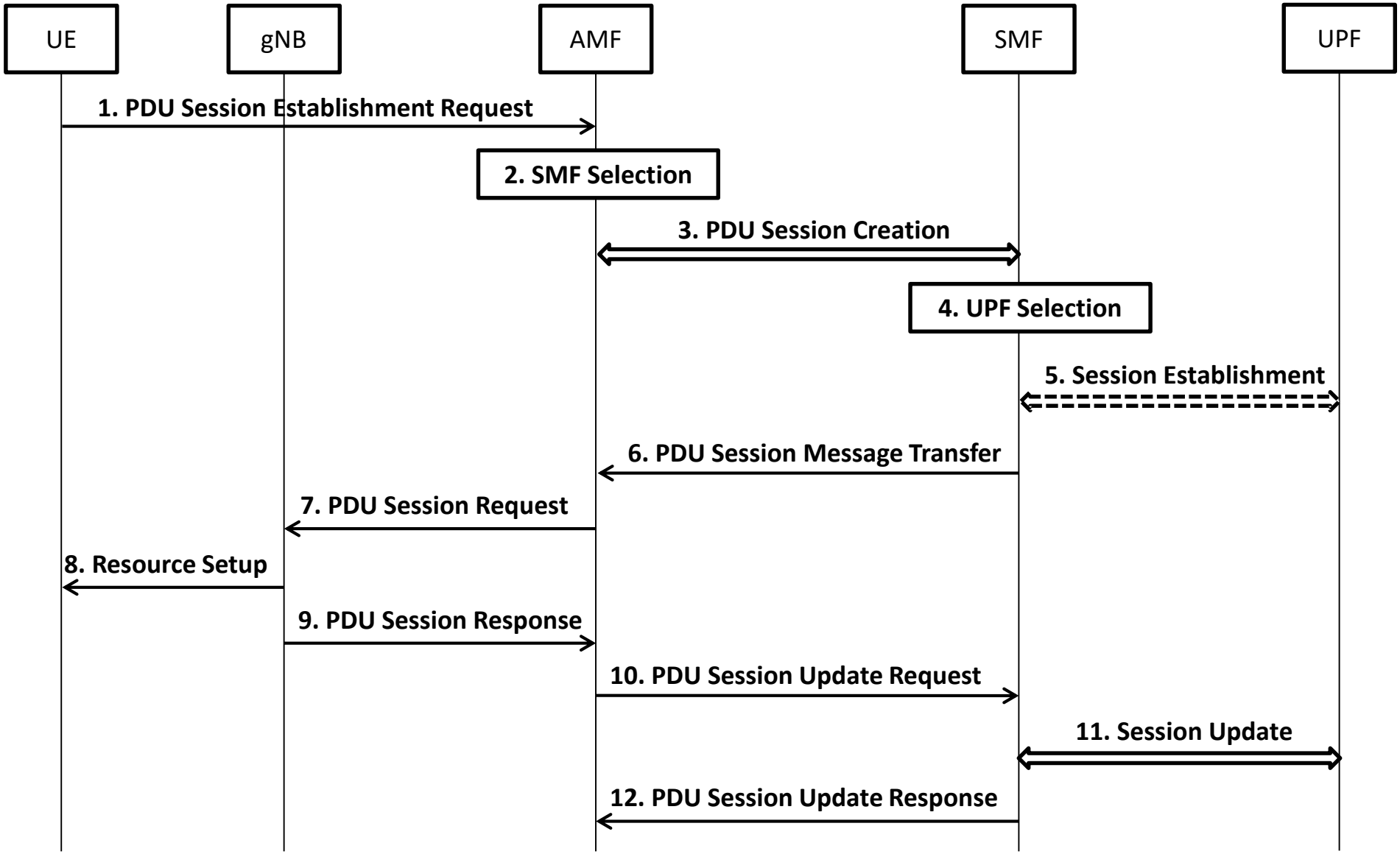
PDU session (2)



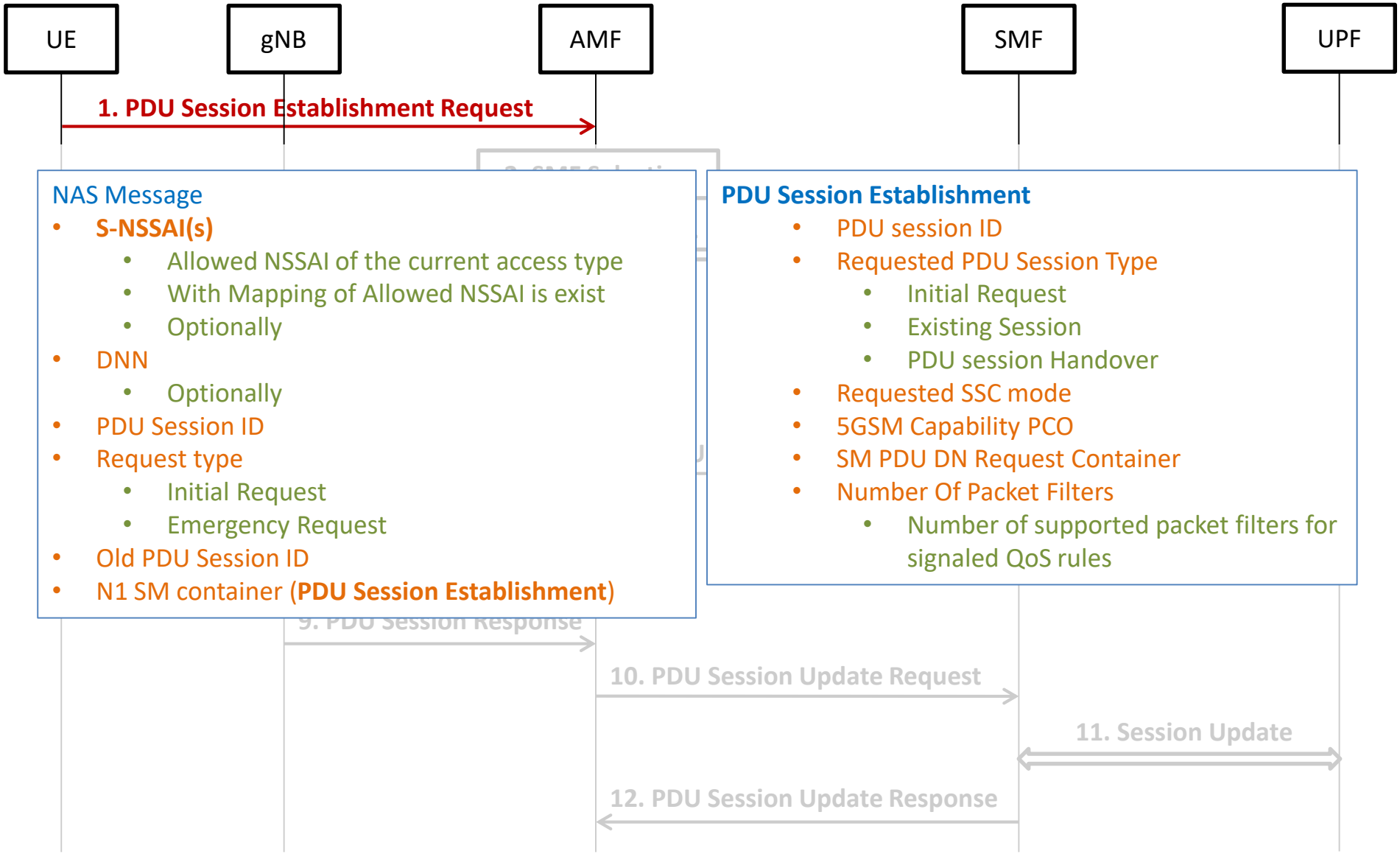




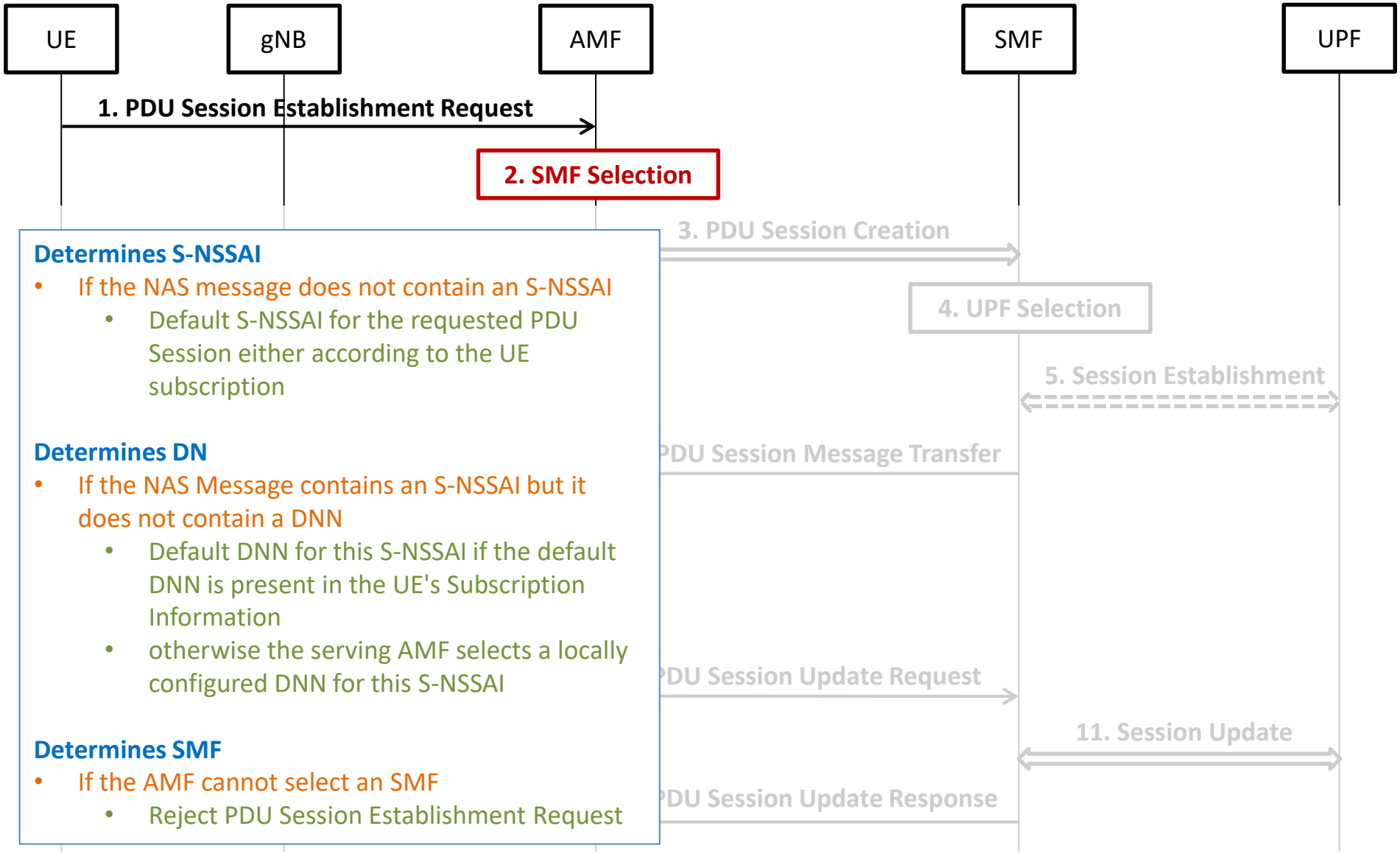
PDU session establishment
Non-roaming and Roaming with Local Breakout



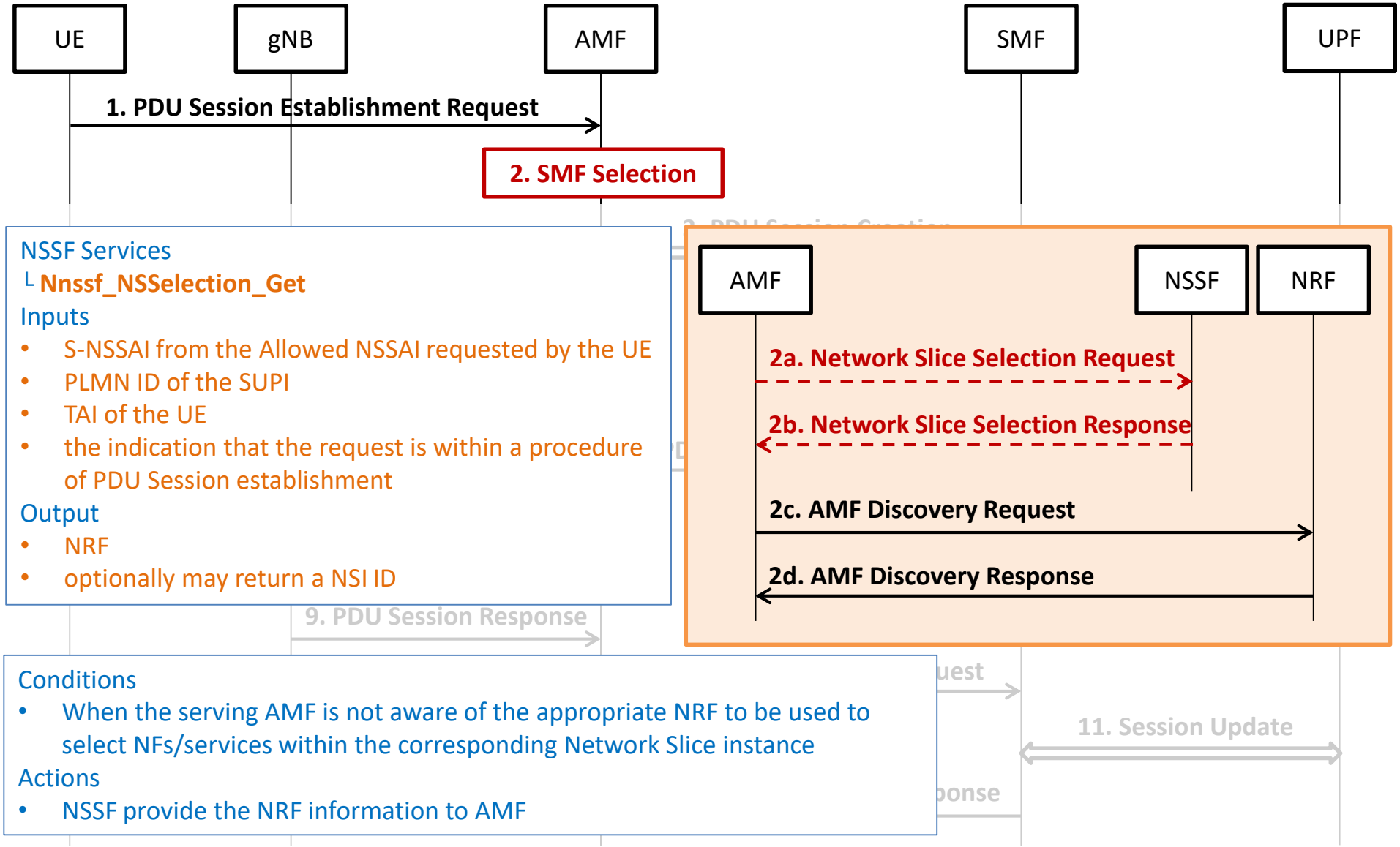
PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 1)



PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 2-1)



PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 2-2)



NSSF Services
└ **Nnssf_NSSelection_Get**

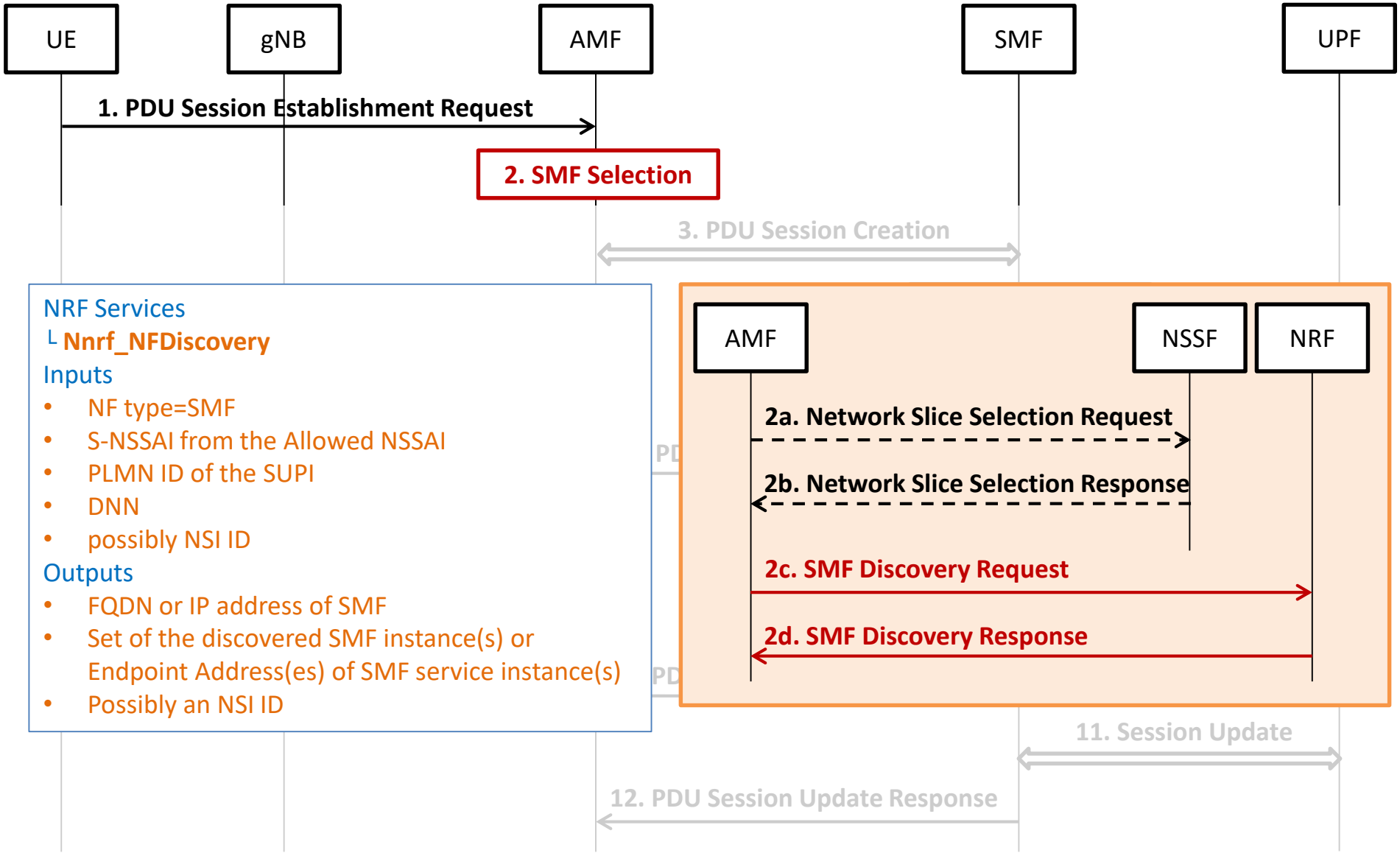
Inputs
- S-NSSAI from the Allowed NSSAI requested by the UE
- PLMN ID of the SUPI
- TAI of the UE
- the indication that the request is within a procedure of PDU Session establishment

Output
- NRF
- optionally may return a NSI ID

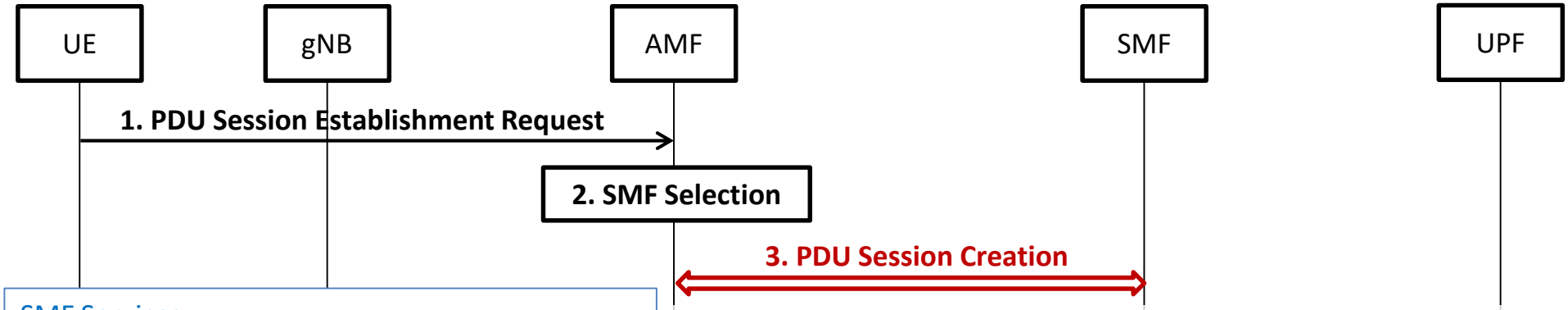
Conditions
- When the serving AMF is not aware of the appropriate NRF to be used to select NFs/services within the corresponding Network Slice instance

Actions
- NSSF provide the NRF information to AMF

PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 2-2)



PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 3)



SMF Services

└ **Nsmf_PDUSession_CreateSMContext**

- Request Type : initial request

└ **Nsmf_PDUSession_UpdateSMContext**

- Request Type : existing PDU Session

Nsmf_PDUSession_UpdateSMContext

Inputs

SUPI, DNN, PDU Session ID, AMF ID, Request Type

- **S-NSSAI(s)**
  - Allowed NSSAI
  - Roaming : [Mapping Of Allowed NSSAI]
- N1 SM container (PDU Session Establishment Request), User location information, Access Type, RAT type, PEI

Outputs

- Cause, SM Context ID or N1 SM container (PDU Session Reject (Cause)

Nsmf_PDUSession_CreateSMContext

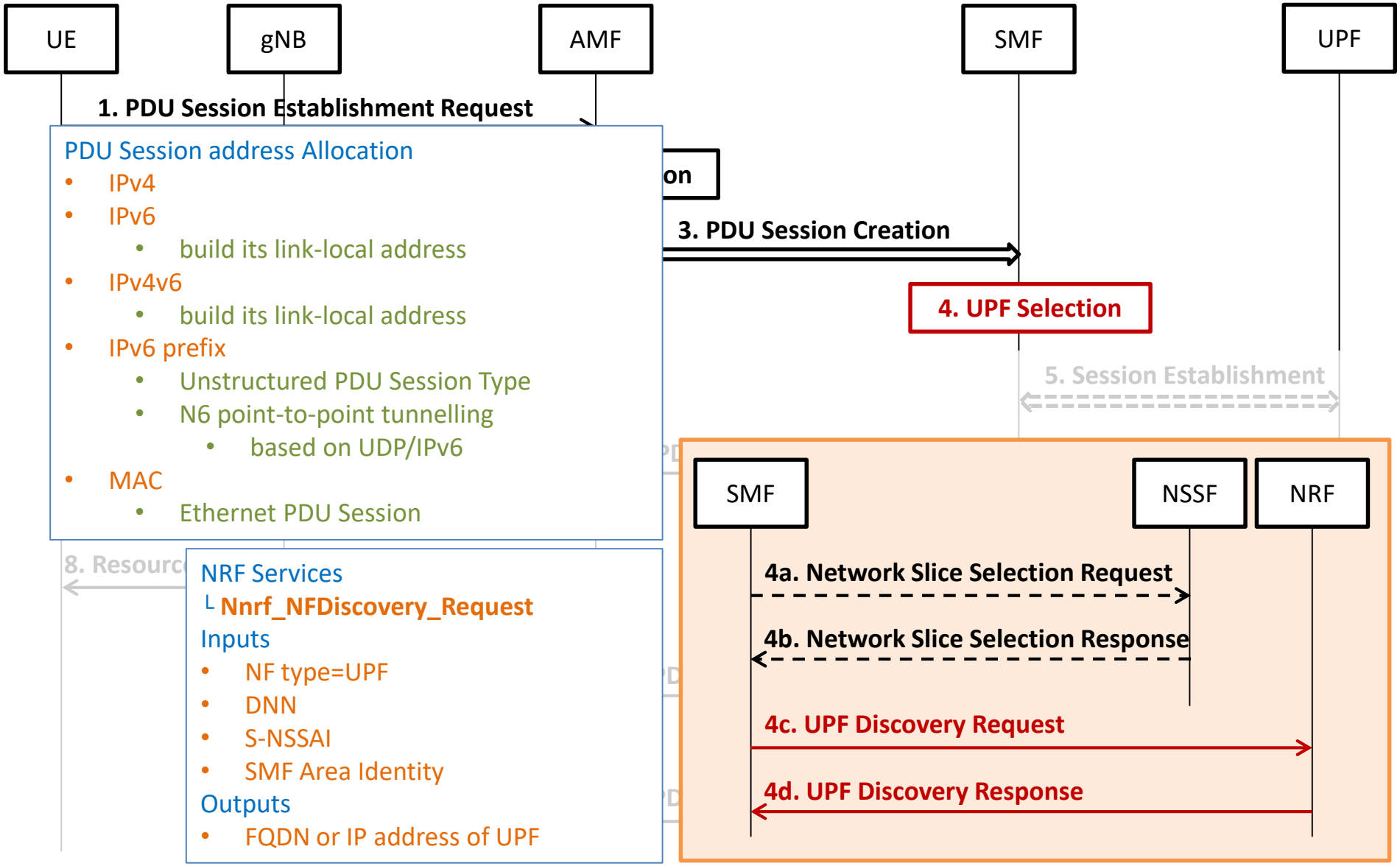
Inputs

- SUPI, DNN, PDU Session ID, AMF ID, Request Type
- **S-NSSAI(s)**
  - Allowed NSSAI
  - Roaming : [Mapping Of Allowed NSSAI]
- PCF ID, Priority Access, N1 SM container (PDU Session Establishment Request), User location information, Access Type, PEI, GPSI, UE presence in LADN service area, Subscription For PDU Session Status Notification, DNN Selection Mode, Trace Requirements

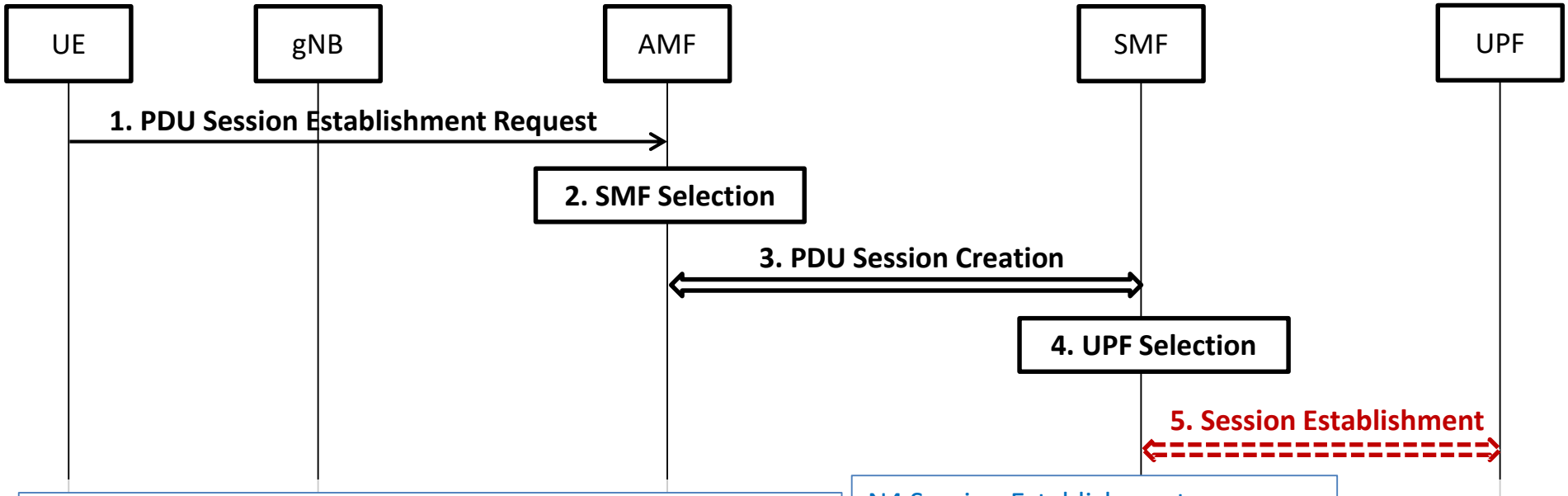
Outputs

- Cause, SM Context ID or N1 SM container (PDU Session Reject (Cause)

PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 4)



PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 5)



N4 Session Establishment/Modification Request

- Packet detection
- Enforcement
- reporting rules
- CN Tunnel
  - If CN Tunnel Info is allocated by the SMF
- Inactivity Timer
  - If the selective User Plane deactivation is required

N4 Session Establishment/Modification Response

- CN Tunnel
  - If CN Tunnel Info is allocated by the UPF0

N4 Session Establishment

- Request Type : initial request

N4 Session Modification

- Otherwise

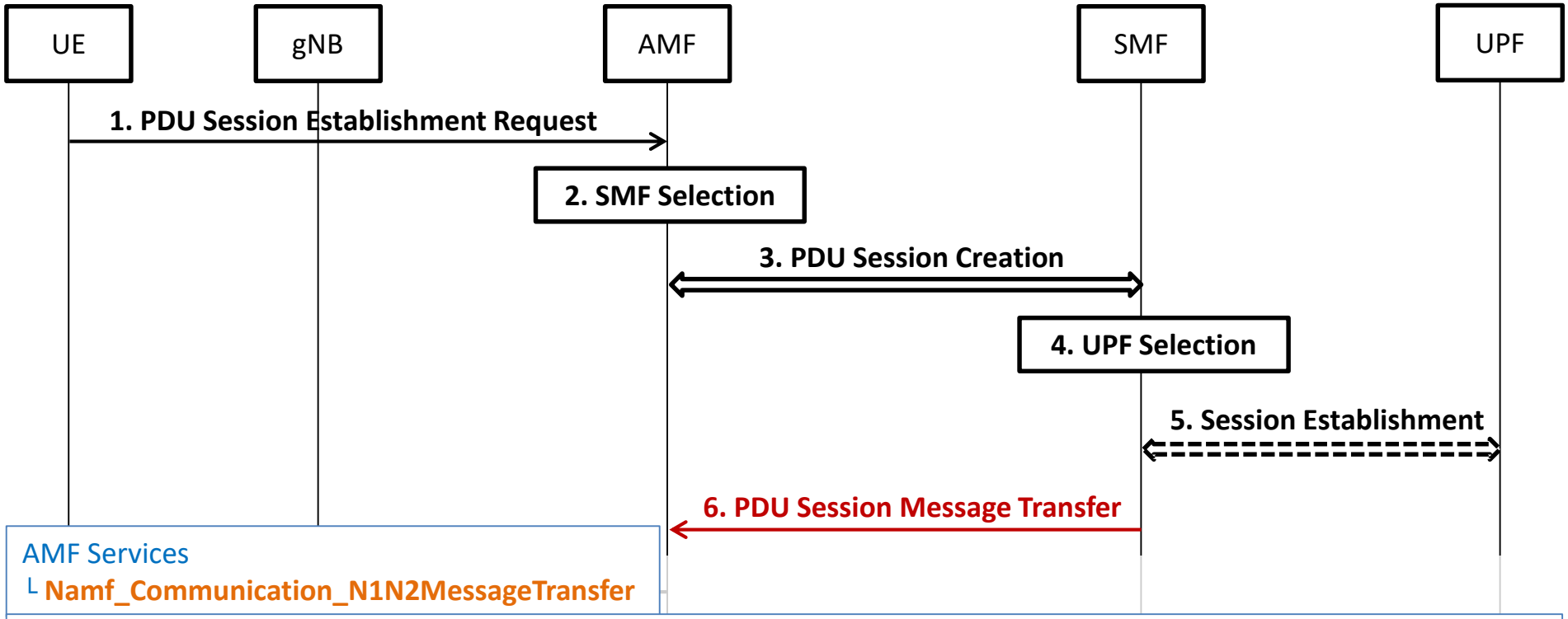
Conditions

- If the Request Type indicates "Existing PDU Session", and the SMF creates CN Tunnel Info, then this step is skipped

Actions

- SMF initiate N4 Session Establishment/Modification procedure with each UPF of the PDU Session

PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 6)

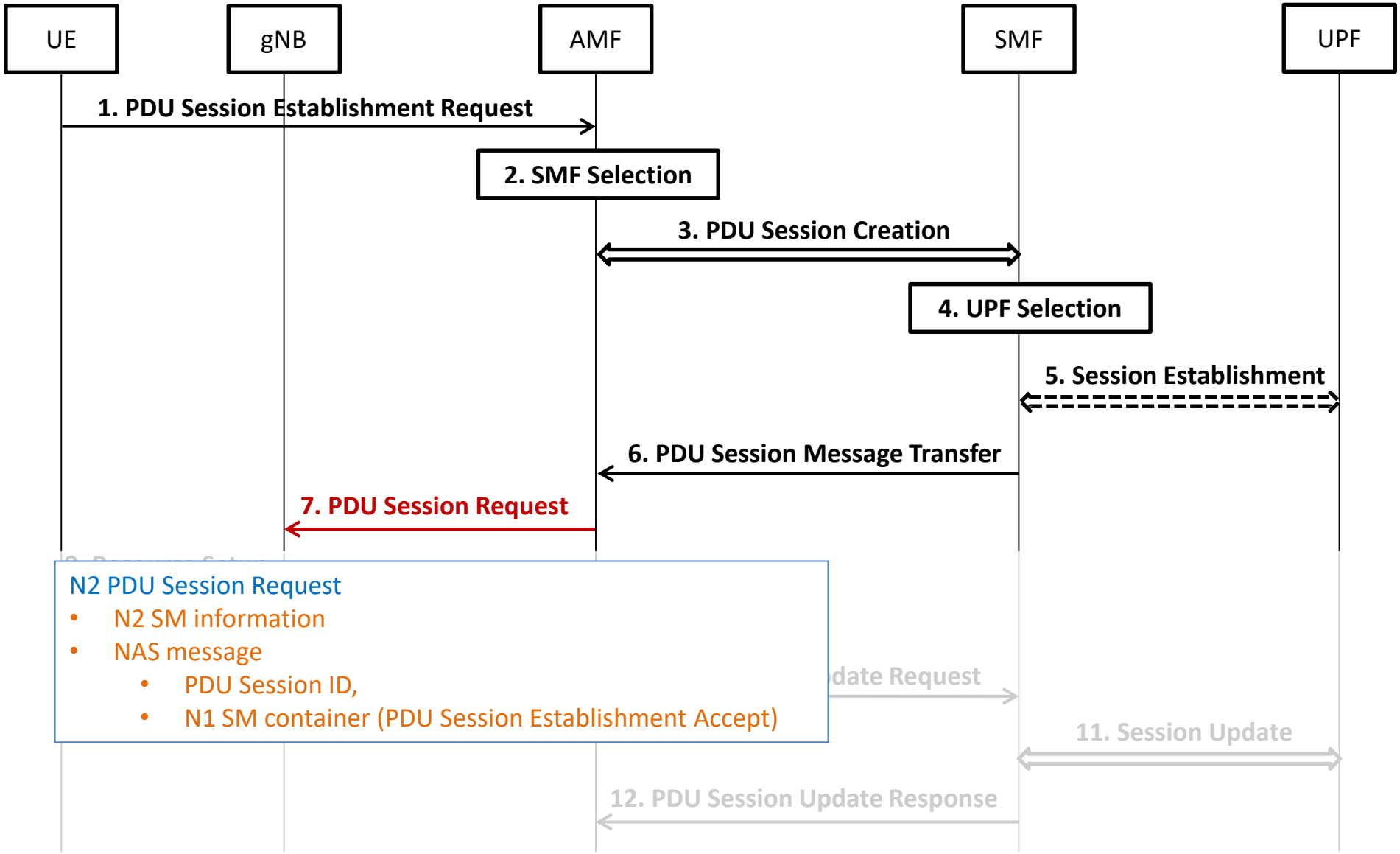


AMF Services
└ **Namf_Communication_N1N2MessageTransfer**

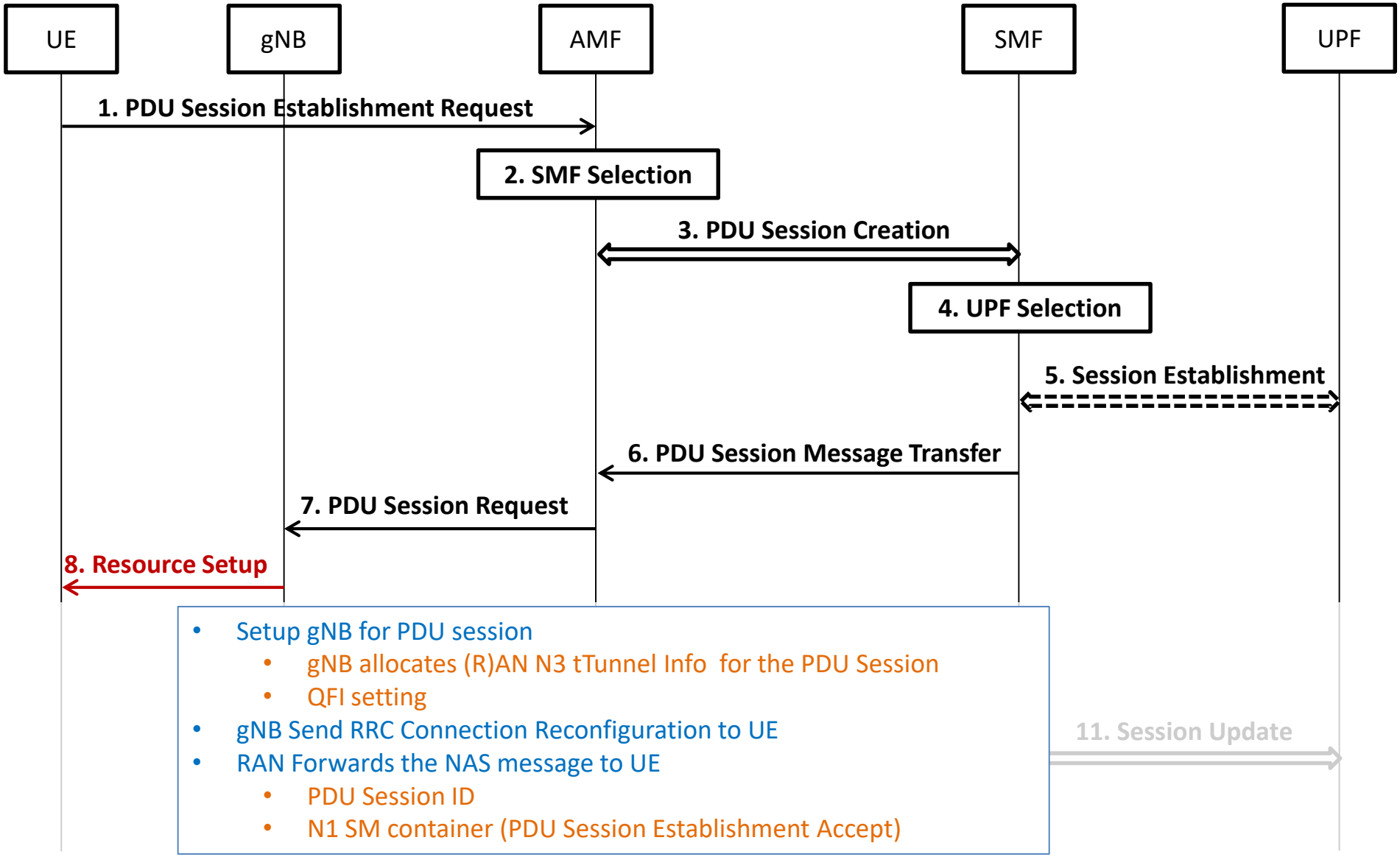
Inputs

- PDU Session ID
- N1 SM container (PDU Session Establishment Accept (QoS Rule(s) and QoS Flow level QoS parameters if needed for the QoS Flow(s) associated with the QoS rule(s), selected SSC mode, **S-NSSAI(s)**, DNN, allocated IPv4 address, interface identifier, Session-AMBR, selected PDU Session Type, Reflective QoS Timer (if available), P-CSCF address(es), [Always-on PDU Session]))
- N2 SM information (PDU Session ID, QFI(s), QoS Profile(s), CN Tunnel Info, **S-NSSAI from the Allowed NSSAI**, Session-AMBR, PDU Session Type, User Plane Security Enforcement information, UE Integrity Protection Maximum Data Rate)

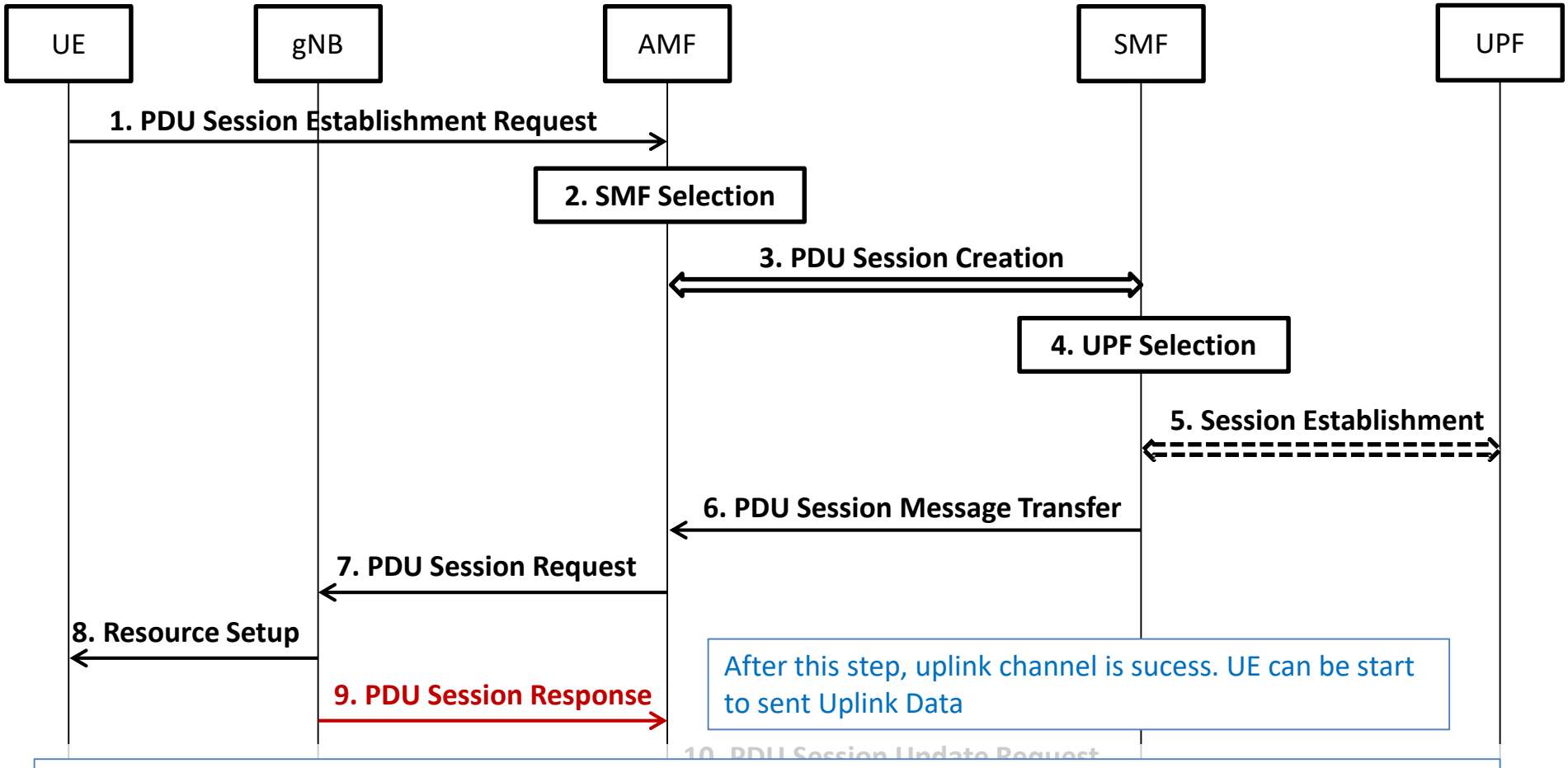
PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 7)



PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 8)

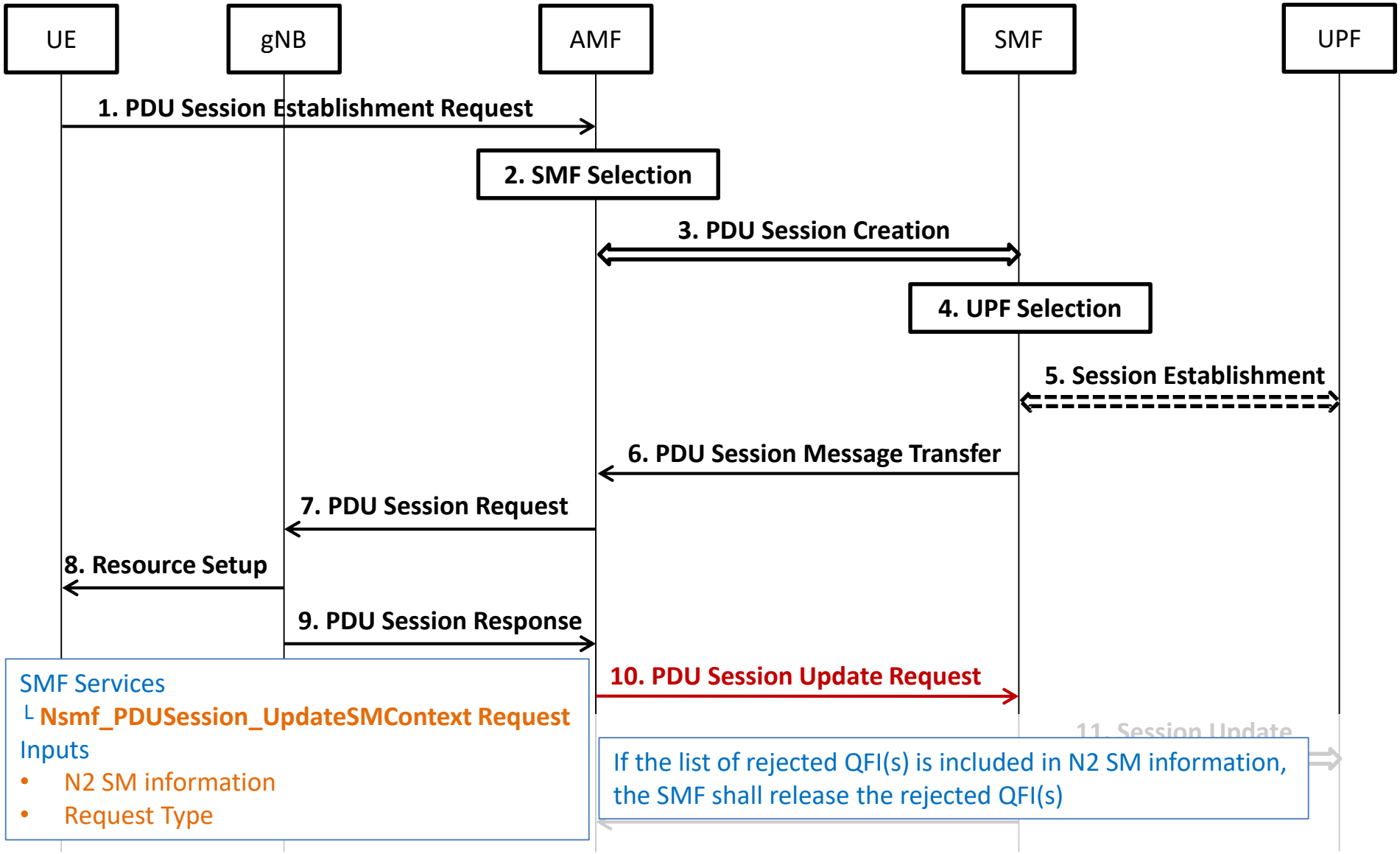


PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 9)

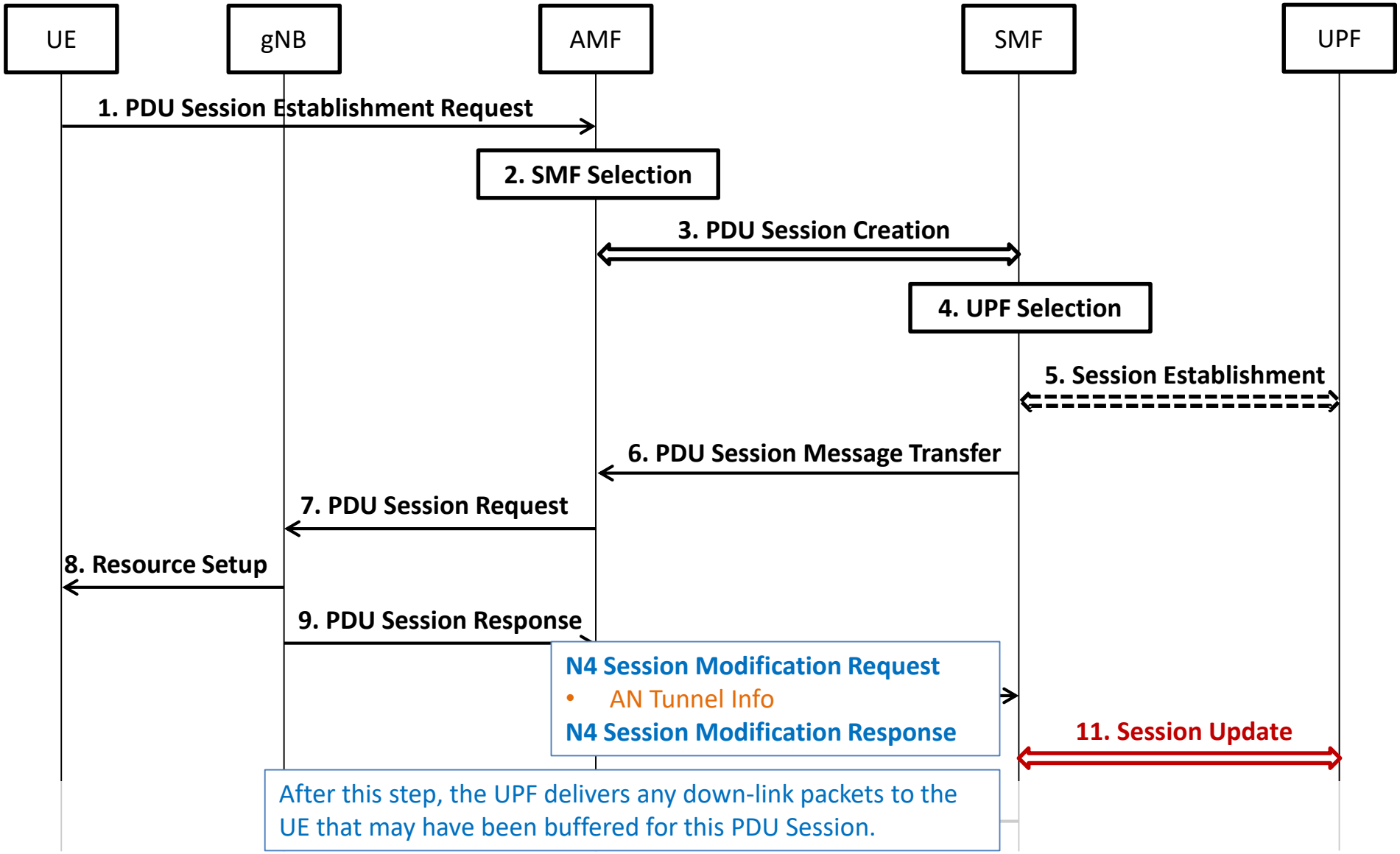


N2 PDU Session Response
- PDU Session ID
- Cause
- N2 SM information (PDU Session ID, AN Tunnel Info, List of accepted/rejected QFI(s), User Plane Enforcement Policy Notification)

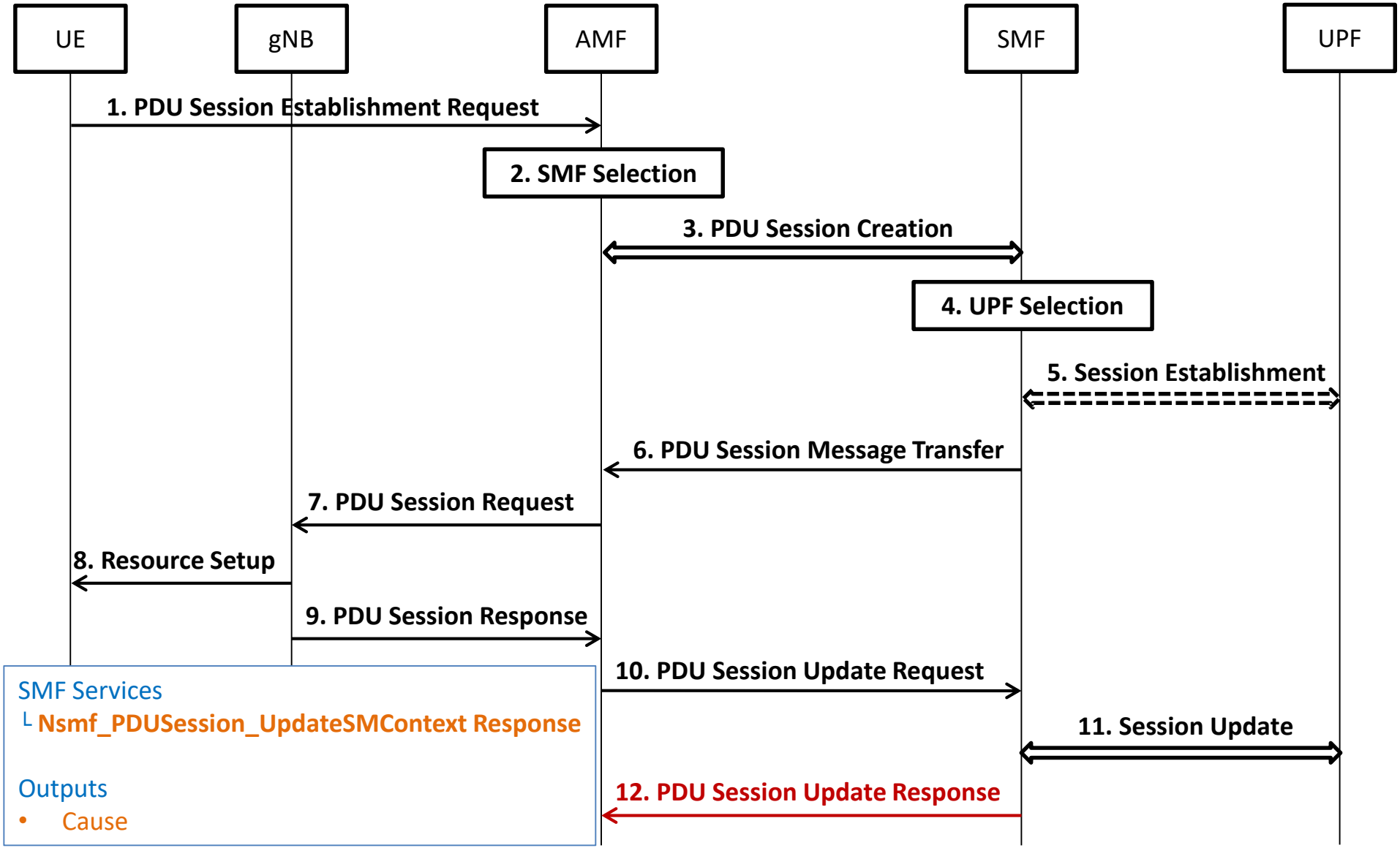
PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 10)



PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 11)

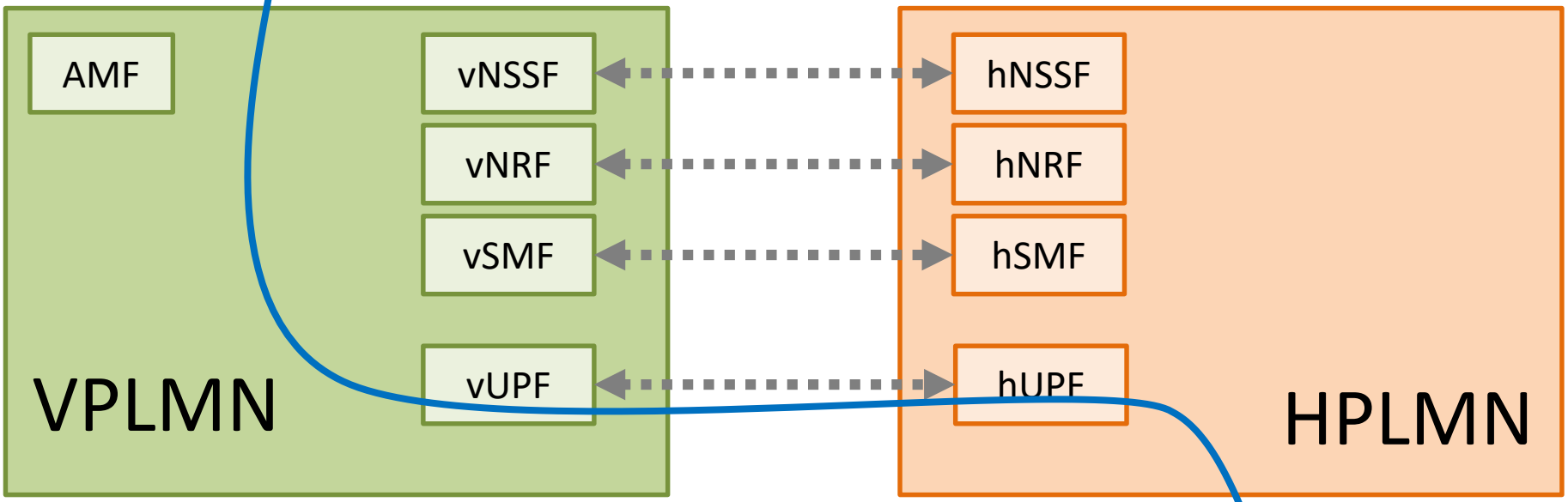


PDU session establishment
Non-roaming and Roaming with Local Breakout (Step 12)



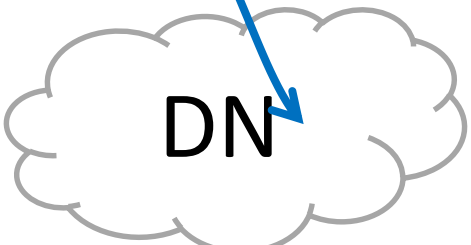
Home-routed Roaming

UE visited to VPLMN using
Home-routed Roaming

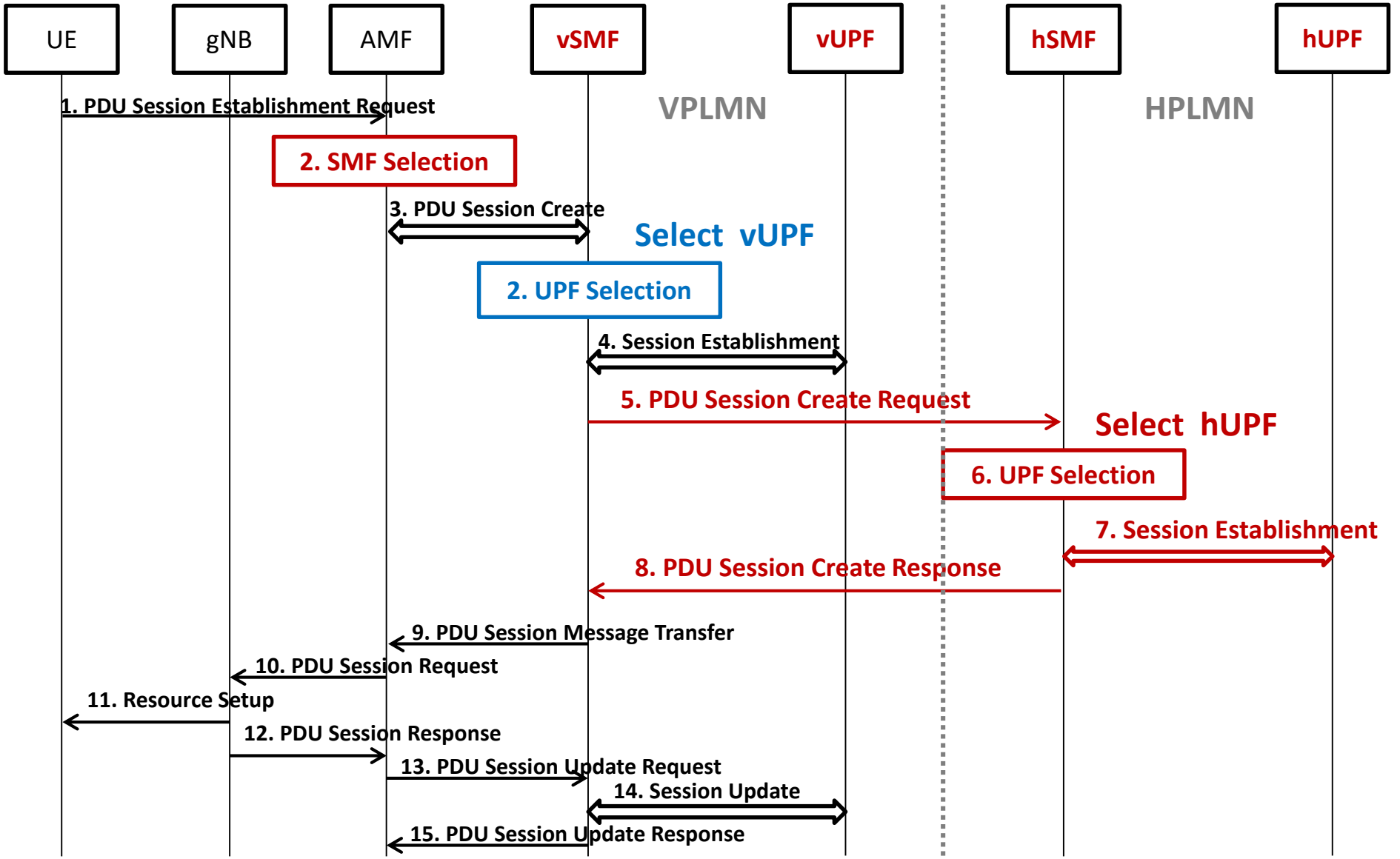


In Home-routed Roaming

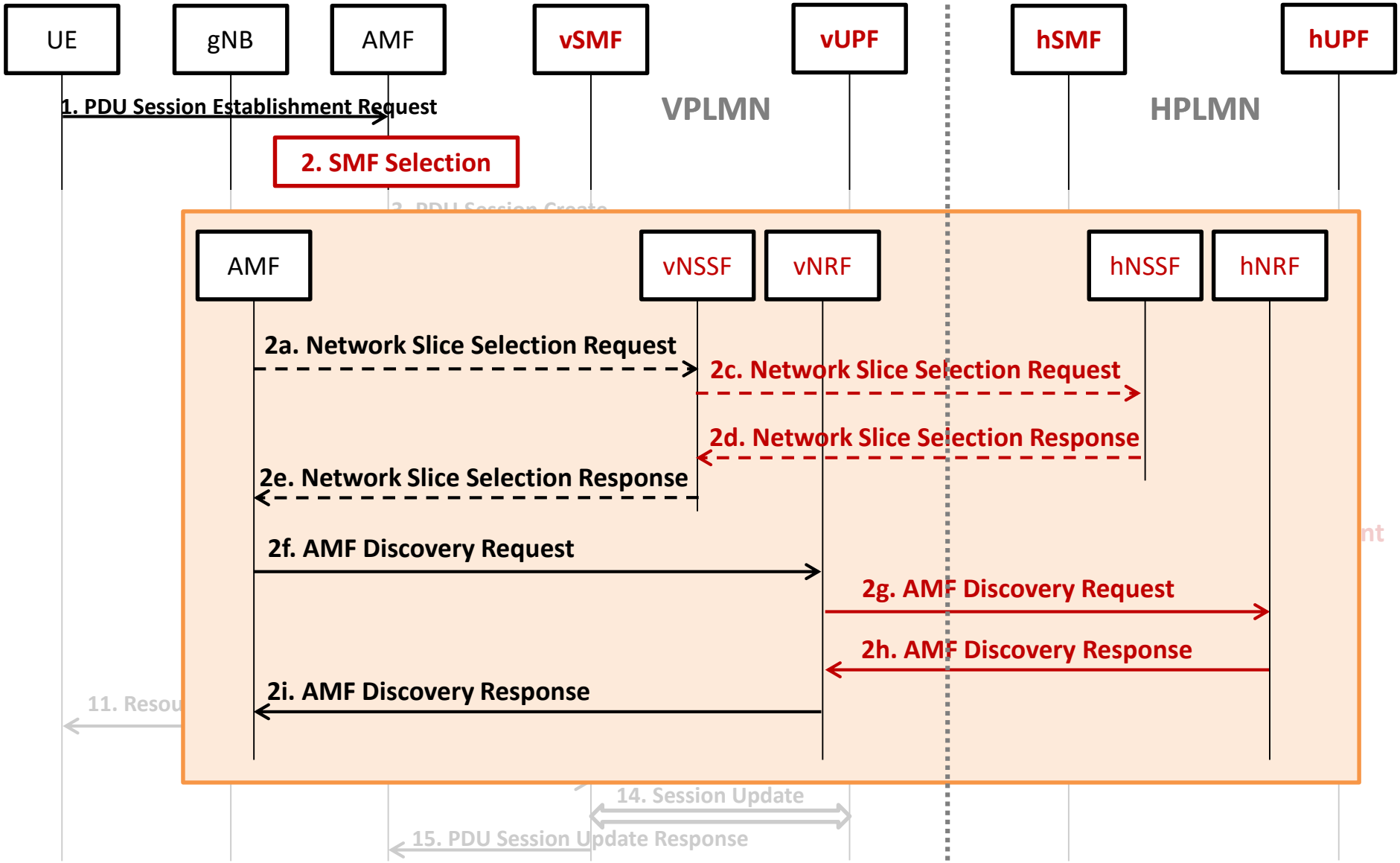
- Data Network connection to PLMN
- PDU session setup to HPLMN



PDU session establishment
Home-routed Roaming



PDU session establishment
Home-routed Roaming



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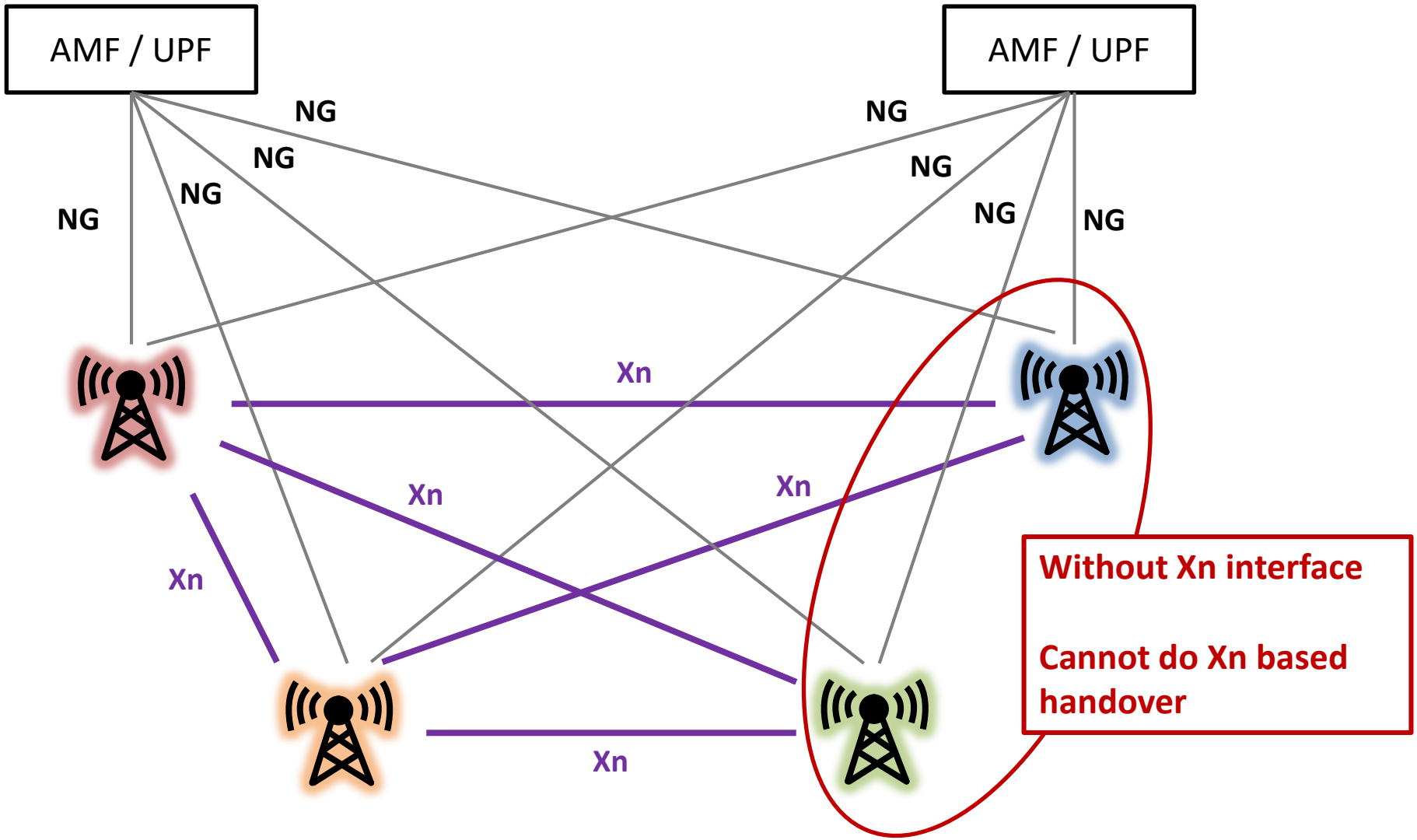
Network Slicing

Network Slicing Handover

Xn based inter NG-RAN handover



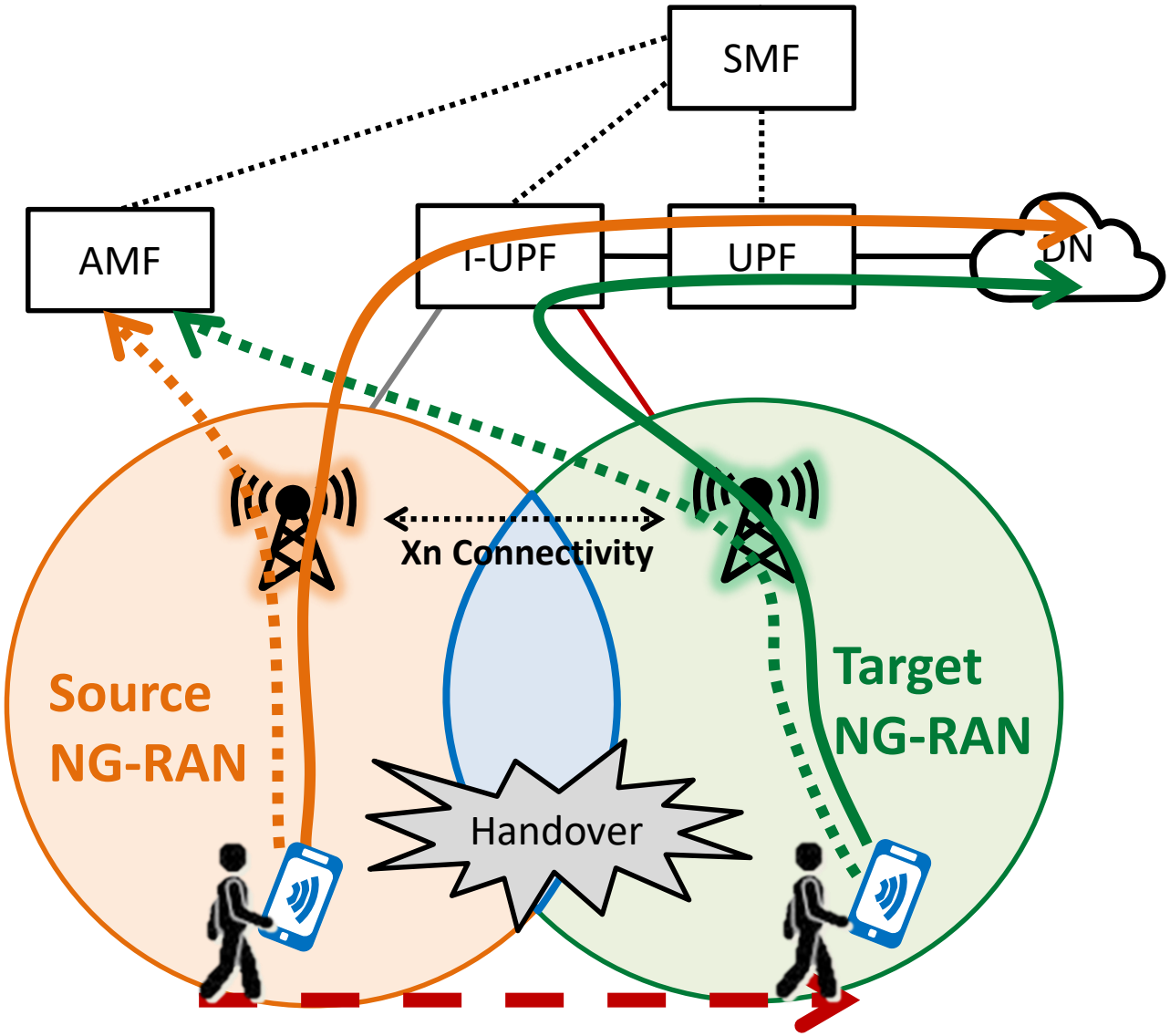
Xn based inter NG-RAN handover Without UPF re-allocation

Hand over a UE from a source NG-RAN to target NG-RAN

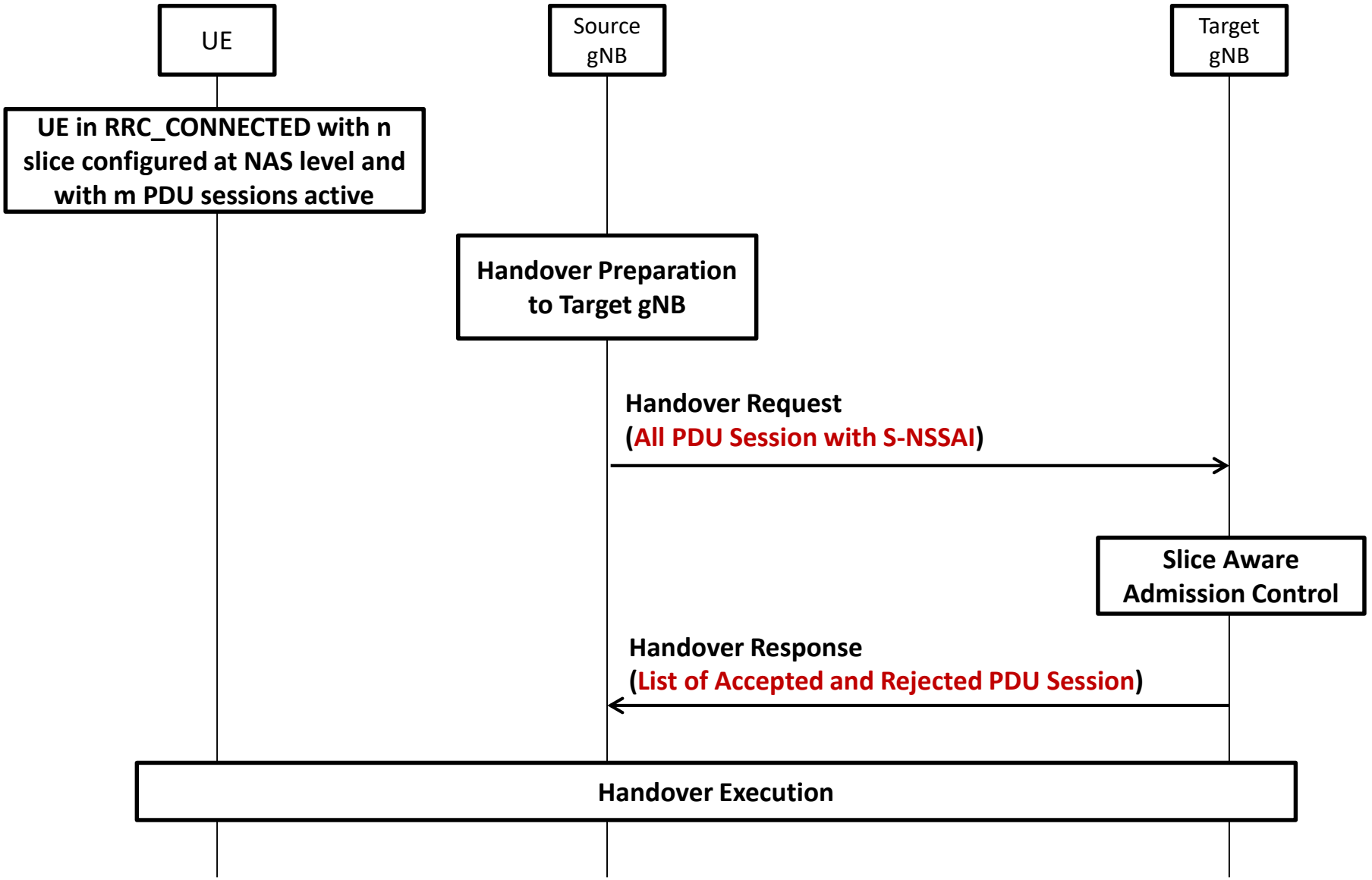
Source NG-RAN have Xn connectivity to the target NG-RAN

AMF is unchanged

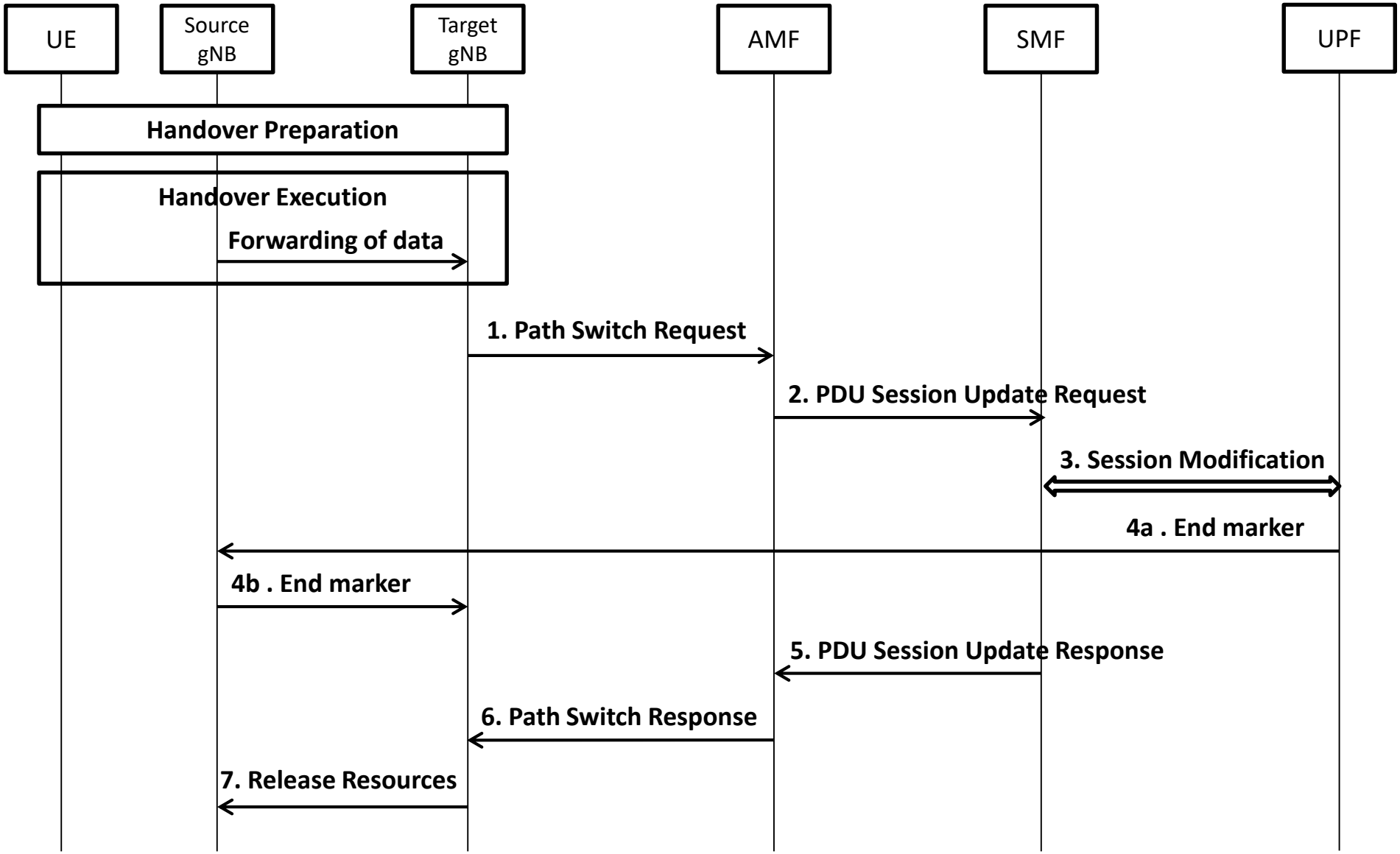
SMF decides to keep the existing UPF and I-UPF



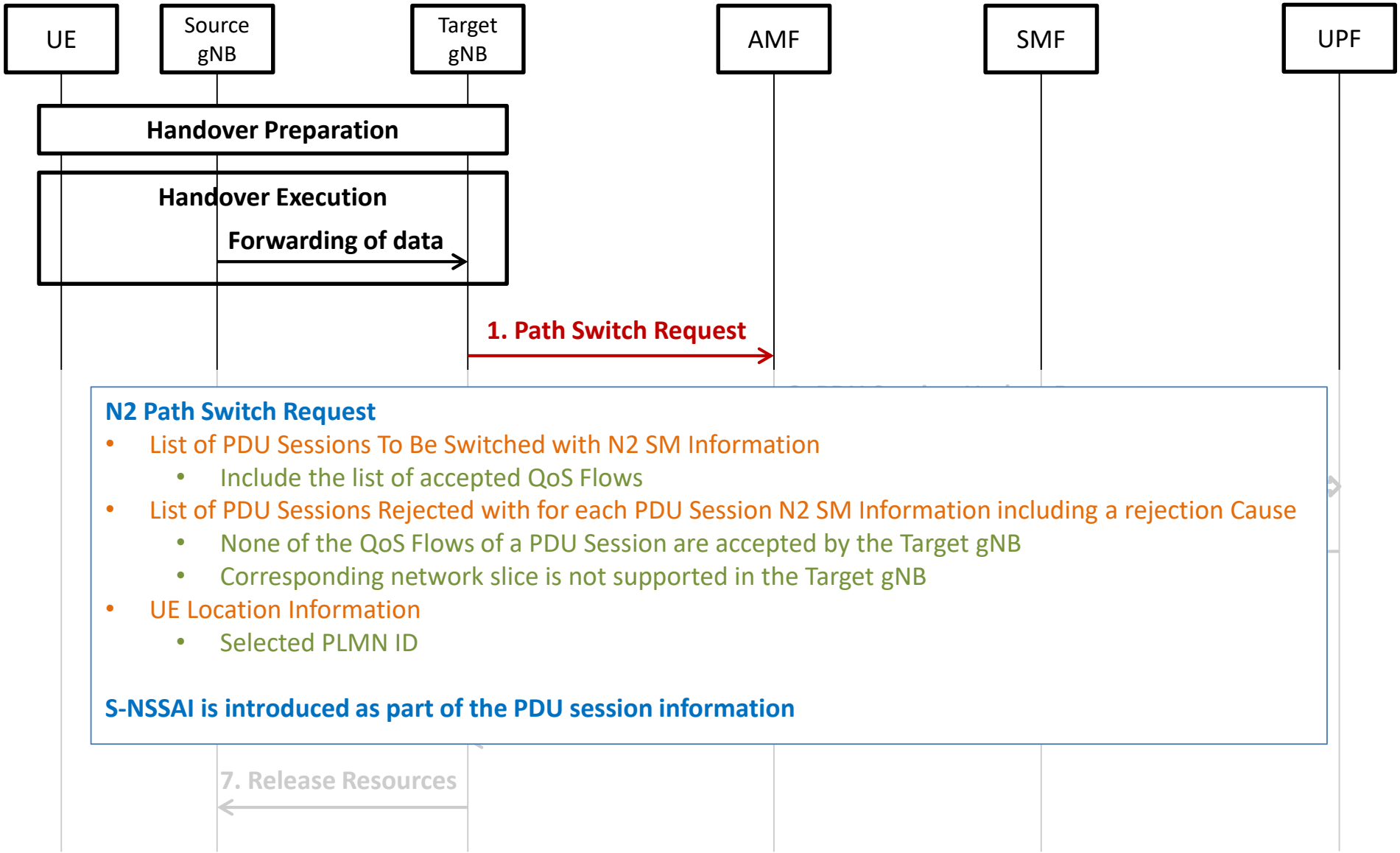
Xn based inter NG-RAN handover Preparation and Execution between gNB



Xn based inter NG-RAN handover
Without UPF re-allocation



Xn based inter NG-RAN handover Without UPF re-allocation (Step 1)

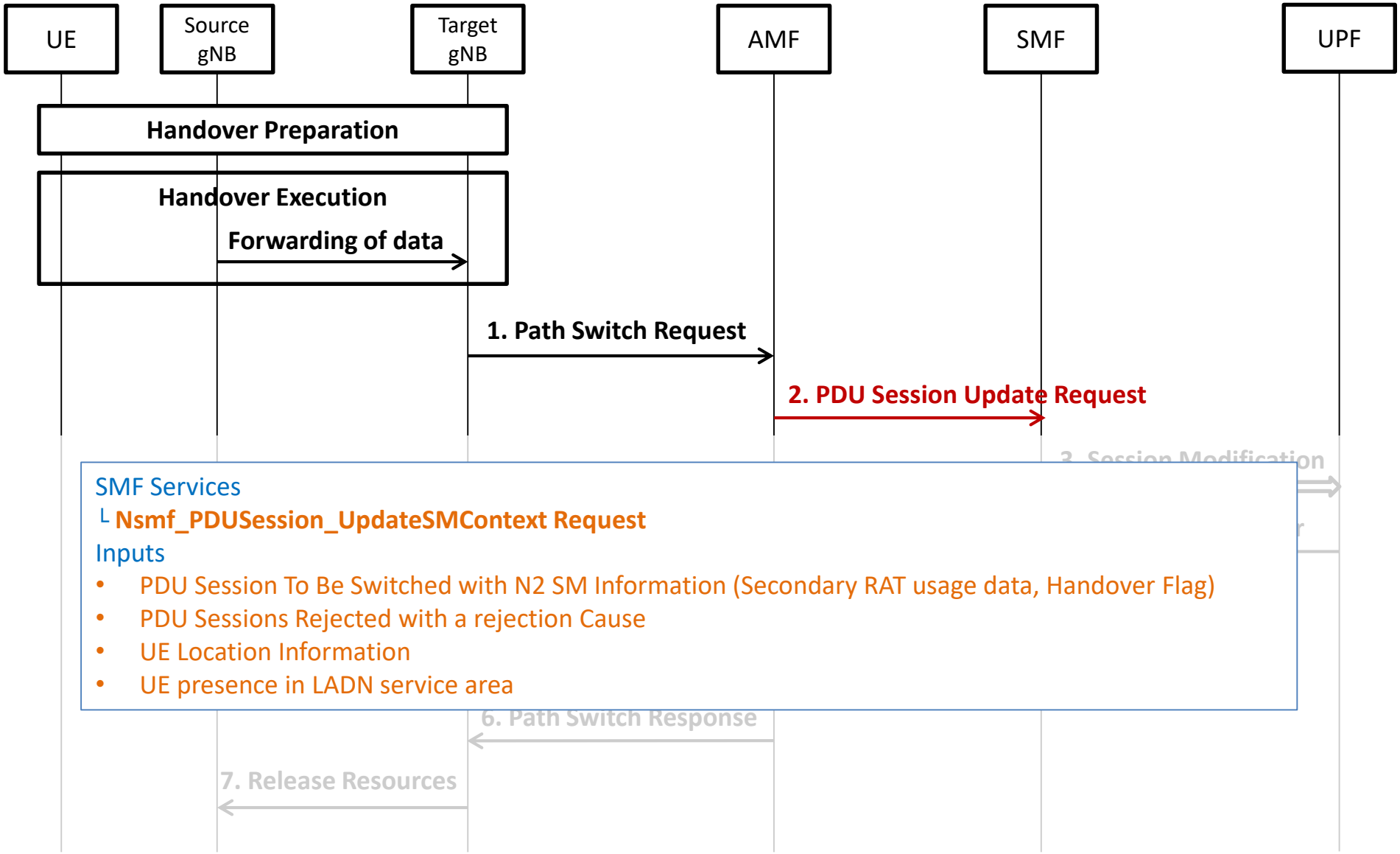


N2 Path Switch Request

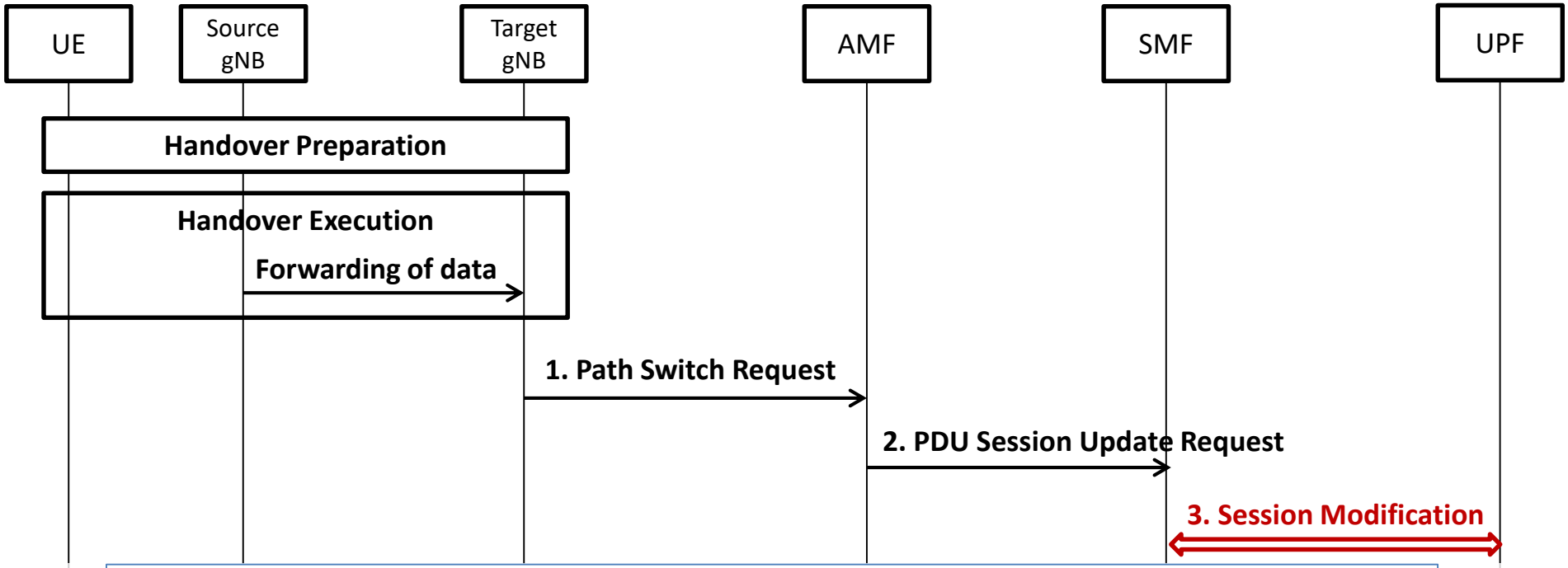
- List of PDU Sessions To Be Switched with N2 SM Information
  - Include the list of accepted QoS Flows
- List of PDU Sessions Rejected with for each PDU Session N2 SM Information including a rejection Cause
  - None of the QoS Flows of a PDU Session are accepted by the Target gNB
  - Corresponding network slice is not supported in the Target gNB
- UE Location Information
  - Selected PLMN ID

S-NSSAI is introduced as part of the PDU session information

Xn based inter NG-RAN handover Without UPF re-allocation (Step 2)



Xn based inter NG-RAN handover Without UPF re-allocation (Step 3)



Modify N3 tunnel (gNB <-> UPF)

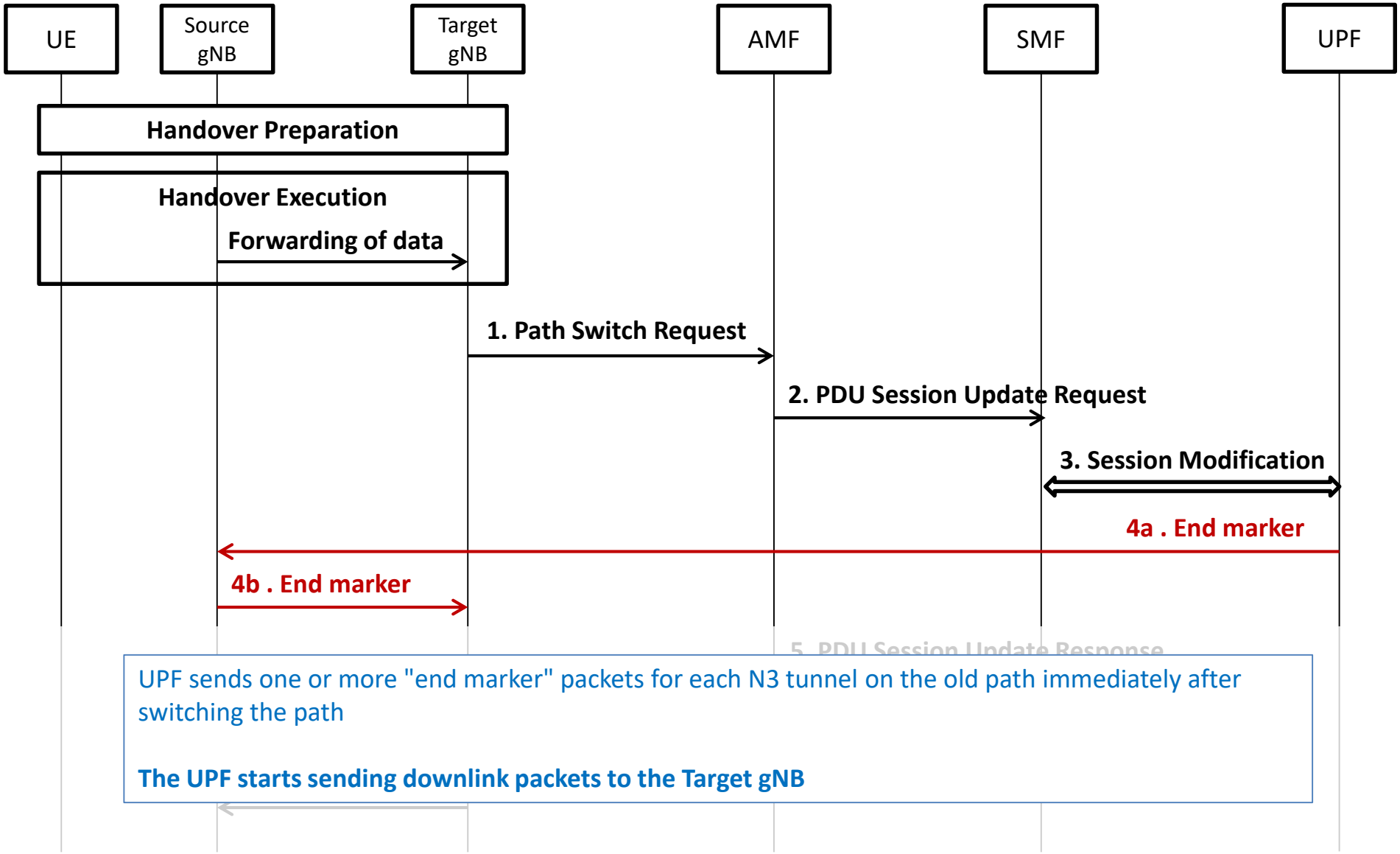
N4 Session Modification Request

- AN Tunnel Info
- CN Tunnel Info
  - UPF used for connection to Target gNB and connection to Source gNB
  - CN Tunnel Info (on N3) of UPF need be re-allocated

N4 Session Modification Response

- CN Tunnel Info
  - N3 (R)AN tunnel information is released

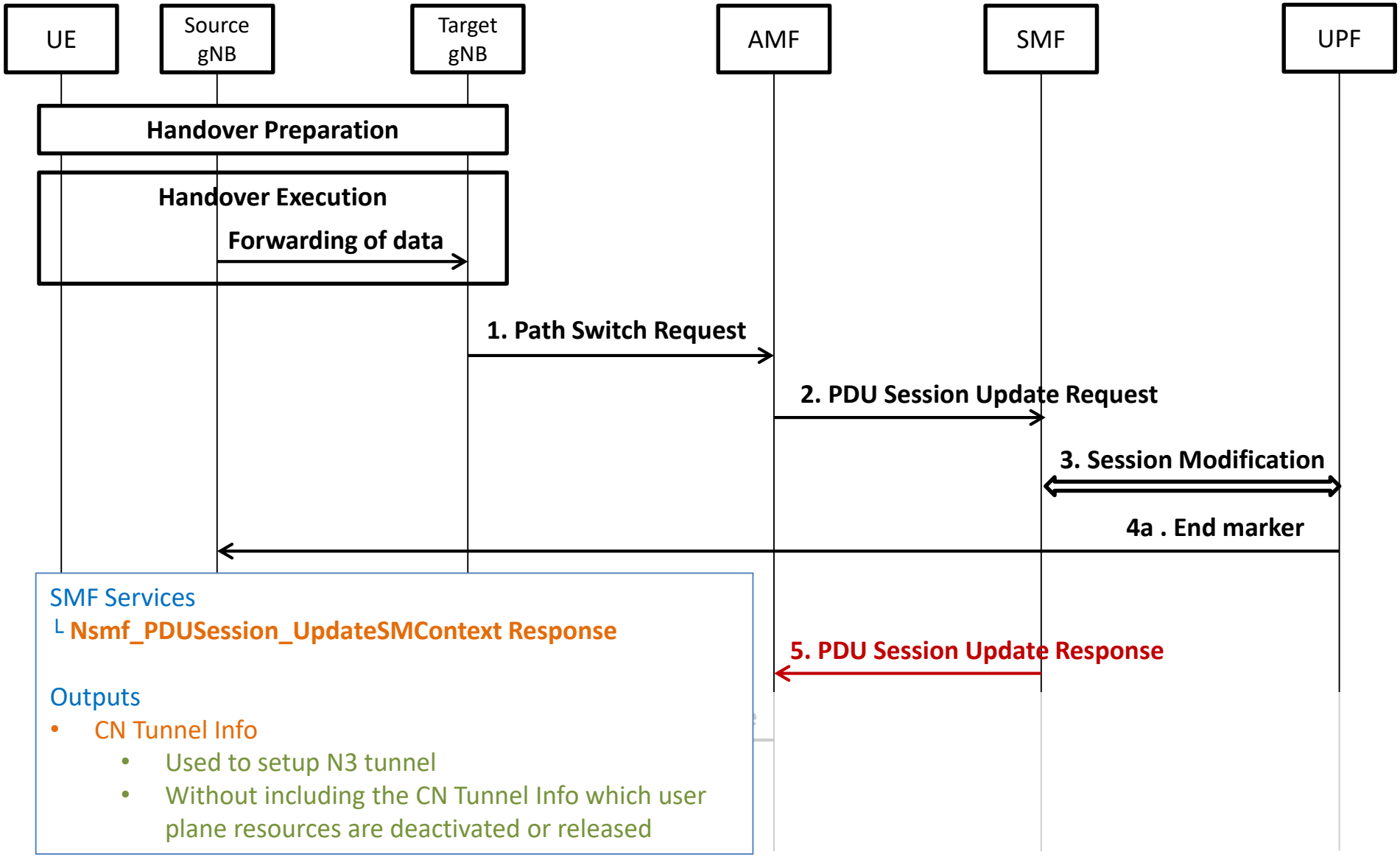
Xn based inter NG-RAN handover Without UPF re-allocation (Step 4)



UPF sends one or more "end marker" packets for each N3 tunnel on the old path immediately after switching the path

The UPF starts sending downlink packets to the Target gNB

Xn based inter NG-RAN handover Without UPF re-allocation (Step 5)



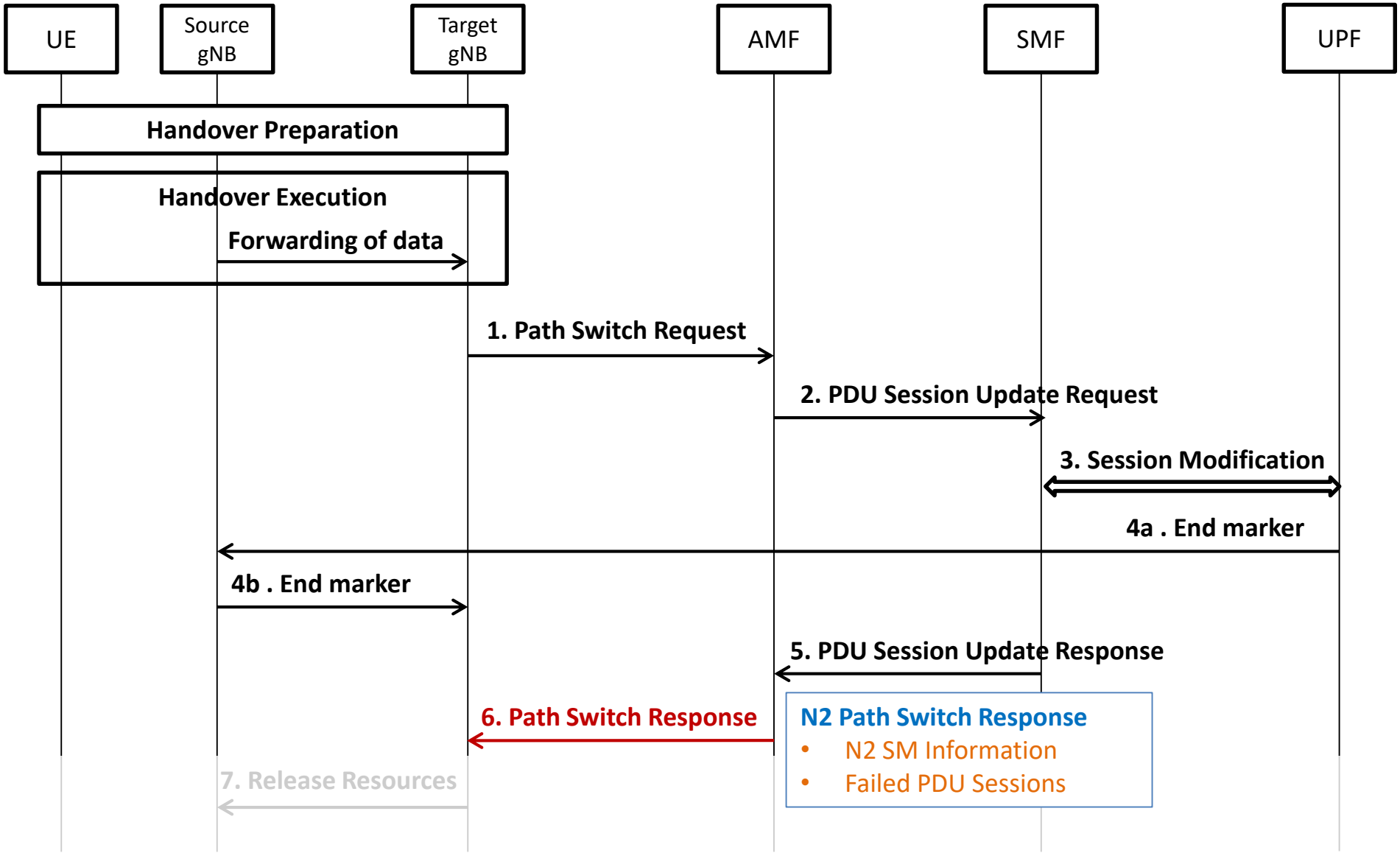
SMF Services

└ **Nsmf_PDUSession_UpdateSMContext Response**

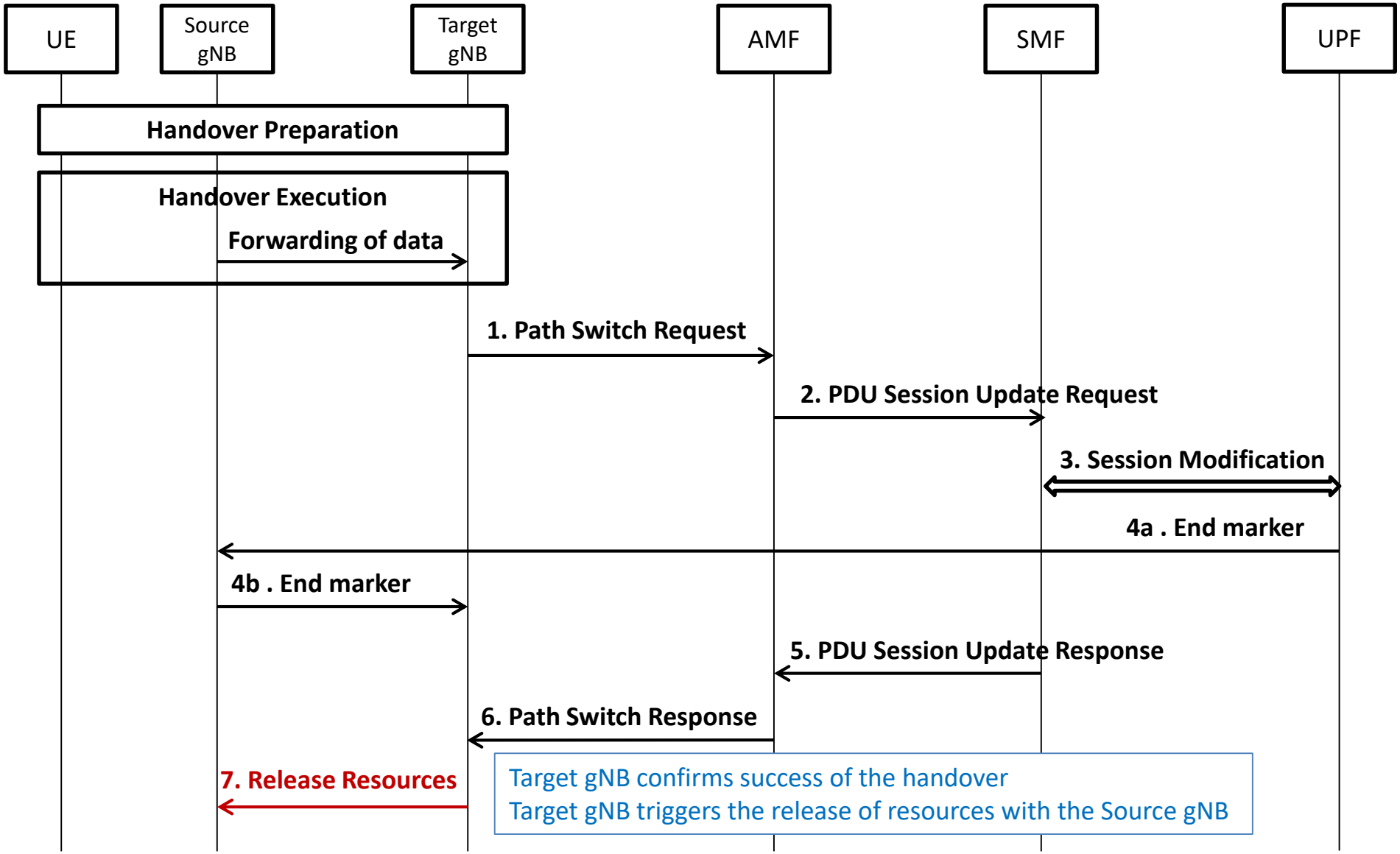
Outputs

- CN Tunnel Info
  - Used to setup N3 tunnel
  - Without including the CN Tunnel Info which user plane resources are deactivated or released

Xn based inter NG-RAN handover Without UPF re-allocation (Step 6)



Xn based inter NG-RAN handover Without UPF re-allocation (Step 7)



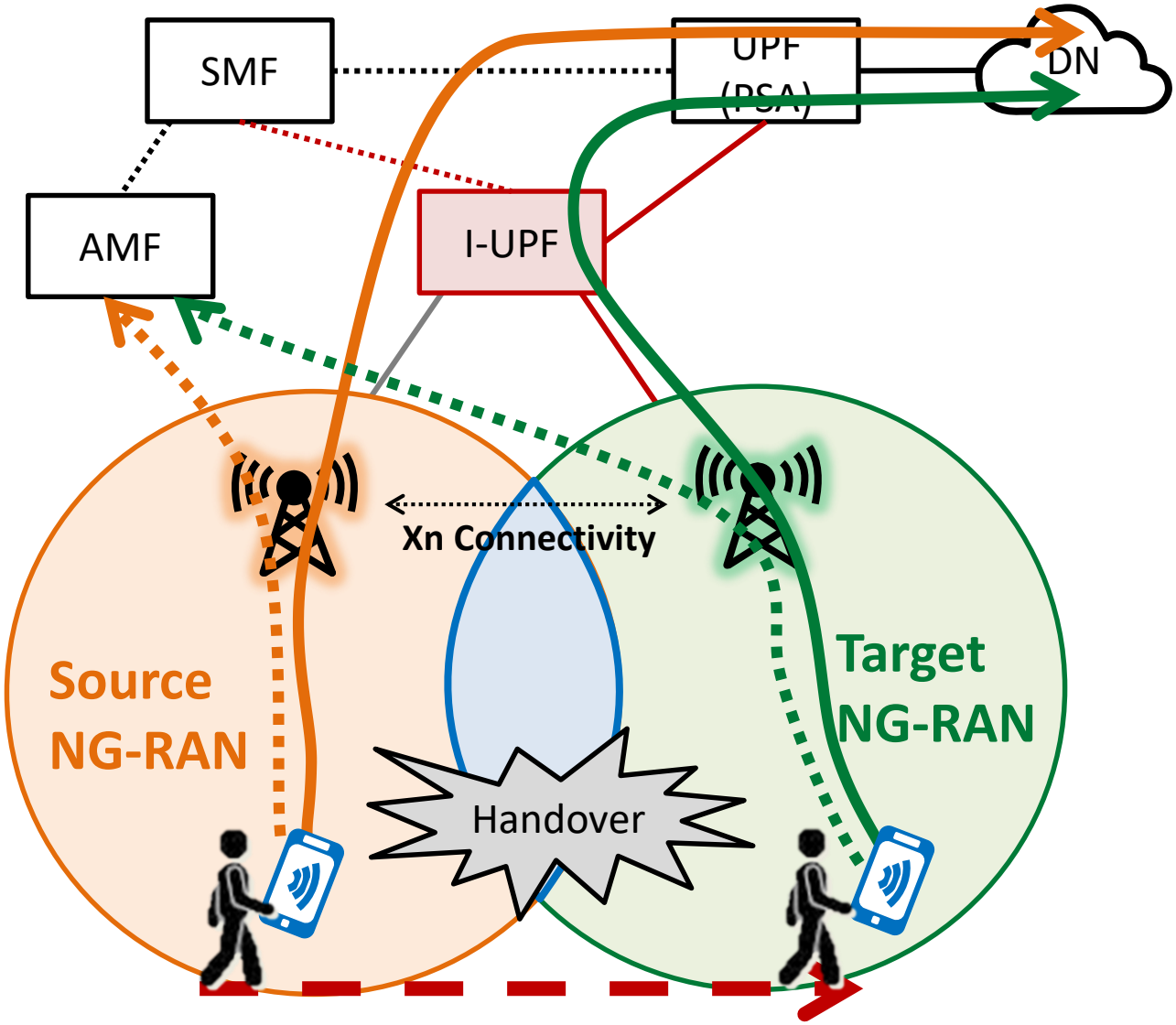
Xn based inter NG-RAN handover
With insertion of intermediate UPF

Hand over a UE from a source NG-RAN to target NG-RAN

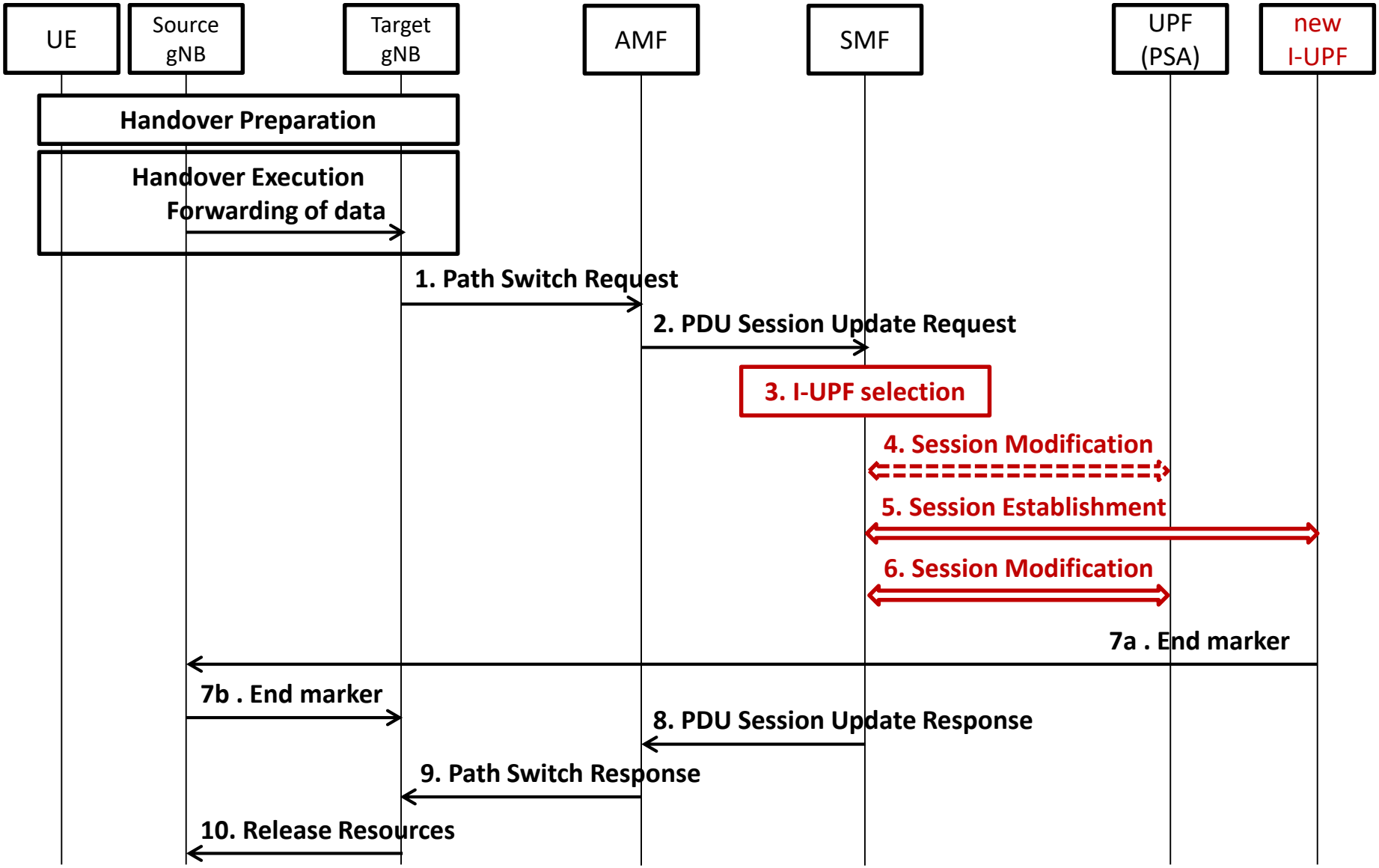
Source NG-RAN have Xn connectivity to the target NG-RAN

AMF is unchanged

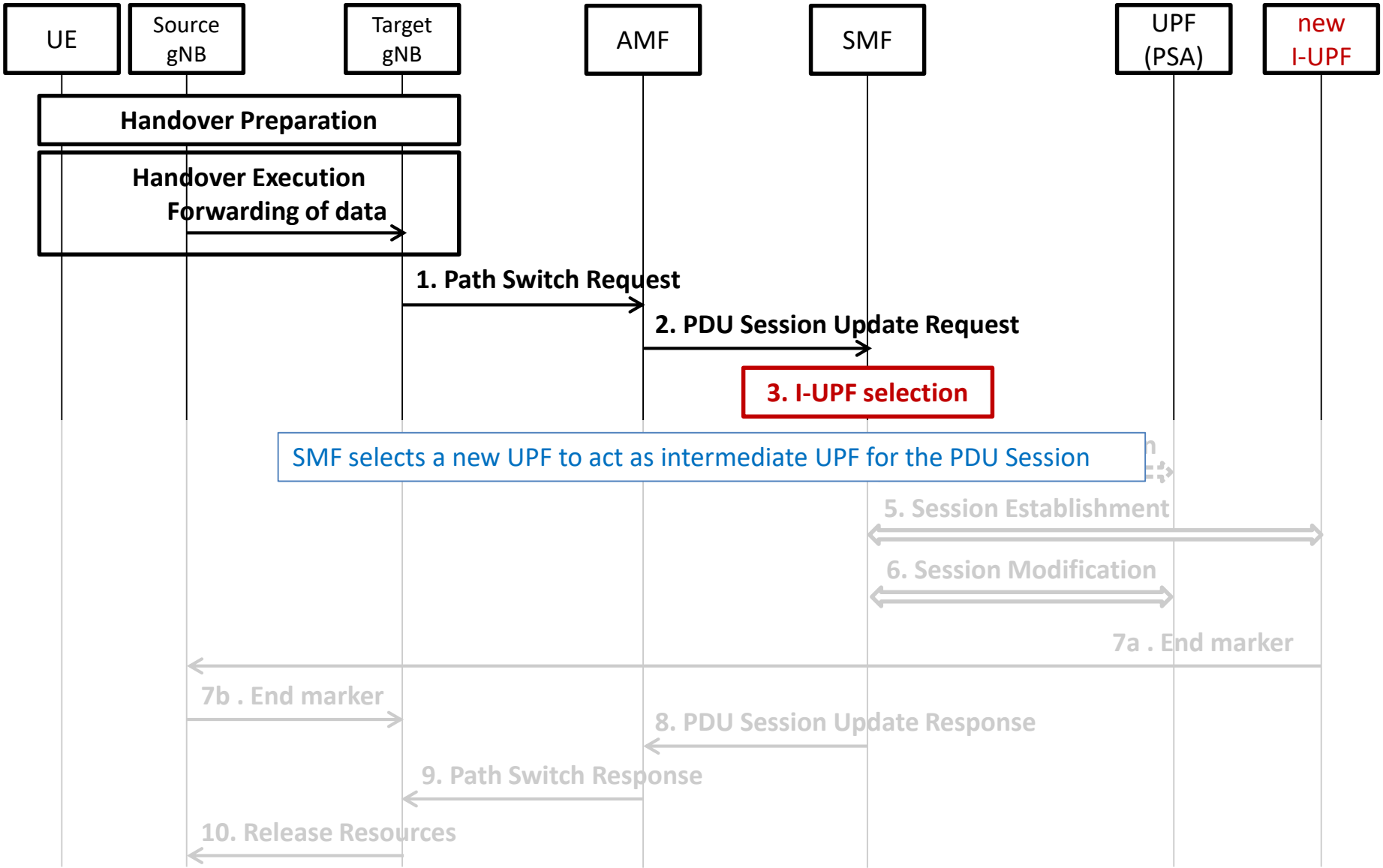
SMF decides that insertion of a new additional I-UPF is needed



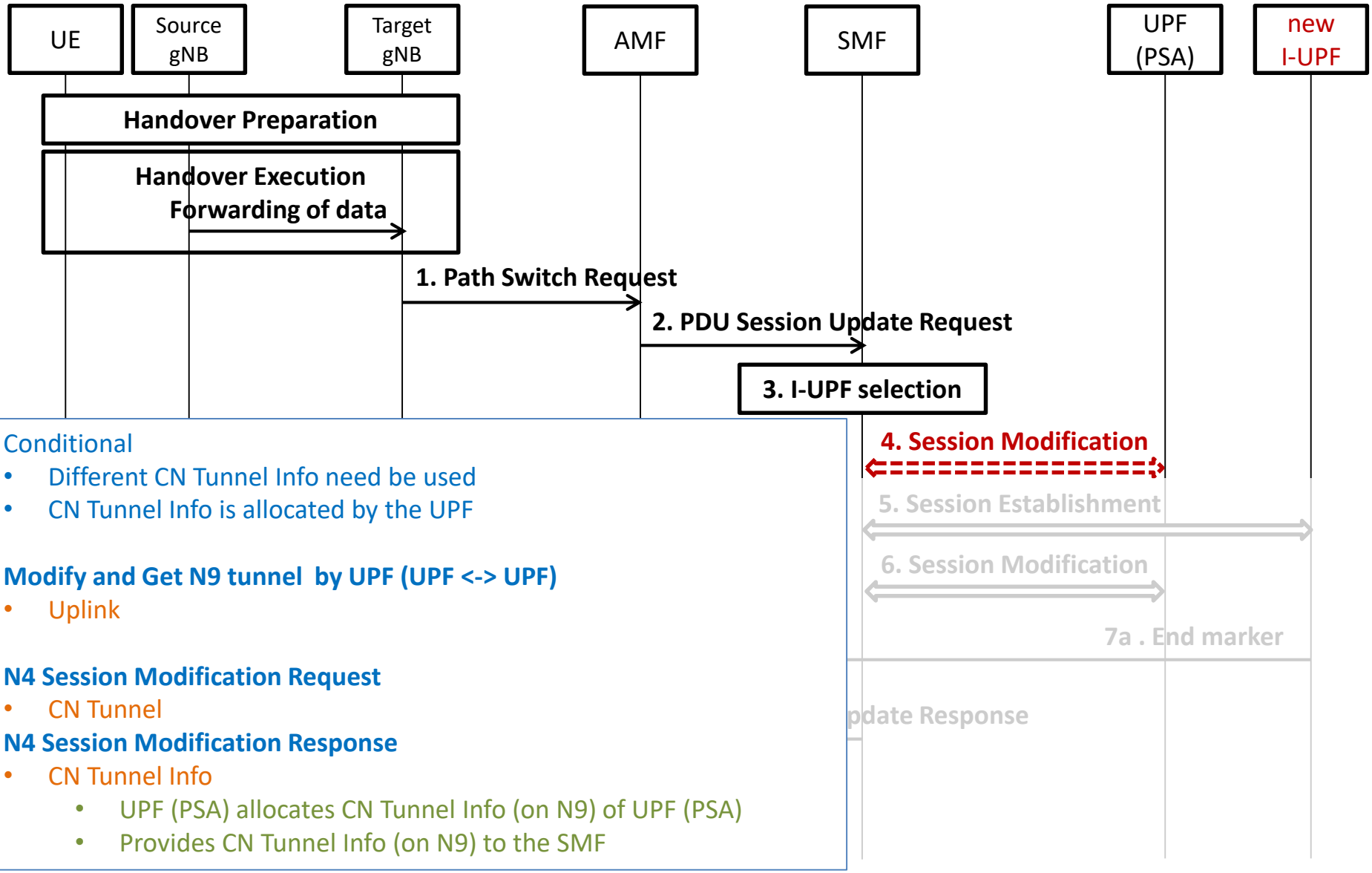
Xn based inter NG-RAN handover
With insertion of intermediate UPF



Xn based inter NG-RAN handover
With insertion of intermediate UPF (Step 3)



Xn based inter NG-RAN handover
With insertion of intermediate UPF (Step 4)



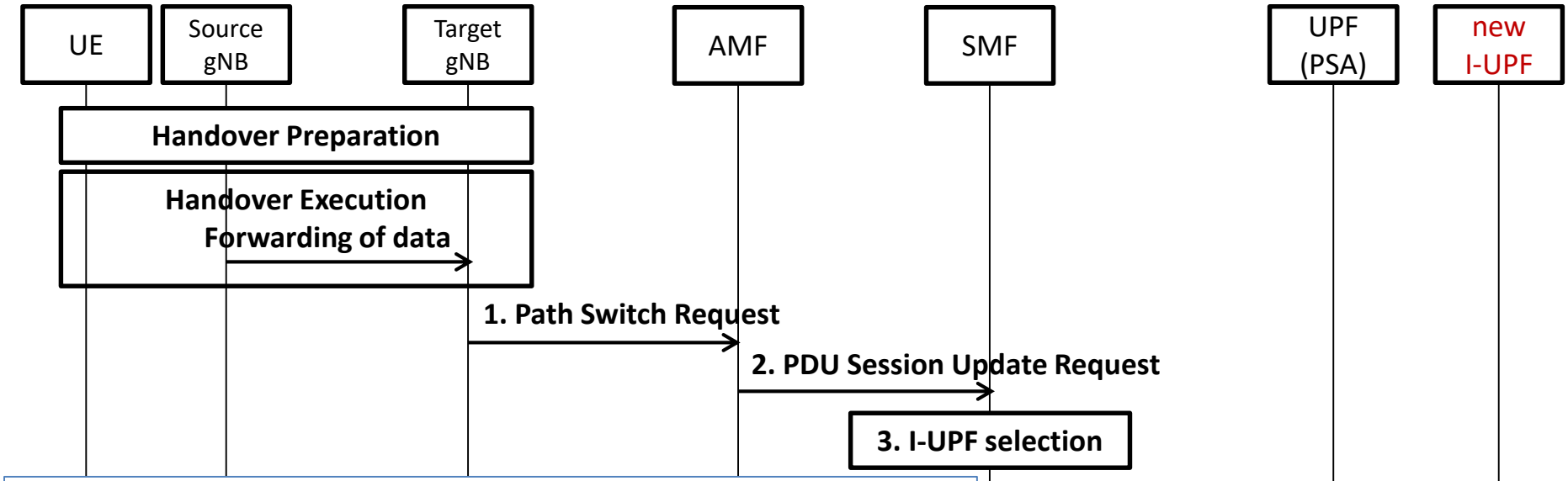
Conditional
- Different CN Tunnel Info need be used
- CN Tunnel Info is allocated by the UPF

Modify and Get N9 tunnel by UPF (UPF <-> UPF)
- Uplink

N4 Session Modification Request
- CN Tunnel

N4 Session Modification Response
- CN Tunnel Info
  - UPF (PSA) allocates CN Tunnel Info (on N9) of UPF (PSA)
  - Provides CN Tunnel Info (on N9) to the SMF

Xn based inter NG-RAN handover
With insertion of intermediate UPF (Step 5)



Establish N9 tunnel by UPF(UPF <-> UPF)

- Uplink and Downlink

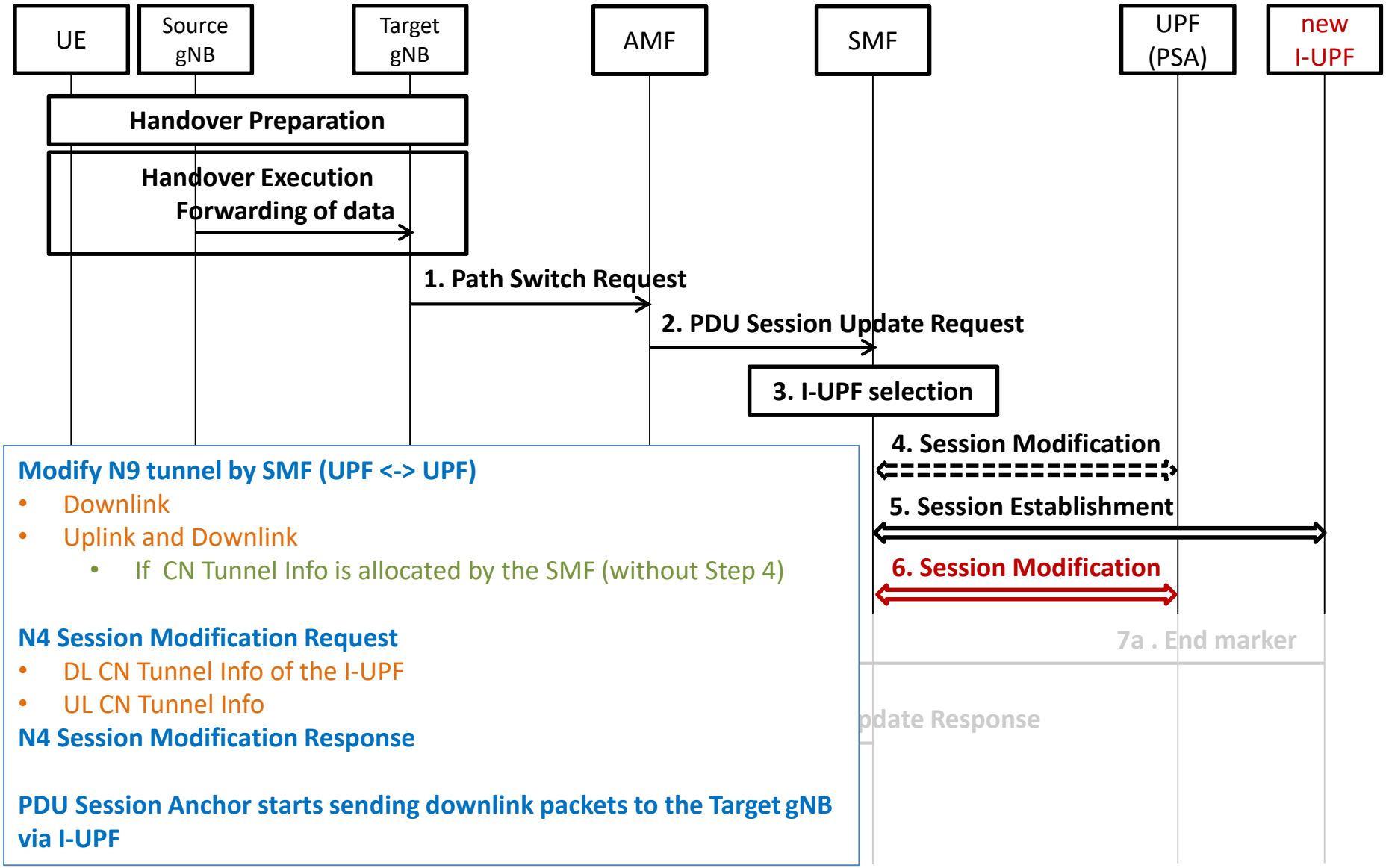
N4 Session Establishment Request

- Target gNB Tunnel Info
- CN Tunnel Info of the PDU Session Anchor (PSA)
  - Used to setup N9 tunnel
  - If the CN Tunnel Info of the I-UPF is allocated by the SMF, provides the UL and DL CN Tunnel Info of I-UPF to the I-UPF

N4 Session Establishment Response

- CN Tunnel
  - If the CN Tunnel Info of the I-UPF is allocated by the UPF, the UL and DL CN Tunnel Info of I-UPF is sent to the SMF

Xn based inter NG-RAN handover
With insertion of intermediate UPF (Step 6)



Modify N9 tunnel by SMF (UPF <-> UPF)

- Downlink
- Uplink and Downlink
  - If CN Tunnel Info is allocated by the SMF (without Step 4)

N4 Session Modification Request

- DL CN Tunnel Info of the I-UPF
- UL CN Tunnel Info

N4 Session Modification Response

PDU Session Anchor starts sending downlink packets to the Target gNB via I-UPF

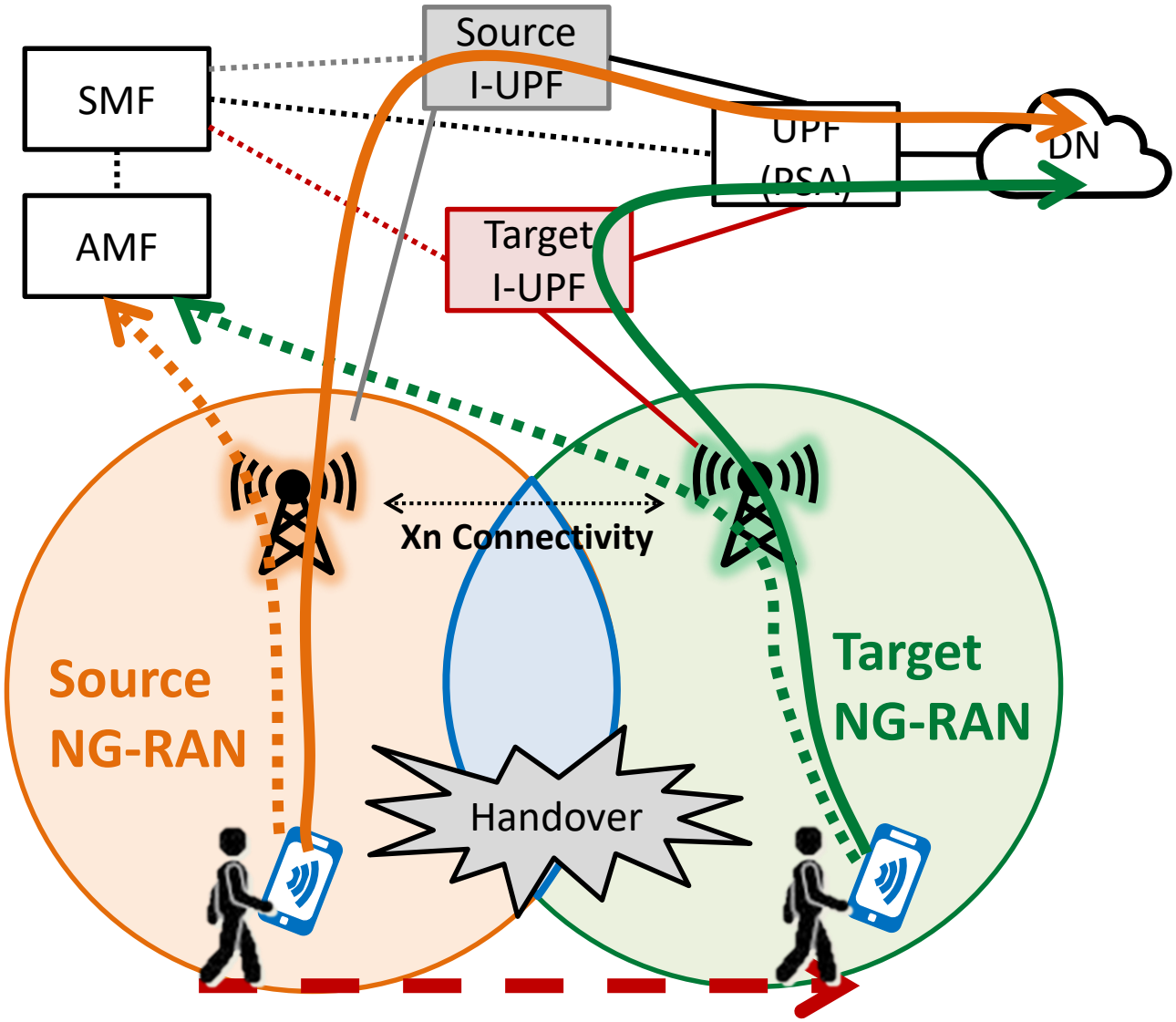
Xn based inter NG-RAN handover
With re-allocation of intermediate UPF

Hand over a UE from a source NG-RAN to target NG-RAN

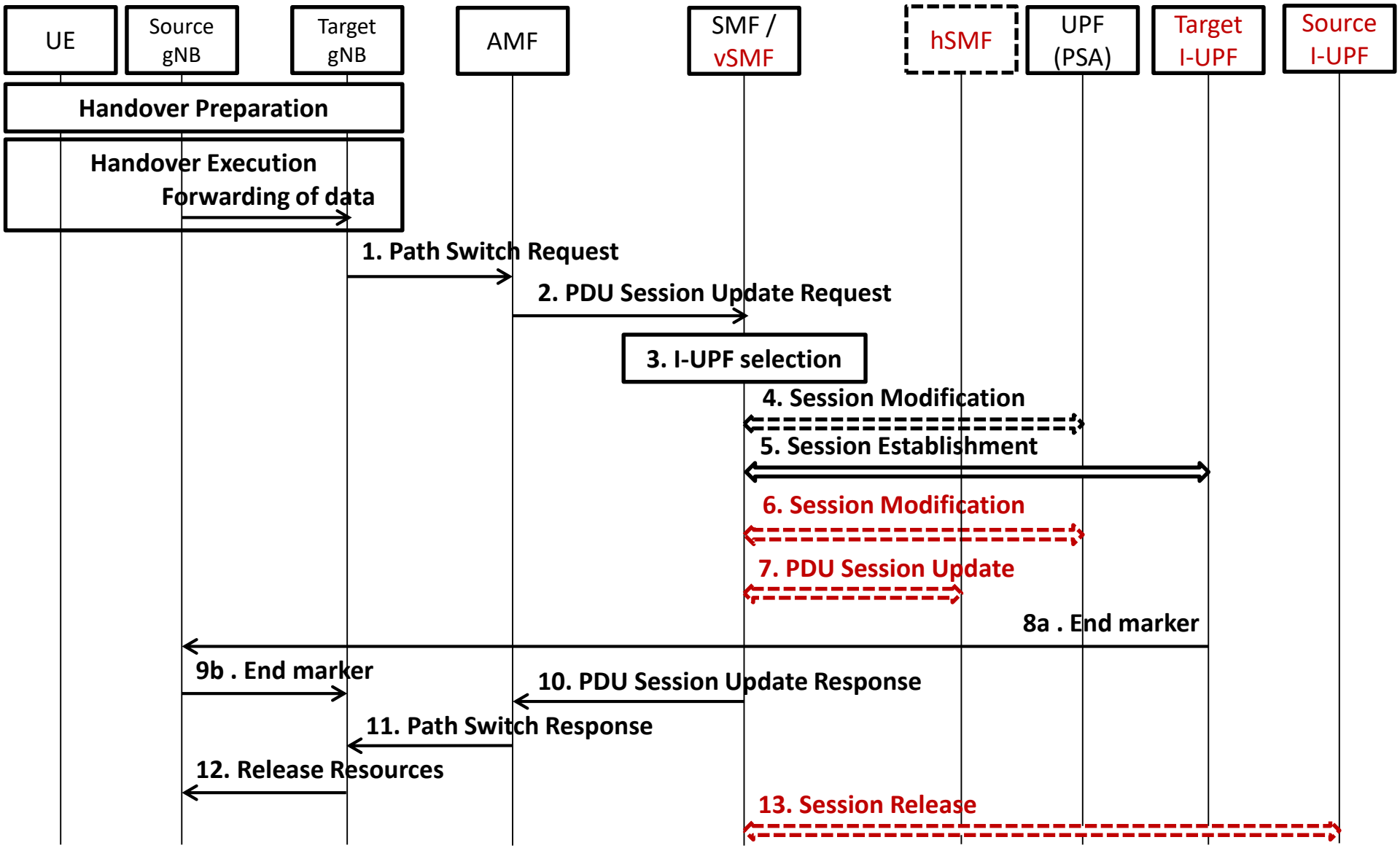
Source NG-RAN have Xn connectivity to the target NG-RAN

AMF is unchanged

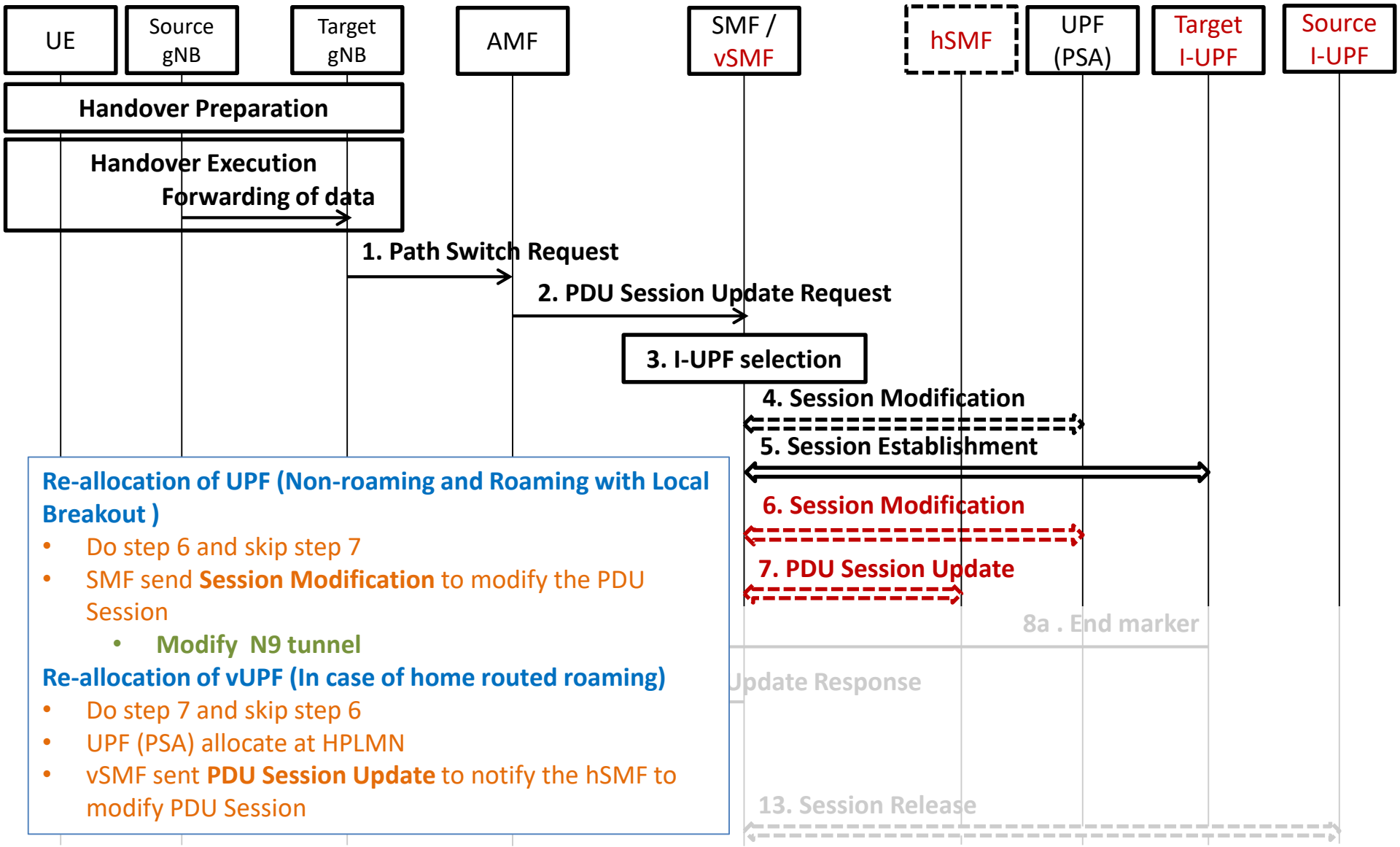
SMF decides that the I-UPF is to be changed



Xn based inter NG-RAN handover
With re-allocation of intermediate UPF



Xn based inter NG-RAN handover
With re-allocation of intermediate UPF (Step 6, 7)



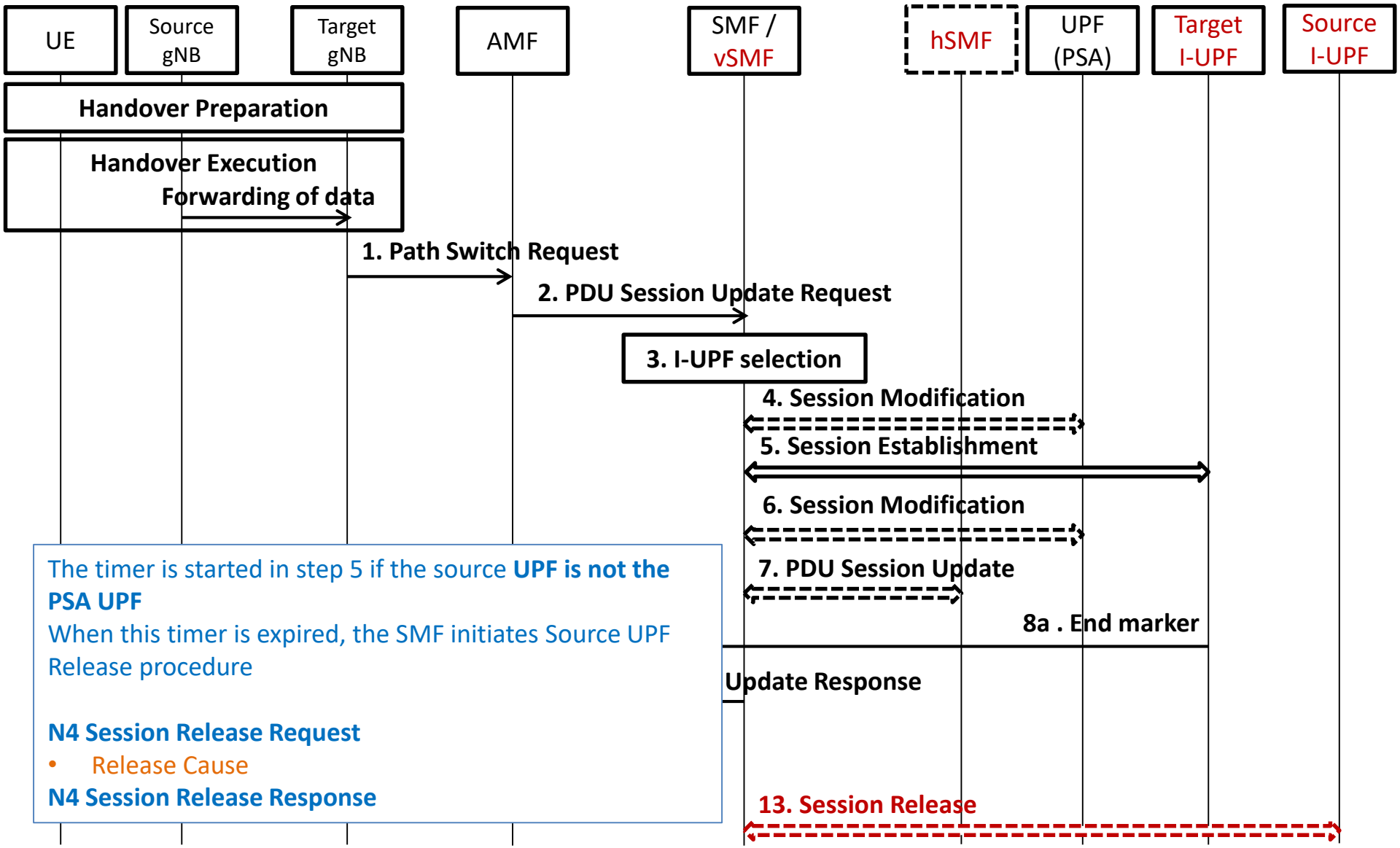
Re-allocation of UPF (Non-roaming and Roaming with Local Breakout)

- Do step 6 and skip step 7
- SMF send **Session Modification** to modify the PDU Session
  - **Modify N9 tunnel**

Re-allocation of vUPF (In case of home routed roaming)

- Do step 7 and skip step 6
- UPF (PSA) allocate at HPLMN
- vSMF sent **PDU Session Update** to notify the hSMF to modify PDU Session

Xn based inter NG-RAN handover
With re-allocation of intermediate UPF (Step 13)



The timer is started in step 5 if the source **UPF is not the PSA UPF**
When this timer is expired, the SMF initiates Source UPF Release procedure

N4 Session Release Request
- Release Cause

N4 Session Release Response

Inter NG-RAN node N2 based handover

New radio conditions or load balancing

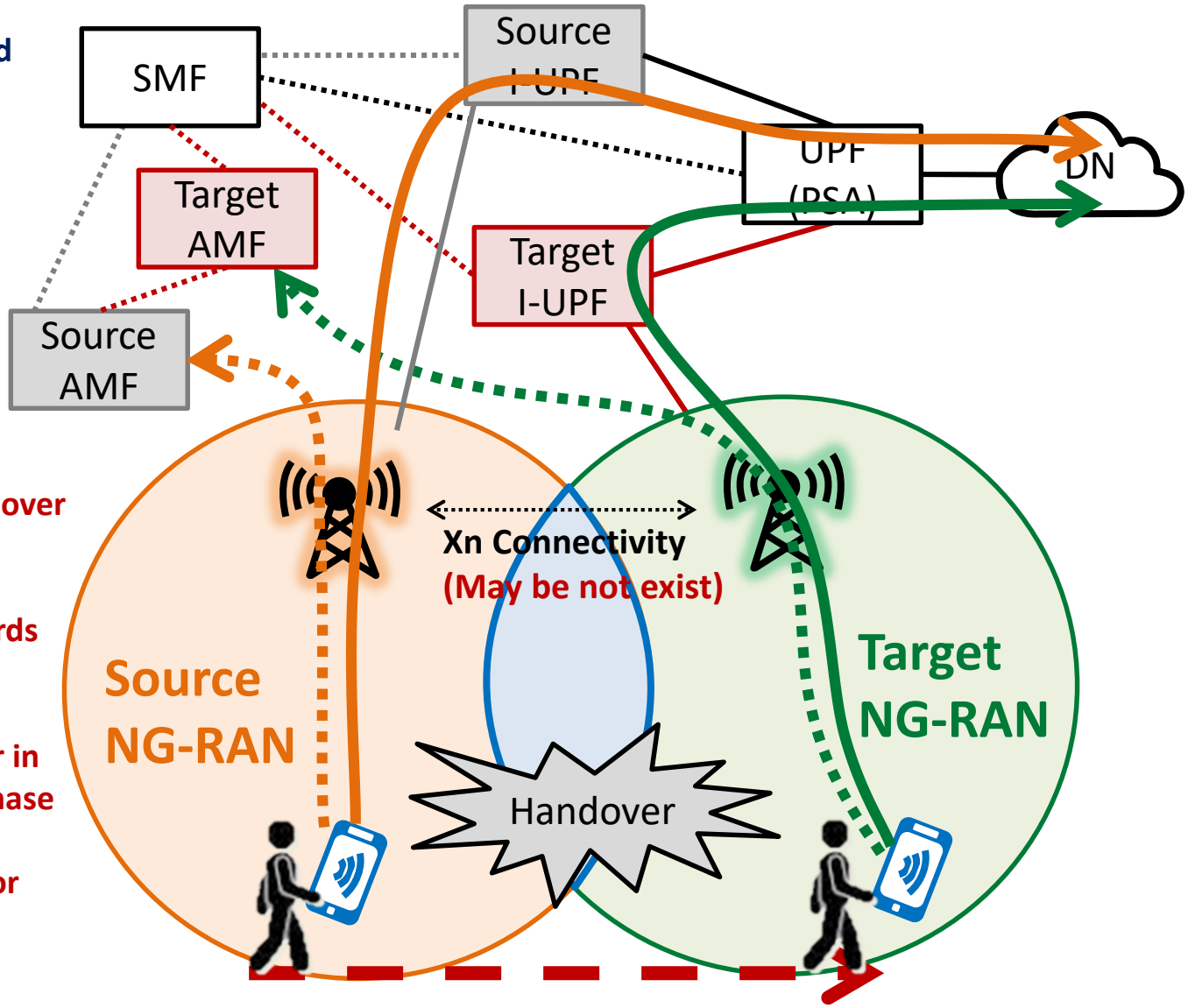
No Xn connectivity to the target NG-RAN

Error indication from the target NG-RAN after an unsuccessful Xn-based handover

AMF may be change at handover
If AMF changed

- **SMF hold any signalling messages targeted towards AMF until handover completed, cancelled or expiry of the guard timer in handover preparation phase**

SMF decides that the I-UPF or UPF (PSA) is to be changed

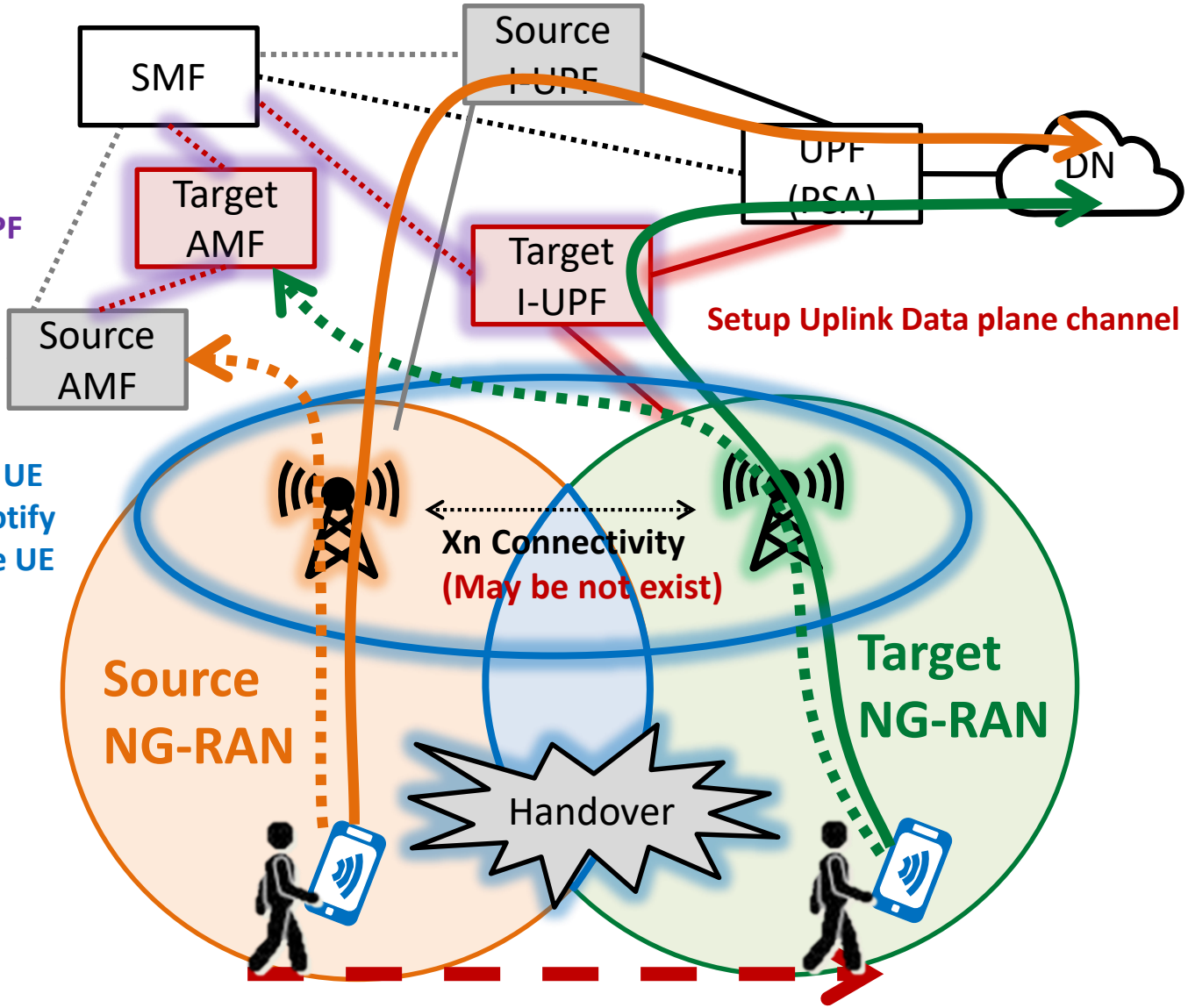


Inter NG-RAN node N2 based handover Preparation phase

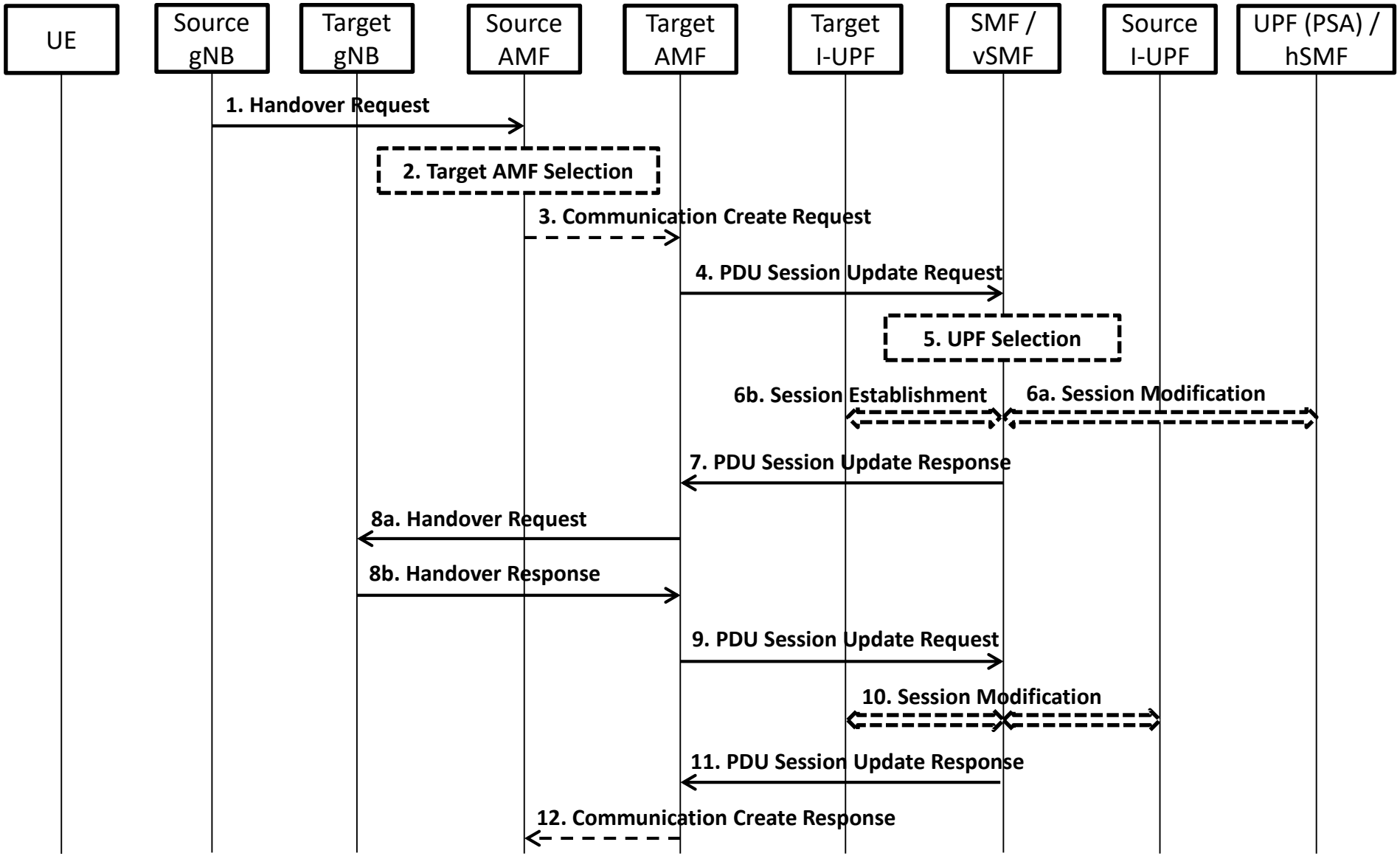
Preparing the control plane channel for handover

- **Determine AMF and I-UPF**

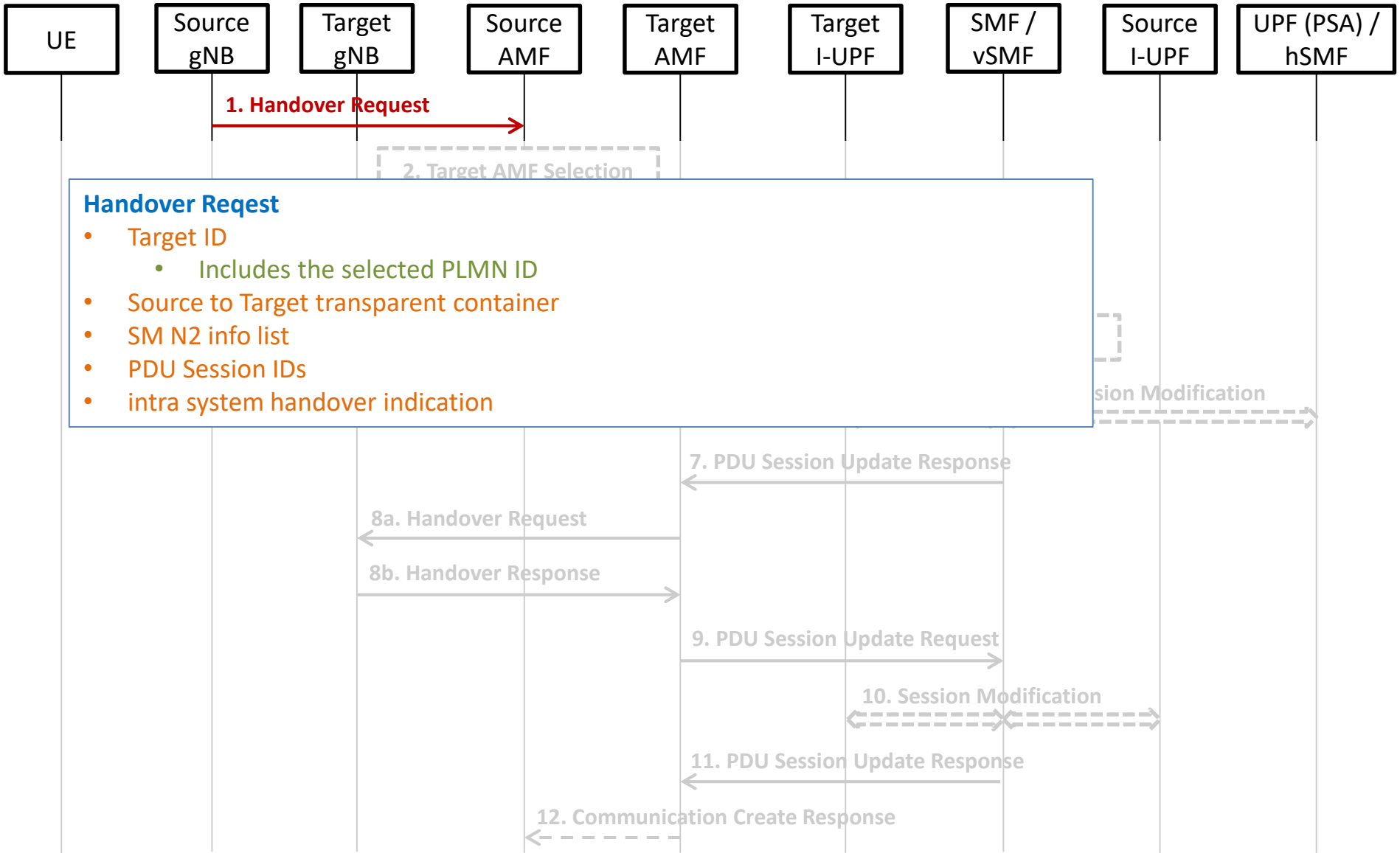
Source gNB detects that the UE is being Handover, then it notify Source AMF to handover the UE



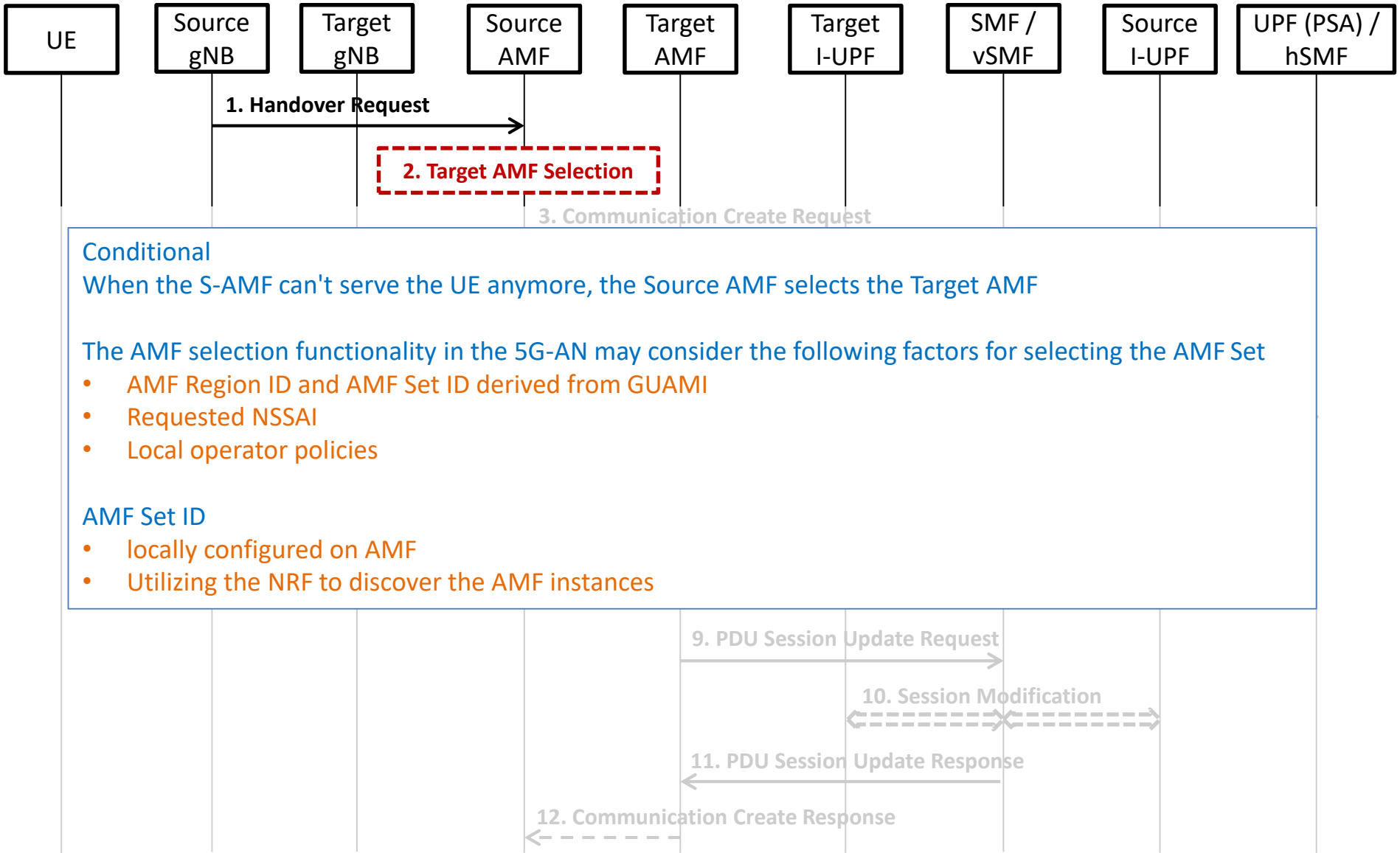
Inter NG-RAN node N2 based handover Preparation phase



Inter NG-RAN node N2 based handover Preparation phase (Step 1)



Inter NG-RAN node N2 based handover Preparation phase (Step 2)



Conditional

When the S-AMF can't serve the UE anymore, the Source AMF selects the Target AMF

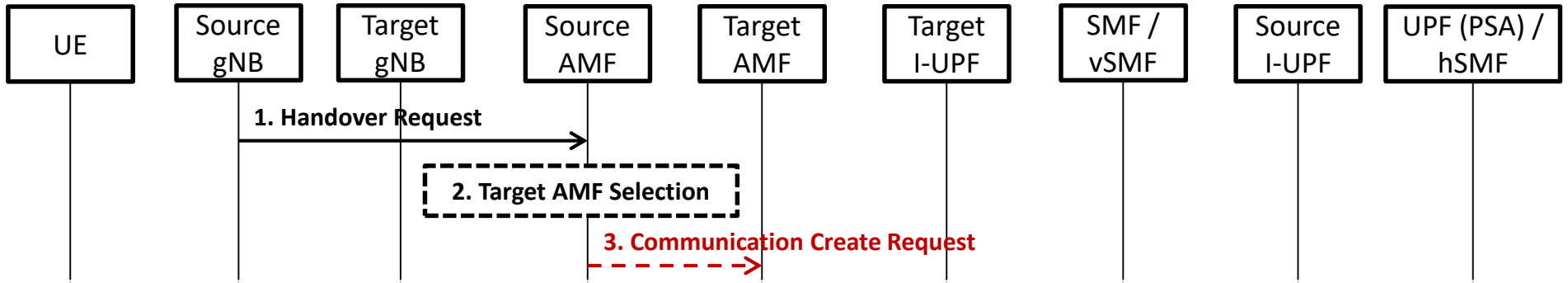
The AMF selection functionality in the 5G-AN may consider the following factors for selecting the AMF Set

- AMF Region ID and AMF Set ID derived from GUAMI
- Requested NSSAI
- Local operator policies

AMF Set ID

- locally configured on AMF
- Utilizing the NRF to discover the AMF instances

Inter NG-RAN node N2 based handover Preparation phase (Step 3)



AMF Services

└ **Namf_Communication_CreateUEContext Request**

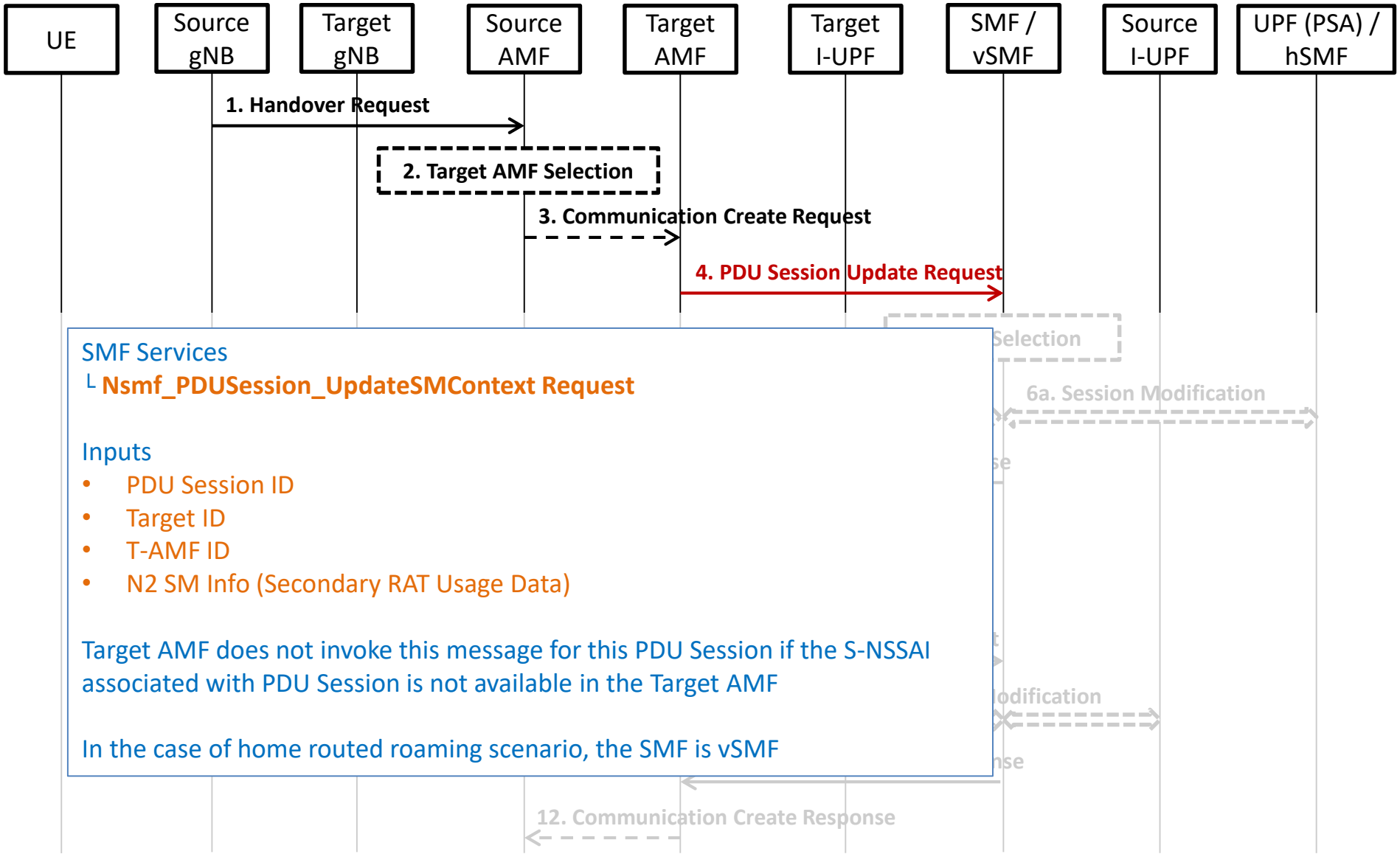
Inputs

- N2 Information
  - Target ID
  - Source to Target transparent container
  - SM N2 information list
  - PDU Session IDs
  - Service area restriction
- UE context information
  - SUPI
  - **Allowed NSSAI for each Access Type if available**
  - Tracing Requirements
  - List of PDU Session IDs along with the corresponding SMF information
  - **Corresponding S-NSSAI(s)**
  - PCF ID(s)
  - DNN

Conditional

- When the Source AMF selects the Target AMF to serve the UE, Source AMF initiates Handover resource allocation to the target AMF

Inter NG-RAN node N2 based handover Preparation phase (Step 4)



SMF Services

└ **Nsmf_PDUSession_UpdateSMContext Request**

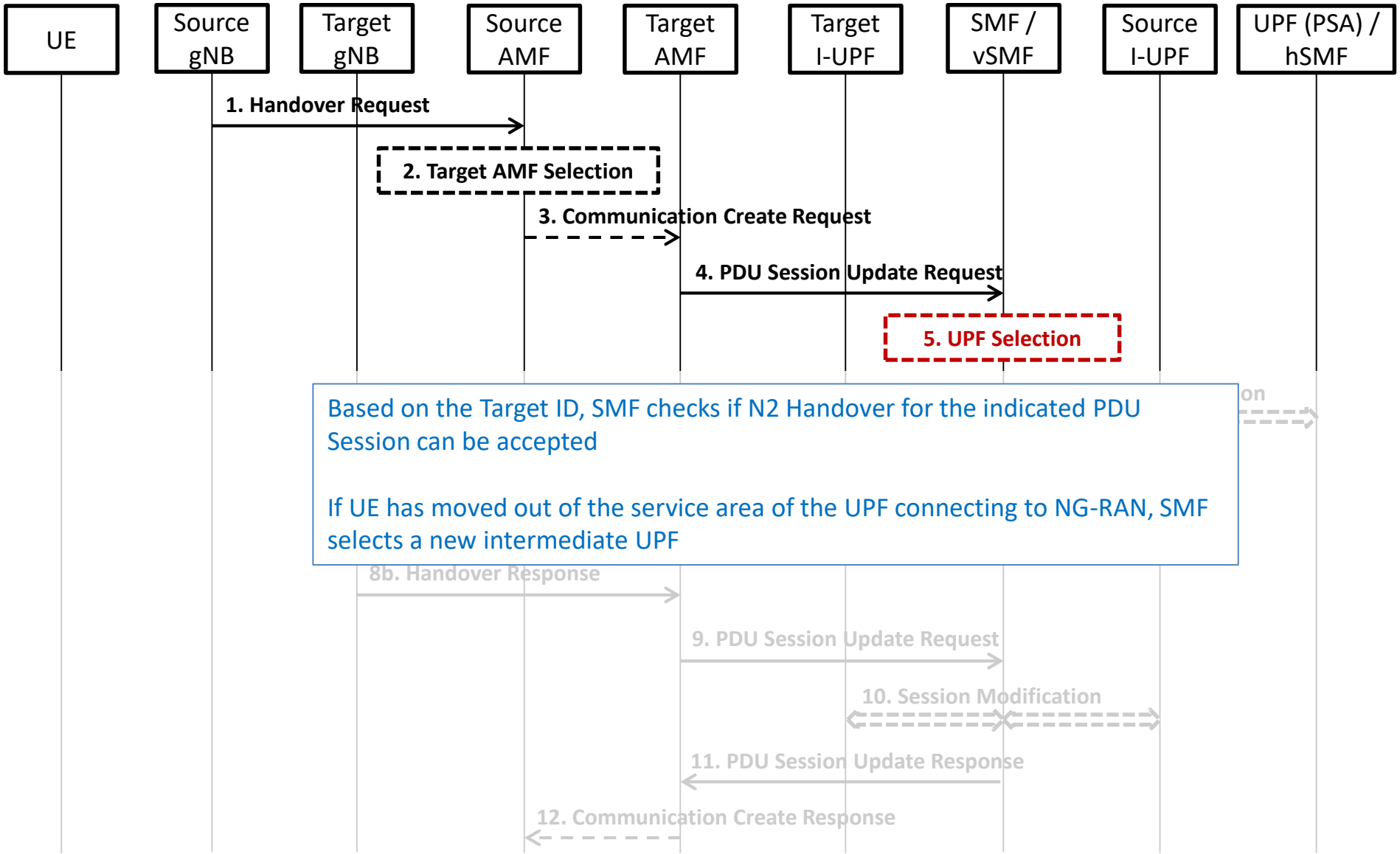
Inputs

- PDU Session ID
- Target ID
- T-AMF ID
- N2 SM Info (Secondary RAT Usage Data)

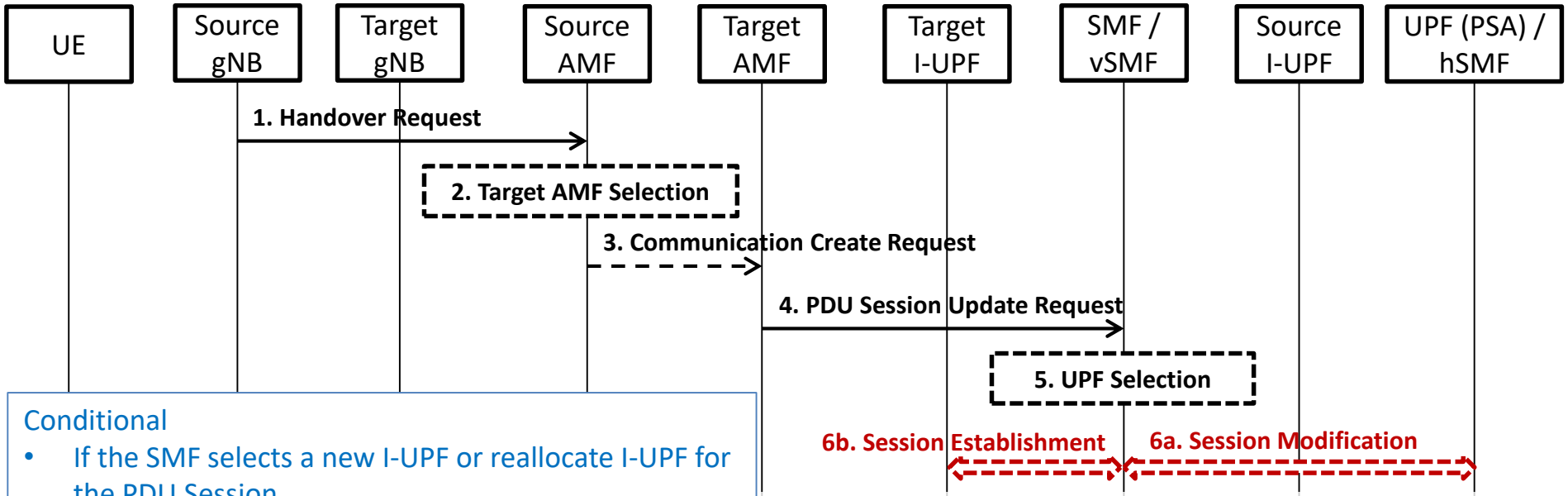
Target AMF does not invoke this message for this PDU Session if the S-NSSAI associated with PDU Session is not available in the Target AMF

In the case of home routed roaming scenario, the SMF is vSMF

Inter NG-RAN node N2 based handover Preparation phase (Step 5)



Inter NG-RAN node N2 based handover Preparation phase (Step 6)



Conditional

- If the SMF selects a new I-UPF or reallocate I-UPF for the PDU Session

SMF -> UPF (PSA)

Modify N9 tunnel (UPF <-> UPF)

- Uplink

N4 Session Modification Request

- CN Tunnel Info (on N9)
  - If the CN Tunnel Info is allocated by the SMF

N4 Session Modification Response

- CN Tunnel Info (on N9)
  - If the CN Tunnel Info is allocated by the UPF

SMF -> Target UPF

Establish N9 tunnel (UPF <-> UPF)

- Uplink

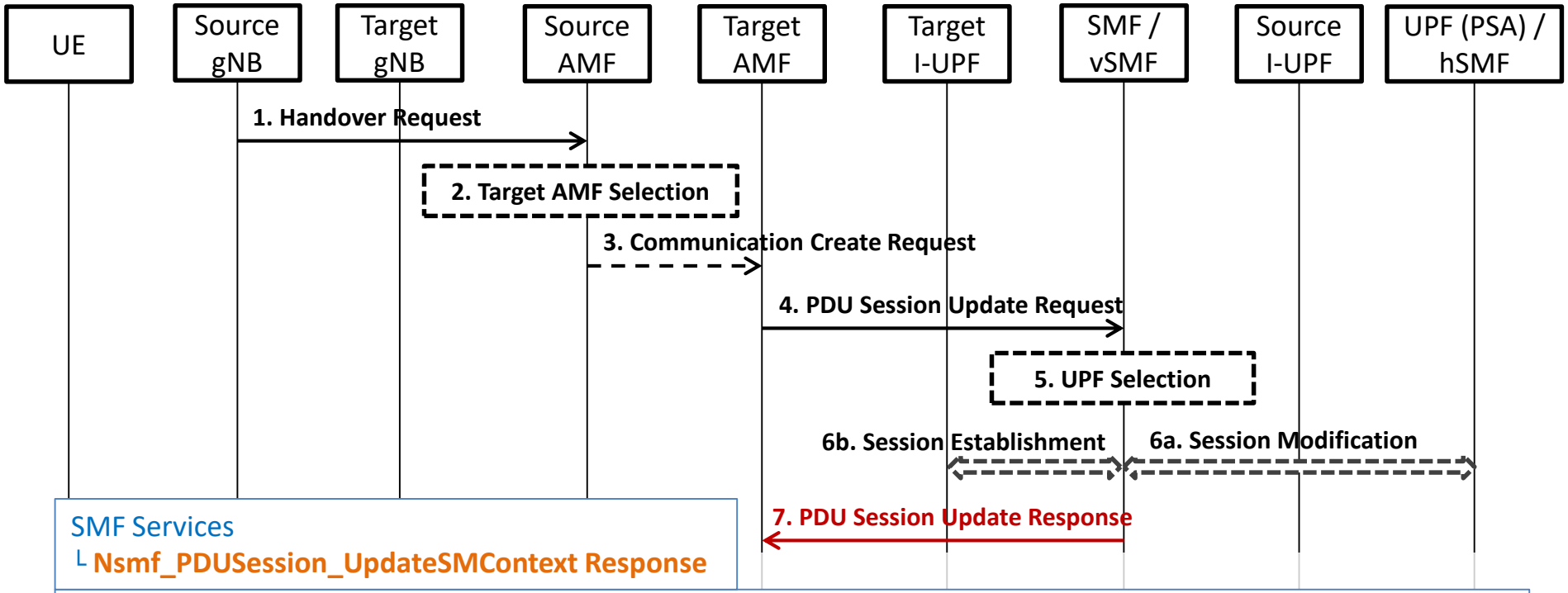
N4 Session Establishment Request

- CN Tunnel Info (on N9) of UPF (PSA) for this PDU Session

N4 Session Establishment Response

- DL CN Tunnel
- UL CN Tunnel

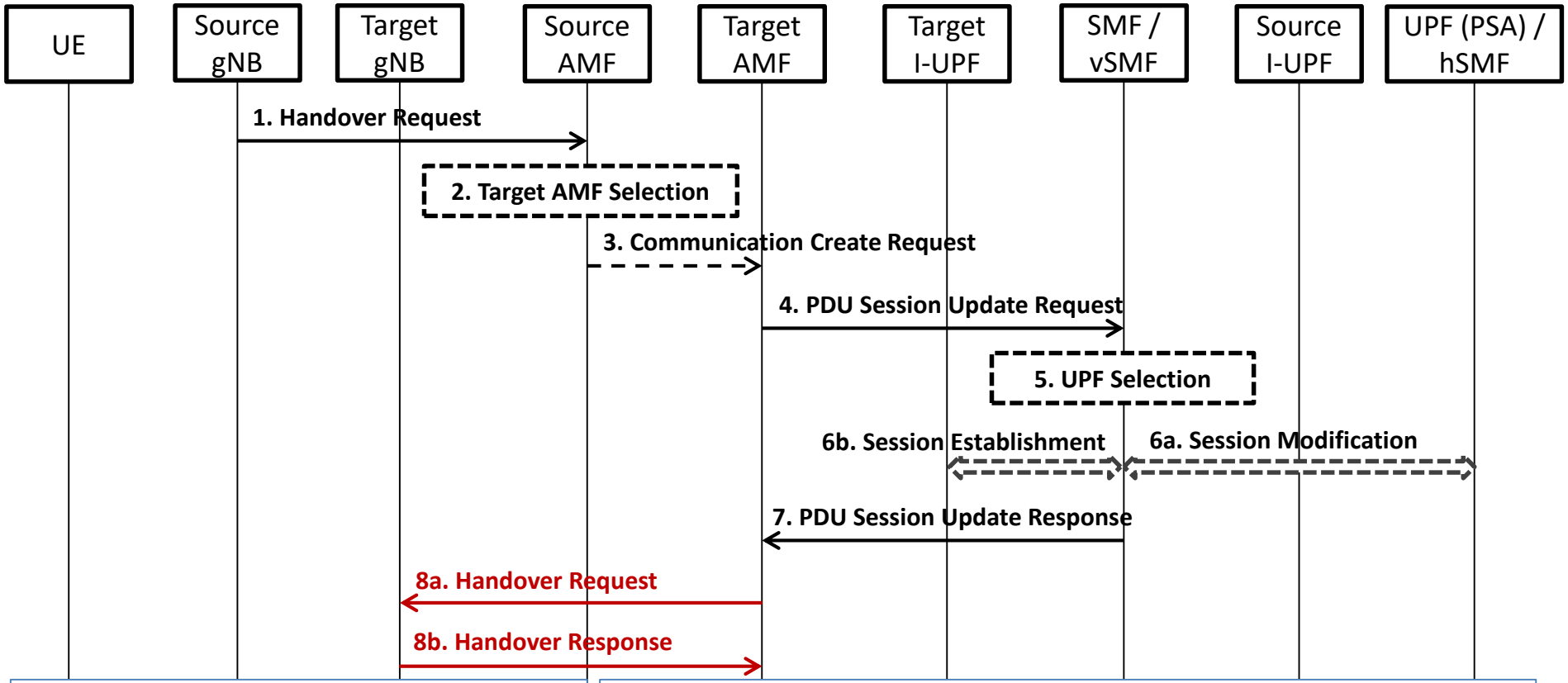
Inter NG-RAN node N2 based handover Preparation phase (Step 7)



SMF Services
└ **Nsmf_PDUSession_UpdateSMContext Response**

Outputs
- PDU Session ID
- N2 SM Information
  - Include if N2 handover for the PDU Session is accepted
  - Only include regarding the PDU Session If the SMF is notified that the UE is only reachable for regulatory prioritized services
    - Avoid establishment of radio resources at the target NG-RAN
- Reason for non-acceptance
  - Include if N2 handover for the PDU Session is not accepted

Inter NG-RAN node N2 based handover Preparation phase (Step 8)



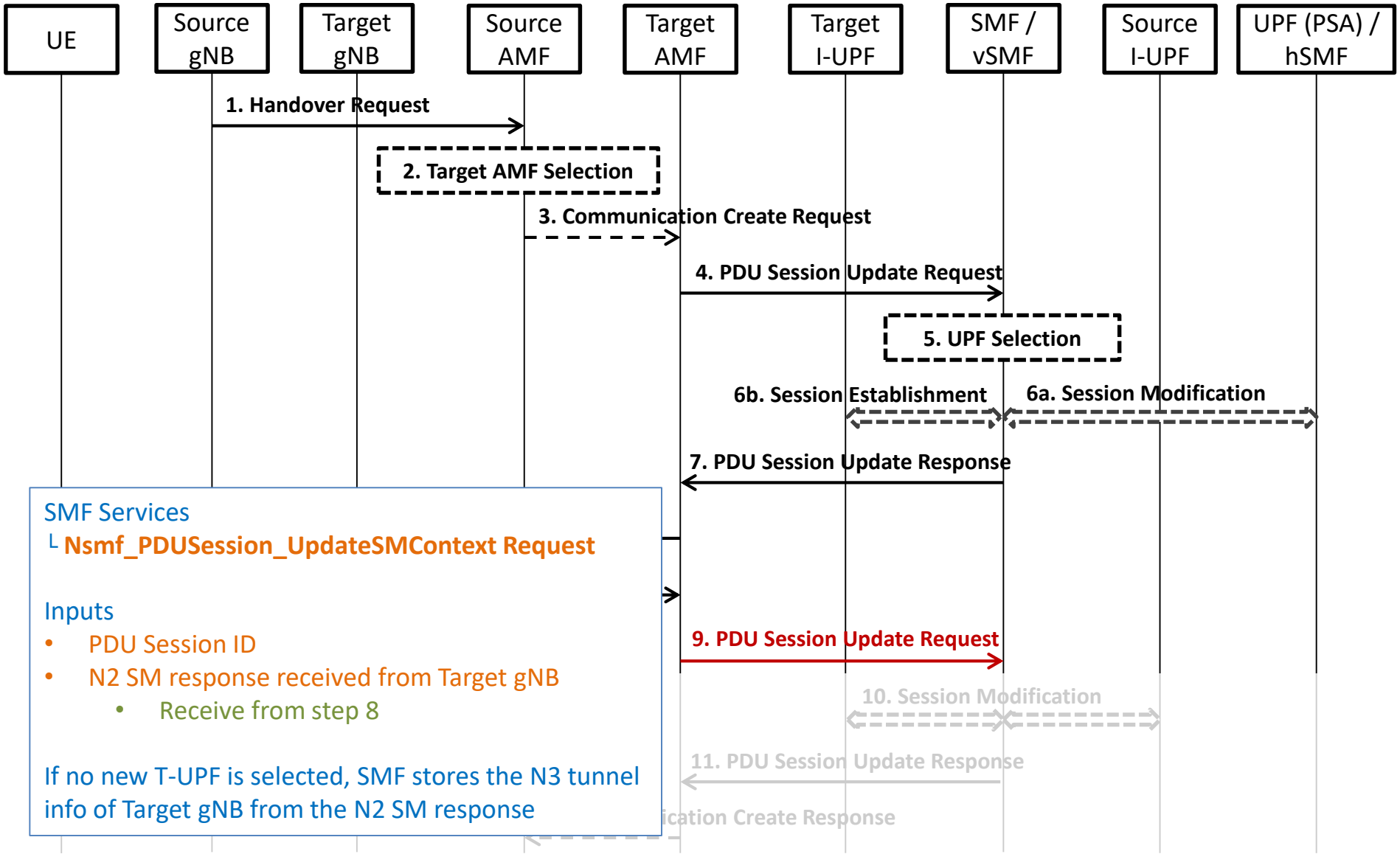
Handover Request

- Source to Target transparent container
- N2 MM Information
- N2 SM Information list
- Tracing Requirements

Handover Request Response

- Target to Source transparent container
- List Of PDU Sessions to Hand-over
  - With for each PDU Session N2 SM information
- List Of PDU Sessions failed to be setup
  - with for each PDU Session N2 SM information containing the reason for failure

Inter NG-RAN node N2 based handover Preparation phase (Step 9)



SMF Services

└ **Nsmf_PDUSession_UpdateSMContext Request**

Inputs

- PDU Session ID
- N2 SM response received from Target gNB
  - Receive from step 8

If no new T-UPF is selected, SMF stores the N3 tunnel info of Target gNB from the N2 SM response

Inter NG-RAN node N2 based handover Preparation phase (Step 10)

Modify N3 tunnel (gNB <-> UPF)

- Uplink

SMF to Target I-UPF

If the SMF selected a Target I-UPF

N4 Session Modification Request

- Target gNB SM N3 forwarding Information list
- Indication to allocate DL forwarding tunnel(s) for indirect forwarding
  - Use for data forwarding at Execution phase

N4 Session Modification Response

- Target I-UPF SM N3 forwarding Information list

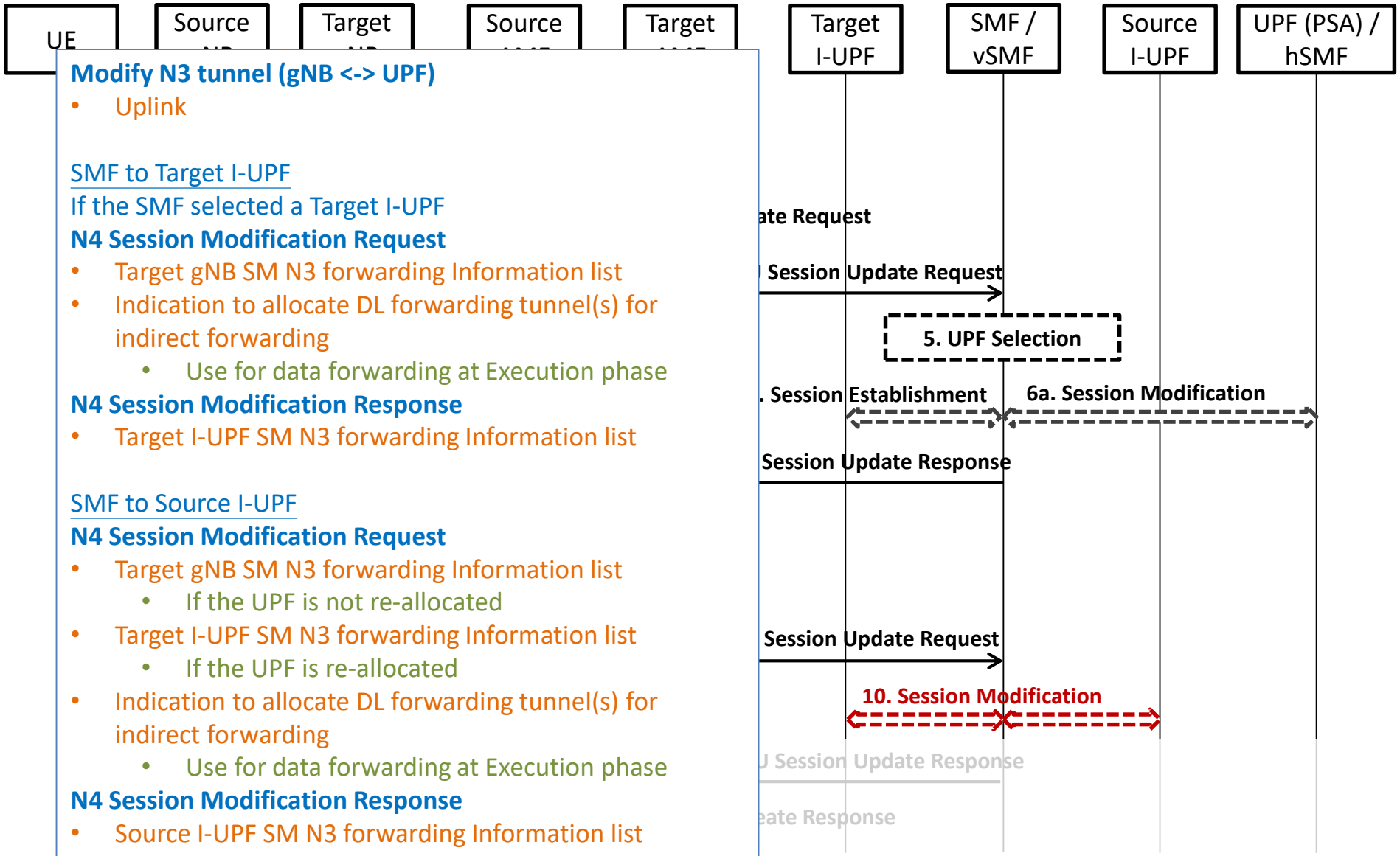
SMF to Source I-UPF

N4 Session Modification Request

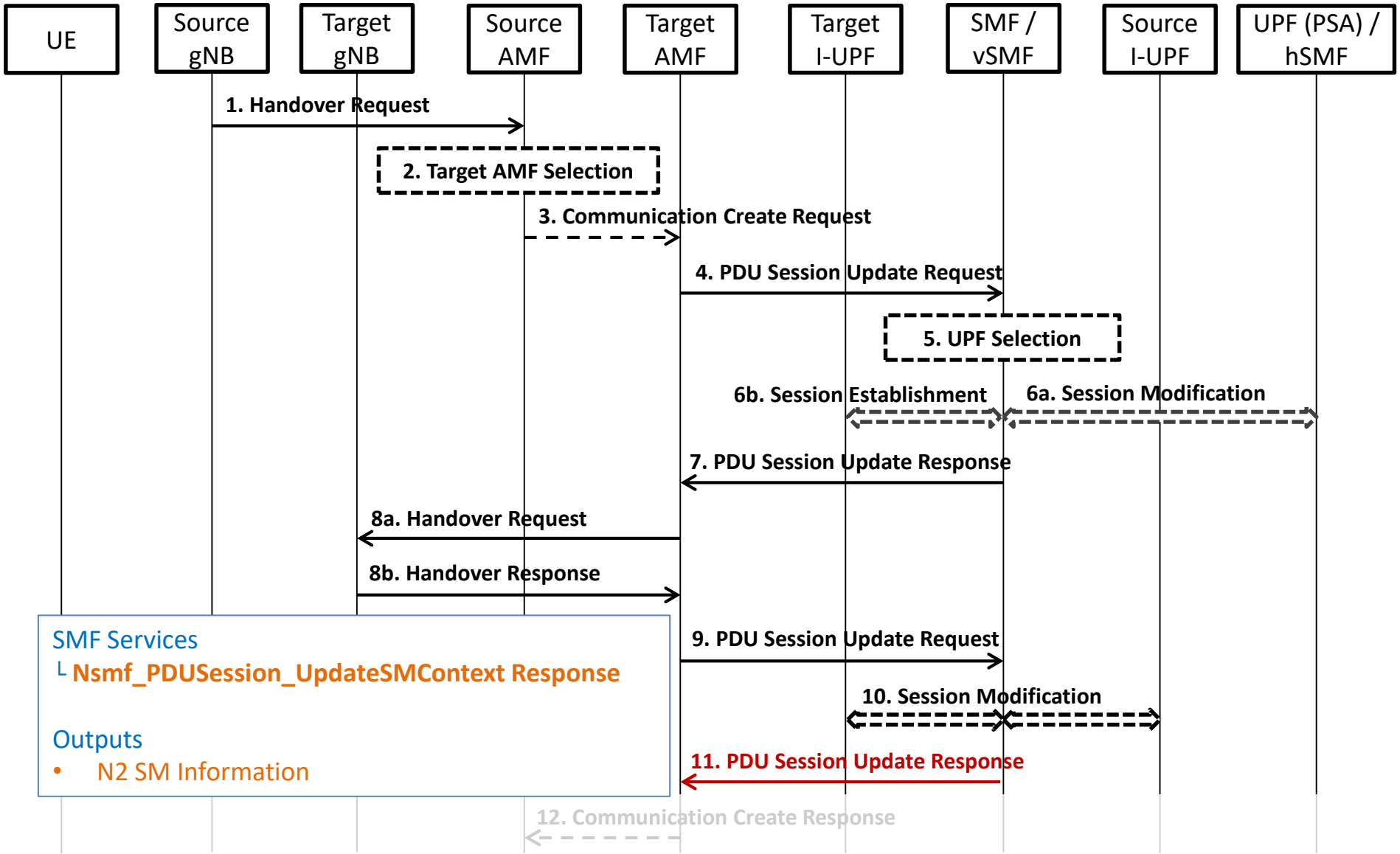
- Target gNB SM N3 forwarding Information list
  - If the UPF is not re-allocated
- Target I-UPF SM N3 forwarding Information list
  - If the UPF is re-allocated
- Indication to allocate DL forwarding tunnel(s) for indirect forwarding
  - Use for data forwarding at Execution phase

N4 Session Modification Response

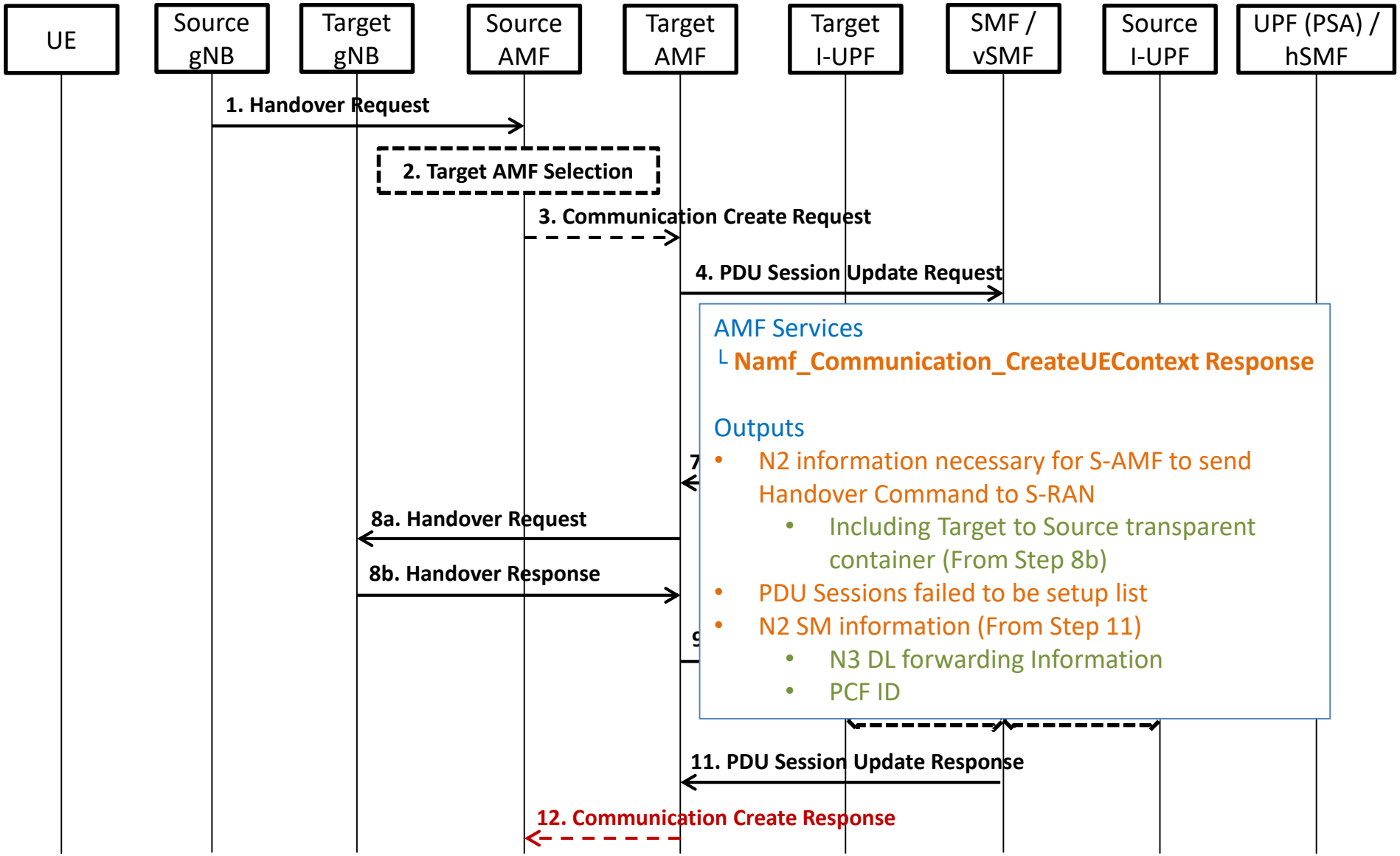
- Source I-UPF SM N3 forwarding Information list



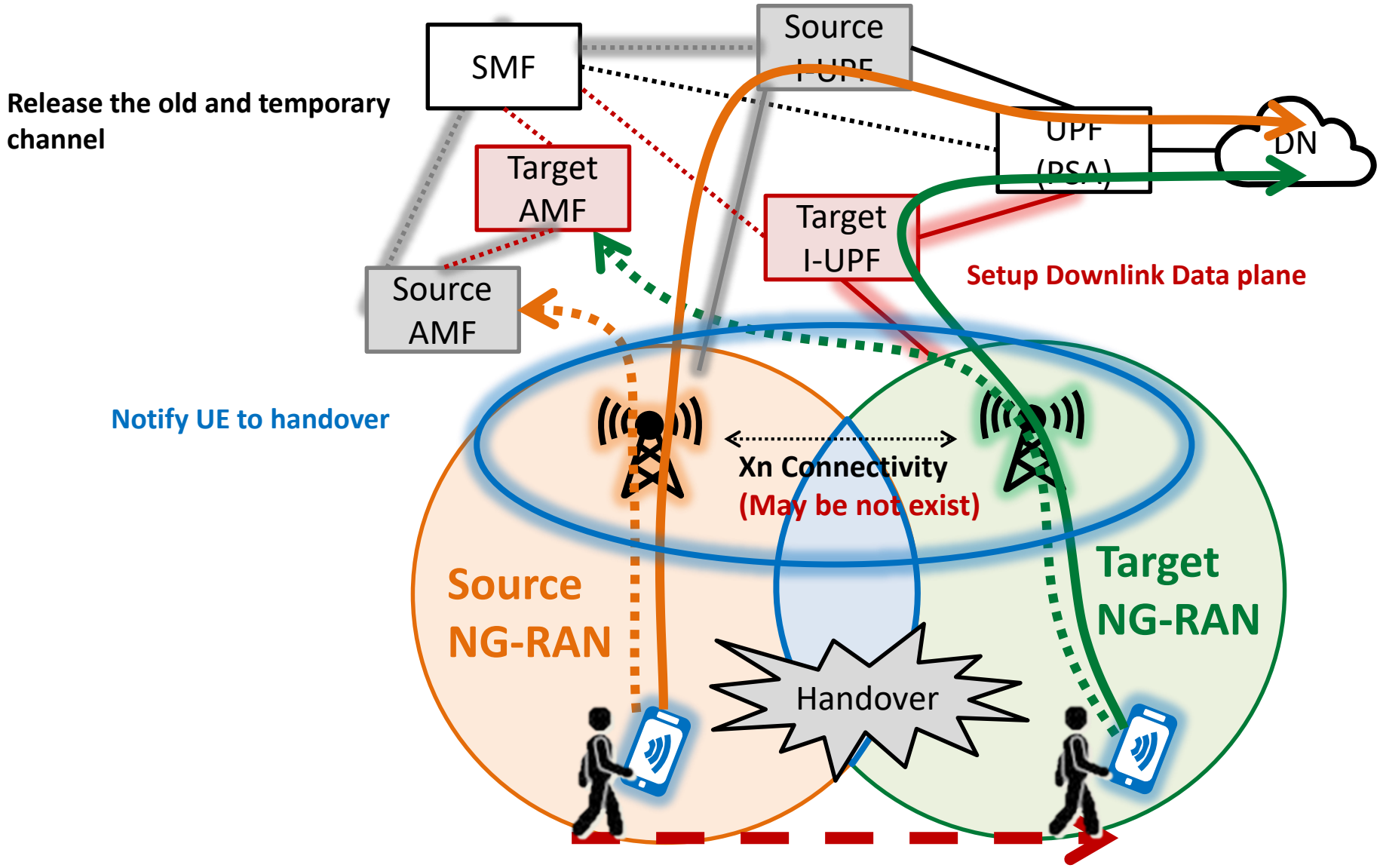
Inter NG-RAN node N2 based handover Preparation phase (Step 11)



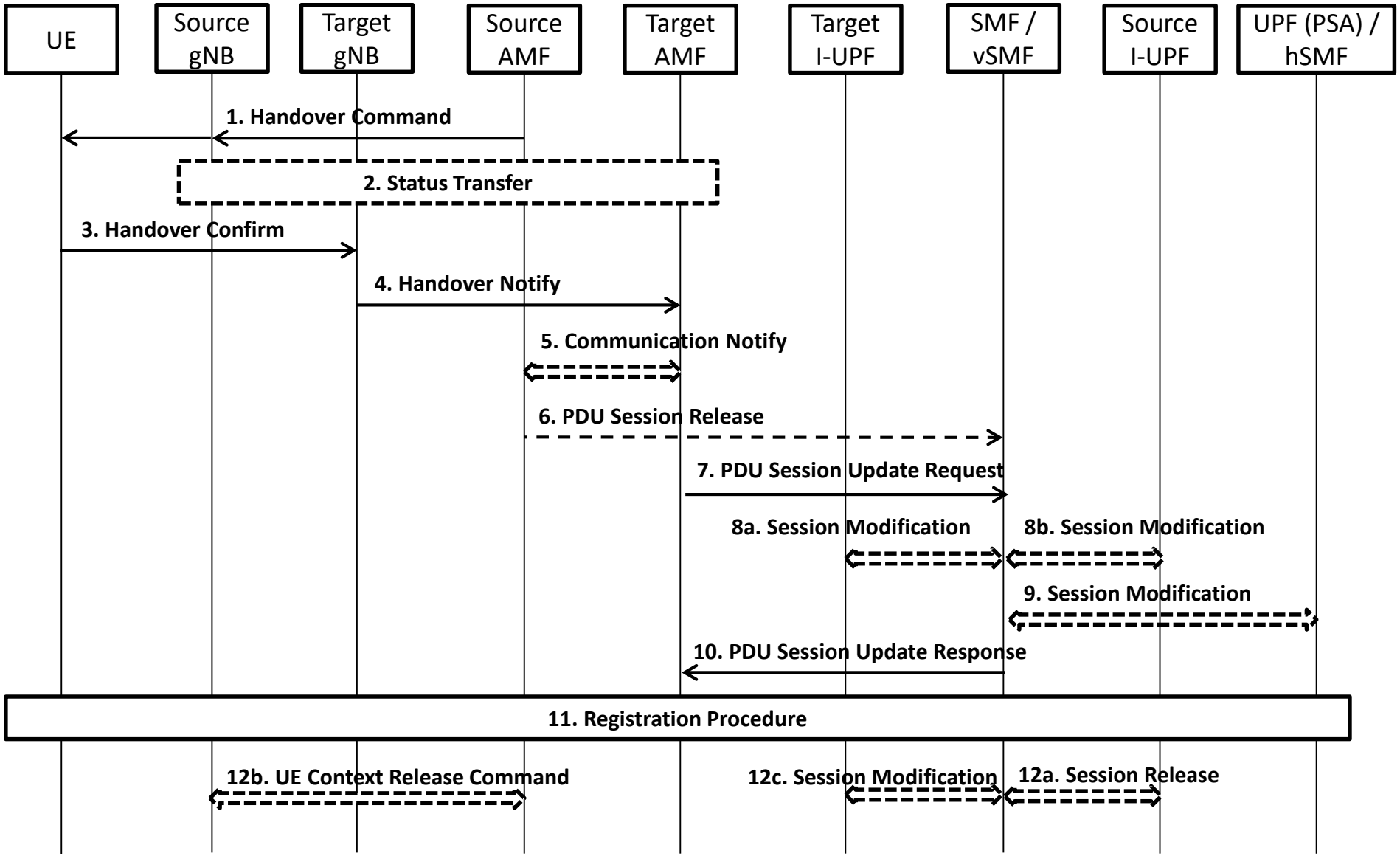
Inter NG-RAN node N2 based handover Preparation phase (Step 12)



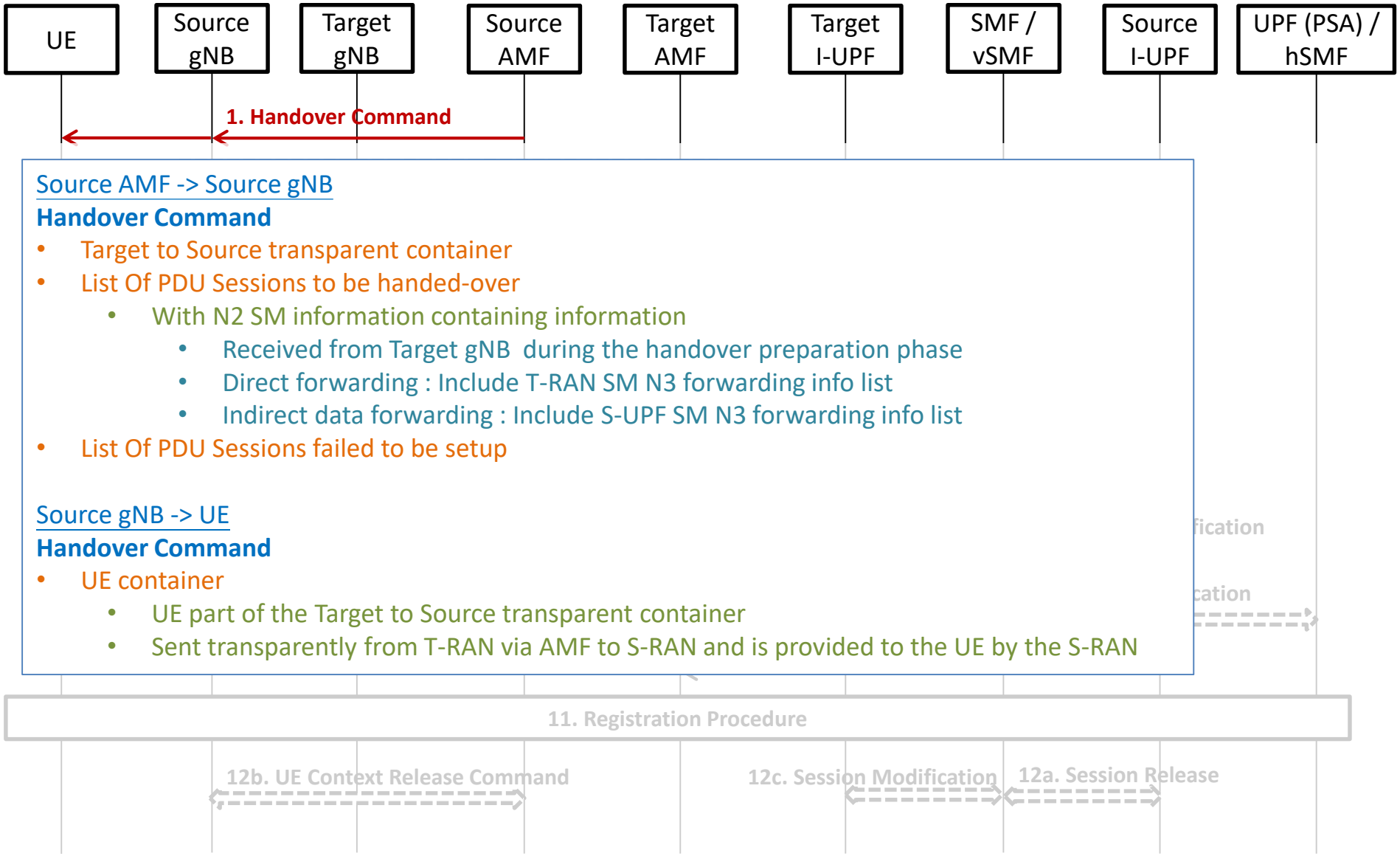
Inter NG-RAN node N2 based handover Execution phase



Inter NG-RAN node N2 based handover Execution phase



Inter NG-RAN node N2 based handover Execution phase (Step 1)



Source AMF -> Source gNB

Handover Command

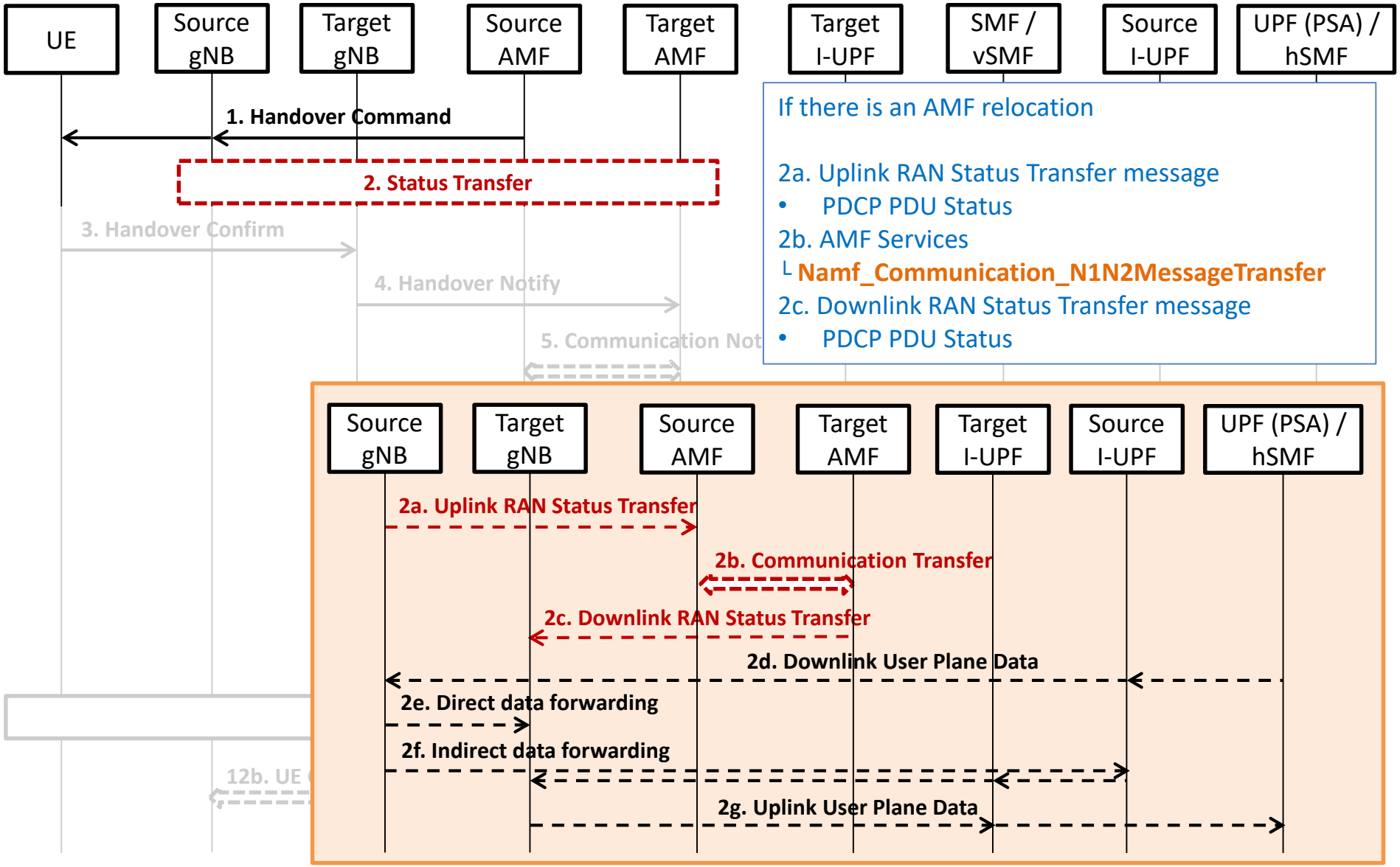
- Target to Source transparent container
- List Of PDU Sessions to be handed-over
  - With N2 SM information containing information
    - Received from Target gNB during the handover preparation phase
    - Direct forwarding : Include T-RAN SM N3 forwarding info list
    - Indirect data forwarding : Include S-UPF SM N3 forwarding info list
- List Of PDU Sessions failed to be setup

Source gNB -> UE

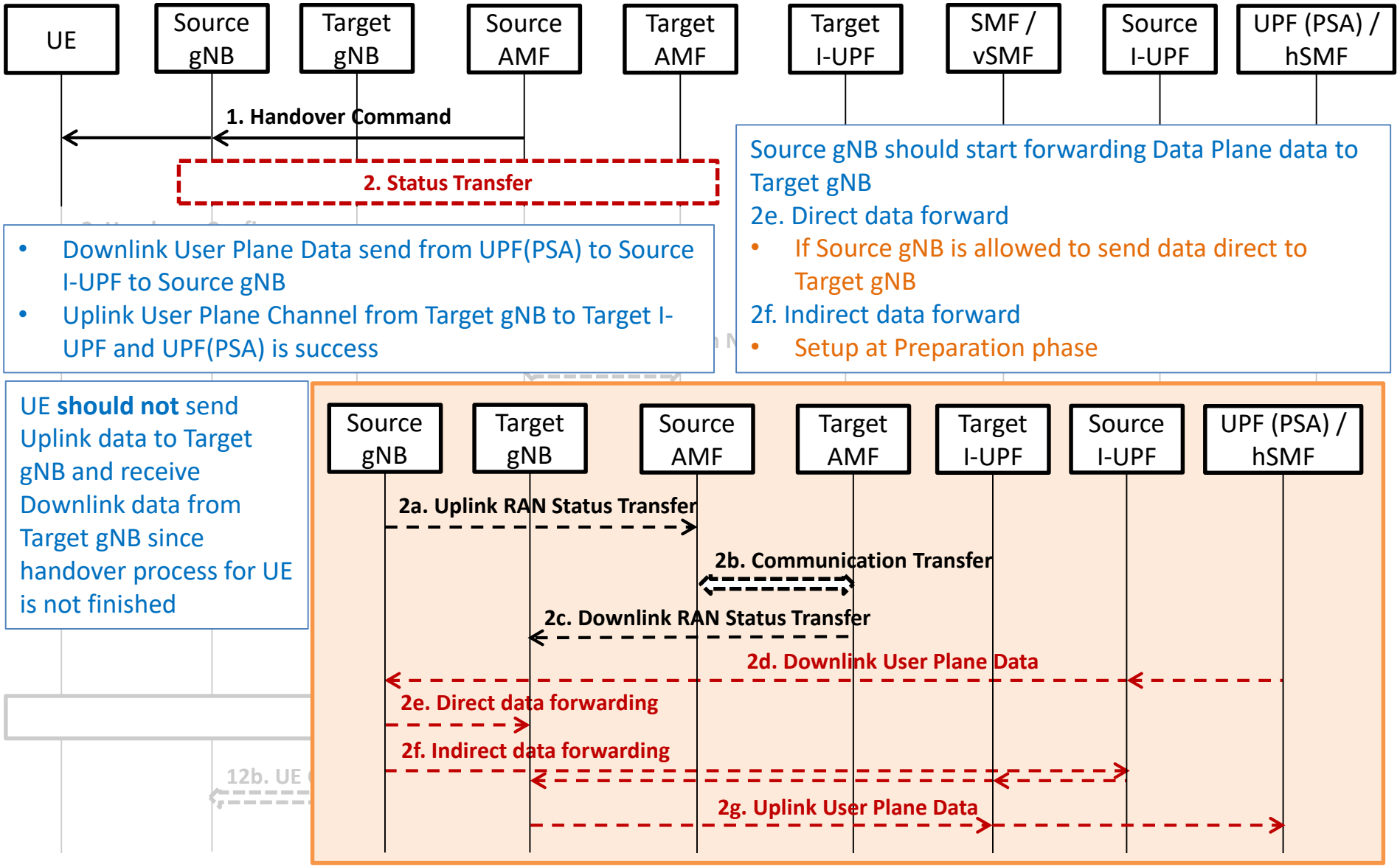
Handover Command

- UE container
  - UE part of the Target to Source transparent container
  - Sent transparently from T-RAN via AMF to S-RAN and is provided to the UE by the S-RAN

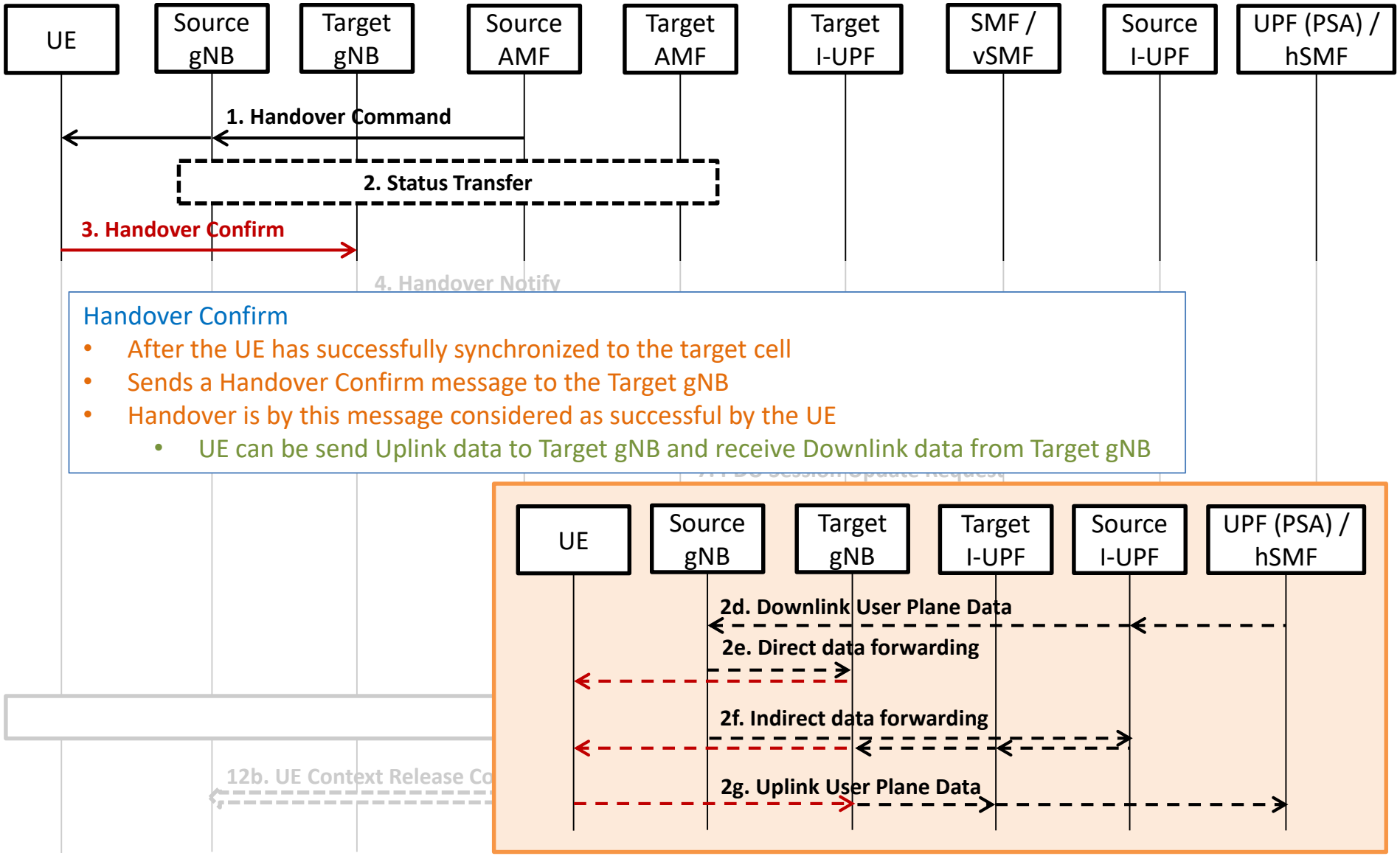
Inter NG-RAN node N2 based handover Execution phase (Step 2-1)



Inter NG-RAN node N2 based handover Execution phase (Step 2-2)



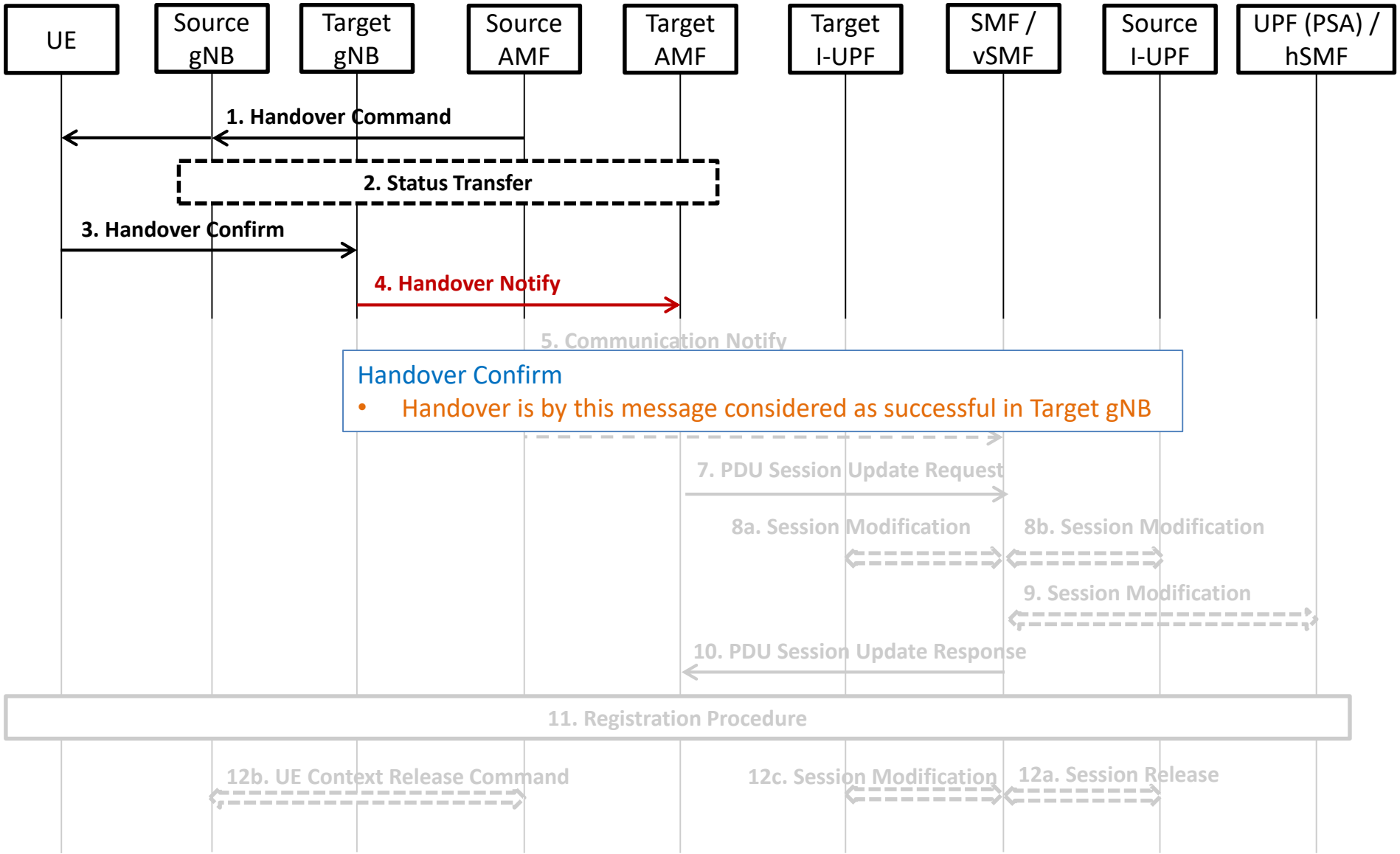
Inter NG-RAN node N2 based handover Execution phase (Step 3)



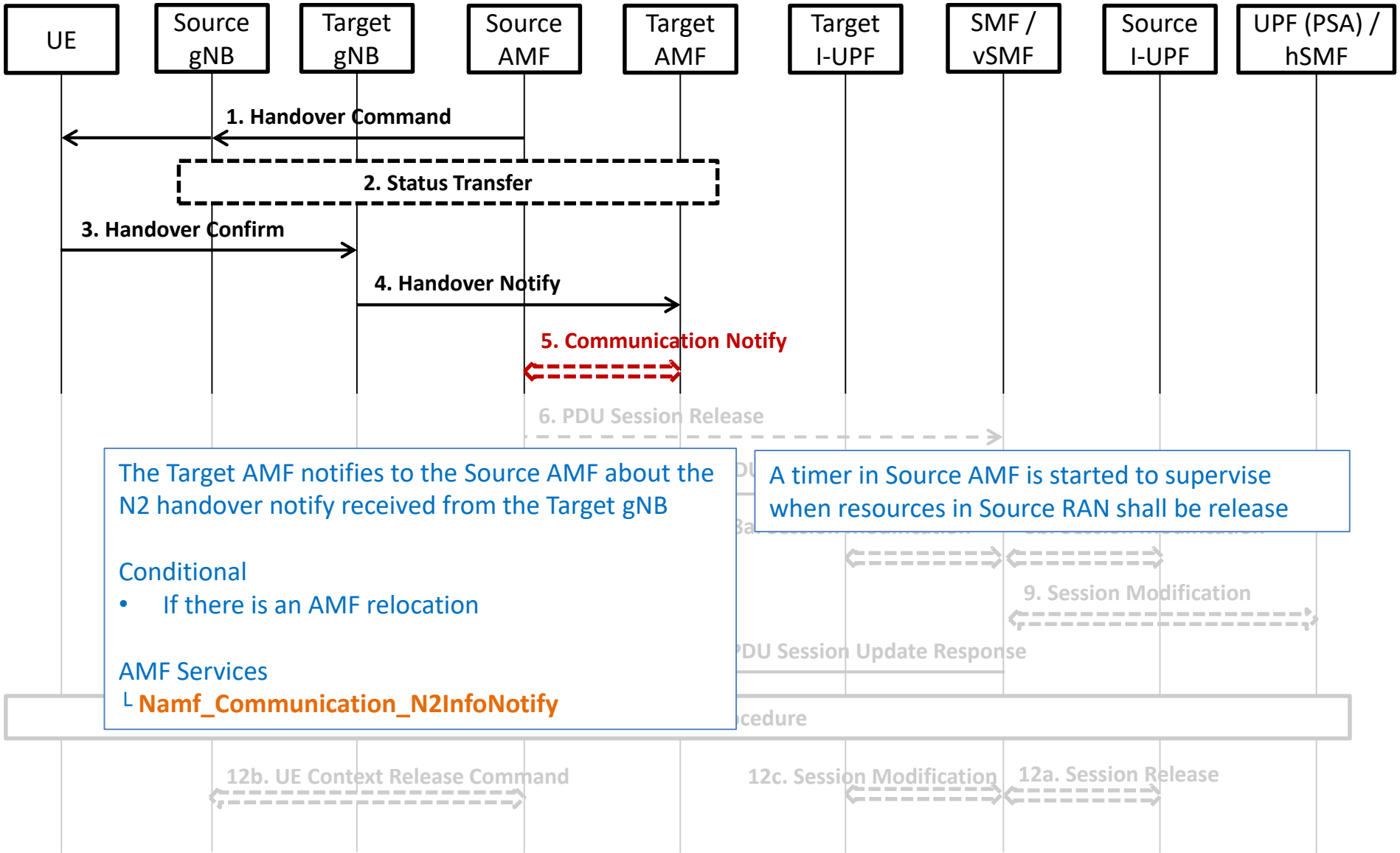
Handover Confirm

- After the UE has successfully synchronized to the target cell
- Sends a Handover Confirm message to the Target gNB
- Handover is by this message considered as successful by the UE
  - UE can be send Uplink data to Target gNB and receive Downlink data from Target gNB

Inter NG-RAN node N2 based handover Execution phase (Step 4)



Inter NG-RAN node N2 based handover Execution phase (Step 5)



The Target AMF notifies to the Source AMF about the N2 handover notify received from the Target gNB

Conditional

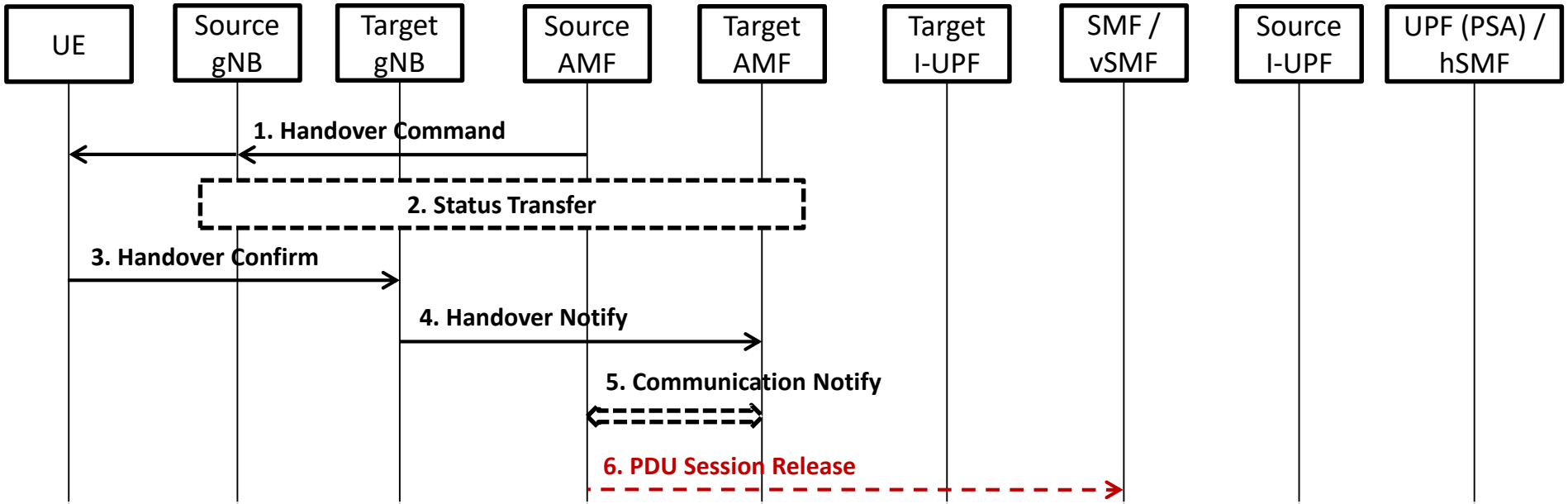
- If there is an AMF relocation

AMF Services

└ **Namf_Communication_N2InfoNotify**

A timer in Source AMF is started to supervise when resources in Source RAN shall be release

Inter NG-RAN node N2 based handover Execution phase (Step 6)



Conditional

- If the PDU Session(s) is not accepted by the Target AMF

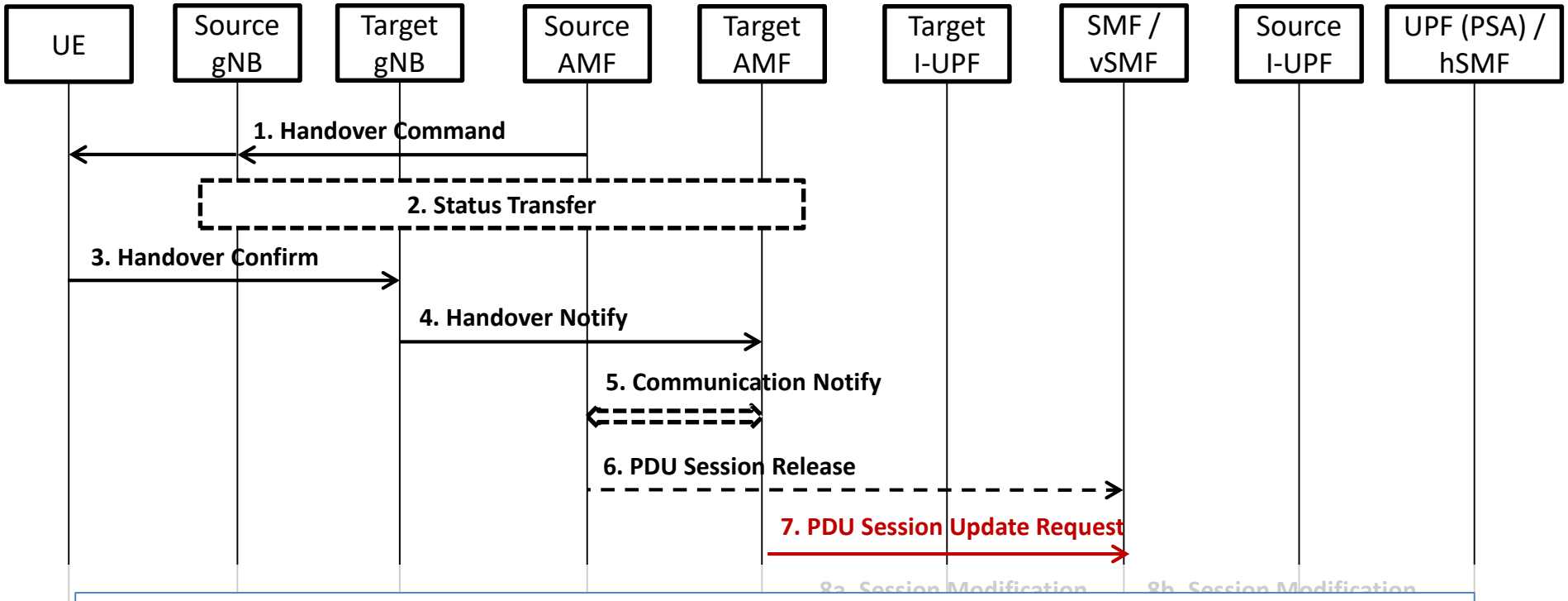
SMF Services

└ **Nsmf_PDUSession_ReleaseSMContext Request**

Input

- SUPI
- PDU Session ID
- N2 SM Information
  - Secondary RAT Usage Data
  - Handover Flag

Inter NG-RAN node N2 based handover Execution phase (Step 7)



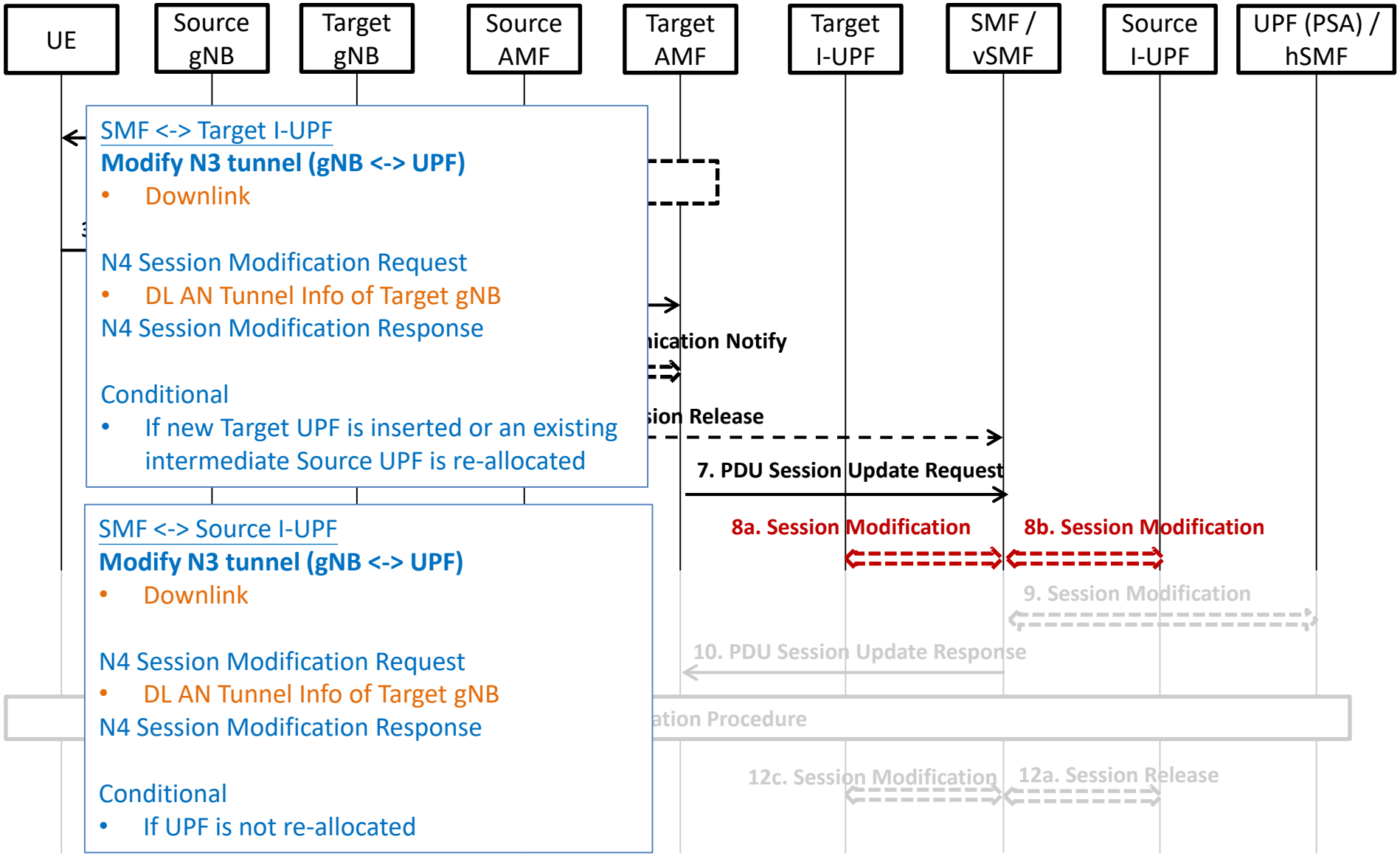
SMF Services

└ **Nsmf_PDUSession_UpdateSMContext Request**

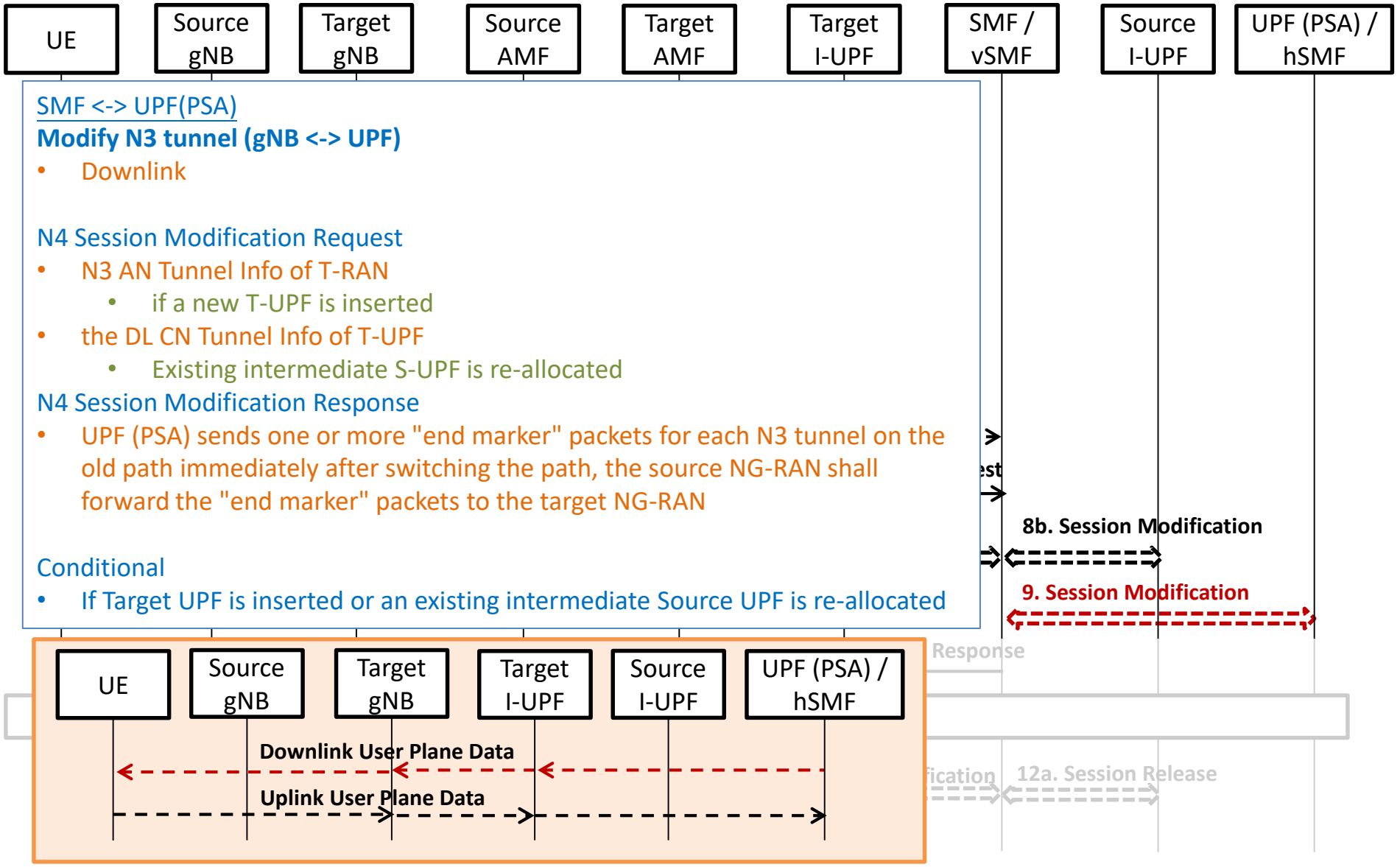
Input

- Handover Complete indication for PDU Session ID
  - Handover Complete indication is sent per each PDU Session to the corresponding SMF
- UE presence in LADN service area
  - If the PDU Session is related to a LADN

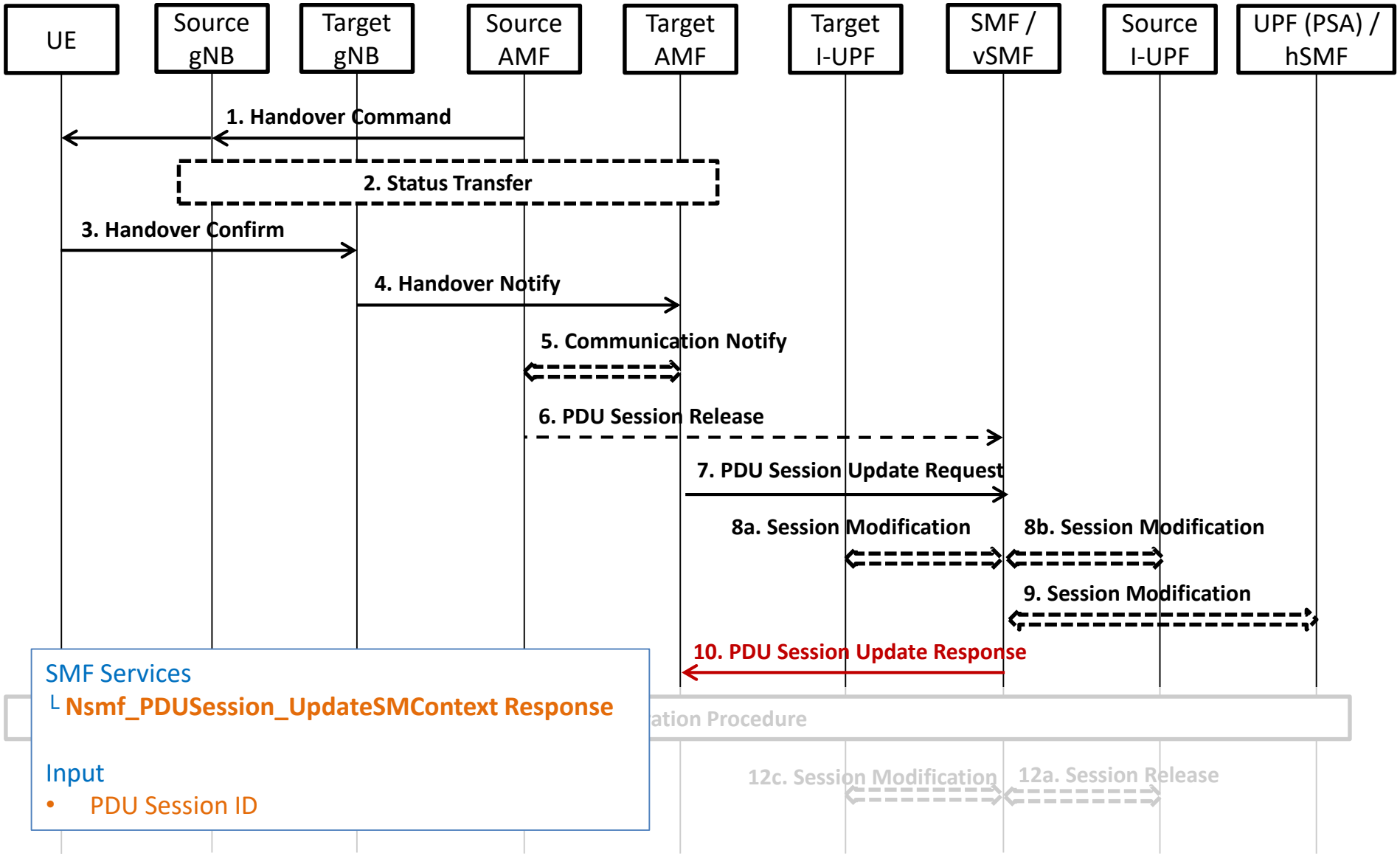
Inter NG-RAN node N2 based handover Execution phase (Step 9)



Inter NG-RAN node N2 based handover Execution phase (Step 9)



Inter NG-RAN node N2 based handover Execution phase (Step 10)



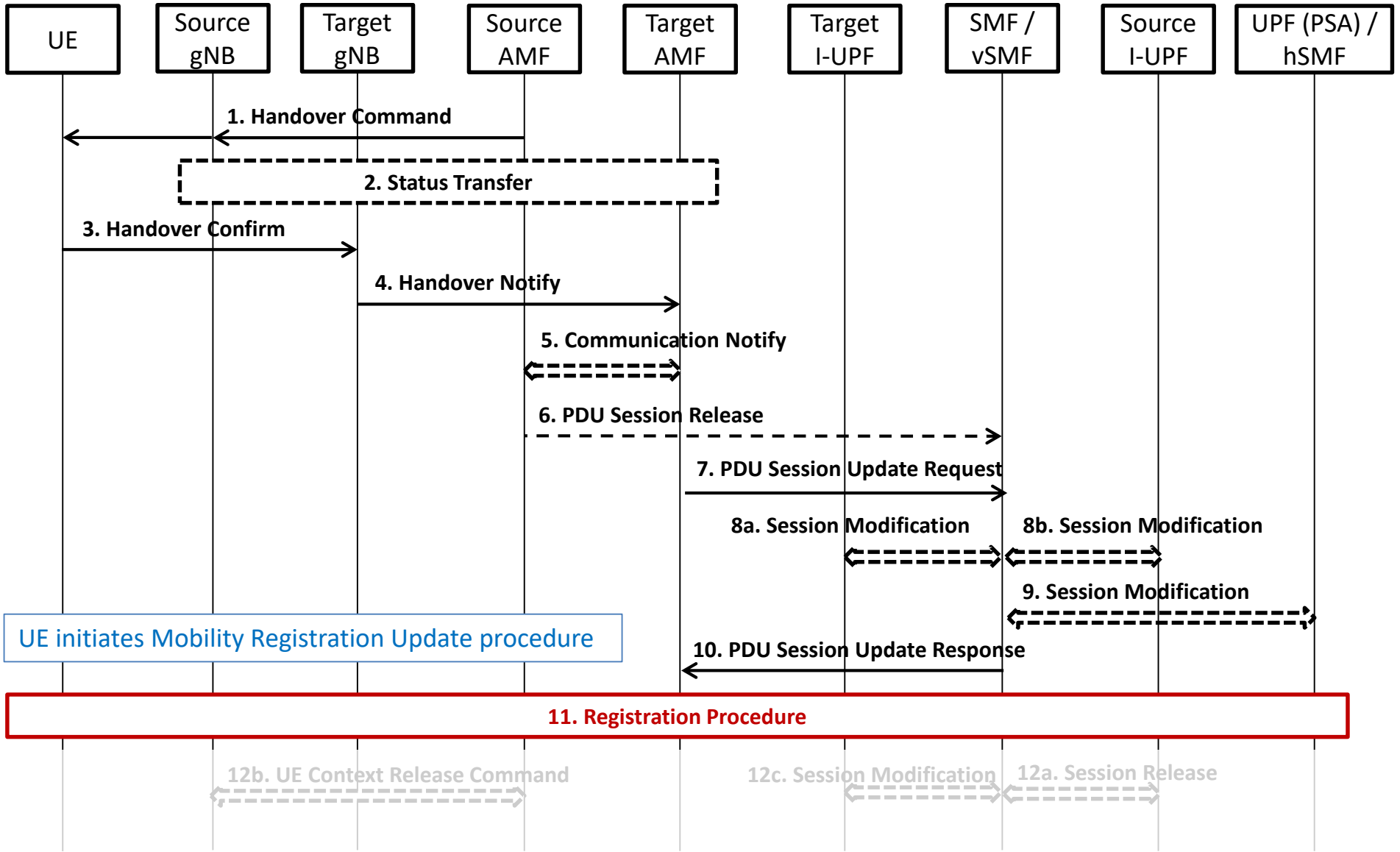
SMF Services

└ **Nsmf_PDUSession_UpdateSMContext Response**

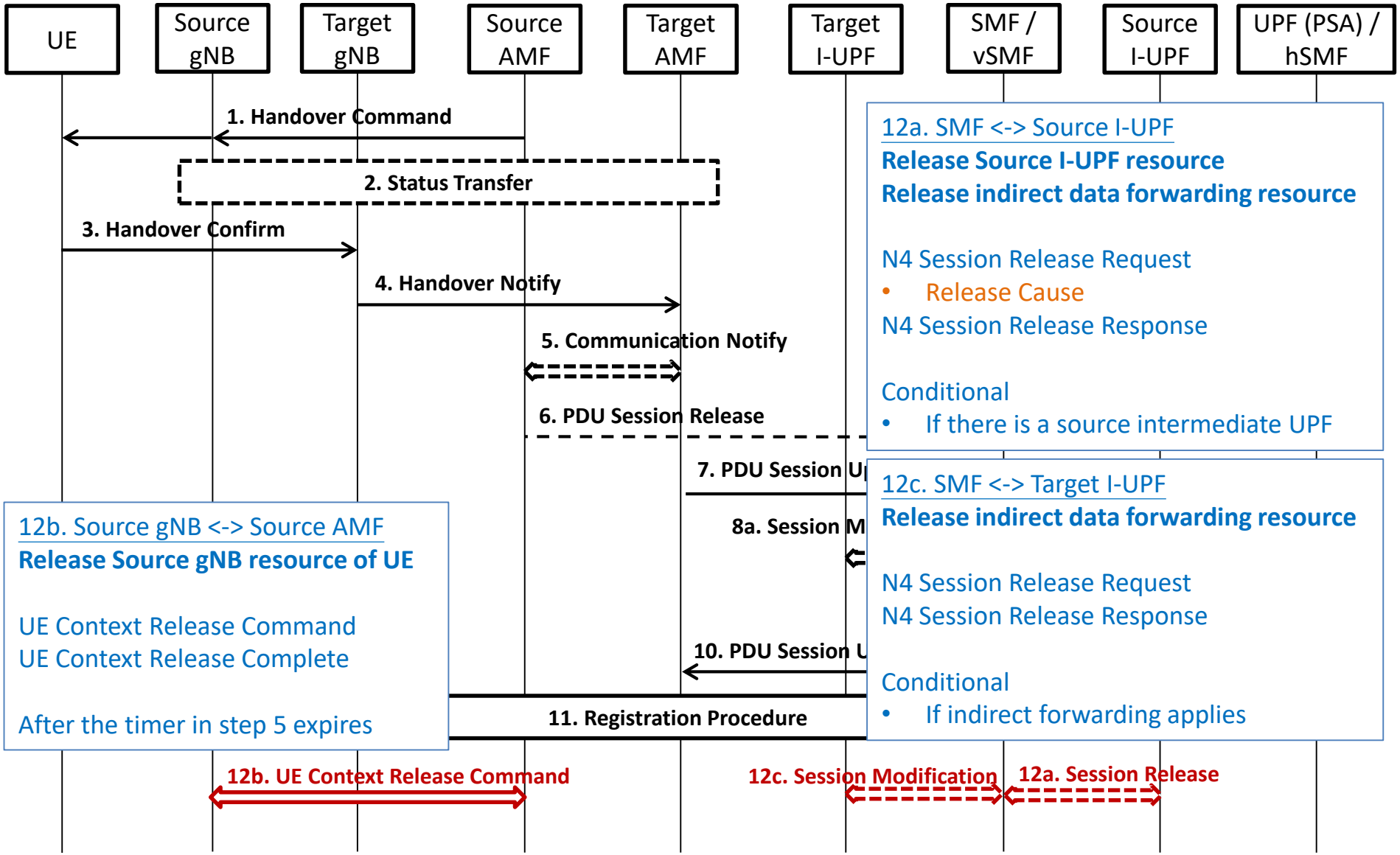
Input

- PDU Session ID

Inter NG-RAN node N2 based handover Execution phase (Step 11)



Inter NG-RAN node N2 based handover Execution phase (Step 12)



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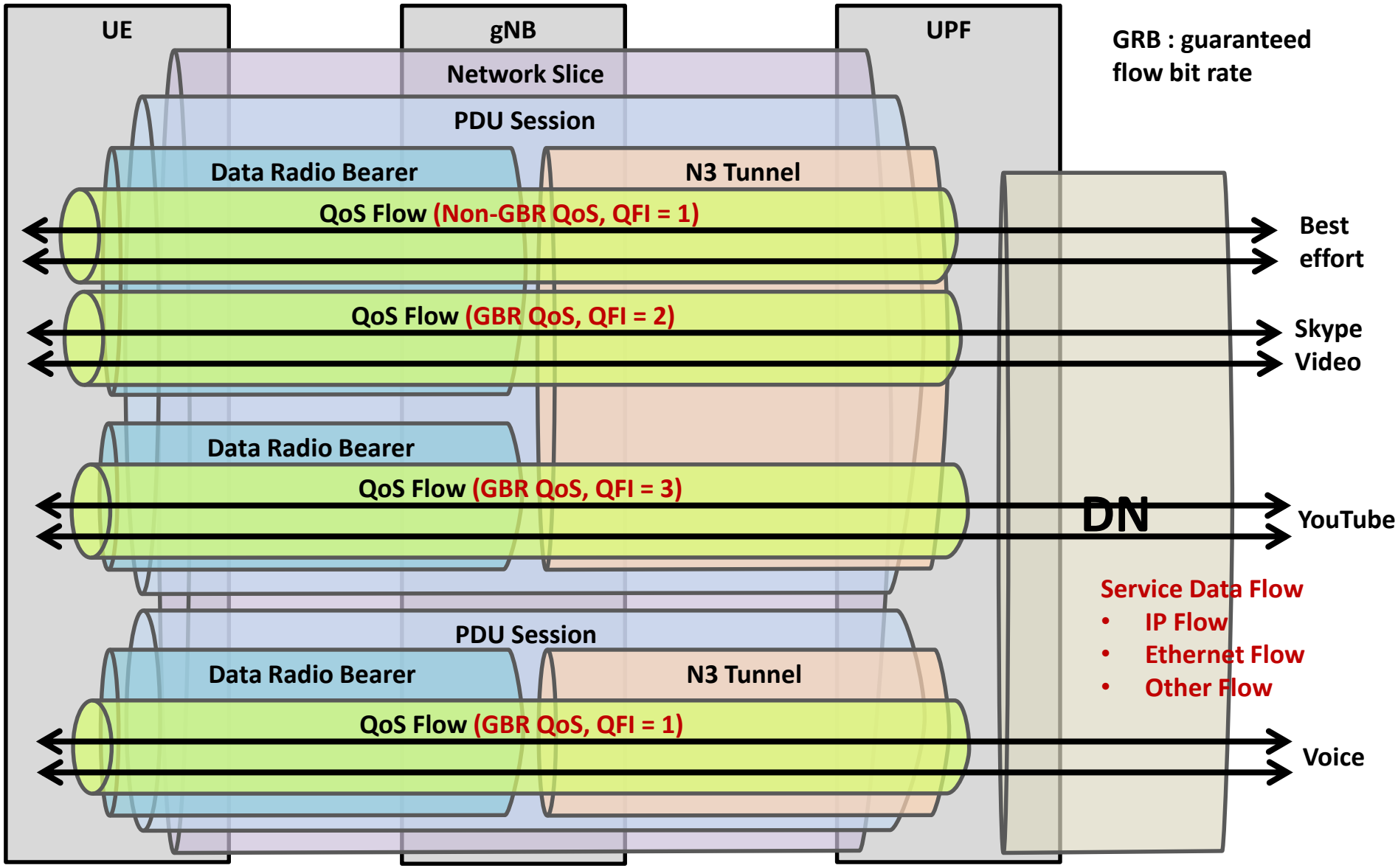
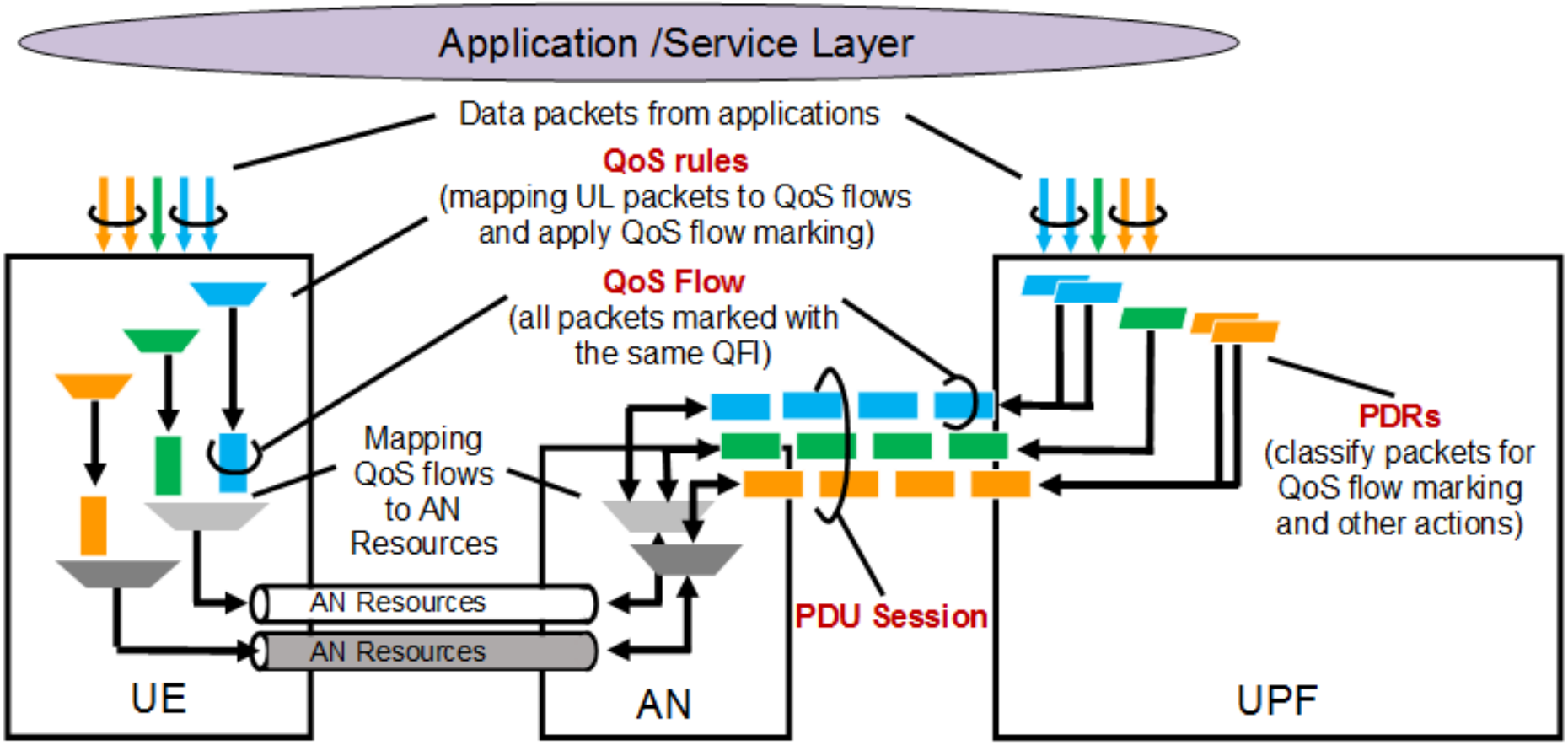
Network Slicing

Network Slicing QoS

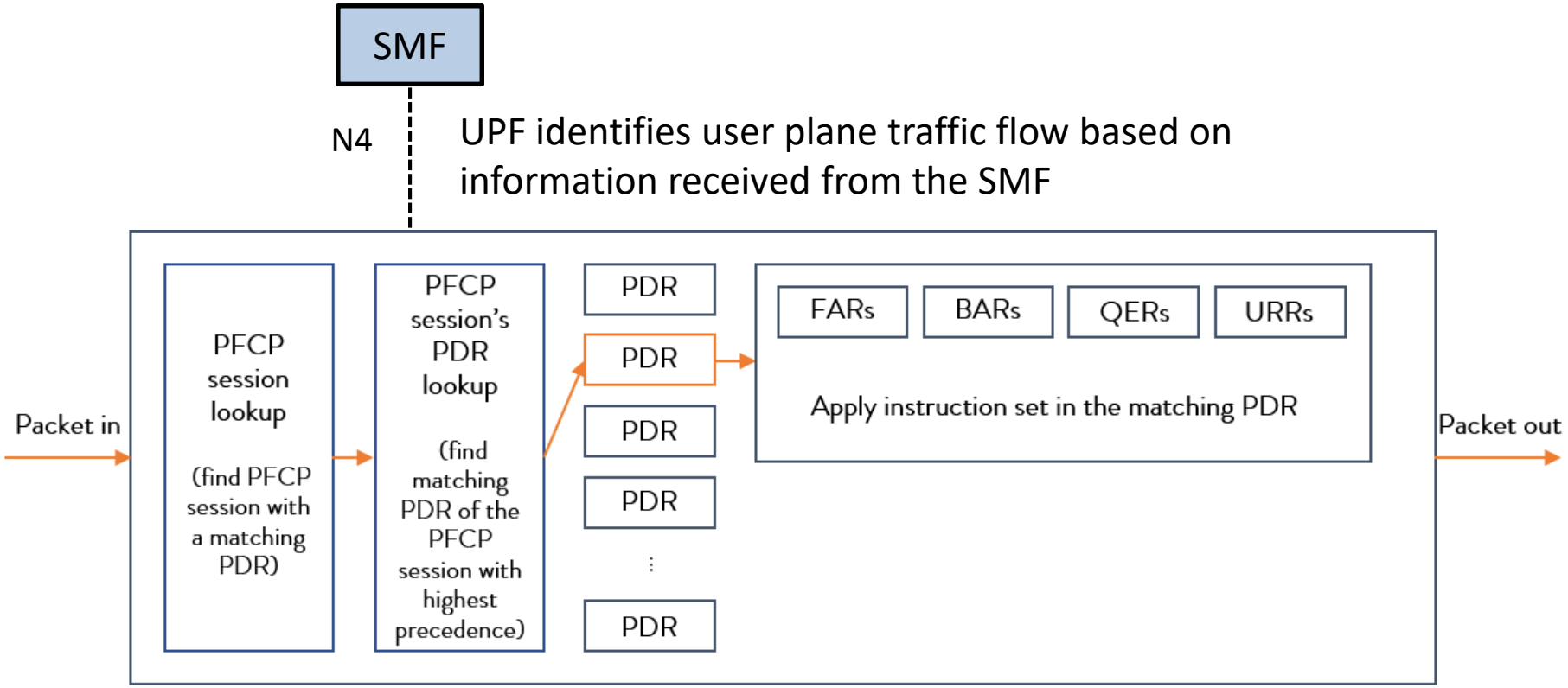
QoS Flow


UE
gNB
UPF
GRB : guaranteed flow bit rate
Network Slice
PDU Session
Data Radio Bearer
N3 Tunnel
QoS Flow (Non-GBR QoS, QFI = 1)
Best effort
QoS Flow (GBR QoS, QFI = 2)
Skype Video
Data Radio Bearer
QoS Flow (GBR QoS, QFI = 3)
DN
YouTube
Service Data Flow
• IP Flow
• Ethernet Flow
• Other Flow
PDU Session
Data Radio Bearer
N3 Tunnel
QoS Flow (GBR QoS, QFI = 1)
Voice

The principle for classification and User Plane marking for QoS Flows and mapping to AN Resources



Packet processing flow in the UPF



Packet Forwarding Control Protocol (PFCP)
Packet Detection Rule (PDR)
Forwarding Action Rules (FARs)
QoS Enforcement Rules (QERs)
Usage Reporting Rules (URRs)

5G QoS Parameters

- 5G QoS Identifier (5QI)
- Allocation and Retention Priority (ARP)
- Reflective QoS Attribute (RQA)
- Notification control
- Flow Bit Rates
- Aggregate Bit Rates
- Default values
- Maximum Packet Loss Rate

5G QoS characteristics associated with 5QI

Resource Type	• GBR (Guaranteed Bit Rate) • Delay critical GBR • Packet delayed more than PDB is counted as lost if the data burst is not exceeding the MDBV within the period of PDB and the QoS Flow is not exceeding the GFBR • Non-GBR
Priority Level	• Priority in scheduling resources among QoS Flows
Packet Delay Budget (PDB)	• Upper bound for the time that a packet may be delayed between the UE and the UPF that terminates the N6 interface • For GBR, PDB shall be interpreted as a Maximum delay with a confidence level of 98 percent if the QoS flow is not exceeding the GFBR
Packet Error Rate (PER)	• Upper bound for a rate of non-congestion related packet losses
Averaging window	• For GBR and Delay-critical GBR resource type only • Represents the duration over which the GFBR and MFBR shall be calculated
Maximum Data Burst Volume (MDBV)	• For Delay-critical GBR resource type only • Denotes the largest amount of data that the 5G-AN is required to serve within a period of 5G-AN PDB

Standardized 5QI to QoS characteristics mapping Resource Type - GRB

5QI Value	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
1	20	100 ms	10^{-2}	N/A	2000 ms	Conversational Voice
2	40	150 ms	10^{-3}	N/A	2000 ms	Conversational Video (Live Streaming)
3	30	50 ms	10^{-3}	N/A	2000 ms	Real Time Gaming, V2X messages Electricity distribution – medium voltage, Process automation - monitoring
4	50	300 ms	10^{-6}	N/A	2000 ms	Non-Conversational Video (Buffered Streaming)
65	7	75 ms	10^{-2}	N/A	2000 ms	Mission Critical user plane Push To Talk voice (e.g., MCPTT)
66	20	100 ms	10^{-2}	N/A	2000 ms	Non-Mission-Critical user plane Push To Talk voice
67	15	100 ms	10^{-3}	N/A	2000 ms	Mission Critical Video user plane
75						

Standardized 5QI to QoS characteristics mapping Resource Type - Non-GRB

5QI Value	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
5	10	100 ms	10^{-6}	N/A	N/A	IMS Signalling
6	60	300 ms	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7	70	100 ms	10^{-3}	N/A	N/A	Voice, Video (Live Streaming) Interactive Gaming
8	80	300 ms	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9	90	300 ms	10^{-6}	N/A	N/A	Same as 5QI Value 7
69	5	60 ms	10^{-6}	N/A	N/A	Mission Critical delay sensitive signalling (e.g., MC-PTT signalling)
70	55	200 ms	10^{-6}	N/A	N/A	Mission Critical Data (e.g. example services are the same as 5QI 6/8/9)
79	65	50 ms	10^{-2}	N/A	N/A	V2X messages
80	68	10 ms	10^{-6}	N/A	N/A	Low Latency eMBB applications Augmented Reality

Standardized 5QI to QoS characteristics mapping Resource Type - Delay Critical GRB

5QI Value	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
82	19	10 ms	10^{-4}	255 bytes	2000 ms	Discrete Automation (see TS 22.261 [2])
83	22	10 ms	10^{-4}	1354 bytes	2000 ms	Discrete Automation (see TS 22.261 [2])
84	24	30 ms	10^{-5}	1354 bytes	2000 ms	Intelligent transport systems (see TS 22.261 [2])
85	21	5 ms	10^{-5}	255 bytes	2000 ms	Electricity Distribution- high voltage (see TS 22.261 [2])

Allocation and Retention Priority (ARP)

- The QoS parameter ARP contains information
  - Priority level
    - Deciding whether a new QoS Flow may be accepted or needs to be rejected in the case of resource limitations
    - Used to decide which existing QoS Flow to pre-empt during resource limitations
    - Range : 1 to 15 with 1 as the highest level of priority
      - Levels 1-8 should only be assigned to resources for services that are authorized to receive prioritized treatment within an operator domain
      - Levels 9-15 may be assigned to resources that are authorized by the home network and thus applicable when a UE is roaming
  - Pre-emption capability
    - A service data flow may get resources that were already assigned to another service data flow with a lower priority level
  - Pre-emption vulnerability
    - A service data flow may lose the resources assigned to it in order to admit a service data flow with higher priority level

Reflective QoS Attribute (RQA)

- The Reflective QoS Attribute (RQA) is an optional parameter which indicates that certain traffic (not necessarily all) carried on this QoS Flow is subject to Reflective QoS.
- Only when the RQA is signalled for a QoS Flow, the (R)AN enables the transfer of the RQI for AN resource corresponding to this QoS Flow.

- Reflective QoS
  - Enables the UE to map UL User Plane traffic to QoS Flows without SMF provided QoS rules and it applies for IP PDU Session and Ethernet PDU Session
  - Creating UE derived QoS rules in the UE based on the received DL traffic

Notification control

- Indicates whether notifications are requested from the NG-RAN when the GFBR can no longer (or can again) be guaranteed for a QoS Flow during the lifetime of the QoS Flow

- For a GBR QoS Flow that enabled notification control
  - NG-RAN determines that the GFBR can no longer be guaranteed, NG-RAN shall send a notification towards SMF and keep the QoS Flow
    - While the NG-RAN is not delivering the requested GFBR for this QoS Flow
  - NG-RAN determines that the GFBR can be guaranteed again for a QoS Flow - for which a notification that the GFBR can no longer be guaranteed has been sent), the NG-RAN sends a notification, informing the SMF that the GFBR can be guaranteed again

Flow Bit Rates

- For GBR QoS Flows only

- Guaranteed Flow Bit Rate (GFBR) - UL and DL
  - Denotes the bit rate that is guaranteed to be provided by the network to the QoS Flow over the Averaging Time Window
- Maximum Flow Bit Rate (MFBR) - UL and DL
  - Limits the bit rate to the highest bit rate that is expected by the QoS Flow

- Bit rates above the GFBR value and up to the MFBR value, may be provided with relative priority determined by the Priority Level of the QoS Flows

Aggregate Bit Rates

- For Non-GBR QoS Flows only

- per Session Aggregate Maximum Bit Rate (Session-AMBR)
  - Limits the aggregate bit rate that can be expected to be provided across all Non-GBR QoS Flows for a specific PDU Session
  - Each PDU Session of a UE is associated Session-AMBR
  - Retrieved by the SMF from UDM
    - SMF may use the subscribed Session-AMBR or modify it based on local policy or use the authorized Session-AMBR received from PCF to get the Session-AMBR

- per UE Aggregate Maximum Bit Rate (UE-AMBR)
  - Limits the aggregate bit rate that can be expected to be provided across all Non-GBR QoS Flows of a UE
  - Each UE is associated UE-AMBR
  - Retrieved from UDM and provided to the (R)AN by the AMF

Default values

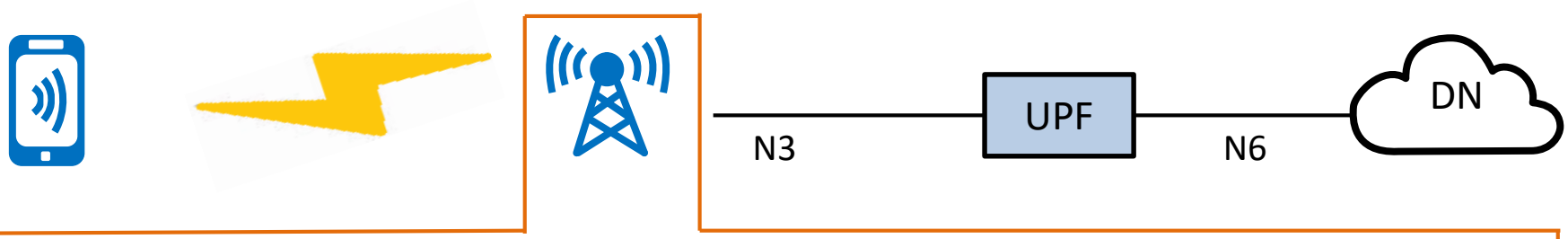
- For each PDU Session Setup, the SMF retrieves the subscribed default 5QI and ARP values from the UDM.
- The subscribed default 5QI value shall be a Non-GBR 5QI from the standardized value range.
- The SMF may change the subscribed default 5QI and ARP values based on local configuration or interaction with the PCF

Maximum Packet Loss Rate

- Indicates the maximum rate for lost packets of the QoS flow that can be tolerated in the uplink and downlink direction

- Provided to the QoS flow if it is compliant to the GFBR

QoS Rules and QoS Profile



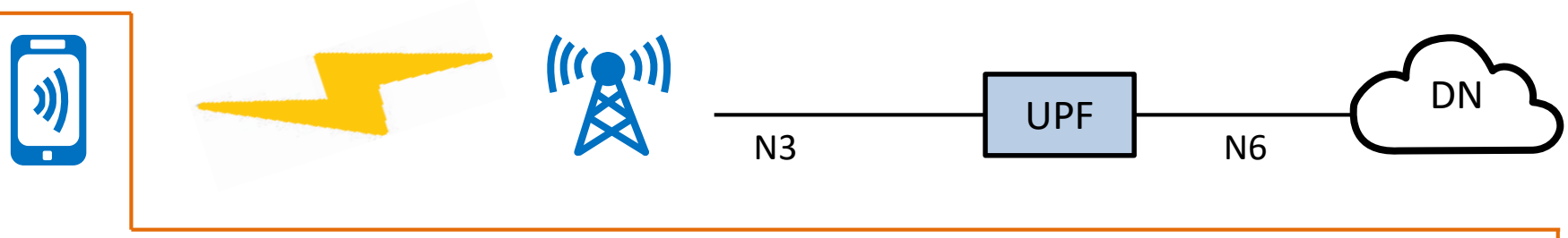
QoS Profile

A QoS Flow may either be 'GBR' or 'Non-GBR' depending on its QoS profile

GBR QoS Flow	Non-GBR QoS Flow

• 5G QoS Identifier (5QI)
• Allocation and Retention Priority (ARP)
• Flow Bit Rate
  • Guaranteed Flow Bit Rate (GFBR)
  • Maximum Flow Bit Rate (MFBR)
• (Optionally) Notification control
• (Optionally) Maximum Packet Loss Rate
	• 5G QoS Identifier (5QI)
	• Allocation and Retention Priority (ARP)
	• (Optionally) Reflective QoS Attribute (RQA)

QoS Rules



QoS Rules

Contains

- QFI of the associated QoS Flow
- UL Packet Filter Set
- precedence value

Configuration

- Explicitly provided to the UE (PDU Session Establishment/Modification procedure)
- Pre-configured in the UE
- Implicitly derived by the UE by applying Reflective QoS

Default QoS rule

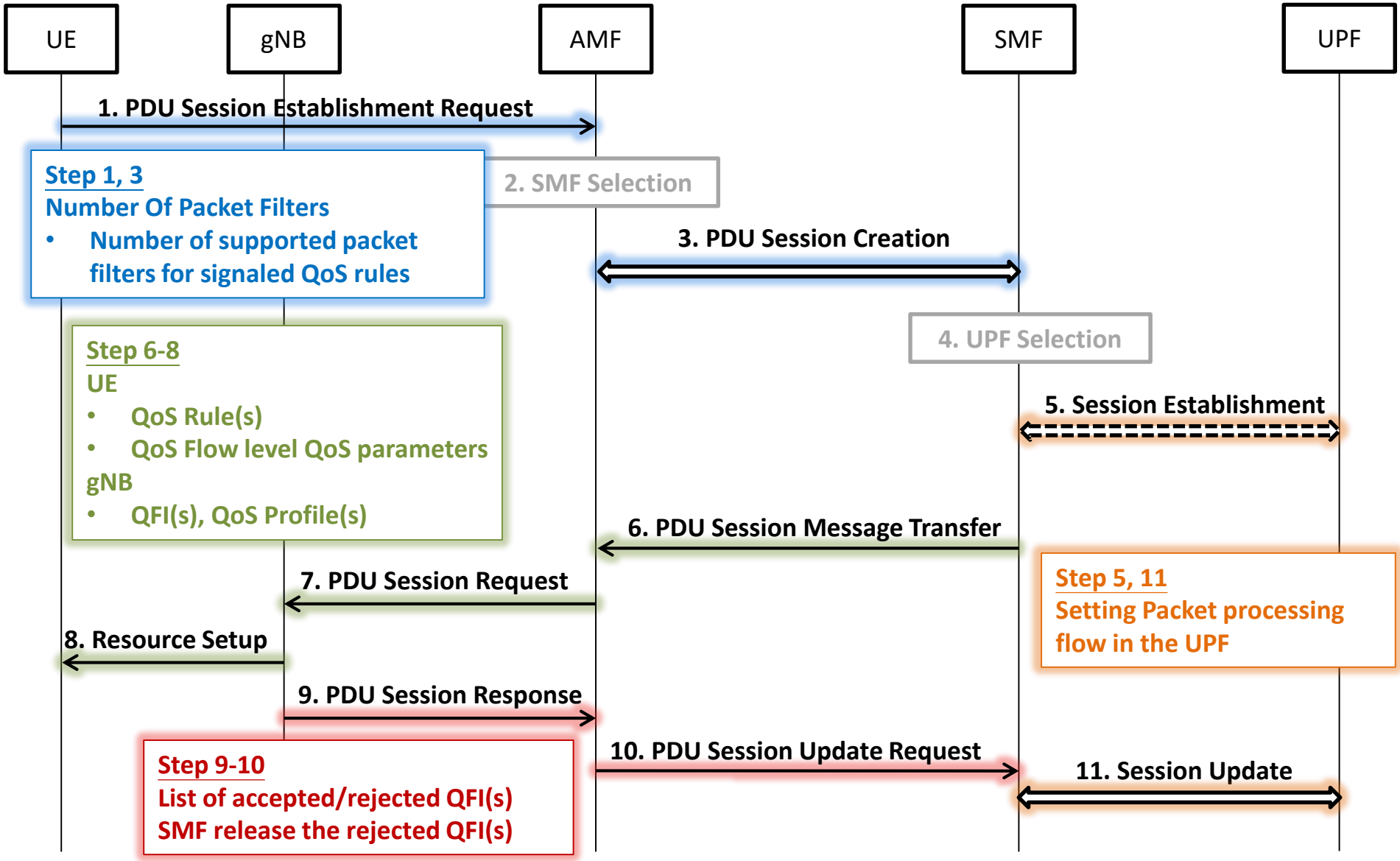
- Required to be sent to the UE for every PDU Session establishment and it is associated with a QoS Flow
- Default QoS rule in **IP or Ethernet type PDU Session**
  - The only QoS rule of a PDU Session with a “match-all filter” Packet Filter Set that allows all UL packets
- Default QoS rule in **Unstructured type PDU Session**
  - Does not contain a Packet Filter Set
    - Defines the treatment of all packets in the PDU Session

Packet Filter Set

- The Packet Filter Set is used in the QoS rule and the PDR to identify one or more packet (IP or Ethernet) flow(s)

- **IP Packet Filter Set** (For IP PDU Session Type)
  - Source/destination IP address or IPv6 prefix
  - Source / destination port number
  - Protocol ID of the protocol above IP/Next header type
  - Type of Service (TOS) (IPv4) / Traffic class (IPv6) and Mask
  - Flow Label (IPv6)
  - Security parameter index
  - Packet Filter direction
- **Ethernet Packet Filter Set** (For Ethernet PDU Session Type)
  - Source/destination MAC address
  - Ethertype
  - Customer-VLAN tag (C-TAG) and/or Service-VLAN tag (S-TAG) VID fields
  - Customer-VLAN tag (C-TAG) and/or Service-VLAN tag (S-TAG) PCP/DEI fields
  - IP Packet Filter Set, in the case that Ethertype indicates IPv4/IPv6 payload
  - Packet Filter direction

Qos Flow within PDU session establishment



Reference

- TS 23.501 System architecture for the 5G System (5GS)
- TS 23.502 Procedures for the 5G System (5GS)
- TS 29.244 Interface between the Control Plane and the User Plane nodes
- TS 38.300 NR; Overall description; Stage-2
- 3GPP SA2_121會議報告