教育部「5G行動寬頻人才培育跨校教學聯盟計畫」
5G行動網路協定與核網技術聯盟中心
「5G行動寬頻協同網路」課程模組

單元6
網路協同存取技術

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Outline

- Overall Architecture
  - Functional Split
  - Network Interfaces
  - Radio Protocol Architecture
- Multi-connectivity
- Non-3GPP Access Architecture
- Access to EPC via non-3GPP

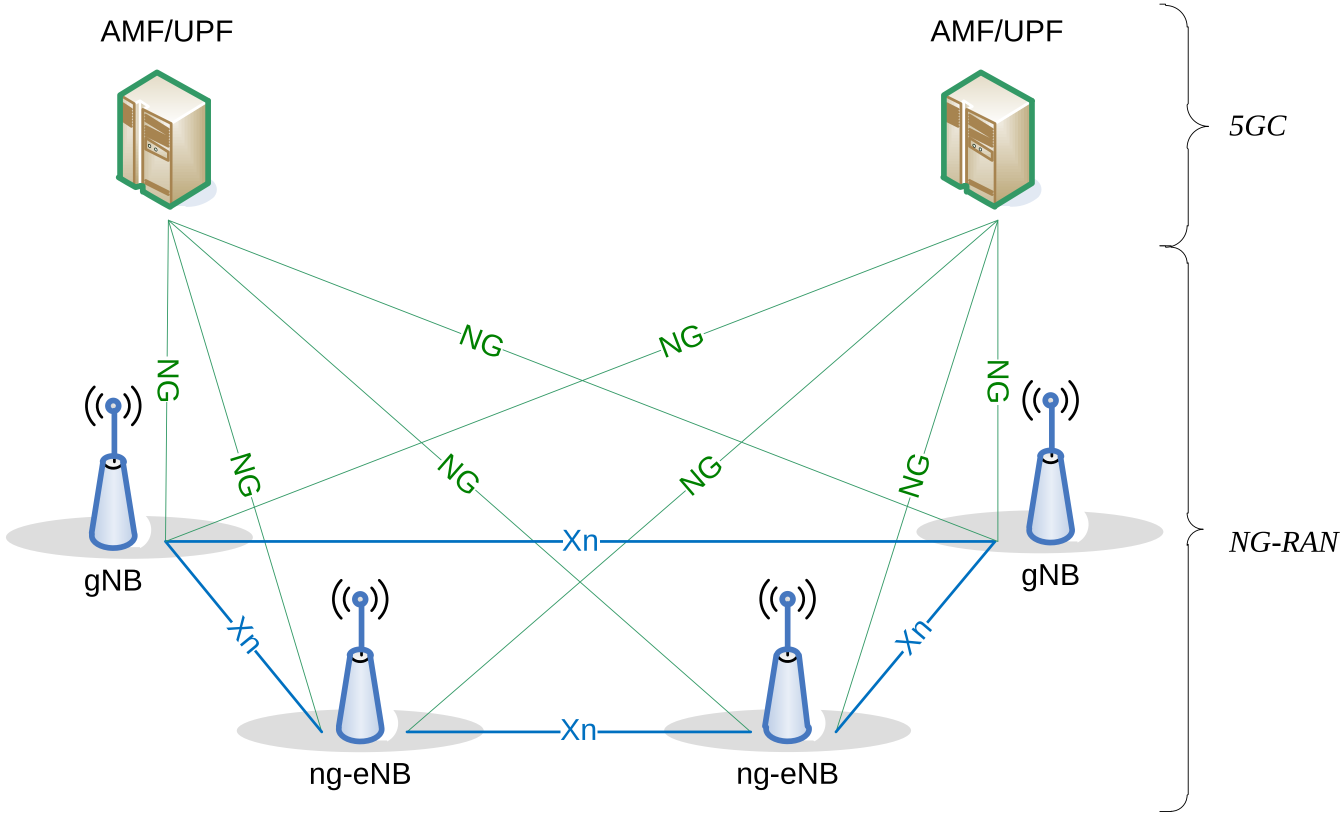
References:

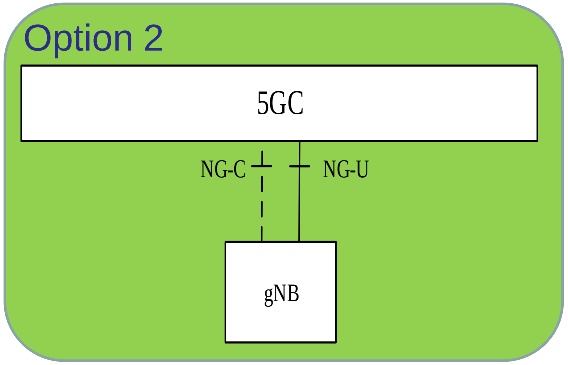
- TS 38.300: NR and NG-RAN Overall Description
- TS 37.340: E-UTRA and NR; Multi-connectivity
- TS 23.402: Architecture enhancements for non-3GPP accesses
- TS 24.302: Access to the 3GPP EPC via non-3GPP access networks

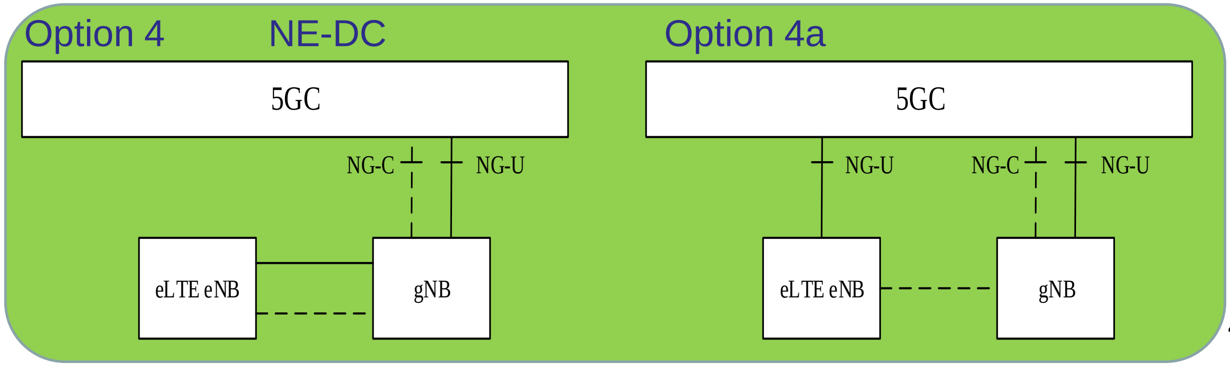
Overall Architecture

- An NG-RAN node is either
  - gNB providing NR, user plane and control plane protocol terminations towards the UE
  - ng-eNB providing E-UTRA, user plane and control plane protocol terminations towards the UE
- The gNBs and ng-eNBs are
  - interconnected with each other by means of the Xn interface
  - connected by means of the NG interfaces to the 5GC (TS 23.501)
    - to the AMF (Access and Mobility Management Function) by means of the NG-C interface and
    - to the UPF (User Plane Function) by means of the NG-U interface

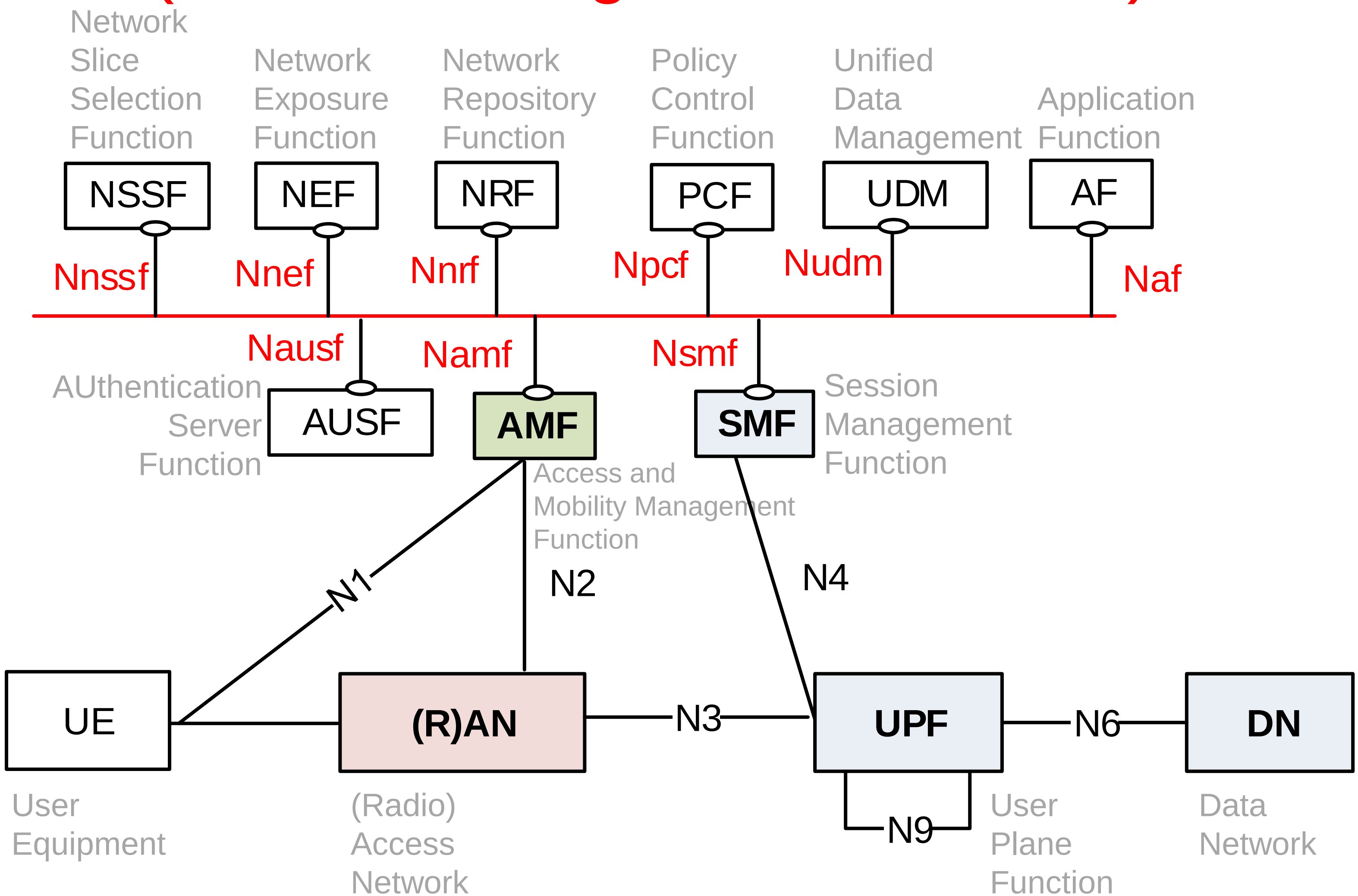
Overall Architecture







5G System Architecture (Non-Roaming Service-Based)



The non-roaming reference architecture with service-based interfaces used within the Control Plane (TS23.501)

gNB and ng-eNB Host Functions

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink
- IP header compression, encryption and integrity protection of data
- Selection of an AMF at UE attachment when no routing to an AMF can be determined from the information provided by the UE
- Routing of User Plane data towards UPF(s)
- Routing of Control Plane information towards AMF
- Connection setup and release
- Scheduling and transmission of paging messages
- Scheduling and transmission of system broadcast information
- Measurement and measurement reporting configuration for mobility and scheduling

gNB and ng-eNB Host Functions (Cont.)

- Transport level packet marking in the uplink
- Session Management
- Support of Network Slicing
- QoS Flow management and mapping to data radio bearers
- Support of UEs in RRC_INACTIVE state
- Distribution function for NAS messages
- Radio access network sharing
- Dual Connectivity
- Tight interworking between NR and E-UTRA

The AMF Hosts the Following Main Functions

- NAS signalling termination
- NAS signalling security
- AS Security control
- Inter CN node signalling for mobility between 3GPP access networks
- Idle mode UE Reachability
- Registration Area management
- Support of intra-system and inter-system mobility
- Access Authentication
- Access Authorization including check of roaming rights
- Mobility management control
- Support of Network Slicing
- SMF selection

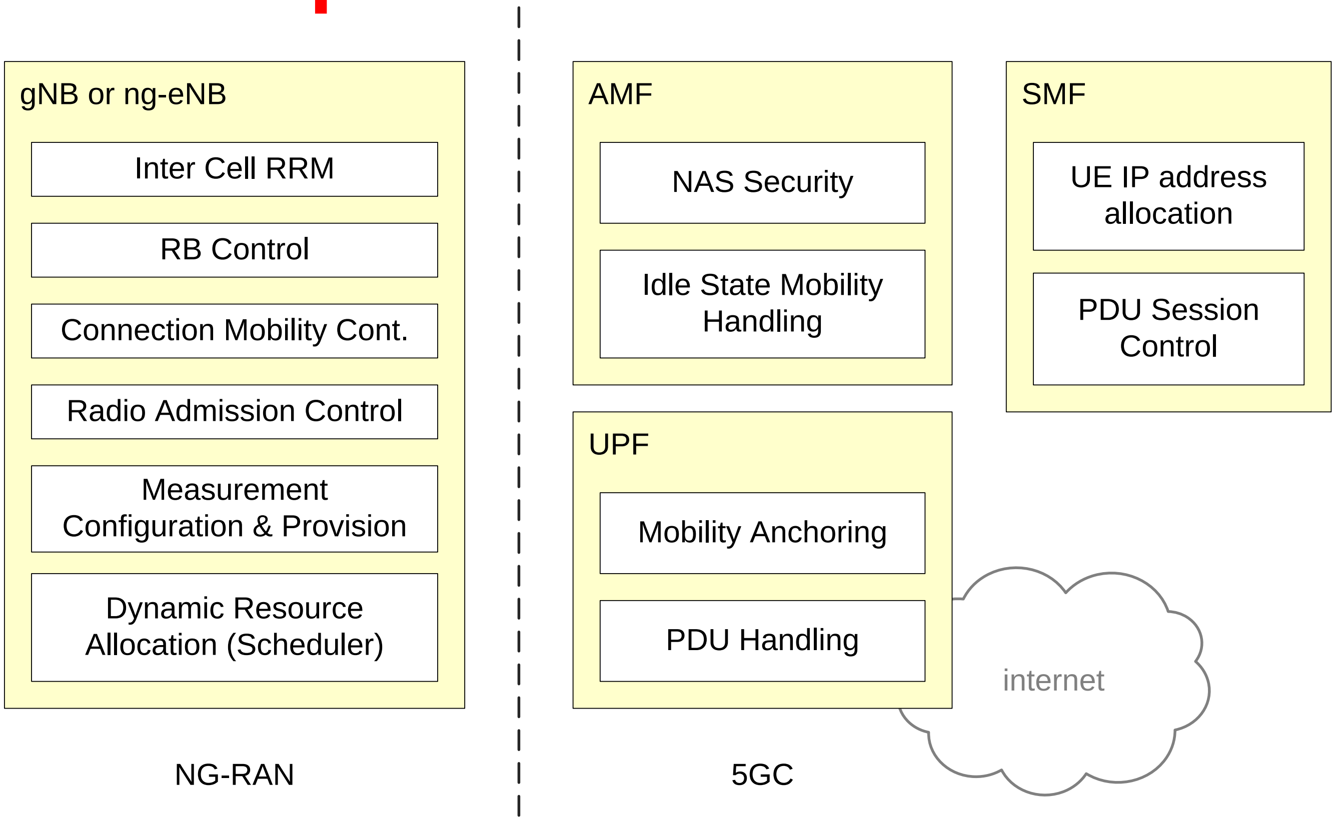
The UPF Hosts the Following Main Functions

- Anchor point for Intra-/Inter-RAT mobility
- External PDU session point of interconnect to Data Network
- Packet routing & forwarding
- Packet inspection and User plane part of Policy rule enforcement
- Traffic usage reporting
- Uplink classifier to support routing traffic flows to a data network
- Branching point to support multi-homed PDU session;
- QoS handling for user plane,
- Uplink Traffic verification
- Downlink packet buffering and downlink data notification triggering

The Session Management function (SMF) Hosts the Following Main Functions

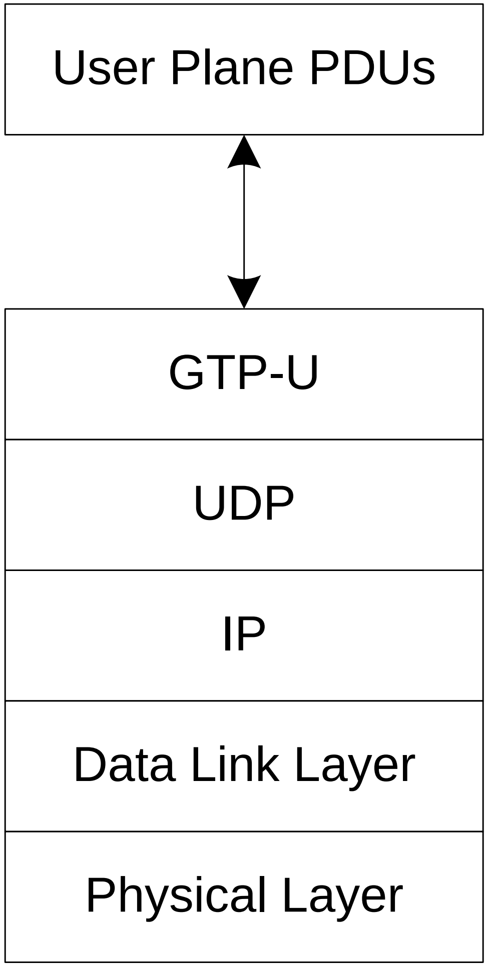
- Session Management
- UE IP address allocation and management
- Selection and control of UP function
- Configures traffic steering at UPF to route traffic to proper destination
- Control part of policy enforcement and QoS
- Downlink Data Notification

Functional Split between NG-RAN and 5GC



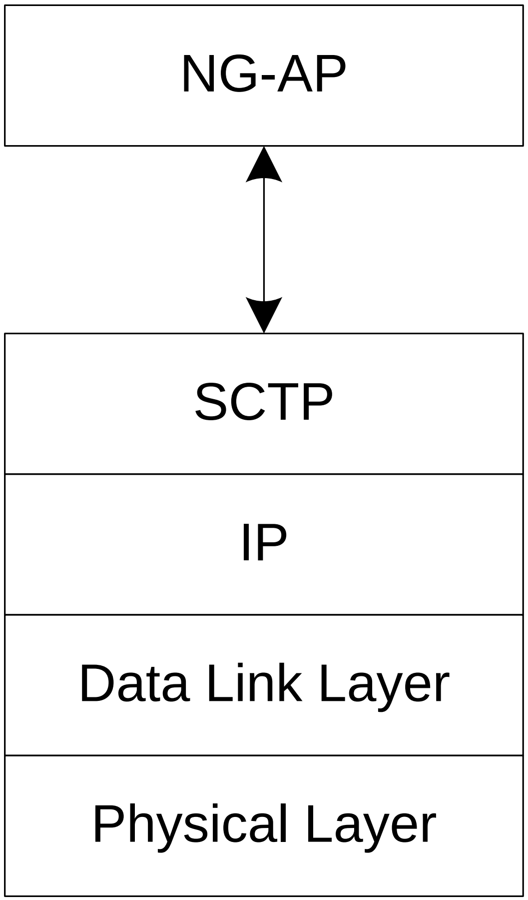
- This is summarized on the figure below where yellow boxes depict the logical nodes and white boxes depict the main functions

NG-U Protocol Stack



- The NG user plane interface is defined between the NG-RAN node and the UPF
- The transport network layer is built on IP transport and GTP-U is used on top of UDP/IP to carry the user plane PDUs between the NG-RAN node and the UPF
- NG-U provides non-guaranteed delivery of user plane PDUs between the NG-RAN node and the UPF
- Further details of NG-U can be found in 3GPP TS 38.410

NG-C Protocol Stack

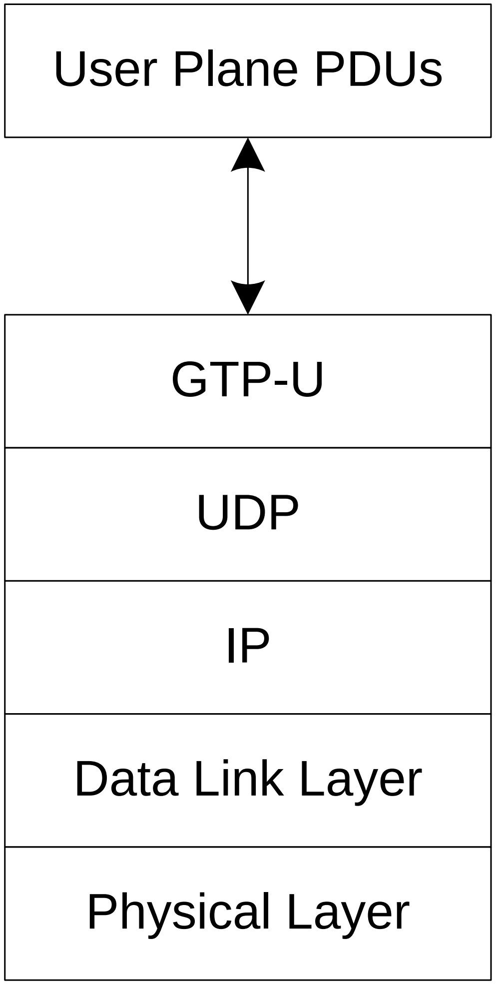


- The NG control plane interface is defined between the NG-RAN node and the AMF
- For the reliable transport of signalling messages, SCTP is added on top of IP
- The SCTP layer provides guaranteed delivery of application layer messages
  - Stream Control Transmission Protocol, RFC4960
- In the transport, IP layer point-to-point transmission is used to deliver the signalling PDUs

NG-C Provides the Following Functions

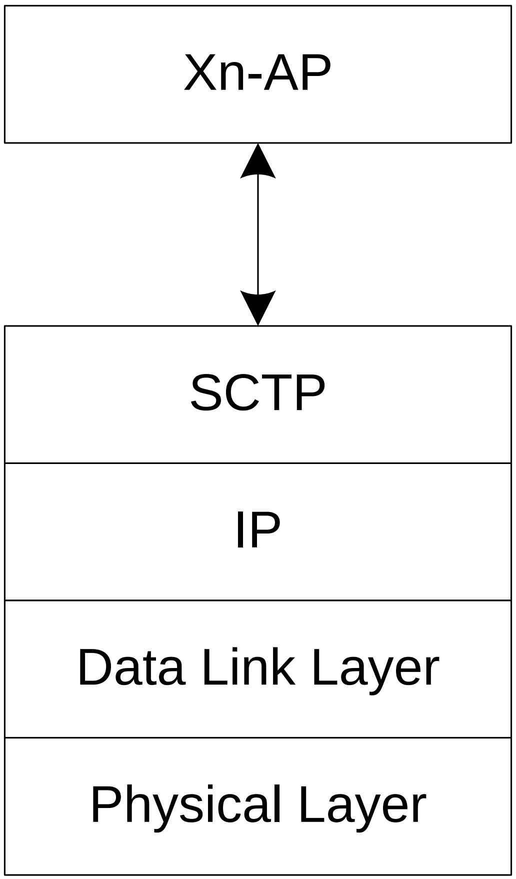
- NG interface management
- UE context management
- UE mobility management
- Transport of NAS messages
- Paging
- PDU Session Management
- Configuration Transfer
- Warning Message Transmission

Xn-U Protocol Stack



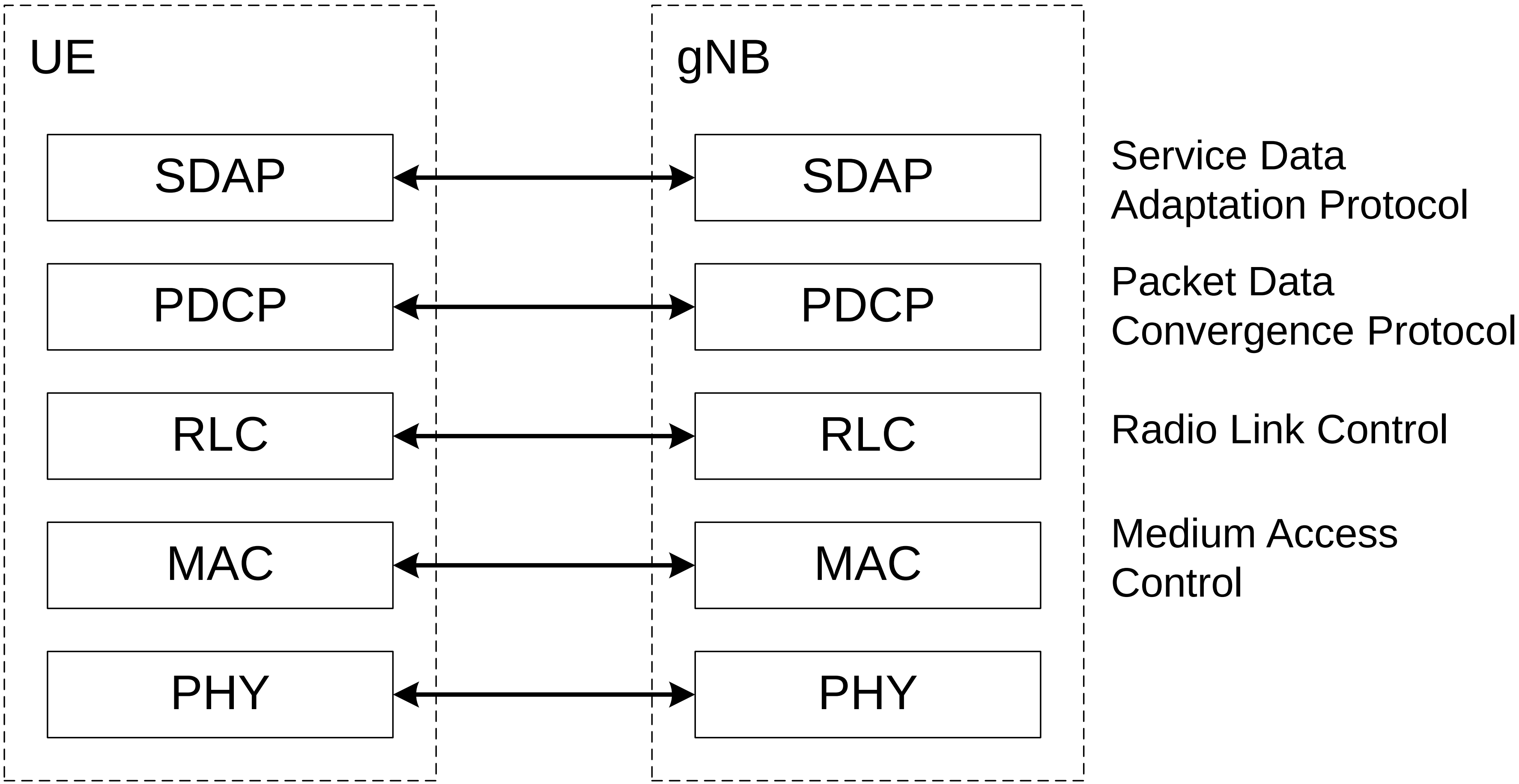
- The Xn User plane (Xn-U) interface is defined between two NG-RAN nodes
- The transport network layer is built on IP transport and GTP-U is used on top of UDP/IP to carry the user plane PDUs
- Xn-U provides non-guaranteed delivery of user plane PDUs and Data forwarding and Flow control

Xn-C Protocol Stack



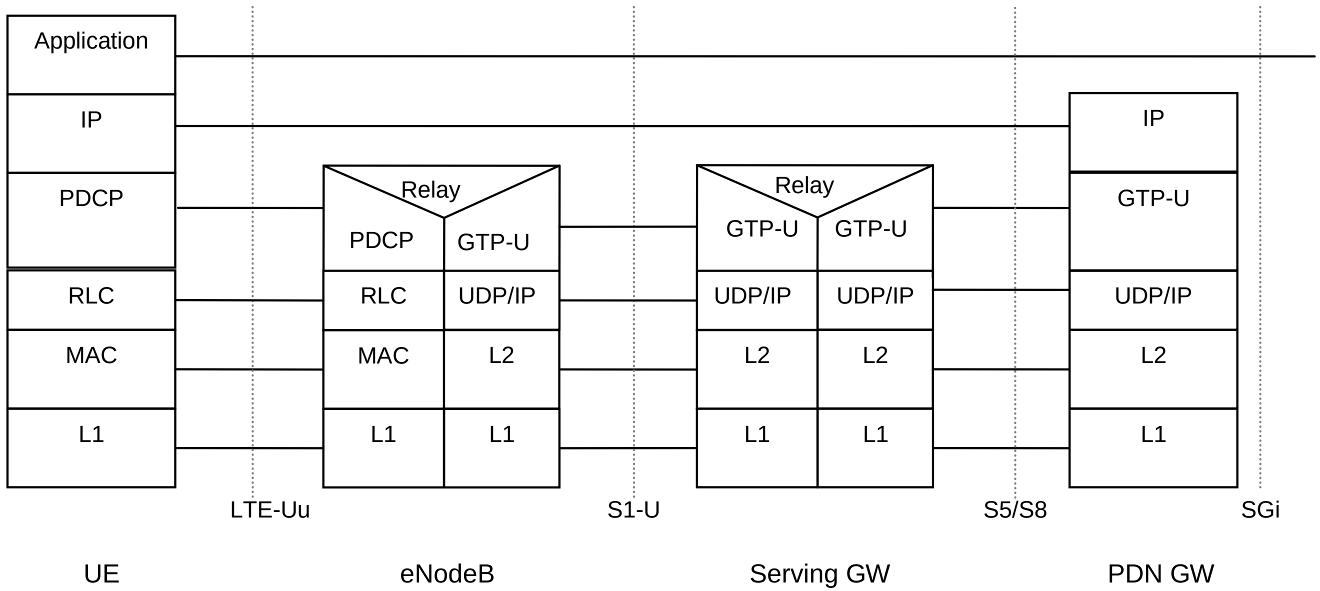
- The Xn control plane interface (Xn-C) is defined between two NG-RAN nodes
- The transport network layer is built on SCTP on top of IP
- The Xn-C interface supports the following functions
  - Xn interface management
  - UE mobility management, including context transfer and RAN paging
  - Dual connectivity

User Plane Protocol Stack

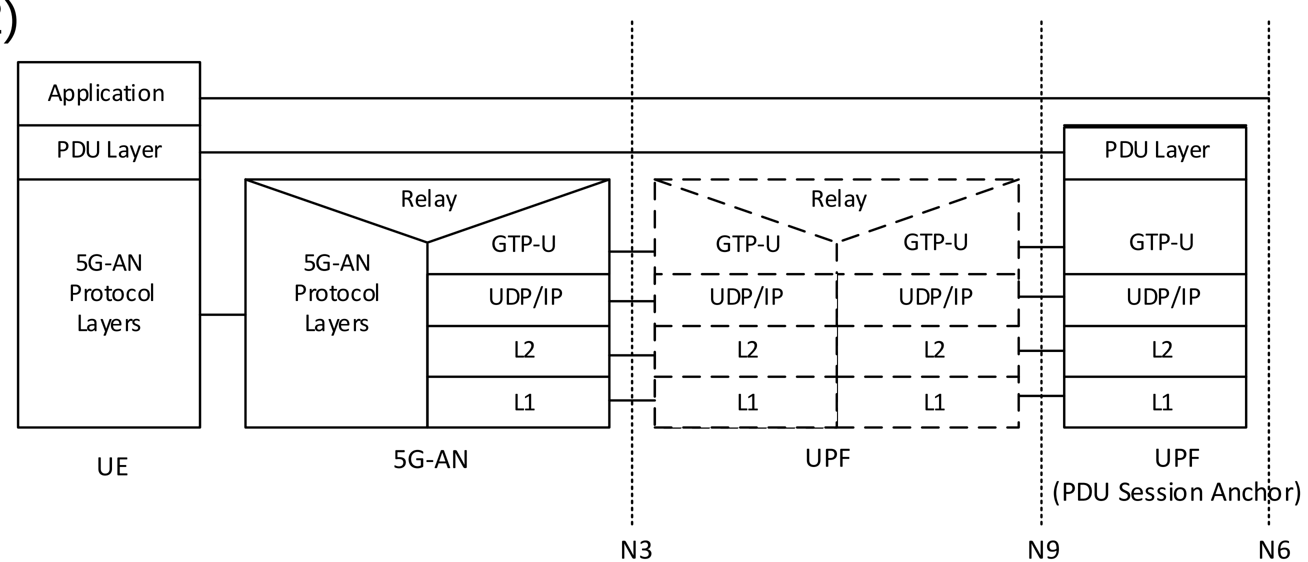


4G/5G User Plane Protocol Stack for 3GPP Access

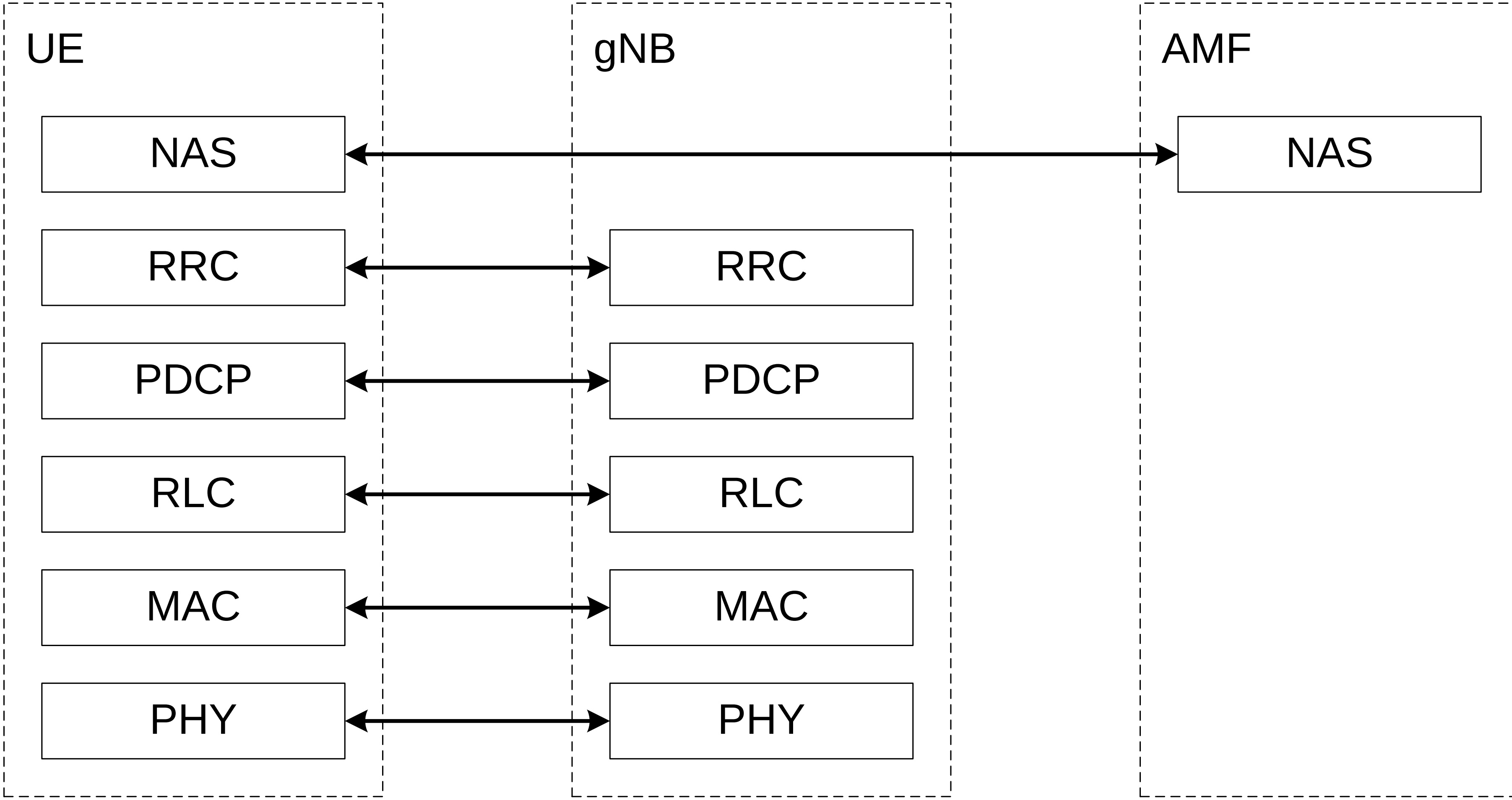
4G (Option 1)



5G (Option 2)

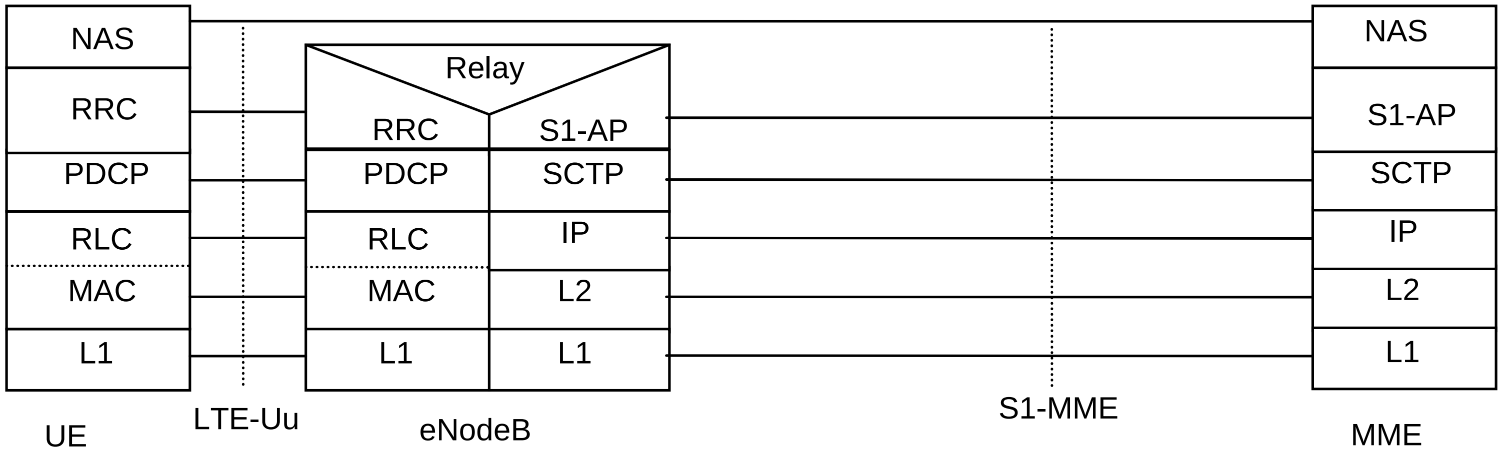


Control Plane Protocol Stack

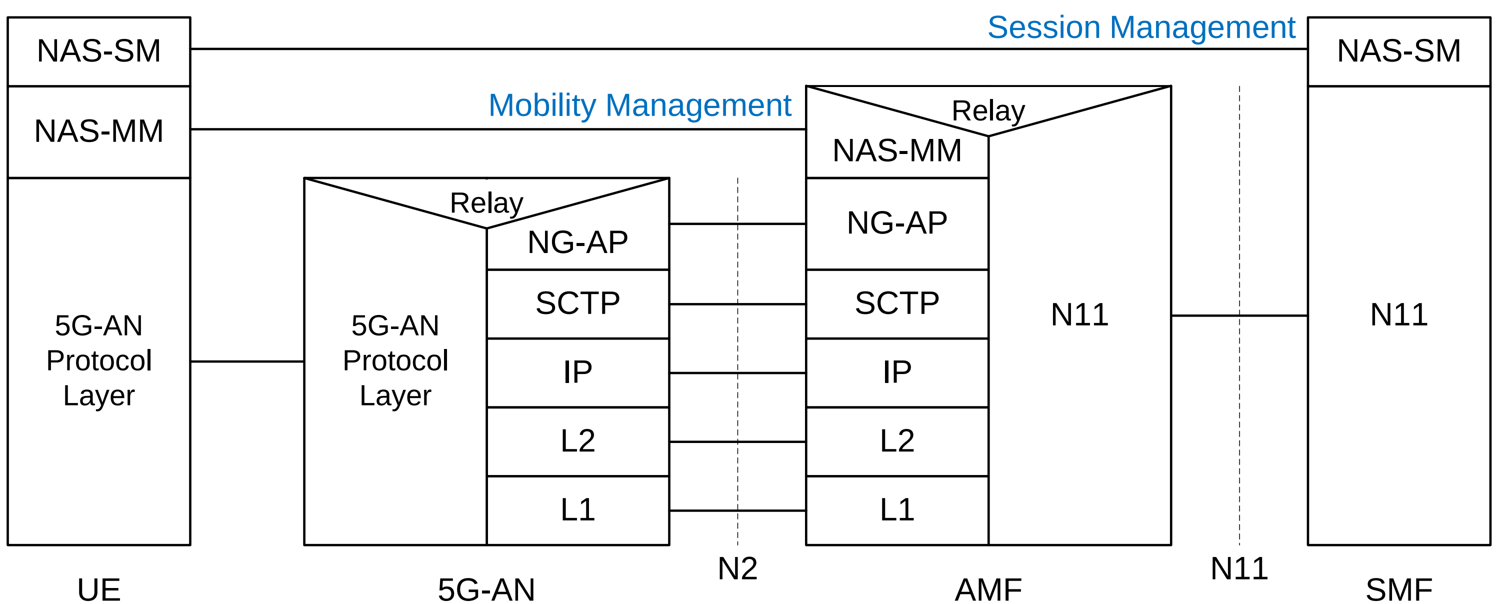


4G/5G Control Plane Protocol Stack

4G (Option 1)



5G (Option 2)



Multi-RAT Dual Connectivity

- NG-RAN supports Multi-RAT Dual Connectivity (MR-DC) operation whereby a UE in RRC_CONNECTED is configured to utilise radio resources provided by two distinct schedulers, located in two different NG-RAN nodes connected via a non-ideal backhaul and providing either E-UTRA or NR access
- Further details of MR-DC operation can be found in 3GPP TS 37.340

Outline

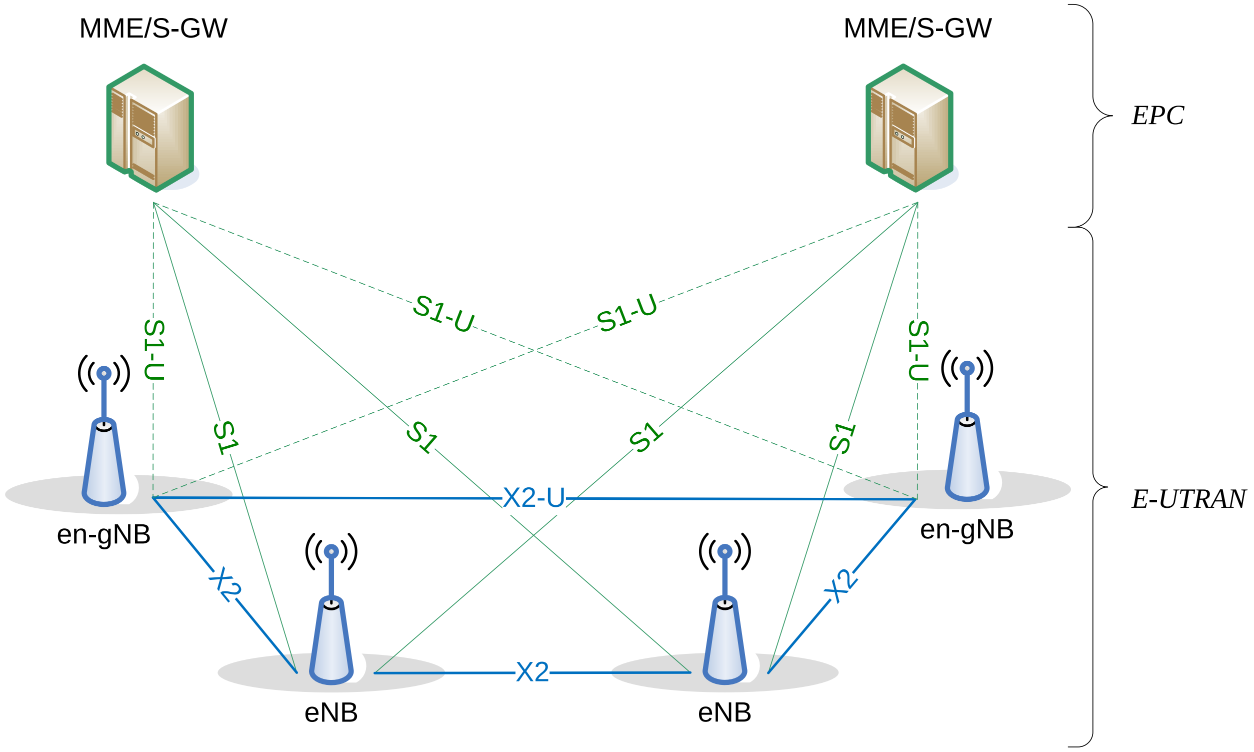
- Overall Architecture
- Multi-connectivity
  - Multi-RAT Dual Connectivity
  - Layer 1 and Layer 2 Related Aspects
  - RRC Related Aspects
  - Bearer Handling Aspects
  - Security Related Aspects
  - Multi-Connectivity Operation Related Aspects
  - Service Related Aspects
  - X2/Xn Interface Related Aspects
- Non-3GPP Access Architecture
- Access to EPC via non-3GPP

Common MR-DC Principles

- Multi-RAT Dual Connectivity (MR-DC) is a generalization of the Intra-E-UTRA Dual Connectivity (DC) described in 36.300
  - A multiple Rx/Tx UE may be configured to utilise resources provided by two different nodes connected via non-ideal backhaul, one providing E-UTRA access and the other one providing NR access
  - One node acts as the MN(Master Node) and the other as the SN(Secondary Node)
  - The MN and SN are connected via a network interface and at least the MN is connected to the core network
- MR-DC is designed based on the assumption of non-ideal backhaul between the different nodes but can also be used in case of ideal backhaul
- All MR-DC normative text and procedures in TS37.340 V15.3.0 show the aggregated node case
- The details about non-aggregated node for MR-DC operation are described in TS38.401

MR-DC with the EPC

- E-UTRAN supports MR-DC via E-UTRA-NR Dual Connectivity (EN-DC), in which a UE is connected to one eNB that acts as a MN and one en-gNB that acts as a SN
- The eNB is connected to the EPC via the S1 interface and to the en-gNB via the X2 interface
- The en-gNB might also be connected to the EPC via the S1-U interface and other en-gNBs via the X2-U interface



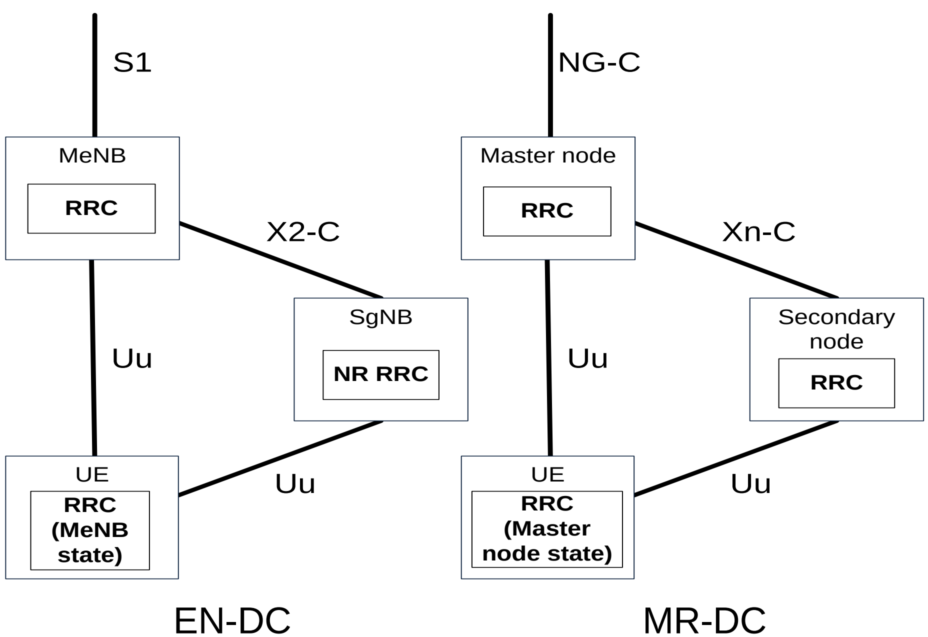
EN-DC Overall Architecture

MR-DC with the 5GC

- E-UTRA-NR Dual Connectivity
  - NG-RAN supports NG-RAN E-UTRA-NR Dual Connectivity (NGEN-DC), in which a UE is connected to one ng-eNB that acts as a MN and one gNB that acts as a SN
  - The ng-eNB is connected to the 5GC and the gNB is connected to the ng-eNB via the Xn interface
- NR-E-UTRA Dual Connectivity
  - NG-RAN supports NR-E-UTRA Dual Connectivity (NE-DC), in which a UE is connected to one gNB that acts as a MN and one ng-eNB that acts as a SN
  - The gNB is connected to 5GC and the ng-eNB is connected to the gNB via the Xn interface

Radio Protocol Architecture (Control Plane)

- In MR-DC, the UE has a single RRC state, based on the MN RRC and a single C-plane connection towards the Core Network
- The Control plane architecture for MR-DC
  - Each radio node has its own RRC entity (E-UTRA version if the node is an eNB or NR version if the node is a gNB) which can generate RRC PDUs to be sent to the UE
- RRC PDUs generated by the SN can be transported via the MN to the UE
  - The MN always sends the initial SN RRC configuration via MCG SRB (SRB1), but subsequent reconfigurations may be transported via MN or SN
  - When transporting RRC PDU from the SN, the MN does not modify the UE configuration provided by the SN
- In EN-DC, at initial connection establishment SRB1 uses E-UTRA PDCP
  - After initial connection establishment MCG SRBs (SRB1 and SRB2) can be configured by the network to use either E-UTRA PDCP or NR PDCP
  - A PDCP version change (release of old PDCP and establish of new PDCP) of SRBs can be supported in either direction (i.e. from E-UTRA PDCP to NR PDCP or viceversa) via a handover procedure (reconfiguration with mobility) or, for the initial change from E-UTRA PDCP to NR PDCP, with a reconfiguration without mobility, when the network knows there is no UL data in buffer and before the initial security activation
  - For EN-DC capable UEs, NR PDCP can be configured for DRBs and SRBs also before EN-DC is configured

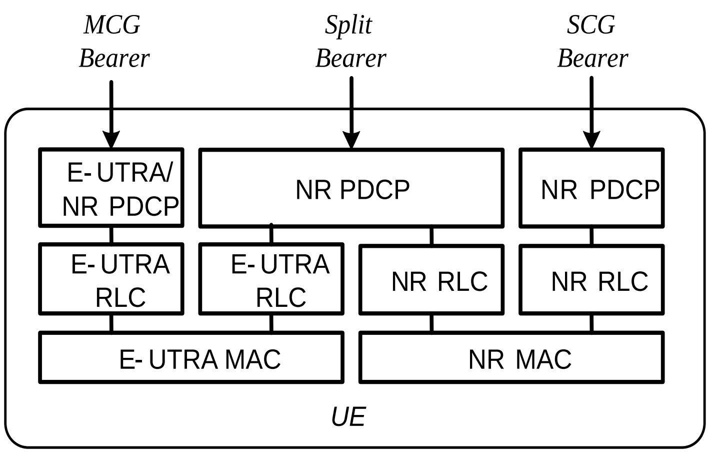


Radio Protocol Architecture (Control Plane) (Cont.)

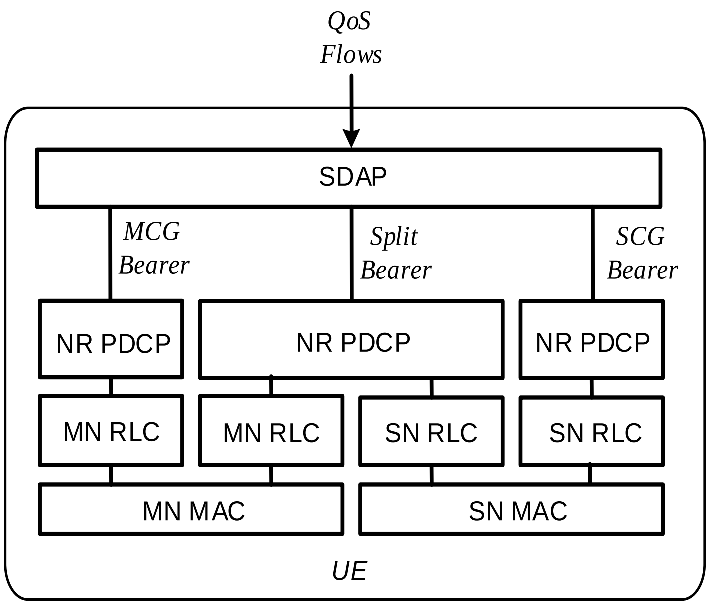
- If the SN is a gNB (i.e. for EN-DC and NGEN-DC)
  - The UE can be configured to establish a SRB with the SN (SRB3) to enable RRC PDUs for the SN to be sent directly between the UE and the SN
  - RRC PDUs for the SN can only be transported directly to the UE for SN RRC reconfiguration not requiring any coordination with the MN
  - Measurement reporting for mobility within the SN can be done directly from the UE to the SN if SRB3 is configured
- Split SRB is supported for all MR-DC options
  - Allowing duplication of RRC PDUs generated by the MN, via the direct path and via the SN
  - Split SRB uses NR PDCP
  - TS37.340 V15.3.0 does not support the duplication of RRC PDUs generated by the SN via the MN and SN paths
- In EN-DC
  - The SCG configuration is kept in the UE during suspension
  - The UE releases the SCG configuration (but not the radio bearer configuration) during resumption initiation

Radio Protocol Architecture (User Plane)

- In MR-DC, from a UE perspective, three bearer types exist
  - MCG bearer
  - SCG bearer
  - Split bearer
- For EN-DC, the network can configure either E-UTRA PDCP or NR PDCP for MN terminated MCG bearers while NR PDCP is always used for all other bearers
- In MR-DC with 5GC, NR PDCP is always used for all bearer types
- In NGEN-DC, E-UTRA RLC/MAC is used in the MN while NR RLC/MAC is used in the SN
- In NE-DC, NR RLC/MAC is used in the MN while E-UTRA RLC/MAC is used in the SN



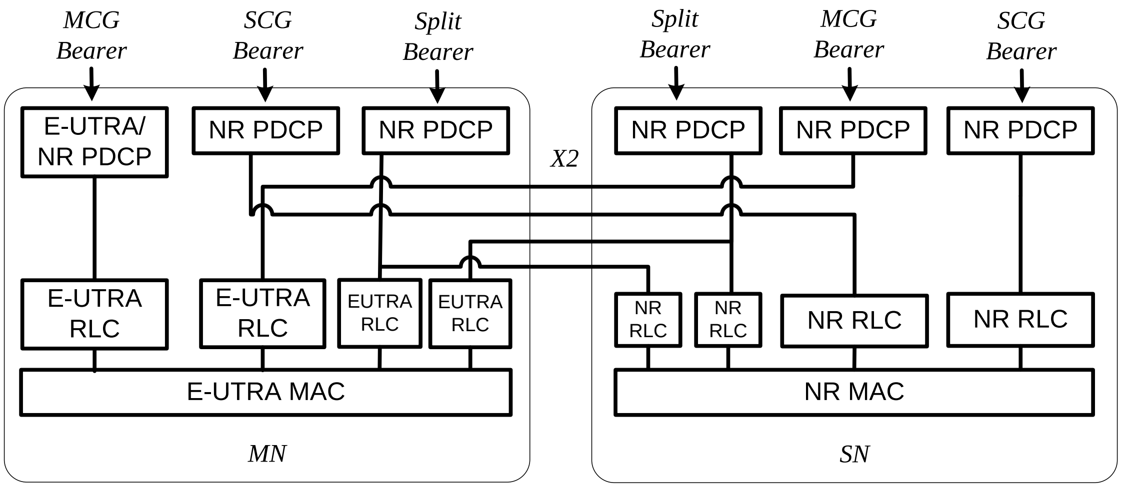
MR-DC with EPC (EN-DC)



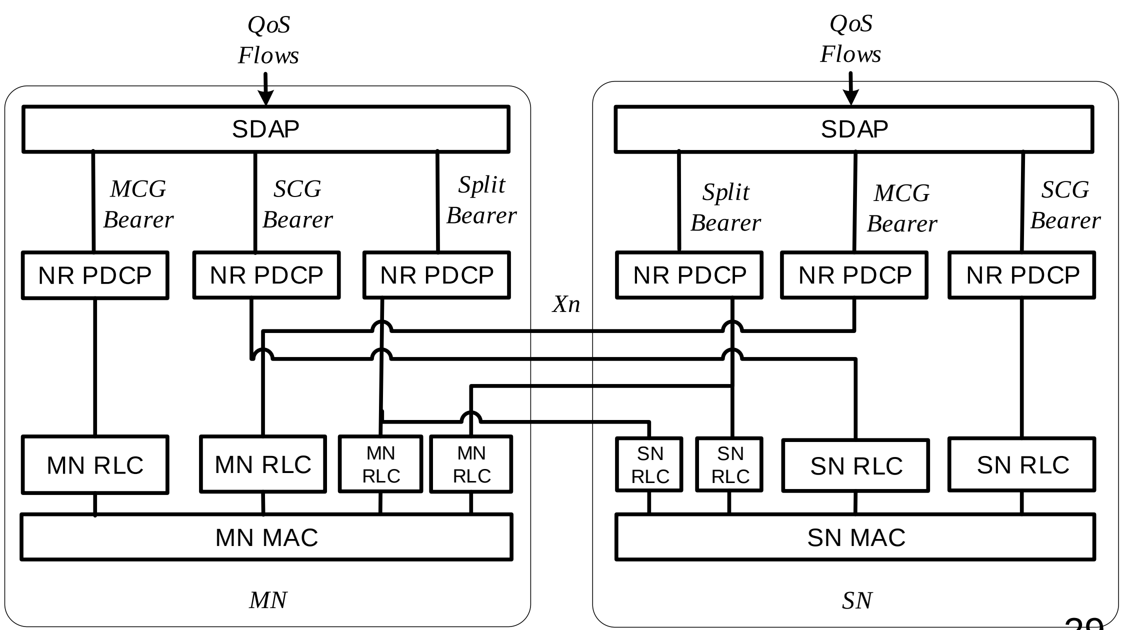
MR-DC with 5GC (NGEN-DC, NE-DC)

Network Side Protocol Termination Options

- From a network perspective, each bearer (MCG, SCG and split bearer) can be terminated either in MN or in SN
- Even if only SCG bearers are configured for a UE, for SRB1 and SRB2 the logical channels are always configured at least in the MCG
  - i.e. this is still an MR-DC configuration and a Pcell always exists
- If only MCG bearers are configured for a UE
  - i.e. there is no SCG, this is still considered an MR-DC configuration, as long as at least one of the bearers is terminated in the SN



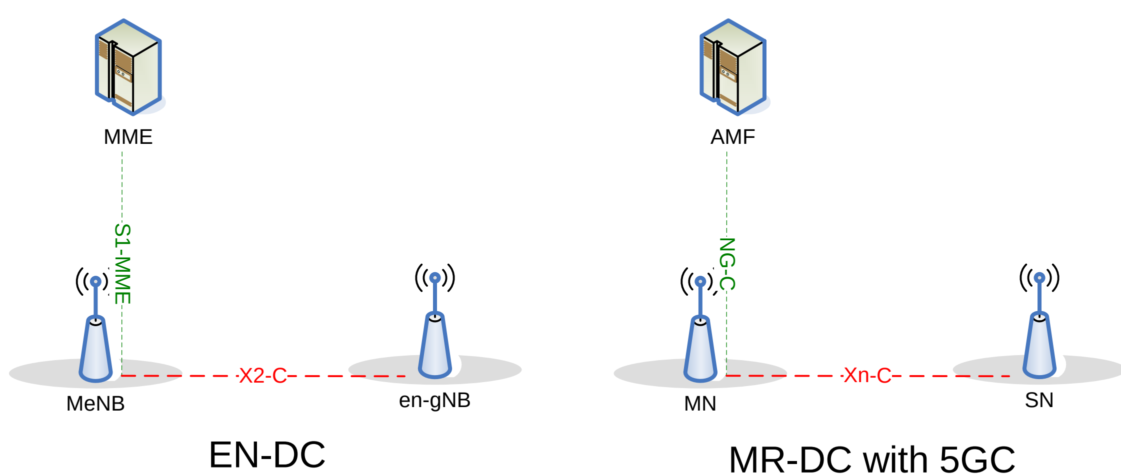
MCG, SCG and split bearers in MR-DC with EPC (EN-DC)



MCG, SCG and split bearers in MR-DC with 5GC (NGEN-DC, NE-DC)

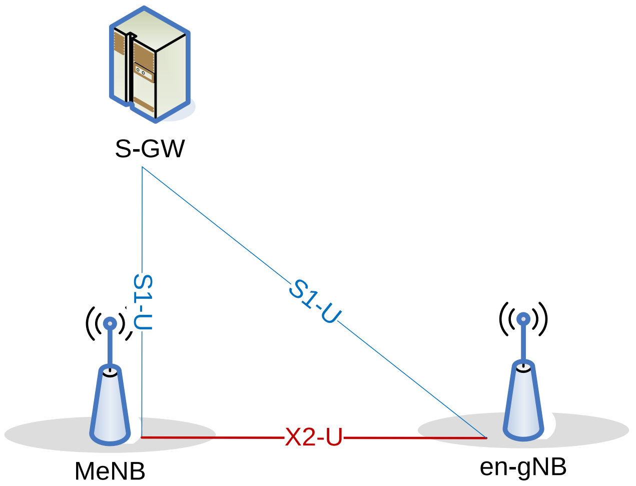
Network Interfaces (Control Plane)

- Common MR-DC principles
  - In MR-DC, there is an interface between the MN and the SN for control plane signalling and coordination
  - For each MR-DC UE, there is also one control plane connection between the MN and a corresponding CN entity
  - The MN and the SN involved in MR-DC for a certain UE control their radio resources and are primarily responsible for allocating radio resources of their cells
- MR-DC with EPC
  - In MR-DC with EPC (EN-DC), the involved core network entity is the MME
  - S1-MME is terminated in MN and the MN and the SN are interconnected via X2-C
- MR-DC with 5GC
  - In MR-DC with 5GC (NGEN-DC, NE-DC), the involved core network entity is the AMF
  - NG-C is terminated in the MN and the MN and the SN are interconnected via Xn-C

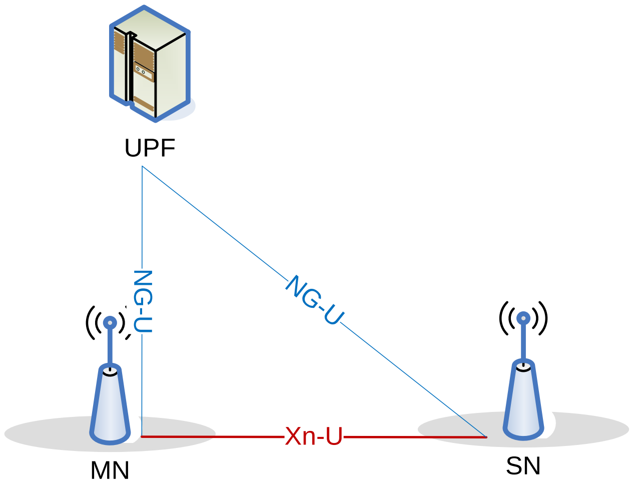


Network Interfaces (User Plane)

- Common MR-DC principles
  - There are different U-plane connectivity options of the MN and SN involved in MR-DC for a certain UE
    - For MN terminated bearers, the user plane connection to the CN entity is terminated in the MN
    - For SN terminated bearers, the user plane connection to the CN entity is terminated in the SN
    - The transport of user plane data over the Uu either involves MCG or SCG radio resources or both
      - –For MCG bearers, only MCG radio resources are involved
      - –For SCG bearers, only SCG radio resources are involved
      - –For split bearers, both MCG and SCG radio resources are involved
    - For split bearers, MN terminated SCG bearers and SN terminated MCG bearers, PDCP data is transferred between the MN and the SN via the MN-SN user plane interface
- MR-DC with EPC
  - For MR-DC with EPC (EN-DC), X2-U interface is the user plane interface between MN and SN, and S1-U is the user plane interface between the MN, the SN or both and the S-GW
- MR-DC with 5GC
  - For MR-DC with 5GC (NGEN-DC, NE-DC), Xn-U interface is the user plane interface between MN and SN, and NG-U is the user plane interface between the MN, the SN or both and the UPF



EN-DC



MR-DC with 5GC

Layer 1 Related Aspects

- In MR-DC, two or more Component Carriers (CCs) may be aggregated over two cell groups
  - A UE may simultaneously receive or transmit on multiple CCs depending on its capabilities
  - The maximum number of configured CCs for a UE is 32 for DL and UL
  - Depending on UE's capabilities, up to 31 CCs can be configured for an E-UTRA cell group when the NR cell group is configured
  - For the NR cell group, the maximum number of configured CCs for a UE is 16 for DL and 16 for UL
- A gNB may configure the same Physical Cell ID (PCI) to more than one NR cell it serves
  - To avoid PCI confusion for MR-DC, NR PCIs should be allocated in a way that an NR cell is uniquely identifyable by a PCell identifier
  - This Pcell is in the coverage area of an NR cell included in the MR-DC operation
  - In addtion, NR PCIs should only be re-used in NR cells on the same SSB frequency sufficiently distant from each other
  - X2-C/Xn-C signalling supports disambiguation of NR PCIs by including the CGI of the PCell in respective X2AP/XnAP messages (e.g. SGNB ADDITION REQUEST/S-NODE ADDITION REQUEST) and by providing neighbour cell relationship via non-UE associated signaling (e.g. via the Xn Setup procedure or the NG-RAN node Configuration Update procedure)

Layer 2 Related Aspects

- MAC Sublayer
  - In MR-DC, the UE is configured with two MAC entities: one MAC entity for the MCG and one MAC entity for the SCG
  - In MR-DC, semi-persistent scheduling (SPS) resources can be configured on both Pcell and PSCell
  - In MR-DC,BSR configuration, triggering and reporting are independently performed per cell group. For split bearers, the PDCP data is considered in BSR in the cell group(s) configured by RRC
  - In EN-DC, separate DRX configurations are provided for MCG and SCG
- RLC Sublayer
  - Both RLC AM and UM can be configured for MR-DC, for all bearer types (MCG, SCG and split bearers)
- PDCP Sublayer
  - In EN-DC
    - CA packet duplication can be applied to CA in the MN and in the SN
    - MCG bearer CA packet duplication can be configured only in combination with E-UTRAN PDCP
    - MCG DRB CA duplication can be configured only if DC packet duplication is not configured for any split DRB
  - In NGEN-DC, CA packet duplication can only be configured for SCG bearer
  - In NE-DC, CA packet duplication can only be configured for MCG bearer.
  - In EN-DC, RoHC can be configured for all the bearer types
- SDAP Sublayer
  - In MR-DC with 5GC, the network may host up to two SDAP protocol entities for each individual PDU session, one for MN and another one for SN
  - The UE is configured with one SDAP protocol entity per PDU session

RRC Related Aspects

- System information handling
  - In MR-DC, the SN is not required to broadcast system information other than for radio frame timing and SFN
  - System information for initial configuration is provided to the UE by dedicated RRC signalling via the MN
  - The UE acquires, at least, radio frame timing and SFN of SCG from the PSS/SSS and MIB (if the SN is an eNB) / NR-PSS/SSS and PBCH (if the SN is a gNB) of the PSCell
  - In EN-DC, upon change of the relevant system information of a configured Scell, the network releases and subsequently adds the concerned Scell (with updated system information), via one or more RRC reconfiguration messages sent on SRB1 or SRB3, if configured
- Measurements
  - The Master node should configure the measurement to the UE
    - If the measurement is configured to the UE in preparation for the Secondary Node Addition procedure
  - The SN should configure the measurement to the UE in coordination with the MN, if required
    - In case of the intra-secondary node mobility
  - The Secondary Node Change procedure can be triggered by both the MN (only for inter-frequency secondary node change) and the SN
    - For secondary node changes triggered by the SN, the RRM measurement configuration is maintained by the SN which also processes the measurement reporting, without providing the measurement results to the MN

RRC Related Aspects (Measurements)

- Measurements can be configured independently by the MN (for inter-RAT measurement) and by the SN (intra-RAT measurements on serving and non-serving frequencies)
  - The MN indicates the maximum number of frequency layers and measurement identities that can be used in the SN to ensure that UE capabilities are not exceeded
  - If MN and SN both configure measurements on the same carrier frequency then the configurations need to be consistent (if the network wants to ensure these are considered as a single measurement layer)
  - Each node (MN and SN) can configure independently a threshold for the SpCell quality
  - When the PCell quality is above the threshold configured by the MN, the UE is still required to perform inter-RAT measurements configured by the MN on the SN RAT (while it's not required to perform intra-RAT measurements)
  - When the PSCell quality is above the threshold configured by the SN, the UE is not required to perform measurements configured by the SN
- The SN cannot renegotiate the number of frequency layers allocated by the MN in TS37.340 V15.3.0 of the protocol
- When SRB3 is not configured, reports for measurements configured by the SN are sent on SRB1
- When SRB3 is configured, reports for measurements configured by the SN are sent on SRB3
- Measurement results related to the target SN can be provided by MN to target SN at MN initiated SN change procedure
- Measurement results of target SN can be forwarded from source SN to target SN via MN at SN initiated SN change procedure
- Measurement results related to the target SN can be provided by source MN to target MN at Inter-MN handover with/without SN change procedure

RRC Related Aspects (Measurements) (Cont.)

- In EN-DC, measurement results according to measurement configuration from the MN are encoded according to NR RRC when they are provided by MN to SN in SgNB Addition Request message
- During SN initiated SN change procedure, measurement results according to measurement configuration from SN are encoded according to NR RRC when they are provided by MN to SN in SgNB Addition Request message
- Per-UE or per-FR measurement gaps can be configured, depending on UE capability and network preference
- Per-UE gap applies to both FR1 (LTE and NR) and FR2 (NR) frequencies
- For per-FR gap, two independent gap patterns (i.e. FR1 gap and FR2 gap) are configured for FR1 and FR2 respectively
- The UE may also be configured with a per-UE gap sharing configuration (applying to per-UE gap) or with two separate gap sharing configurations (applying to FR1 and FR2 measurement gaps respectively)
- In EN-DC, if per-UE gap is used, the MN decides the gap pattern and the related gap sharing configuration
- If per-FR gap is used, the MN decides the FR1 gap pattern and the related gap sharing configuration for FR1
  - While the SN decides the FR2 gap pattern and the related gap sharing configuration for FR2
- The measurement gap configuration from the MN to the UE indicates if the configuration from the MN is a per-UE gap or an FR1 gap configuration
  - The MN also indicates the configured per-UE or FR1 measurement gap pattern and the gap purpose (per-UE or per-FR1) to the SN
- Measurement gap configuration assistance information can be exchanged between the MN and the SN
- For the case of per-UE gap, the SN indicates to the MN the list of SN configured frequencies in FR1 and FR2 measured by the UE. For the per-FR gap case, the SN indicates to the MN the list of SN configured frequencies in FR1 measured by the UE and the MN indicates to the SN the list of MN configured frequencies in FR2 measured by the UE

RRC Related Aspects(UE Capability Coordination)

- In MR-DC, the capabilities of a UE supporting both E-UTRA and NR are provided to both MN and SN
- MR-DC band combinations, listing the supported E-UTRA and NR band combinations, as well as NR PDCP capabilities (included in both E-UTRA Capability and NR capability) are visible to both the MN and SN
- Other RAT specific capabilities need not be visible to the node of the other RAT
- For the UE capabilities requiring coordination between E-UTRA and NR
  - i.e. band combinations, baseband processing capabilities and the maximum power for FR1 the UE can use in SCG
  - It is up to the MN to decide on how to resolve the dependency between MN and SN configurations
- The MN then provides the resulting UE capabilities usable for SCG configuration to the SN
- As part of an SN initiated SN modification, the SN may indicate the desired UE capabilities usable for SCG configuration, and it is up to the MN to make the final decision whether to accept or reject the request

RRC Related Aspects (Handling of Combined MN/SN RRC Messages)

- When both MCG and SCG reconfiguration is required due to the need for coordination with the MN
  - The SN RRC reconfiguration message is encapsulated in an MN RRC message that also carries the corresponding MCG reconfiguration that ensures that the combined configuration can be jointly processed by the UE
- If the MN terminates a bearer using NR PDCP
  - The NR PDCP configuration is generated by the MN itself
- If the SN terminates the bearer
  - The SN generates the NR PDCP configuration and sends it to the MN as a separate container
- The UE uses a joint success/failure procedure for messages in an encapsulating MN RRC message
- A failure of the MN RRC messages
  - Including one encapsulated SN RRC message with or without any MCG reconfiguration fields
  - Triggers a re-establishment procedure
- Each SN RRC reconfiguration message should have its own RRC response message even when the SN RRC message is encapsulated in an MN RRC message
- The SN RRC response message is forwarded over X2/Xn to the SN
- If a SN RRC reconfiguration message is contained in a MN RRC message, the UE sends a MN RRC response message that encapsulates the SN RRC response message
- If the MN RRC message does not encapsulate an SN RRC reconfiguration message (i.e. an SCG configuration) but only information elements generated by the SN (e.g. the PDCP configuration for an SN terminated bearer)
  - The UE will not send an SN RRC response message

RRC Related Aspects (SCG/MCG Failure Handling)

- RLF is declared separately for the MCG and for the SCG
- If radio link failure is detected for MCG, UE initiates RRC connection re-establishment procedure
- In EN-DC and NGEN-DC, the following SCG failure cases are supported
  - SCG RLF
  - SN change failure
  - SCG configuration failure (only for messages on SRB3)
  - SCG RRC integrity check failure (on SRB3)
- In EN-DC and NGEN-DC, upon SCG failure the UE suspends SCG transmissions for all radio bearers and reports the SCG Failure Information to the MN, instead of triggering re-establishment
- In all SCG failure cases, the UE maintains the current measurement configurations from both the MN and the SN and the UE continues measurements based on configuration from the MN and the SN if possible
- The SN measurements configured to be routed via the MN will continue to be reported after the SCG failure
- UE may not continue measurements based on configuration from the SN after SCG failure in certain cases
  - e.g. UE can not maintain the timing of PSCell
- The UE includes in the SCG Failure Information message the measurement results available according to current measurement configuration of both the MN and the SN
- The MN handles the SCG Failure Information message and may decide to keep, change, or release the SN/SCG
- In all the cases, the measurement results according to the SN configuration and the SCG failure type may be forwarded to the old SN and/or to the new SN

RRC Related Aspects (UE Identities & Inter-node Resource Coordination)

- UE identities
  - In MR-DC, two C-RNTIs are independently allocated to the UE
  - one for MCG, and one for SCG
- Inter-node resource coordination
  - For EN-DC operation, MN and SN may coordinate their UL and DL radio resources in semi-static manner via UE associated signalling

Bearer Handling Aspects (QoS Aspects)

- In EN-DC
  - The E-UTRAN QoS framework defined in TS 36.300
  - An S1-U bearer is established between the EPC and the SN for SN terminated bearers
  - An X2-U bearer is established between the MN and the SN for split bearers, MN terminated SCG bearers and SN terminated MCG bearers
  - MN terminated and SN terminated bearers may have either MCG or SCG radio resources or both, MCG and SCG radio resources, established
  - The MN decides the DL UE AMBR and UL UE AMBR limits to be assigned to the SN, and indicates these to the SN
    - The PDCP entity at the SN applies the received DL UE AMBR limit to the set of all bearers for which the SN hosts PDCP for the UE
    - The MAC entity at the SN applies the received UL UE AMBR limit to the scheduled uplink radio traffic at the SN for the UE
- In MR-DC with 5GC
  - The NG-RAN QoS framework defined in TS 38.300
  - QoS flows belonging to the same PDU session may be mapped to different bearer types and as a result there may be two different SDAP entities for the same PDU session
    - One at the MN and another one at the SN, in which case the MN decides which QoS flows are assigned to the SDAP entity in the SN
    - If the SN decides that its SDAP entity cannot host a given QoS flow any longer, the SN informs the MN and the MN cannot reject the request
  - The MN or SN node that hosts the SDAP entity for a given QoS flow decides how to map the QoS flow to DRBs
  - If the SDAP entity for a given QoS flow is hosted by the MN and the MN decides that SCG resources are to be configured it provides to the SN
    - DRB QoS flow level QoS parameters, which the SN may reject.
    - QoS flow to DRB mapping information and the respective per QoS flow information
  - If the SDAP entity for a given QoS flow is hosted by the SN and the SN configures MCG resources, based on offered MCG resource information from the MN, the SN provides to the MN
    - DRB QoS flow level QoS parameters, which the MN may reject
    - QoS flow to DRB mapping information and the respective per QoS flow information
  - If the SDAP entity for a given QoS flow is hosted by the SN, the MN provides sufficient QoS related information to enable the SN to configure appropriate SCG resources and to request the configuration of appropriate MCG resources
    - The MN may offer MCG resources to the SN and may indicate for GBR QoS flows the amount offered to the SN on a per QoS flow level
  - MN decides the PDU session AMBR limits to be assigned to the SN, and indicates these to the SN

Bearer Handling Aspects (QoS Aspects) (Cont.)

- To support PDU sessions mapped to different bearer types, MR-DC with 5GC provides the possibility for the MN to request the 5GC
  - For some PDU sessions of a UE
    - Direct the User Plane traffic of the whole PDU session either to the MN or to the SN.
    - There is a single NG-U tunnel termination at the NG-RAN for such PDU session
    - The MN may request to change this assignment during the life time of the PDU session
  - For some other PDU sessions of a UE
    - Direct the User Plane traffic of a subset of the QoS flows of the PDU session to the SN (respectively MN) while the rest of the QoS flows of the PDU session is directed to the MN (respectively SN)
    - There are two NG-U tunnel terminations at the NG-RAN for such PDU session
    - The MN may request to change this assignment during the life time of the PDU session
- To support notification control indication for GBR QoS flows along the QoS framework specified in 38.300 for MR-DC with 5GC
  - SN and MN may mutually indicate whenever QoS requirements for GBR QoS flows cannot be fulfilled anymore or can be fulfilled again

Bearer Handling Aspects (Bearer Type Selection)

- In EN-DC, for each radio bearer the MN decides the location of the PDCP entity and in which cell group(s) radio resources are to be configured
- Once an SN terminated split bearer is established
  - e.g. by means of the Secondary Node Addition procedure or MN initiated Secondary Node Modification procedure
  - The SN may remove and later on add SCG resources for the respective E-RAB, as long as the QoS for the respective E-RAB is guaranteed
- In MR-DC with 5GC, the following principles apply
  - The MN decides per PDU session the location of the SDAP entity
    - Whether it shall be hosted by the MN or the SN or by both
  - If the MN decides to host an SDAP entity
    - It may decide some of the related QoS flows to be realized as MCG bearer
    - Some as SCG bearer
    - Others to be realized as split bearer
  - If the MN decides that an SDAP entity shall be hosted in the SN
    - Some of the related QoS flows may be realized as SCG bearer
    - Some as MCG bearer
    - Others may be realized as split bearer
    - The SN may remove or add SCG resources for the respective QoS flows, as long as the QoS for the respective QoS flow is guaranteed

Bearer Handling Aspects (Bearer Type Change)

- In MR-DC, all the possible bearer type change options are supported
  - MCG bearer to/from split bearer
  - MCG bearer to/from SCG bearer
  - SCG bearer to/from split bearer
- Bearer termination point change is supported for all bearer types, and can be performed with or without bearer type change
  - MN terminated bearer to/from SN terminated bearer
- For EN-DC
  - When the security key is changed for a bearer, the associated PDCP and RLC entities are re-established
    - MAC behavior might depend on the solution selected by the network, e.g. MAC reset, change of LCID, etc
  - For MCG bearer, split bearer and SCG bearer, during handover MCG/SCG PDCP and RLC are re-established and MCG/SCG MAC is reset
  - If a bearer type change happens through handover procedure then for MCG bearer, split bearer and SCG bearer
    - MCG/SCG PDCP/RLC are re-established and MCG/SCG MAC is reset
  - If a bearer type change happens through SN change procedure, then SN terminated PDCP /RLC are re-established and SCG MAC is reset
  - One step (direct) bearer type change between MN terminated bearer types without using the handover procedure is supported
  - One step (direct) bearer type change between SN terminated bearer types without using the handover or SN change procedure is supported
  - One step (direct) bearer type change from/to MN terminated bearer to/from SN terminated bearer without using the handover procedure is supported
  - Upon bearer type change from SCG bearer to MCG bearer MAC is not reset
    - The associated NR RLC entity is released and the associated LTE RLC entity is established
  - PDCP version change for DRB or PDCP SN length change for an AM DRB or RLC mode change for DRB is performed using a release and add of the DRBs (in a single message) or full configuration
  - One step (direct) bearer type change with PDCP version change is supported
  - Upon bearer type change from MCG bearer to SCG bearer or from split bearer to SCG bearer, the associated LTE RLC entity is first re-established and then released
    - The associated NR RLC entity is established for MCG bearer to SCG bearer

Bearer Handling Aspects (User Data Forwarding)

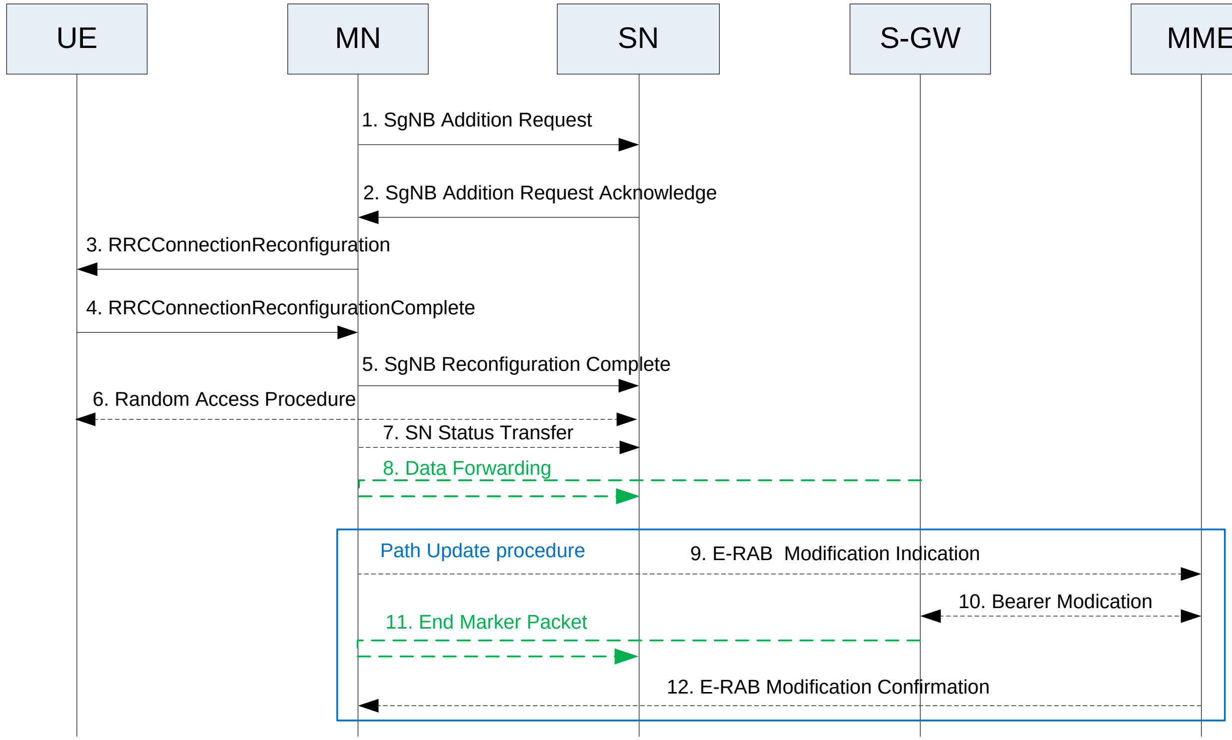
- Upon EN-DC specific activities, user data forwarding may be performed for E-RABs for which the bearer type change from/to MN terminated bearer to/from SN terminated bearer is performed
  - The behaviour of the node from which data is forwarded is the same as specified for the "source eNB" for handover, the behaviour of the node to which data is forwarded is the same as specified for the "target eNB" for handover
- For MR-DC with 5GC, user data forwarding may be performed between NG-RAN nodes whenever the logical node hosting the PDCP entity changes
  - The behaviour of the node from which data is forwarded is the same as specified for the "source NG-RAN node" for handover, the behaviour of the node to which data is forwarded is the same as specified for the "target NG-RAN node" for handover
- For mobility scenarios which involve more than two RAN nodes, either direct or indirect data forwarding may be applied

Security Related Aspects

- EN-DC can only be configured after security activation in the MN.
- In EN-DC
  - For bearers terminated in the MN the network configures the UE with KeNB
  - For bearers terminated in the SN the network configures the UE with S-KgNB
- For mobility scenarios that involve only a change of the SCG (i.e. no Pcell handover and hence no KeNB change)
  - S-KgNB key refresh is not required if the PDCP termination point of the SN is not changed
- In EN-DC, the UE supports the NR security algorithms corresponding to the E-UTRA security algorithms signalled at NAS level and the UE NR AS Security capability is not signalled to the MN over RRC. Mapping from E-UTRA security algorithms to the corresponding NR security algorithms, where necessary, is performed at the MN.
- For MR-DC with 5GC, UP integrity protection can be configured on a per radio bearer basis

Multi-Connectivity Operation Related Aspects

- Similar procedures in TS 36.300 (Dual Connectivity operation) apply for MR-DC
- Secondary Node Addition (EN-DC)
  - The Secondary Node Addition procedure is initiated by the MN and is used to establish a UE context at the SN to provide radio resources from the SN to the UE
  - For bearers requiring SCG radio resources, this procedure is used to add at least the first cell of the SCG
  - This procedure can also be used to configure an SN terminated MCG bearer (where no SCG configuration is needed)



EN-DC Secondary Node Addition Procedure

1. The MN decides to request the SN to allocate radio resources for a specific E-RAB, indicating E-RAB characteristics (E-RAB parameters, TNL address information corresponding to bearer type)
   - For bearers requiring SCG radio resources, MN indicates the requested SCG configuration information, including the entire UE capabilities and the UE capability coordination result
   - In this case, the MN also provides the latest measurement results for SN to choose and configure the SCG cell(s)
   - The MN may request the SN to allocate radio resources for split SRB operation
   - The MN always provides all the needed security information to the SN (even if no SN terminated bearers are setup) to enable SRB3 to be setup based on SN decision
   - In case of bearer options that require X2-U resources between the MN and the SN, the MN provides X2-U TNL address information for the respective E-RAB, X2-U DL TNL address information for SN terminated bearers, X2-U UL TNL address information for MN terminated bearers
   - In case of SN terminated split bearers the MN provides the maximum QoS level that it can support
   - The SN may reject the request

- For split bearers, MCG and SCG resources may be requested of such an amount, that the QoS for the respective E-RAB is guaranteed by the exact sum of resources provided by the MCG and the SCG together, or even more
- For MN terminated split bearers, the MNs decision is reflected in step 1 by the E-RAB parameters signalled to the SN, which may differ from E-RAB parameters received over S1
- For a specific E-RAB, the MN may request the direct establishment of an SCG or a split bearer
  - i.e., without first having to establish an MCG bearer
  - It is also allowed that all E-RABs can be configured as SN terminated bearers, i.e. there is no E-RAB established as an MN terminated bearer

EN-DC Secondary Node Addition Procedure (Step 2)

2. If the RRM entity in the SN is able to admit the resource request, it allocates respective radio resources and, dependent on the bearer option, respective transport network resources
   - For bearers requiring SCG radio resources, the SN triggers Random Access so that synchronisation of the SN radio resource configuration can be performed
   - The SN decides the Pscell and other SCG Scells and provides the new SCG radio resource configuration to the MN in a NR RRC configuration message contained in the SgNB Addition Request Acknowledge message
   - In case of bearer options that require X2-U resources between the MN and the SN, the SN provides X2-U TNL address information for the respective E-RAB, X2-U UL TNL address information for SN terminated bearers, X2-U DL TNL address information for MN terminated bearers
   - For SN terminated bearers, the SN provides the S1-U DL TNL address information for the respective E-RAB and security algorithm
   - If SCG radio resources have been requested, the SCG radio resource configuration is provided

- For the SN terminated split bearer option, the SN may either decide to request resources from the MN of such an amount, that the QoS for the respective E-RAB is guaranteed by the exact sum of resources provided by the MN and the SN together, or even more
- The SNs decision is reflected in step 2 by the E-RAB parameters signalled to the MN, which may differ from E-RAB parameters received in step 1
- The QoS level requested from the MN shall not exceed the level that the MN offered when setting up the split bearer in step 1
- In case of MN terminated bearers, transmission of user plane data may take place after step 2
- In case of SN terminated bearers , data forwarding and the SN Status Transfer may take place after step 2

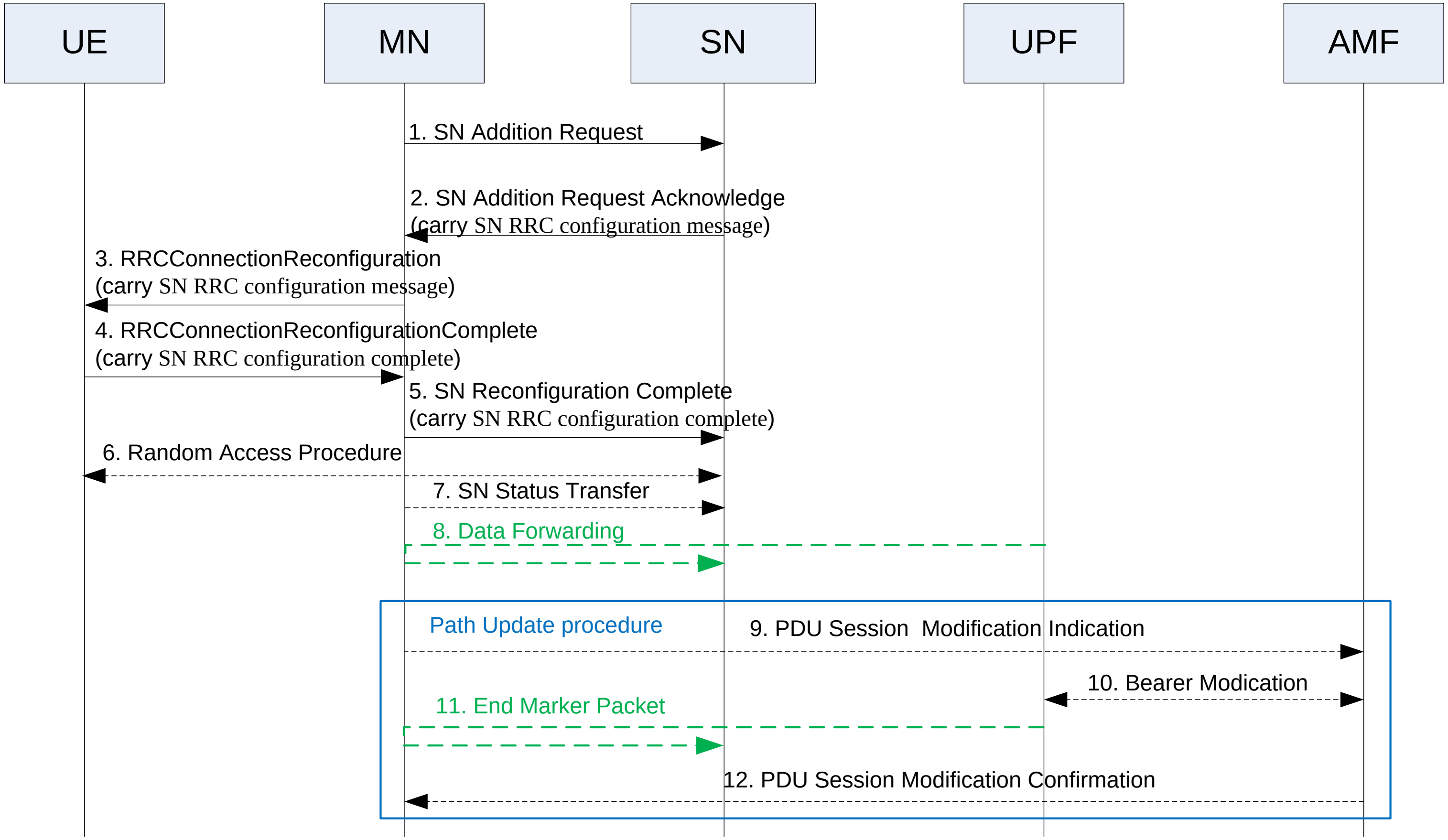
EN-DC Secondary Node Addition Procedure (Step 3-12)

3. The MN sends to the UE the *RRCConnectionReconfiguration* message including the NR RRC configuration message, without modifying it
4. The UE applies the new configuration and replies to MN with *RRCConnectionReconfigurationComplete* message, including a NR RRC response message, if needed
   - In case the UE is unable to comply with (part of) the configuration included in the *RRCConnectionReconfiguration* message, it performs the reconfiguration failure procedure
5. The MN informs the SN that the UE has completed the reconfiguration procedure successfully via *SgNB ReconfigurationComplete* message, including the encoded NR RRC response message, if received from the UE
6. If configured with bearers requiring SCG radio resources, the UE performs synchronisation towards the PSCell of the SN
   - The order the UE sends the *RRCConnectionReconfigurationComplete* message and performs the Random Access procedure towards the SCG is not defined
   - The successful RA procedure towards the SCG is not required for a successful completion of the RRC Connection Reconfiguration procedure
7. In case of SN terminated bearers using RLC AM, the MN sends SN Status Transfer
8. In case of SN terminated bearers using RLC AM, and dependent on the bearer characteristics of the respective E-RAB, the MN may take actions to minimise service interruption due to activation of EN-DC (Data forwarding)

9-12. For SN terminated bearers, the update of the UP path towards the EPC is performed

MR-DC with 5GC SN Addition Procedure

- The Secondary Node (SN) Addition procedure is initiated by the MN and is used to establish a UE context at the SN in order to provide radio resources from the SN to the UE
  - For bearers requiring SCG radio resources, this procedure is used to add at least the initial SCG serving cell of the SCG
  - This procedure can also be used to configure an SN terminated MCG bearer (where no SCG configuration is needed)



MR-DC with 5GC SN Addition Procedure (Step 1)

1. The MN decides to request the target SN to allocate radio resources for one or more specific PDU Sessions/QoS Flows, indicating QoS Flows characteristics (QoS Flow Level QoS parameters, PDU session level TNL address information, and PDU session level Network Slice info)
   - In addition, for bearers requiring SCG radio resources, MN indicates the requested SCG configuration information, including the entire UE capabilities and the UE capability coordination result
   - In this case, the MN also provides the latest measurement results for SN to choose and configure the SCG cell(s)
   - The MN may request the SN to allocate radio resources for split SRB operation
   - The MN always provides all the needed security information to the SN (even if no SN terminated bearers are setup) to enable SRB3 to be setup based on SN decision
   - For bearer options that require Xn-U resources between the MN and the SN, MN needs to provide Xn-U TNL address information, Xn-U DL TNL address information for SN terminated bearers and Xn-U UL TNL address information for MN terminated bearers
   - The SN may reject the request

- For split bearers, MCG and SCG resources may be requested of such an amount, that the QoS for the respective QoS Flow is guaranteed by the exact sum of resources provided by the MCG and the SCG together, or even more. For MN terminated split bearers, the MN decision is reflected in step 1 by the QoS Flow parameters signalled to the SN, which may differ from QoS Flow parameters received over NG.
- For a specific QoS flow, the MN may request the direct establishment of SCG and/or split bearers
  - i.e. without first having to establish MCG bearers
  - It is also allowed that all QoS flows can be mapped to SN terminated bearers
    - i.e. there is no QoS flow mapped to an MN terminated bearer

MR-DC with 5GC SN Addition Procedure (Step 2)

2. If the RRM entity in the SN is able to admit the resource request, it allocates respective radio resources and, dependent on the bearer type options, respective transport network resources
   - For bearers requiring SCG radio resources the SN triggers UE Random Access so that synchronisation of the SN radio resource configuration can be performed
   - The SN decides for the PScell and other SCG Scells and provides the new SCG radio resource configuration to the MN in a SN RRC configuration message contained in the SN Addition Request Acknowledge message
   - In case of bearer options that require Xn-U resources between MN and the SN, the SN provides Xn-U TNL address information for the respective E-RAB, Xn-U UL TNL address information for SN terminated bearers, Xn-U DL TNL address information for MN terminated bearers
   - For SN terminated bearers, the SN provides the NG-U DL TNL address information for the respective PDU Session and security algorithm
   - If SCG radio resources have been requested, the SCG radio resource configuration is provided

- In case of MN terminated bearers, transmission of user plane data may take place after step 2
- In case of SN terminated bearers, data forwarding and the SN Status Transfer may take place after step 2
- For MN terminated NR SCG bearers for which PDCP duplication with CA is configured the MN allocates 2 separate Xn-U bearers
- For SN terminated NR MCG bearers for which PDCP duplication with CA is configured the SN allocates 2 separate Xn-U bearers

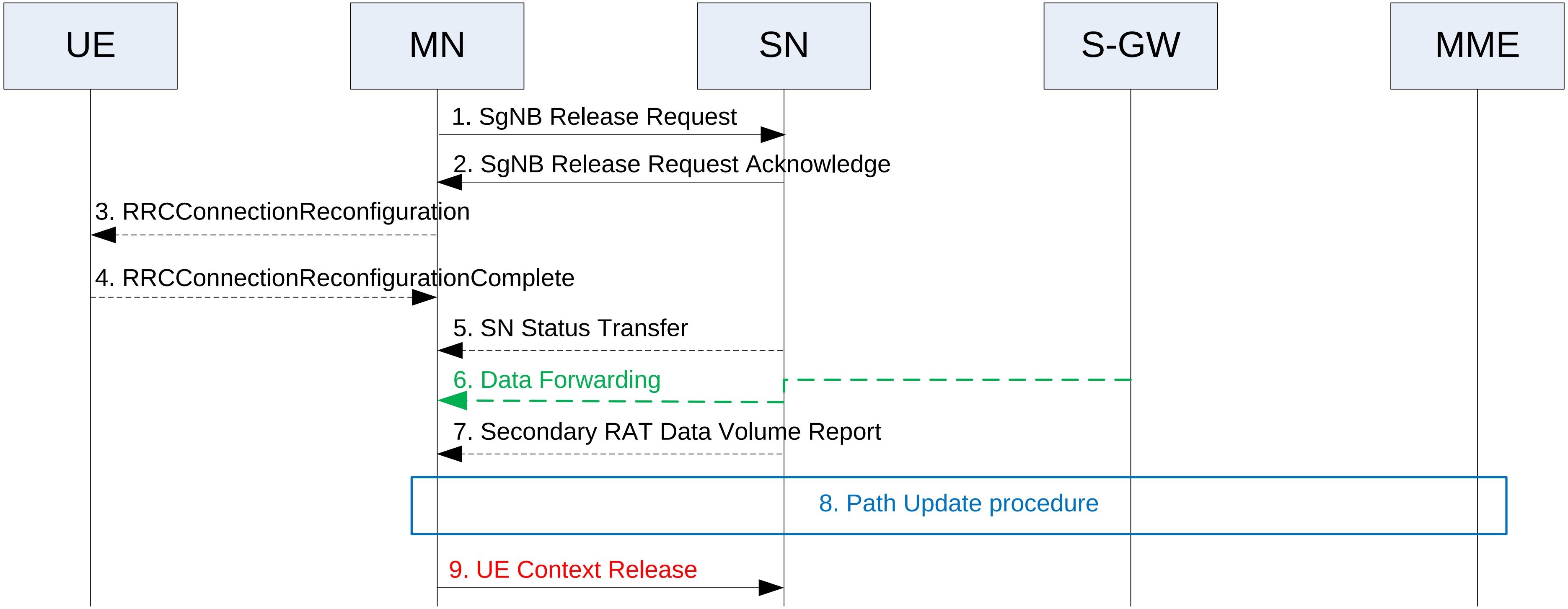
MR-DC with 5GC SN Addition Procedure (Step 3-12)

3. The MN sends the MN RRC reconfiguration message to the UE including the SN RRC configuration message, without modifying it
4. The UE applies the new configuration and replies to MN with MN RRC reconfiguration complete message, including a SN RRC response message for SN, if needed
   - In case the UE is unable to comply with (part of) the configuration included in the MN RRC reconfiguration message, it performs the reconfiguration failure procedure
5. The MN informs the SN that the UE has completed the reconfiguration procedure successfully via SN Reconfiguration Complete message, including the encoded SN RRC response message, if received from the UE
6. If configured with bearers requiring SCG radio resources, the UE performs synchronisation towards the PSCell configured by the SN
   - The order the UE sends the MN RRC reconfiguration complete message and performs the Random Access procedure towards the SCG is not defined
   - The successful RA procedure towards the SCG is not required for a successful completion of the RRC Connection Reconfiguration procedure
7. In case of SN terminated bearers using RLC AM, the MN sends SN Status Transfer
8. In case of SN terminated bearers using RLC AM, and dependent on the bearer characteristics of the respective QoS Flows, the MN may take actions to minimise service interruption due to activation of MR-DC (Data forwarding)

9-12. For SN terminated bearers, the update of the UP path towards the 5GC is performed via PDU Session Path Update procedure

EN-DC Secondary Node Release(MN/SN Initiated)

- The Secondary Node Release procedure may be initiated either by the MN or by the SN and is used to initiate the release of the UE context at the SN
  - The recipient node of this request can reject it
  - e.g., if a SN change procedure is triggered by the SN
- It does not necessarily need to involve signalling towards the UE
  - e.g., in case of the RRC connection re-establishment due to Radio Link Failure in MN



EN-DC SN Release Procedure – MN Initiated

1. The MN initiates the procedure by sending the SgNB Release Request message
   - If data forwarding is requested, the MN provides data forwarding addresses to the SN
2. The SN confirms SN Release by sending the SgNB Release Request Acknowledge message
   - If appropriate, the SN may reject SN Release
   - e.g. if the SN change procedure is triggered by the SN

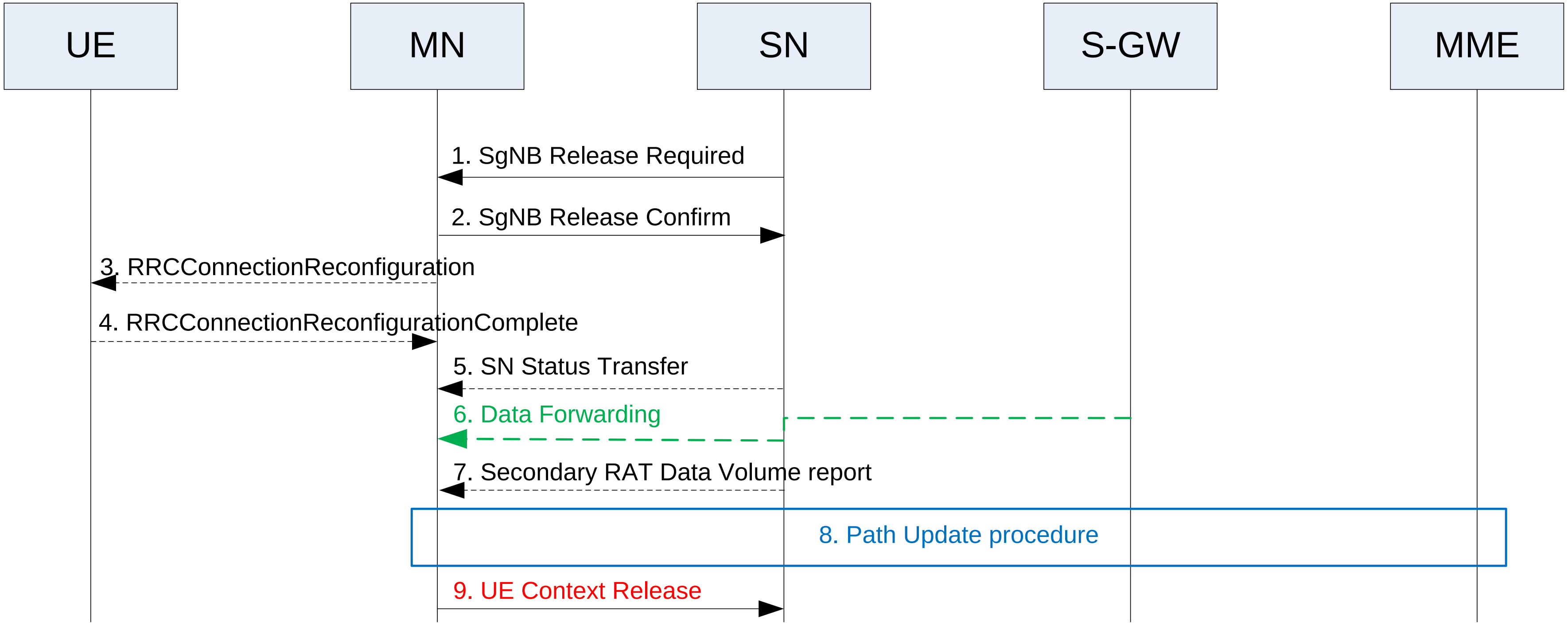
3/4. If required, the MN indicates in the *RRCConnectionReconfiguration* message towards the UE that the UE shall release the entire SCG configuration

   - In case the UE is unable to comply with (part of) the configuration included in the *RRCConnectionReconfiguration* message, it performs the reconfiguration failure procedure
   - If data forwarding is applied, timely coordination between steps 1 and 2 may minimize gaps in service provision, this is however regarded to be an implementation matter

5. If the released bearers use RLC AM, the SN sends the SN Status transfer
6. Data forwarding from the SN to the MN takes place
7. The SN sends the *Secondary RAT Data Volume Report* message to the MN and includes the data volumes delivered to the UE over the NR radio for the related E-RABs
   - The order the SN sends the Secondary RAT Data Volume Report message and performs data forwarding with MN is not defined
   - The SN may send the report when the transmission of the related bearer is stopped
8. If applicable, the path update procedure is initiated
9. Upon reception of the UE Context Release message, the SN can release radio and C-plane related resource associated to the UE context
   - Any ongoing data forwarding may continue

EN-DC SN Initiated SN Release

1. The SN initiates the procedure by sending the SgNB Release Required message which does not contain inter-node message
2. If data forwarding is requested, the MN provides data forwarding addresses to the SN in the SgNB Release Confirm message
   – The SN may start data forwarding and stop providing user data to the UE as early as it receives the SgNB Release Confirm message



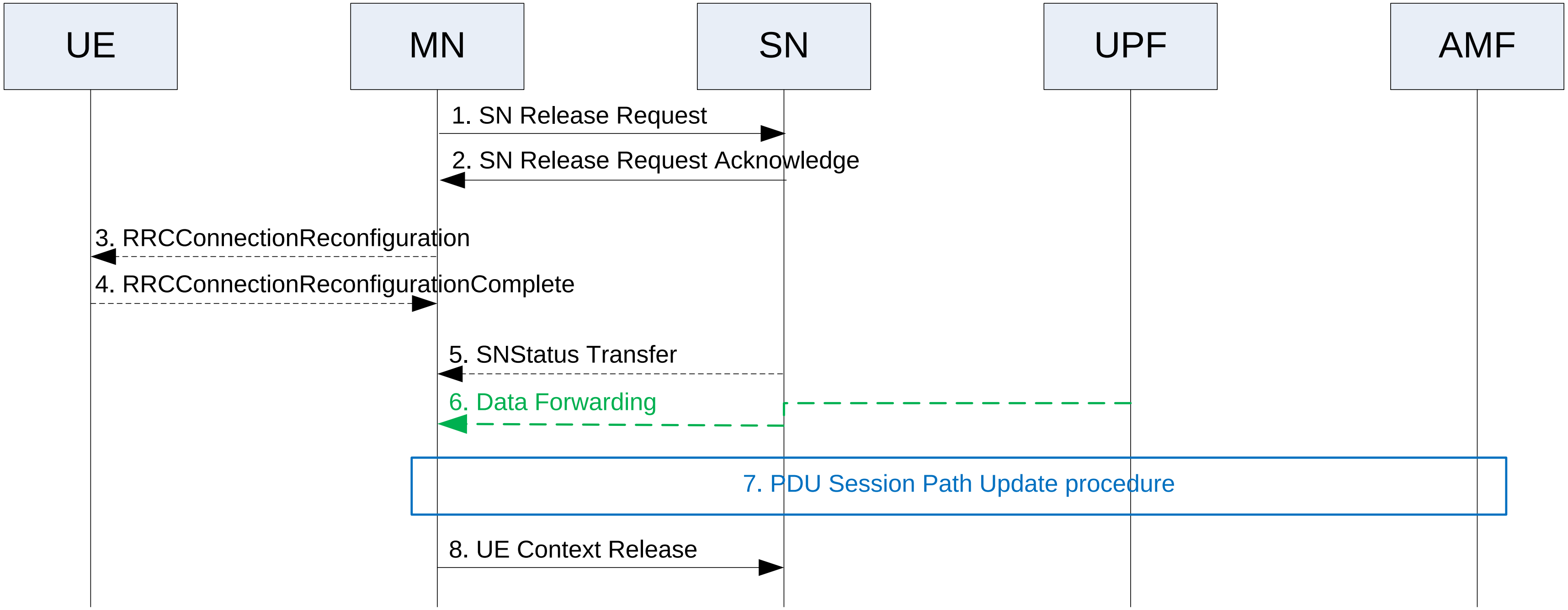
EN-DC SN Release Procedure – SN Initiated

3/4. If required, the MN indicates in the *RRCConnectionReconfiguration* message towards the UE that the UE shall release the entire SCG configuration
  - In case the UE is unable to comply with (part of) the configuration included in the *RRCConnectionReconfiguration* message, it performs the reconfiguration failure procedure
  - If data forwarding is applied, timely coordination between steps 2 and 3 may minimize gaps in service provision
  - This is however regarded to be an implementation matter

5. If the released bearers use RLC AM, the SN sends the SN Status transfer
6. Data forwarding from the SN to the MN takes place
7. The SN sends the *Secondary RAT Data Volume Report* message to the MN and includes the data volumes delivered to the UE over the NR radio for the related E-RABs
   - The order the SN sends the Secondary RAT Data Volume Report message and performs data forwarding with MN is not defined
   - The SN may send the report when the transmission of the related bearer is stopped
8. If applicable, the path update procedure is initiated
9. Upon reception of the UE Context Release message, the SN can release radio and C-plane related resource associated to the UE context. Any ongoing data forwarding may continue

MR-DC with 5GC MN Initiated SN Release

- The SN Release procedure may be initiated either by the MN or by the SN and is used to initiate the release of the UE context and relevant resources at the SN
- The recipient node of this request can reject it
  - e.g., if a SN change procedure is triggered by the SN



MR-DC with 5GC SN Release Procedure - MN Initiated

1. The MN initiates the procedure by sending the SN Release Request message
   - If data forwarding is requested, the MN provides data forwarding addresses to the SN
2. The SN confirms SN Release by sending the SN Release Request Acknowledge message. If appropriate, the SN may reject SN Release
   - e.g., if the SN change procedure is triggered by the SN

3/4. If required, the MN indicates in the MN RRC reconfiguration message towards the UE that the UE shall release the entire SCG configuration

- In case the UE is unable to comply with (part of) the configuration included in the MN RRC reconfiguration message, it performs the reconfiguration failure procedure
- If data forwarding is applied, timely coordination between steps 1 and 2 may minimize gaps in service provision, this is however regarded to be an implementation matter

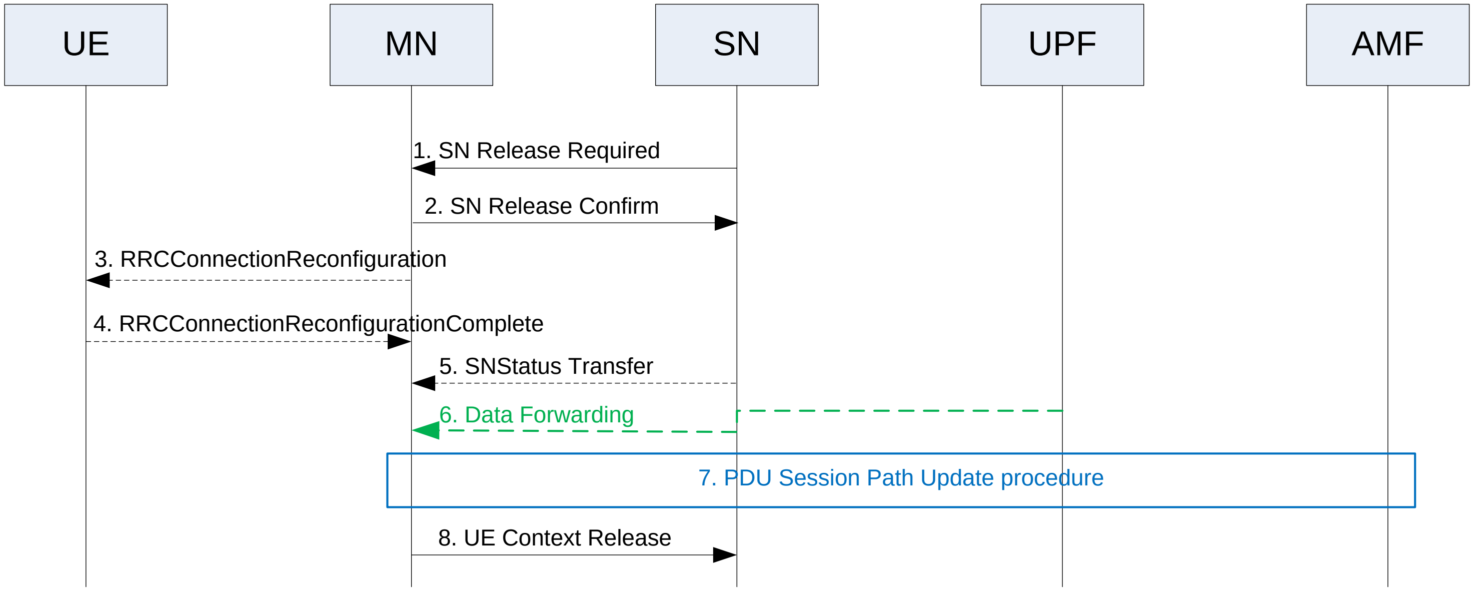
5. If the released bearers use RLC AM, the SN sends the SN Status transfer
6. Data forwarding from the SN to the MN takes place
7. If applicable, the PDU Session path update procedure is initiated
8. Upon reception of the UE Context Release message, the SN can release radio and C-plane related resource associated to the UE context
   - Any ongoing data forwarding may continue

MR-DC with 5GC SN Initiated SN Release

1. The SN initiates the procedure by sending the SN Release Required message which does not contain any inter-node message
2. If data forwarding is requested, the MN provides data forwarding addresses to the SN in the SN Release Confirm message
   - The SN may start data forwarding and stop providing user data to UE as early as it receives the SN Release Confirm message

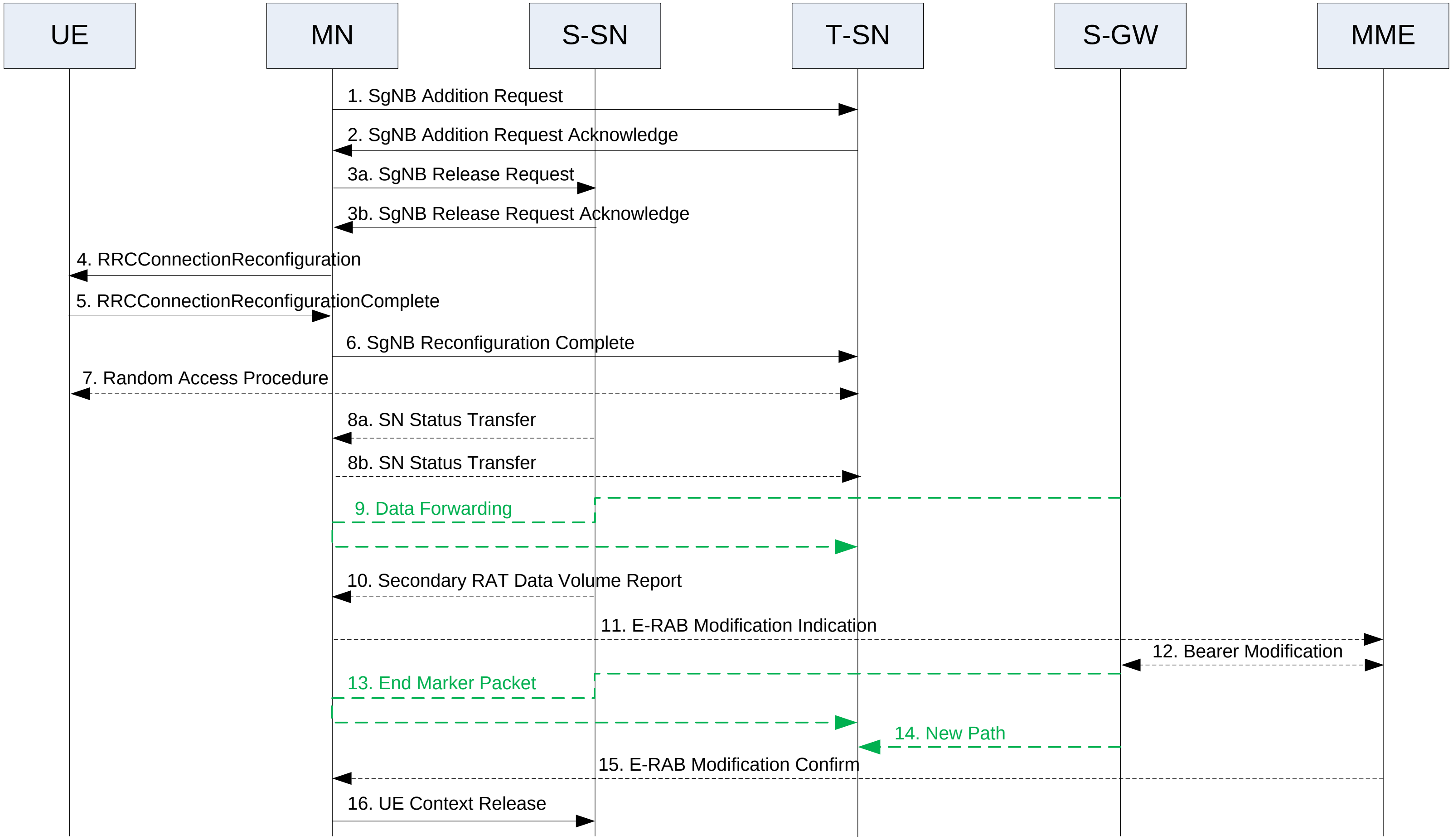
3/4. If required, the MN indicates in the MN RRC reconfiguration message towards the UE that the UE shall release the entire SCG configuration
   - In case the UE is unable to comply with (part of) the configuration included in the MN RRC reconfiguration message, it performs the reconfiguration failure procedure
   - If data forwarding is applied, timely coordination between steps 2 and 3 may minimize gaps in service provision
   - This is however regarded to be an implementation matter

5. If the released bearers use RLC AM, the SN sends the SN Status transfer
6. Data forwarding from the SN to the MN takes place
7. If applicable, the PDU Session path update procedure is initiated
8. Upon reception of the UE Context Release message, the SN can release radio and C-plane related resource associated to the UE context. Any ongoing data forwarding may continue



EN-DC Secondary Node Change (MN/SN Initiated)

- The Secondary Node Change procedure is initiated either by MN or SN and used to transfer a UE context from a source SN to a target SN and to change the SCG configuration in UE from one SN to another
  - Inter-RAT SN change procedure with single RRC reconfiguration is not supported in this version of the protocol (i.e. no transition from EN-DC to DC)
- The Secondary Node Change procedure always involves signalling over MCG SRB towards the UE



EN-DC Signalling Flow for the MN Initiated Secondary Node Change (Step 1-5)

1/2. The MN initiates the SN change by requesting the target SN to allocate resources for the UE by means of the SgNB Addition procedure
  - The MN may include measurement results related to the target SN
  - If forwarding is needed, the target SN provides forwarding addresses to the MN
  - The target SN includes the indication of the full or delta RRC configuration
  - The MN may send the SgNB Modification Request message (to the source SN) to request the current SCG configuration before step 1

3. If the allocation of target SN resources was successful, the MN initiates the release of the source SN resources including a Cause indicating SCG mobility
  - The Source SN may reject the release
  - If data forwarding is needed the MN provides data forwarding addresses to the source SN
  - If direct data forwarding is used for SN terminated bearers, the MN provides data forwarding addresses as received from the target SN to source SN
  - Reception of the SgNB Release Request message triggers the source SN to stop providing user data to the UE and, if applicable, to start data forwarding

4/5. The MN triggers the UE to apply the new configuration. The MN indicates to the UE the new configuration in the *RRCConnectionReconfiguration* message including the NR RRC configuration message generated by the target SN
  - The UE applies the new configuration and sends the *RRCConnectionReconfigurationComplete* message, including the encoded NR RRC response message for the target SN, if needed
  - In case the UE is unable to comply with (part of) the configuration included in the *RRCConnectionReconfiguration* message, it performs the reconfiguration failure procedure

EN-DC Signalling Flow for the MN Initiated Secondary Node Change (Step 6-16)

6. If the RRC connection reconfiguration procedure was successful, the MN informs the target SN via *SgNBReconfigurationComplete* message with the encoded NR RRC response message for the target SN, if received from the UE
7. If configured with bearers requiring SCG radio resources, the UE synchronizes to the target SN
8. For SN terminated bearers using RLC AM, the source SN sends the SN Status transfer, which the MN sends then to the target SN
9. If applicable, data forwarding from the source SN takes place
   – It may be initiated as early as the source SN receives the SgNB Release Request message from the MN
10. The source SN sends the *Secondary RAT Data Volume Report* message to the MN and includes the data volumes delivered to the UE over the NR radio for the related E-RABs
    – The order the SN sends the Secondary RAT Data Volume Report message and performs data forwarding with MN is not defined
    – The SN may send the report when the transmission of the related bearer is stopped

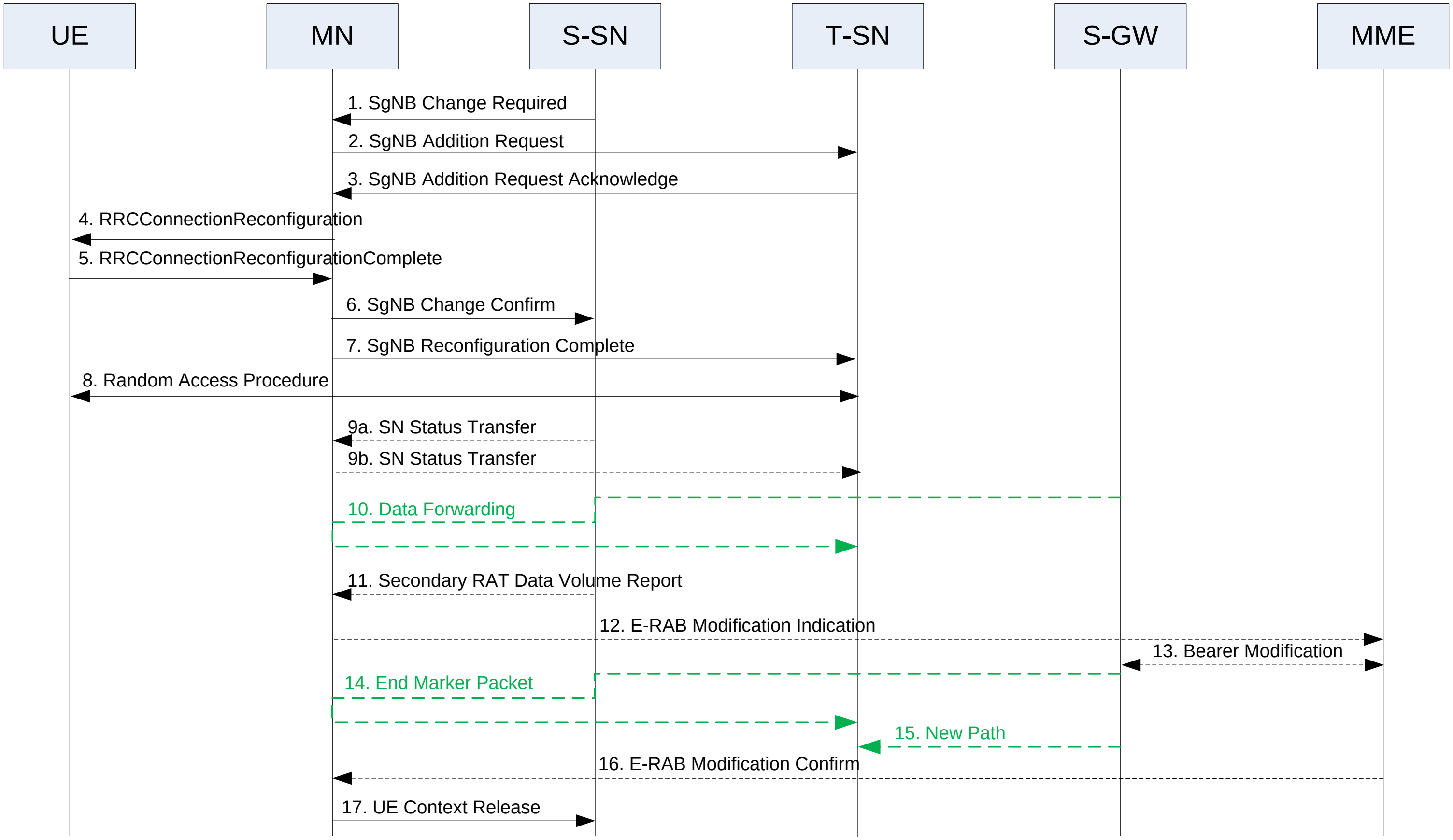
11-15. If one of the bearer was terminatedat the source SN, path update is triggered by the MN

16. Upon reception of the UE Context Release message, the source SN can release radio and C-plane related resource associated to the UE context
    – Any ongoing data forwarding may continue

EN-DC Signalling Flow for the Secondary Node Change Initiated by the SN (Step 1-3)

1. The source SN initiates the SN change procedure by sending SgNB Change Required message which contains target SN ID information and may include the SCG configuration (to support delta configuration) and measurement results related to the target SN

2/3. The MN requests the target SN to allocate resources for the UE by means of the SgNB Addition procedure, including the measurement results related to the target SN received from the source SN
   - If forwarding is needed, the target SN provides forwarding addresses to the MN
   - The target SN includes the indication of the full or delta RRC configuration



EN-DC Signalling Flow for the Secondary Node Change Initiated by the SN (Step 4-17)

4/5. The MN triggers the UE to apply the new configuration
- The MN indicates the new configuration to the UE in the *RRCConnectionReconfiguration* message including the NR RRC configuration message generated by the target SN
- The UE applies the new configuration and sends the *RRCConnectionReconfigurationComplete* message, including the encoded NR RRC response message for the target SN, if needed
- In case the UE is unable to comply with (part of) the configuration included in the *RRCConnectionReconfiguration* message, it performs the reconfiguration failure procedure

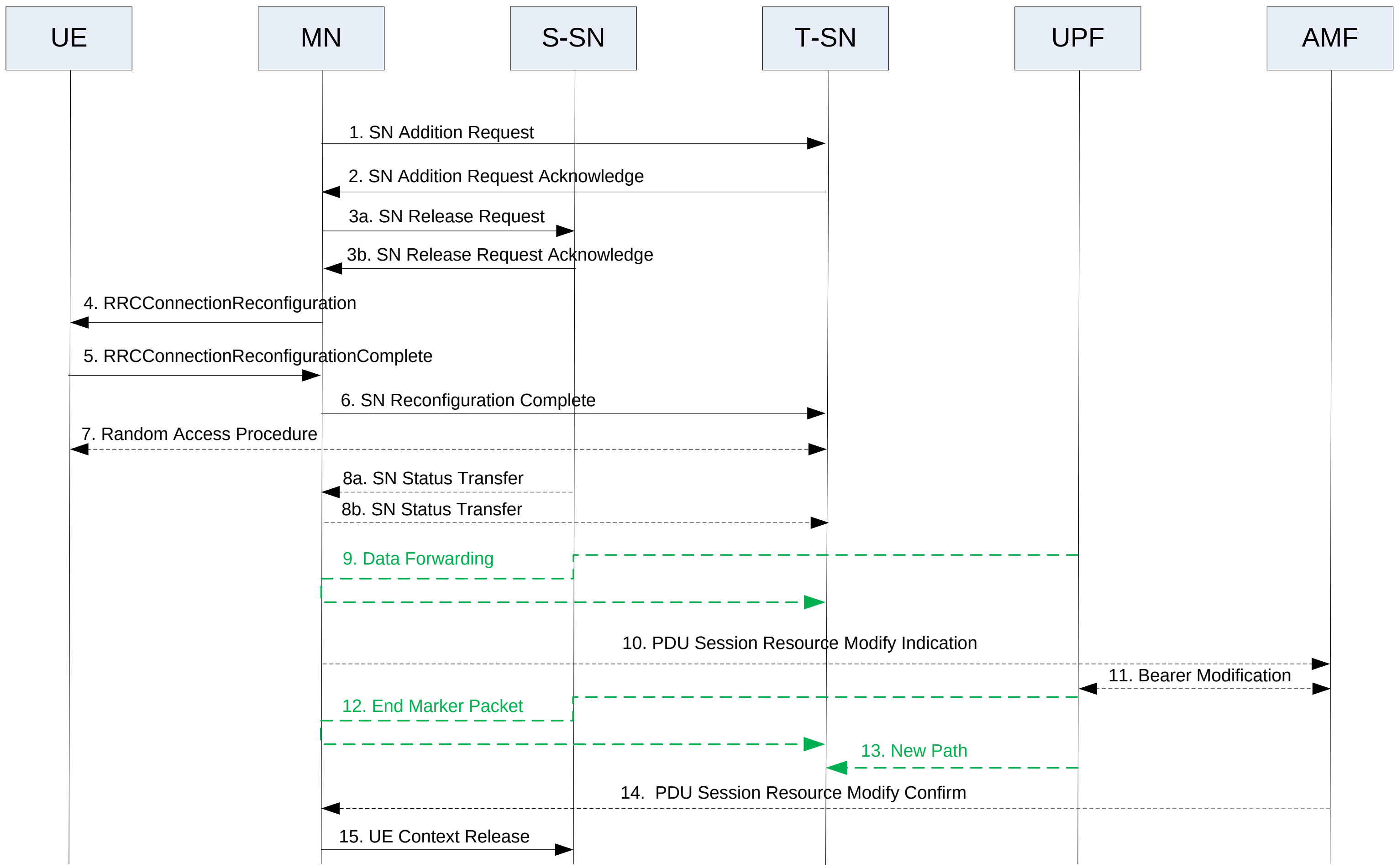
6. If the allocation of target SN resources was successful, the MN confirms the release of the source SN resources
   - If data forwarding is needed the MN provides data forwarding addresses to the source SN. If direct data forwarding is used for SN terminated bearers, the MN provides data forwarding addresses as received from the target SN to source SN
   - Reception of the SgNB Change Confirm message triggers the source SN to stop providing user data to the UE and, if applicable, to start data forwarding
7. If the RRC connection reconfiguration procedure was successful, the MN informs the target SN via SgNB Reconfiguration Complete message with the encoded NR RRC response message for the target SN, if received from the UE
8. The UE synchronizes to the target SN
9. For SN terminated bearers using RLC AM, the source SN sends the SN Status transfer, which the MN sends then to the target SN
10. If applicable, data forwarding from the source SN takes place
    - It may be initiated as early as the source SN receives the SgNB Change Confirm message from the MN
11. The source SN sends the *Secondary RAT Data Volume Report* message to the MN and includes the data volumes delivered to the UE over the NR radio for the related E-RABs
    - The order the source SN sends the Secondary RAT Data Volume Report message and performs data forwarding with MN/target SN is not defined
    - The SgNB may send the report when the transmission of the related bearer is stopped

12-16. If one of the bearer was terminated at the source SN, path update is triggered by the MN

17. Upon reception of the UE Context Release message, the source SN can release radio and C-plane related resource associated to the UE context
    - Any ongoing data forwarding may continue

MR-DC with 5GC MN Initiated SN Change

- The MN initiated SN change procedure is used to transfer a UE context from the source SN to a target SN and to change the SCG configuration in UE from one SN to another
- The Secondary Node Change procedure always involves signalling over MCG SRB towards the UE



MR-DC with 5GC Signalling Flow for the Secondary Node Change Initiated by the SN (Step 1-6)

1/2. The MN initiates the SN change by requesting the target SN to allocate resources for the UE by means of the SN Addition procedure
   - The MN may include measurement results related to the target SN
   - If data forwarding is needed, the target SN provides data forwarding addresses to the MN
   - The target SN includes the indication of the full or delta RRC configuration
   - The MN may send the SN Modification Request message (to the source SN) to request the current SCG configuration before step 1

3. If the allocation of target SN resources was successful, the MN initiates the release of the source SN resources including a Cause indicating SCG mobility
   - The Source SN may reject the release
   - If data forwarding is needed the MN provides data forwarding addresses to the source SN
   - If direct data forwarding is used for SN terminated bearers, the MN provides data forwarding addresses as received from the target SN to source SN
   - Reception of the SN Release Request message triggers the source SN to stop providing user data to the UE and, if applicable, to start data forwarding

4/5. The MN triggers the UE to apply the new configuration
   - The MN indicates the new configuration to the UE in the MN RRC reconfiguration message including the target SN RRC configuration message
   - The UE applies the new configuration and sends the MN RRC reconfiguration complete message, including the encoded SN RRC response message for the target SN, if needed
   - In case the UE is unable to comply with (part of) the configuration included in the MN RRC reconfiguration message, it performs the reconfiguration failure procedure

6. If the RRC connection reconfiguration procedure was successful, the MN informs the target SN via SN Reconfiguration Complete message with the encoded SN RRC response message for the target SN, if received from the UE

MR-DC with 5GC Signalling Flow for the Secondary Node Change Initiated by the SN (Step 7-15)

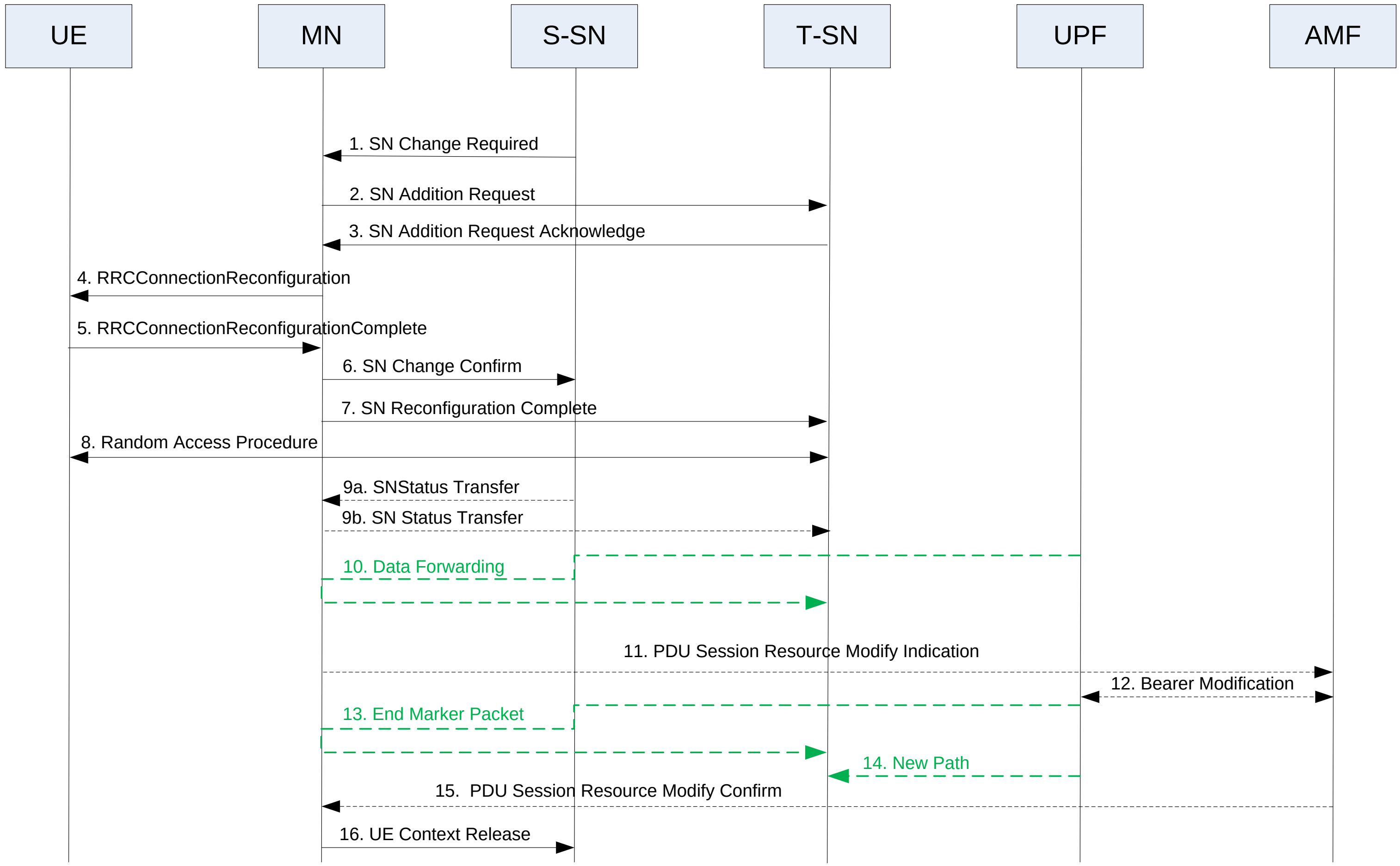
7. If configured with bearers requiring SCG radio resources the UE synchronizes to the target SN
8. For SN terminated bearers using RLC AM, the source SN sends the SN Status transfer, which the MN sends then to the target SN
9. If applicable, data forwarding from the source SN takes place
   - It may be initiated as early as the source SN receives the SN Release Request message from the MN

10-14. If one of the PDU session/QoS Flow was terminated at the source SN, path update procedure is triggered by the MN

15. Upon reception of the UE Context Release message, the source SN can release radio and C-plane related resource associated to the UE context
    - Any ongoing data forwarding may continue

MR-DC with 5GC SN Initiated SN Change

- The SN initiated SN change procedure is used to transfer a UE context from the source SN to a target SN and to change the SCG configuration in UE from one SN to another



MR-DC with 5GC Signalling Flow for the SN Change Initiated by the SN (Step 1-6)

1. The source SN initiates the SN change procedure by sending the SN Change Required message, which contains a candidate target node ID and may include the SCG configuration (to support delta configuration) and measurement results related to the target SN

2/3. The MN requests the target SN to allocate resources for the UE by means of the SN Addition procedure, including the measurement results related to the target SN received from the source SN
   - If data forwarding is needed, the target SN provides data forwarding addresses to the MN
   - The target SN includes the indication of the full or delta RRC configuration

4/5. The MN triggers the UE to apply the new configuration. The MN indicates the new configuration to the UE in the MN RRC reconfiguration message including the SN RRC configuration message generated by the target SN
   - The UE applies the new configuration and sends the MN RRC reconfiguration complete message, including the encoded SN RRC response message for the target SN, if needed
   - In case the UE is unable to comply with (part of) the configuration included in the MN RRC reconfiguration message, it performs the reconfiguration failure procedure

6. If the allocation of target SN resources was successful, the MN confirms the change of the source SN
   - If data forwarding is needed the MN provides data forwarding addresses to the source SN
   - If direct data forwarding is used for SN terminated bearers, the MN provides data forwarding addresses as received from the target SN to source SN
   - Reception of the SN Change Confirm message triggers the source SN to stop providing user data to the UE and, if applicable, to start data forwarding

MR-DC with 5GC Signalling Flow for the SN Change Initiated by the SN (Step 7-16)

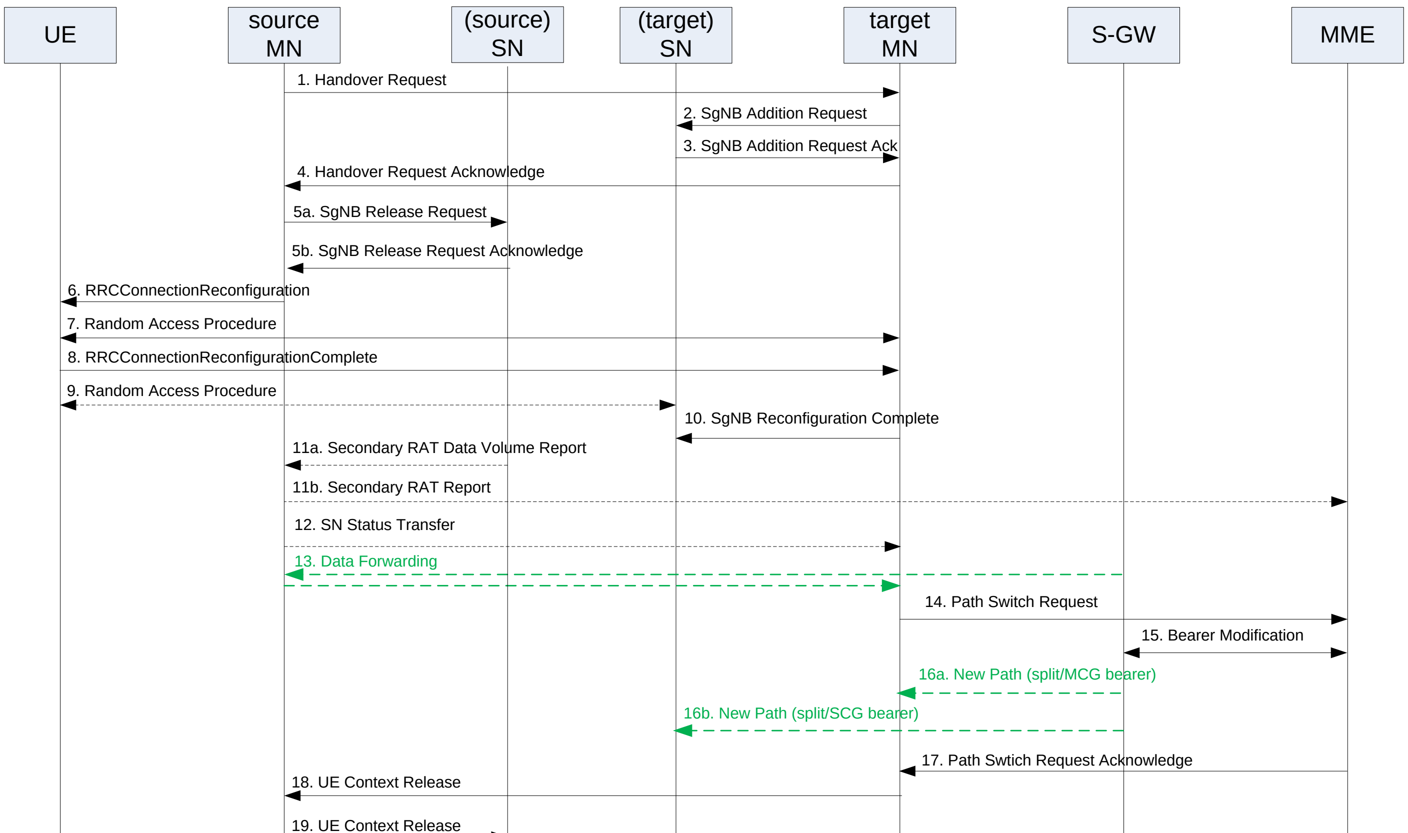
7. If the RRC connection reconfiguration procedure was successful, the MN informs the target SN via SN Reconfiguration Complete message with the encoded SN RRC response message for the target SN, if received from the UE
8. The UE synchronizes to the target SN
9. For SN terminated bearers using RLC AM, the source SN sends the SN Status transfer, which the MN sends then to the target SN
10. If applicable, data forwarding from the source SN takes place
    - It may be initiated as early as the source SN receives the SN Change Confirm message from the MN

11-15. If one of the PDU session/QoS Flow was terminated at the source SN, path update procedure is triggered by the MN

16. Upon reception of the UE Context Release message, the source SN can release radio and C-plane related resource associated to the UE context. Any ongoing data forwarding may continue

EN-DC Inter-Master Node Handover with/without Secondary Node Change

- Inter-Master Node handover with/without MN initiated Secondary Node change is used to transfer context data from a source MN to a target MN while the context at the SN is kept or moved to another SN
  - During an Inter-Master Node handover, the target MN decides whether to keep or change the SN (or release the SN)
  - Inter-RAT Inter-Master node handover with/without SN change is not supported in this version of the protocol (i.e. no transition from EN-DC to NR-NR DC)



EN-DC Signaling Flow for Inter-Master Node Handover with or without MN Initiated Secondary Node Change (Step 1-6)

1. The source MN starts the handover procedure by initiating the X2 Handover Preparation procedure including both MCG and SCG configuration
   - The source MN includes the (source) SN UE X2AP ID, SN ID and the UE context in the (source) SN in the Handover Request message
   - The source MN may send the SgNB Modification Request message (to the source SN) to request the current SCG configuration before step 1
2. If the target MN decides to keep the SN, the target MN sends SN Addition Request to the SN including the SN UE X2AP ID as a reference to the UE context in the SN that was established by the source MN
   - If the target MN decides to change the SN, the target MN sends the SgNB Addition Request to the target SN including the UE context in the source SN that was established by the source MN
3. The (target) SN replies with SN Addition Request Acknowledge
   - The (target) SN may include the indication of the full or delta RRC configuration
4. The target MN includes within the Handover Request Acknowledge message a transparent container to be sent to the UE as an RRC message to perform the handover, and may also provide forwarding addresses to the source MN
   - The target MN indicates to the source MN that the UE context in the SN is kept if the target MN and the SN decided to keep the UE context in the SN in step 2 and step 3
5. The source MN sends SN Release Request to the (source) SN including a Cause indicating MCG mobility
   - The (source) SN acknowledges the release request
   - The source MN indicates to the (source) SN that the UE context in SN is kept, if it receives the indication from the target MN
   - If the indication as the UE context kept in SN is included, the SN keeps the UE context
6. The source MN triggers the UE to apply the new configuration

EN-DC Signaling Flow for Inter-Master Node Handover with or without MN Initiated Secondary Node Change (Step 7-19)

7/8. The UE synchronizes to the target MN and replies with *RRCConnectionReconfigurationComplete* message

9. If configured with bearers requiring SCG radio resources, the UE synchronizes to the (target) SN

10. If the RRC connection reconfiguration procedure was successful, the target MN informs the (target) SN via SgNB Reconfiguration Complete message

11a. The SN sends the Secondary RAT Data Volume Report message to the source MN and includes the data volumes delivered to the UE over the NR radio for the related E-RABs
   - The order the source SN sends the Secondary RAT Data Volume Report message and performs data forwarding with MN/target SN is not defined
   - The SgNB may send the report when the transmission of the related bearer is stopped

11b. The source MN sends the Secondary RAT Report message to MME to provide information on the used NR resource

12. For bearers using RLC AM, the source MN sends the SN Status transfer to the target MN

13. Data forwarding from the source MN takes place
   - If the SN is kept, data forwarding may be omitted for SCG bearers and SCG split bearers

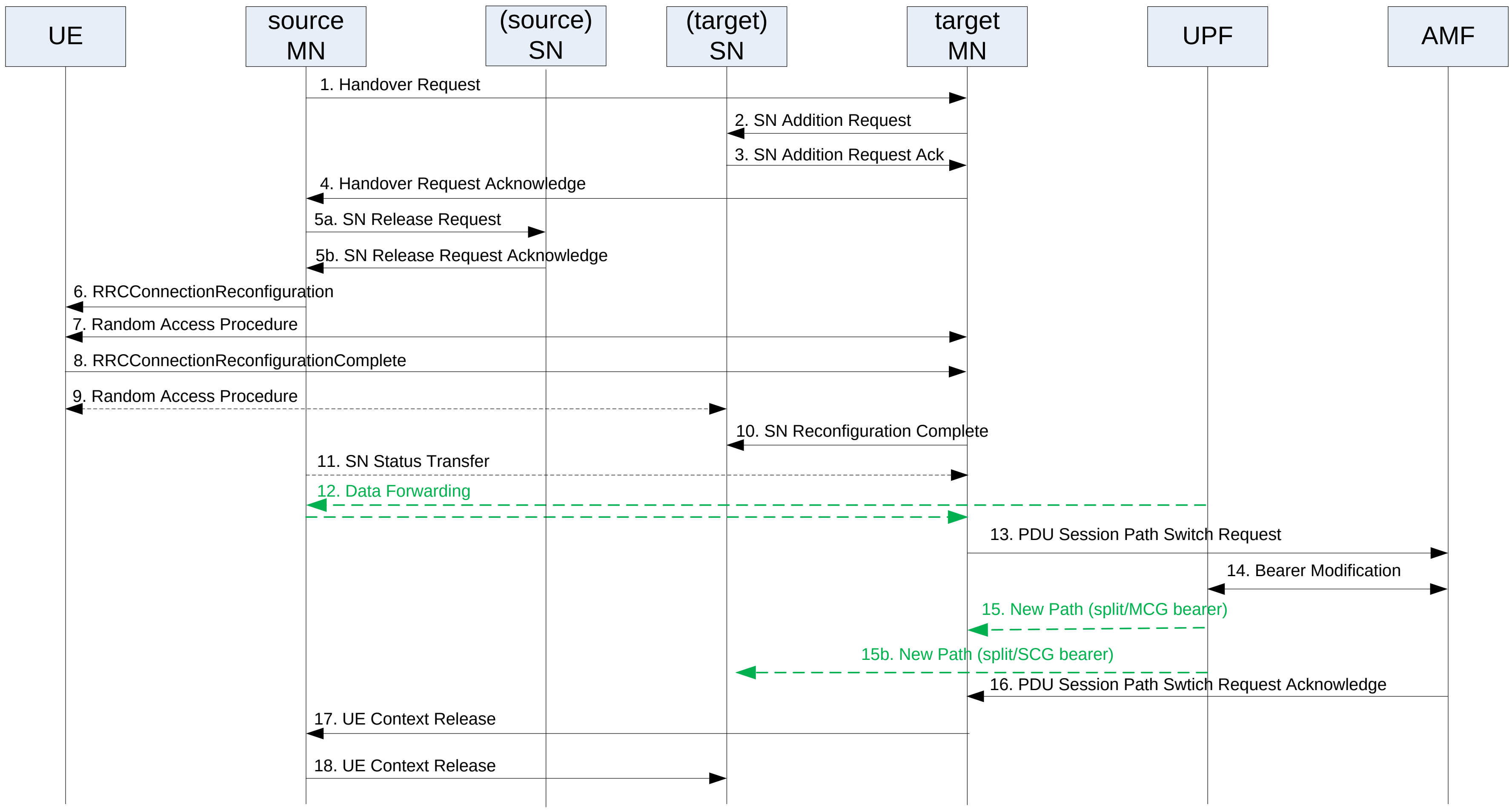
14-17. The target MN initiates the S1 Path Switch procedure
   - If new UL TEIDs of the S-GW are included, the target MN performs MN initiated SN Modification procedure to provide them to the SN

18. The target MN initiates the UE Context Release procedure towards the source MN

19. Upon reception of the UE Context Release message, the (source) SN can release C-plane related resource associated to the UE context towards the source MN
   - Any ongoing data forwarding may continue
   - The SN shall not release the UE context associated with the target MN if the indication was included in the SN Release Request in step 5

MR-DC with 5GC Inter-Master Node Handover with/without Secondary Node Change

- Inter-MN handover with/without MN initiated SN change is used to transfer UE context data from a source MN to a target MN while the UE context at the SN is kept or moved to another SN
  - During an Inter-Master Node handover, the target MN decides whether to keep or change the SN (or release the SN)



MR-DC with 5GC Signaling flow for Inter-Master Node Handover with or without MN Initiated Secondary Node Change (Step 1-6)

1. The source MN starts the handover procedure by initiating the Xn Handover Preparation procedure including both MCG and SCG configuration
   - The source MN includes the source SN UE XnAP ID, SN ID and the UE context in the source SN in the Handover Request message
   - The source MN may send the SN Modification Request message (to the source SN) to request the current SCG configuration before step 1
2. If the target MN decides to keep the source SN, the target MN sends SN Addition Request to the SN including the SN UE XnAP ID as a reference to the UE context in the SN that was established by the source MN
   - If the target MN decides to change the SN, the target MN sends the SN Addition Request to the target SN including the UE context in the source SN that was established by the source MN
3. The (target) SN replies with SN Addition Request Acknowledge
   - The (target) SN may include the indication of the full or delta RRC configuration
4. The target MN includes within the Handover Request Acknowledge message a transparent container to be sent to the UE as an RRC message to perform the handover, and may also provide forwarding addresses to the source MN
   - The target MN indicates to the source MN that the UE context in the SN is kept if the target MN and the SN decided to keep the UE context in the SN in step 2 and step 3
5. The source MN sends SN Release Request message to the (source) SN including a Cause indicating MCG mobility
   - The (source) SN acknowledges the release request
   - The source MN indicates to the (source) SN that the UE context in SN is kept, if it receives the indication from the target MN
   - If the indication as the UE context kept in SN is included, the SN keeps the UE context
6. The source MN triggers the UE to perform handover and apply the new configuration

MR-DC with 5GC Signaling flow for Inter-Master Node Handover with or without MN Initiated Secondary Node Change (Step 7-18)

7/8. The UE synchronizes to the target MN and replies with MN RRC reconfiguration complete message

9.If configured with bearers requiring SCG radio resources, the UE synchronizes to the (target) SN

10.If the RRC connection reconfiguration procedure was successful, the target MN informs the (target) SN via SN Reconfiguration Complete message

11.For bearers using RLC AM, the source MN sends the SN Status transfer to the target MN

12.Data forwarding from the source MN takes place

- If the SN is kept, data forwarding may be omitted for SCG bearers and SCG split bearers

13-16. The target MN initiates the PDU Session Path Switch procedure

- If new UL TEIDs of the UPF for SN are included, the target MN performs MN initiated SN Modification procedure to provide them to the SN

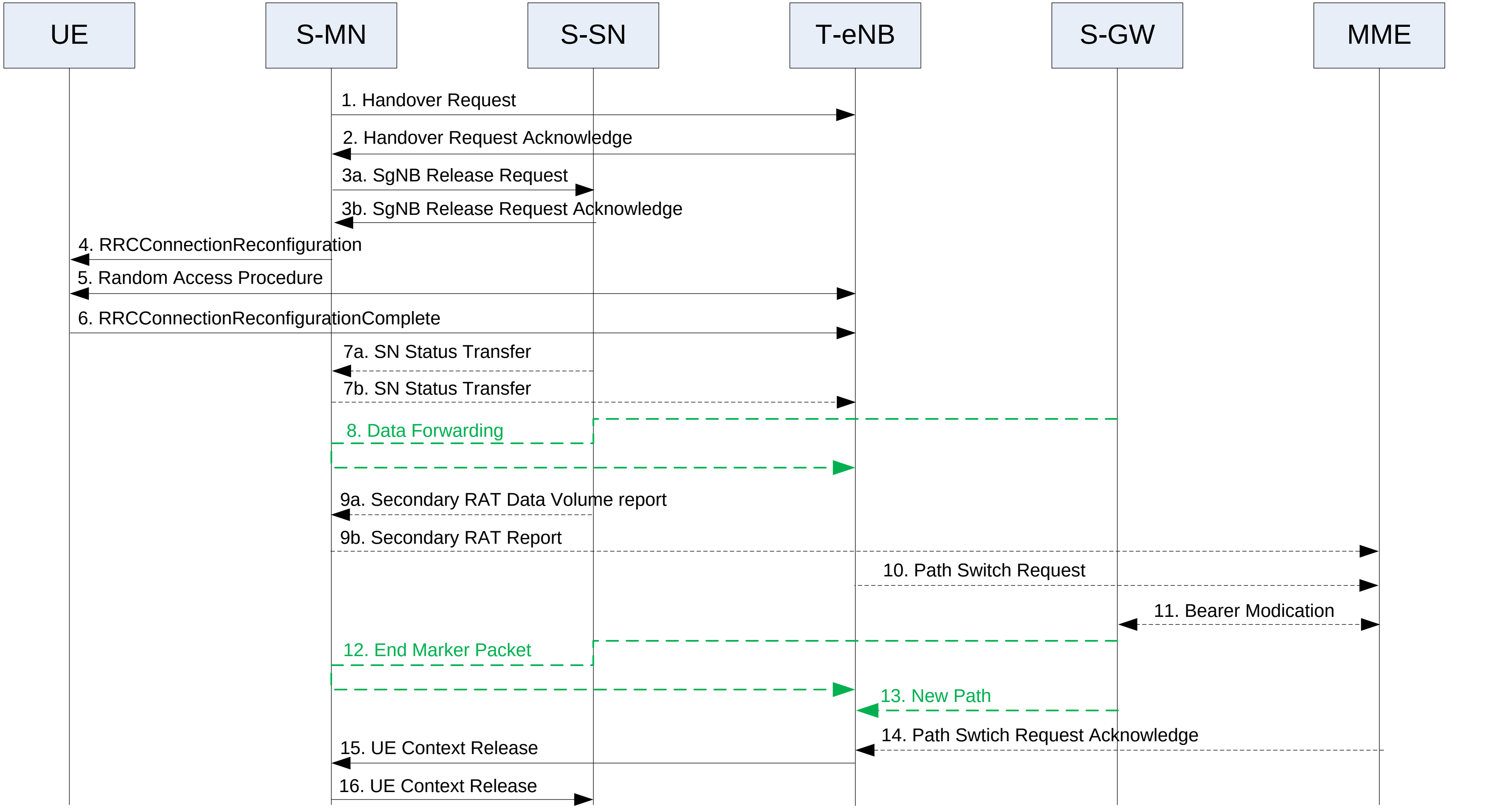
17.The target MN initiates the UE Context Release procedure towards the source MN

18.Upon reception of the UE Context Release message from source MN, the (source) SN can release C-plane related resource associated to the UE context towards the source MN

- Any ongoing data forwarding may continue
- The SN shall not release the UE context associated with the target MN if the indication was included in the SN Release Request message in step 5

EN-DC Master Node to eNB/gNB Change

- The Master Node to eNB Change procedure is used to transfer context data from a source MN/SN to a target eNB



EN-DC Master Node to eNB Change Procedure (Step 1-9a)

1. The source MN starts the MN to eNB Change procedure by initiating the X2 Handover Preparation procedure, including both MCG and SCG configuration
   - The source MN may send the SgNB Modification Request message (to the source SN) to request the current SCG configuration before step 1
2. The target eNB includes the field in HO command which releases SCG configuration, and may also provide forwarding addresses to the source MN
3. If the allocation of target eNB resources was successful, the MN initiates the release of the source SN resources towards the source SN including a Cause indicating MCG mobility
   - The SN acknowledges the release request. If data forwarding is needed, the MN provides data forwarding addresses to the source SN
   - Reception of the SgNB Release Request message triggers the source SN to stop providing user data to the UE and, if applicable, to start data forwarding
4. The MN triggers the UE to apply the new configuration
   - Upon receiving the new configuration, the UE releases the entire SCG configuration

5/6. The UE synchronizes to the target eNB

7. For SN terminated bearers using RLC AM, the SN sends the SN Status transfer, which the source MN sends then to the target eNB
8. If applicable, data forwarding from the source SN takes place
   - It may start as early as the source SN receives the SgNB Release Request message from the MN

9a. The source SN sends the *Secondary RAT Data Volume Report* message to the source MN and includes the data volumes delivered to the UE over the NR radio for the related E-RABs
   - The order the SN sends the Secondary RAT Data Volume Report message and performs data forwarding with MN is not defined
   - The SN may send the report when the transmission of the related bearer is stopped

EN-DC Master Node to eNB Change Procedure (Step 9b-16)

9b. The source MN sends the Secondary RAT Report message to MME to provide information on the used NR resource

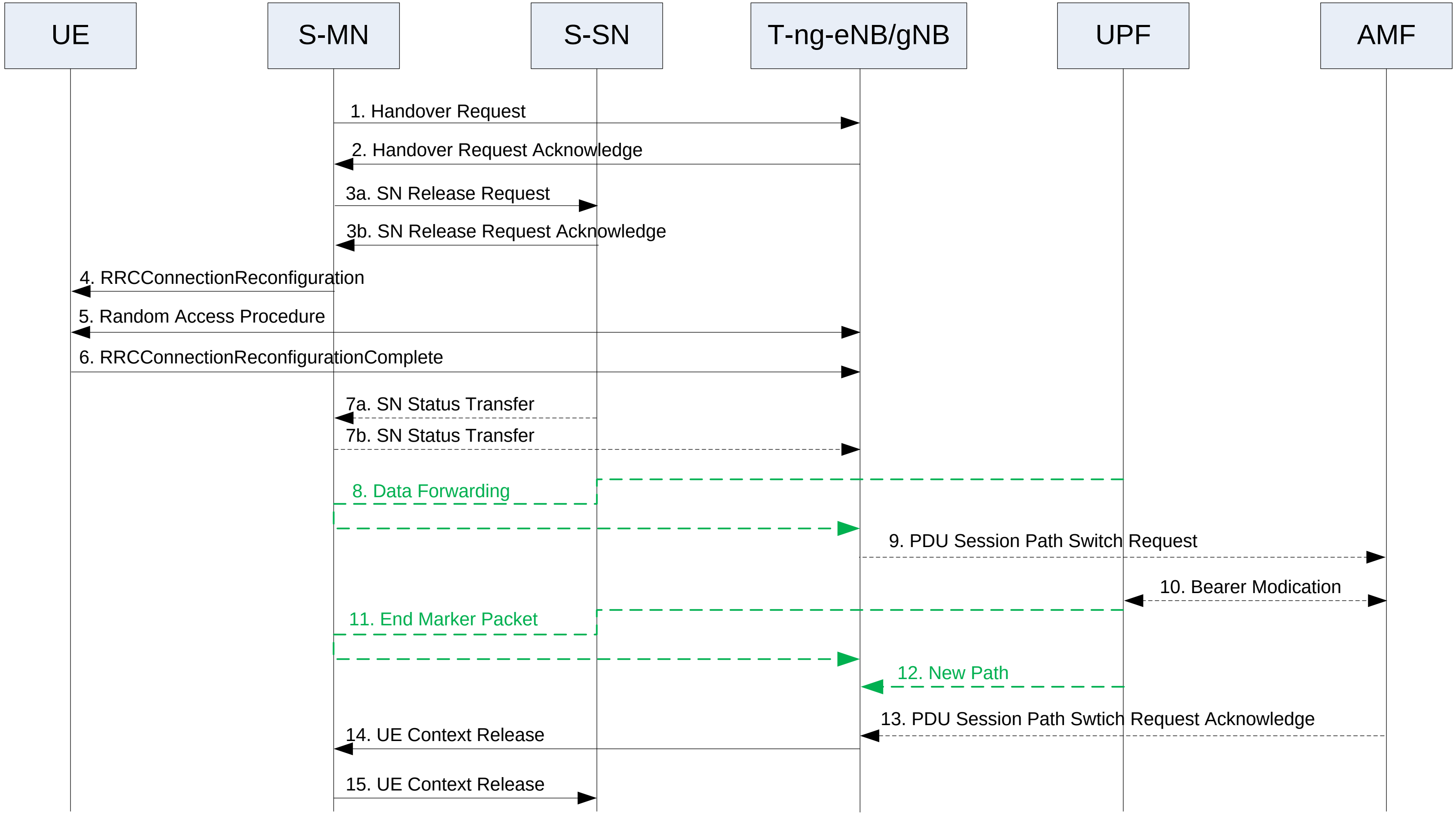
10-14. The target eNB initiates the S1 Path Switch procedure

15. The target eNB initiates the UE Context Release procedure towards the source MN

16. Upon reception of the UE CONTEXT RELEASE message, the S-SN can release radio and C-plane related resource associated to the UE context
    - Any ongoing data forwarding may continue

MR-DC with 5GC Master Node to eNB/gNB Change

- The MN to ng-eNB/gNB Change procedure is used to transfer UE context data from a source MN/SN to a target ng-eNB/gNB



MR-DC with 5GC MN to ng-eNB/gNB Change Procedure

1. The source MN starts the MN to ng-eNB/gNB Change procedure by initiating the Xn Handover Preparation procedure, including both MCG and SCG configuration
   - The source MN may send the SN Modification Request message (to the source SN) to request the current SCG configuration before step 1
2. The target ng-eNB/gNB includes the field in HO command which releases the SCG configuration, and may also provide forwarding addresses to the source MN
3. If the resource allocation of target ng-eNB/gNB was successful, the MN initiates the release of the source SN resources towards the source SN including a Cause indicating MCG mobility
   - The SN acknowledges the release request
   - If data forwarding is needed, the MN provides data forwarding addresses to the source SN. Reception of the SN Release Request message triggers the source SN to stop providing user data to the UE and, if applicable, to start data forwarding
4. The MN triggers the UE to perform HO and apply the new configuration
   - Upon receiving the new configuration, the UE releases the entire SCG configuration

5/6. The UE synchronizes to the target ng-eNB/gNB

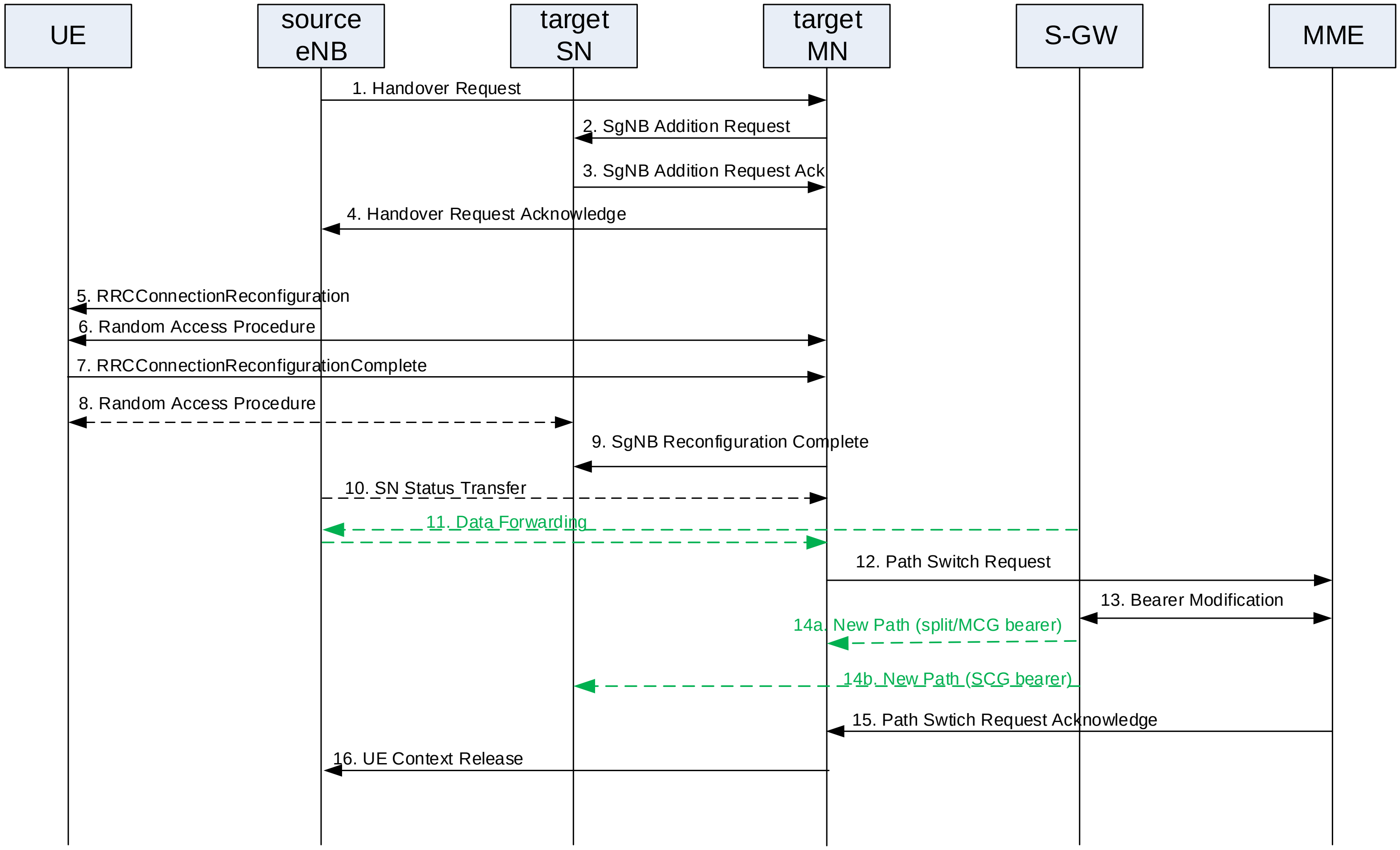
7. For SN terminated bearers using RLC AM, the SN sends the SN Status transfer, which the source MN sends then to the target ng-eNB/gNB
8. If applicable, data forwarding from the source SN takes place
   - It may start as early as the source SN receives the SN Release Request message from the MN

9-13. The target ng-eNB/gNB initiates the PDU Session Path Switch procedure

14. The target ng-eNB/gNB initiates the UE Context Release procedure towards the source MN
15. Upon reception of the UE Context Release message from MN, the source SN can release radio and C-plane related resource associated to the UE context
    - Any ongoing data forwarding may continue

EN-DC eNB/gNB to Master Node Change

- The eNB to Master Node change procedure is used to transfer context data from a source eNB to a target MN that adds an SN during the handover



EN-DC eNB to Master Node change

1. The source eNB starts the handover procedure by initiating the X2 Handover Preparation procedure
2. The target MN sends SgNB Addition Request to the target SN
3. The target SN replies with SgNB Addition Request Acknowledge
   - If data forwarding is needed, the target SN provides forwarding addresses to the target MN
4. The target MN includes within the Handover Request Acknowledge message a transparent container to be sent to the UE as an E-UTRA RRC message, including a NR RRC configuration message which also includes the SCG configuration, to perform the handover, and may also provide forwarding addresses to the source eNB
5. The source eNB triggers the UE to apply the new configuration

6/7. The UE synchronizes to the target MN and replies with *RRCConnectionReconfigurationComplete* message

8. If configured with bearers requiring SCG radio resources, the UE synchronizes to the target SN
9. If the RRC connection reconfiguration procedure was successful, the target MN informs the target SN
10. For bearers using RLC AM, the source eNB sends the SN Status transfer to the target MN
11. Data forwarding from the source eNB takes place

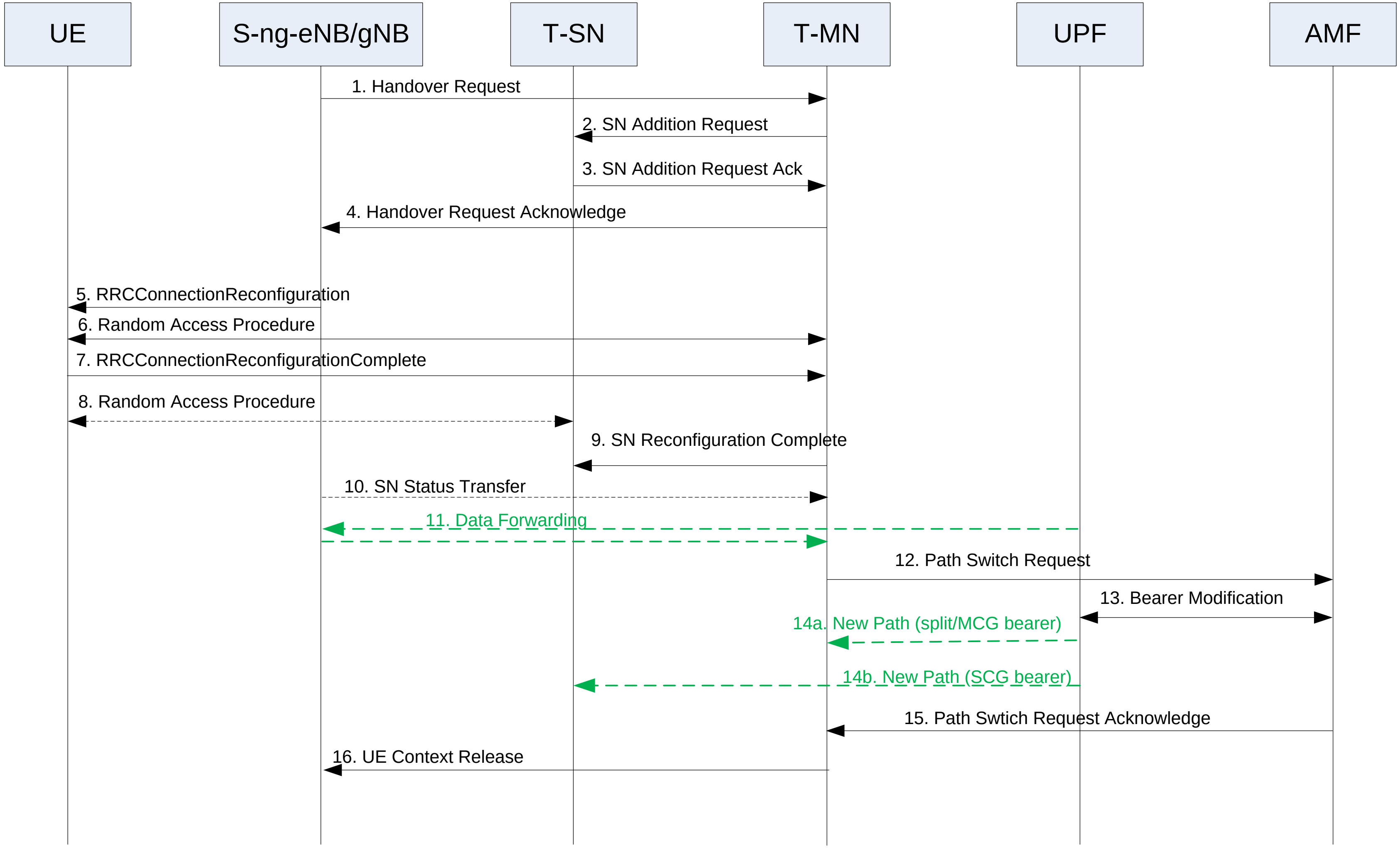
12-15. The target MN initiates the S1 Path Switch procedure

   - If new UL TEIDs of the S-GW are included, the target MN performs MN initiated SN Modification procedure to provide them to the target SN

16. The target MN initiates the UE Context Release procedure towards the source eNB

MR-DC with 5GC eNB/gNB to Master Node Change

- The ng-eNB/gNB to MN change procedure is used to transfer UE context data from a source ng-eNB/gNB to a target MN that adds an SN during the handover



MR-DC with 5GC ng-eNB/gNB to MN Change Procedure

1. The source ng-eNB/gNB starts the handover procedure by initiating the Xn Handover Preparation procedure
2. The target MN sends SN Addition Request to the target SN
3. The target SN replies with SN Addition Request Acknowledge
   – If data forwarding is needed, the target SN provides forwarding addresses to the target MN
4. The target MN includes within the Handover Request Acknowledge message a transparent container to be sent to the UE as an MN RRC message including a SN RRC configuration message which also includes the SCG configuration, to perform the handover, and may also provide forwarding addresses to the source ng-eNB/gNB
5. The source ng-eNB/gNB triggers the UE to perform handover and apply the new configuration

6/7. The UE synchronizes to the target MN and replies with MN RRC reconfiguration complete message

8. If configured with bearers requiring SCG radio resources, the UE synchronizes to the target SN
9. If the RRC connection reconfiguration procedure was successful, the target MN informs the target SN via SN Reconfiguration Complete message
10. For bearers using RLC AM, the source ng-eNB/gNB sends the SN Status transfer to the target MN
11. Data forwarding from the source ng-eNB/gNB takes place

12-15. The target MN initiates the PDU Session Path Switch procedure

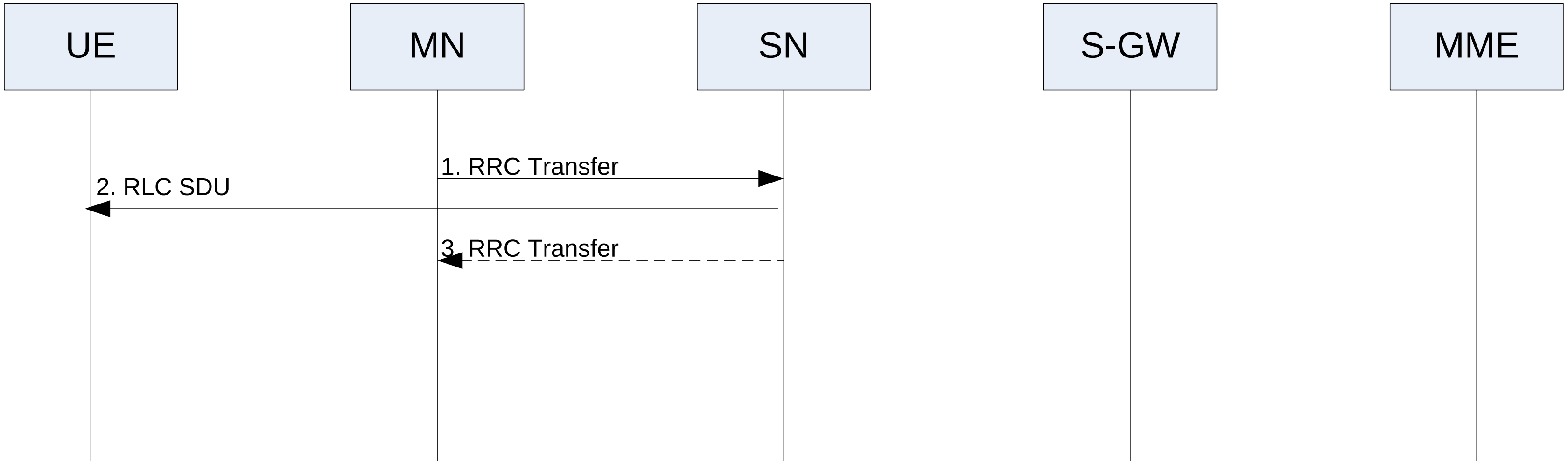
   – If new UL TEIDs of the UPF are included, the target MN performs MN initiated SN Modification procedure to provide them to the target SN

16. The target MN initiates the UE Context Release procedure towards the source ng-eNb/gNB

EN-DC RRC Transfer Procedure for Split SRB (DL Operation)

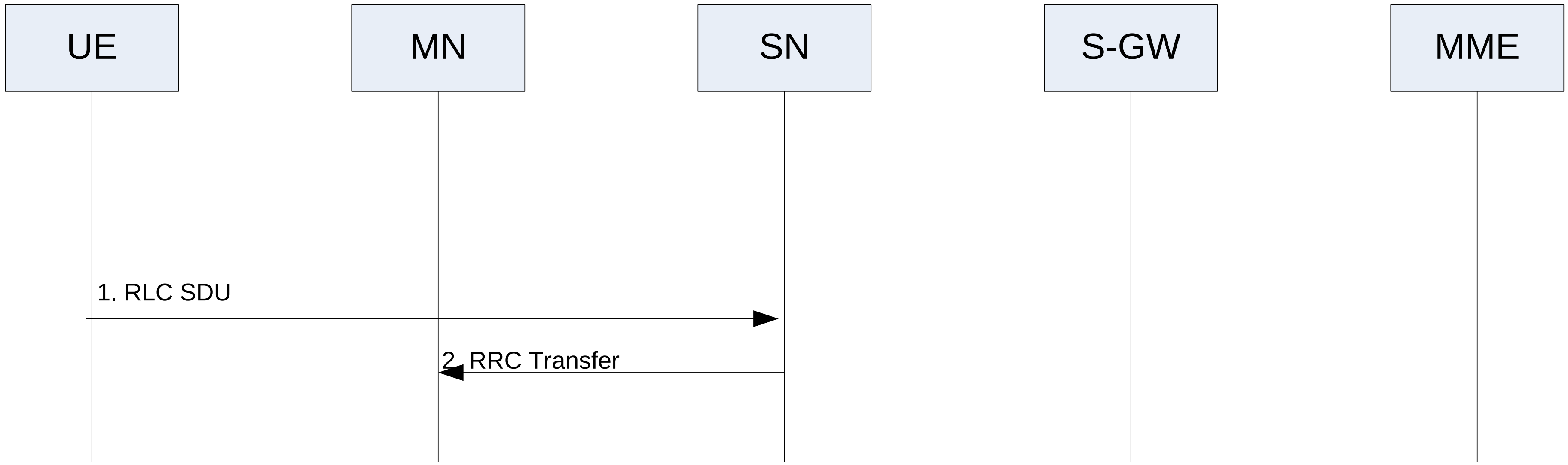
- The RRC Transfer procedure is used to exchange RRC messages between the MN and the UE via the SN (split SRB) and to provide NR measurement reports from the UE to the SN

1. The MN, when it decides to use the split SRBs, starts the procedure by initiating the RRC Transfer procedure
   - The MN encapsulates the RRC message in a PDCP-C PDU and ciphers with own keys
   - The usage of the split SRBs shall be indicated in the Secondary Node Addition procedure or Modification procedure
2. The SN forwards the RRC message to the UE
3. The SN may send PDCP delivery acknowledgement of the RRC message forwarded in step 2



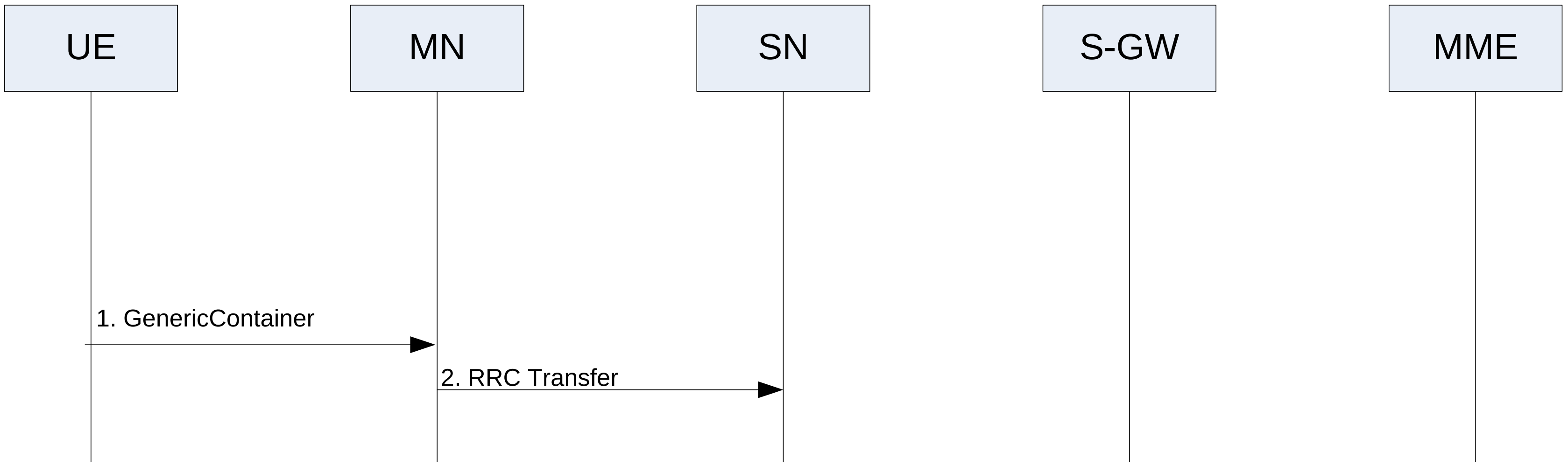
EN-DC RRC Transfer Procedure for Split SRB (UL Operation)

1. When the UE provides response to the RRC message, it sends it to the SN
2. The SN initiates the RRC Transfer procedure, in which it transfers the received PDCP-C PDU with encapsulated RRC message



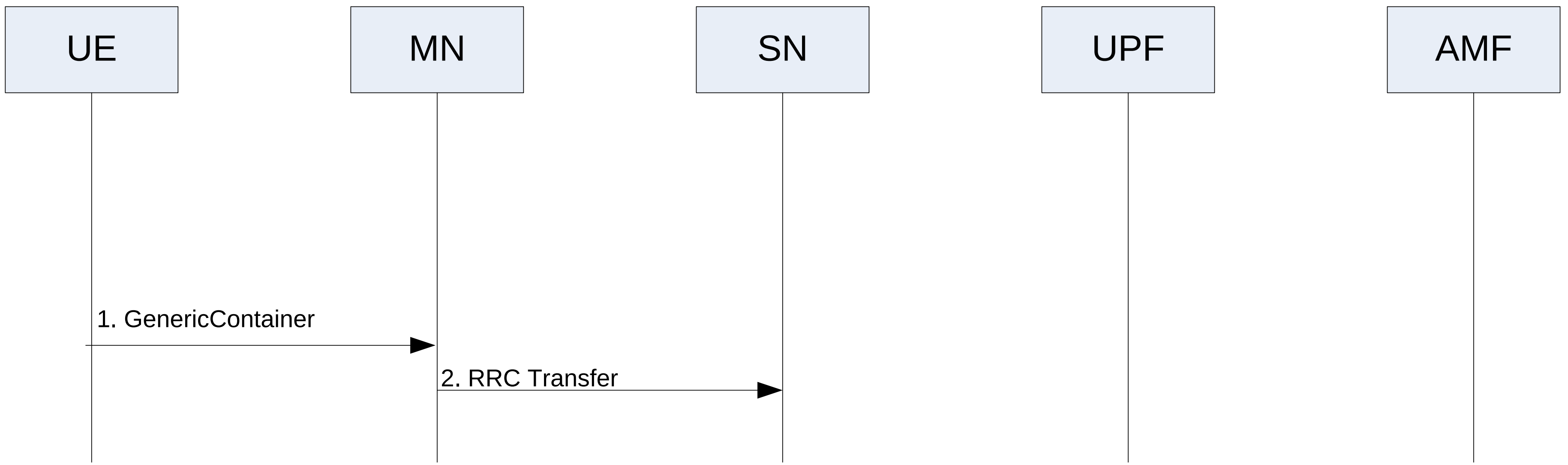
EN-DC RRC Transfer Procedure for NR Measurement Report

1. When the UE sends a measurement report, it sends it to the MN in the *GenericContainer*
2. The MN initiates the RRC Transfer procedure, in which it transfers the received NR measurement report as an octet string



MR-DC with 5GC RRC Transfer Procedure for NR Measurement Report

- When the UE sends a measurement report, it sends it to the MN in the *GenericContainer*
- The MN initiates the RRC Transfer procedure, in which it transfers the received NR measurement report as an octet string

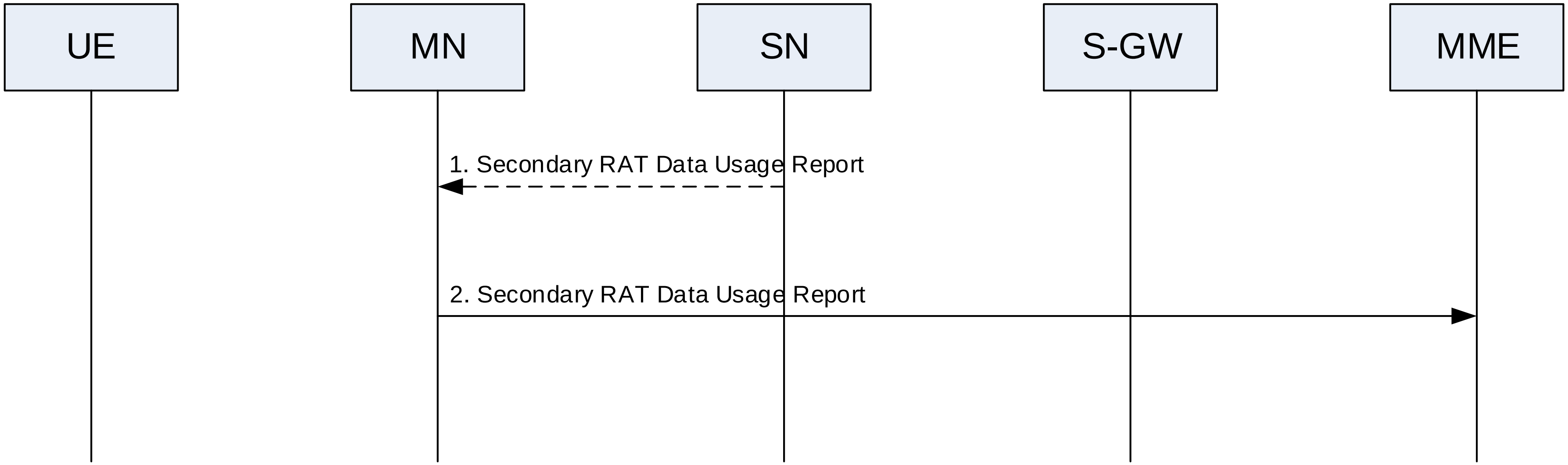


EN-DC Secondary RAT Data Volume Reporting

- The secondary RAT data volume reporting function is used to report the data volume of secondary RAT to CN
- In EN-DC, if configured, the MN reports the uplink and downlink data volumes of used NR resources to the EPC on a per EPS bearer basis as specified in TS 36.300
- Periodic reporting is performed by periodically sending the Secondary RAT Data Volume Report messages to the MME
- The data volume is counted by the node hosting PDCP. Downlink data volume is counted in bytes of PDCP SDUs successfully delivered to the UE over NR (for RLC AM) or transmitted to the UE over NR (for RLC UM)
- Uplink data volume is counted in bytes of PDCP SDUs received by the node hosting PDCP over NR
- Forwarded packets shall not be counted when PDCP entity is relocated
- When PDCP duplication is activated, packets shall be counted only once

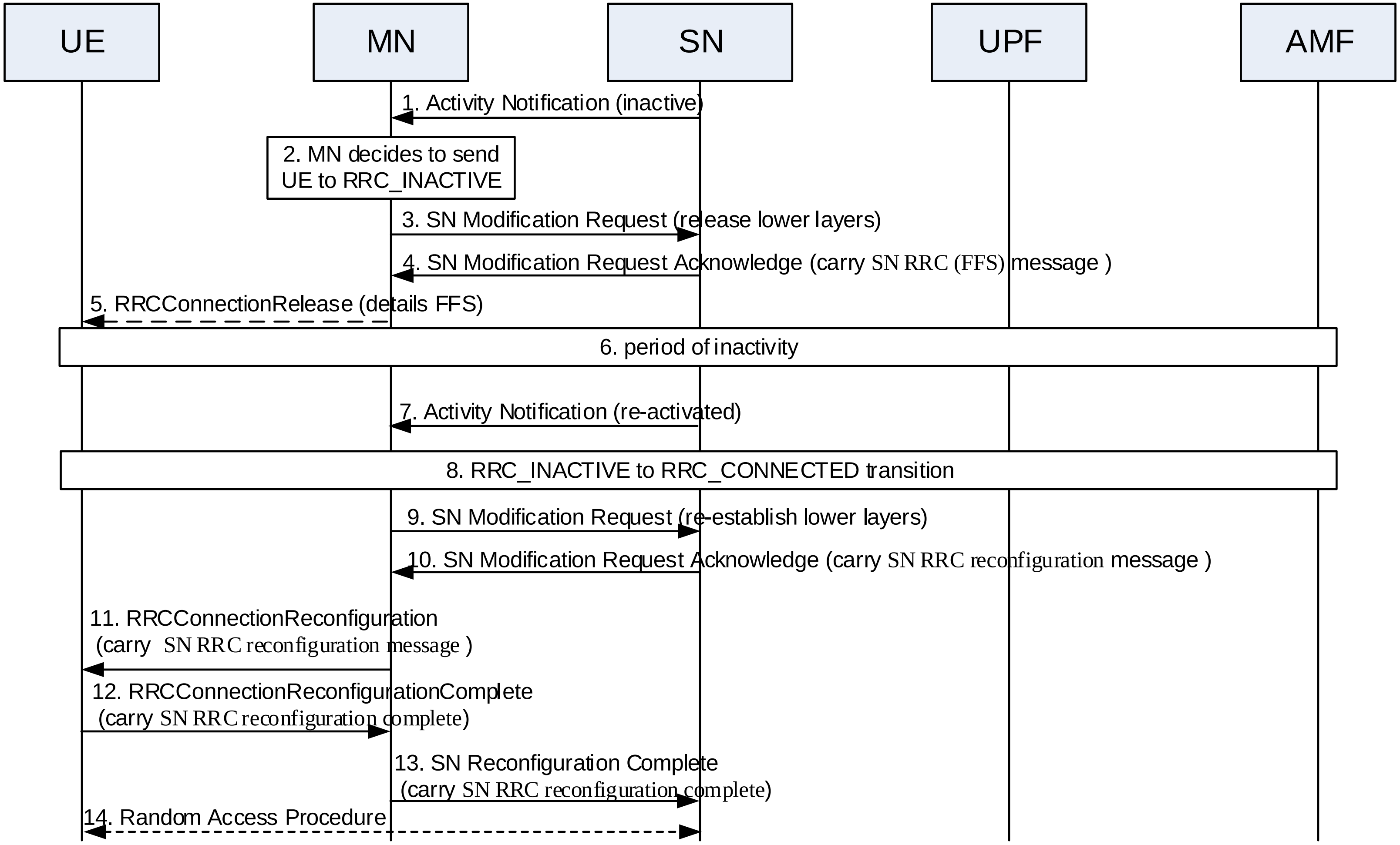
Signalling Flow for Secondary RAT Data Volume Periodic Reporting

1. If the periodic reporting is configured, then the SN periodically sends the *Secondary RAT Data Usage Report* message to the MN and includes the data volumes of used NR radio resources for the related SN-terminated E-RABs
2. The MN sends the *Secondary RAT Data Usage Report* message to MME to provide information on the used NR resource
   - The Secondary RAT Data Usage Report message sent by the MN may also include secondary RAT report information of MN-terminated bearers



MR-DC with 5GC with RRC_INACTIVE

- The Activity Notification function may be used to enable MR-DC with 5GC with RRC_INACTIVE operation
- The MN node may decide, after inactivity is reported from the SN and also MN resources show no activity, to send the UE to RRC_INACTIVE
- Resumption to RRC_CONNECTED may take place after activity is reported from the SN for SN terminated bearers



Service Related Aspects

- Roaming and Access Restrictions
  - The principles for conveying roaming and access restriction info for EN-DC are described in TS 36.300
  - For MR-DC with 5GC, SCG (re)selection at the SN is based on roaming and access restriction information in SN
  - If roaming and access restriction information is not available at the SN, the SN shall consider that there is no restriction for SCG (re)selection
  - Therefore, MN needs to convey the up-to-date roaming and access restriction information to SN via XnAP messages

X2/Xn Interface Related Aspects

- Stage 2 specification for X2-C procedures for EN-DC is contained in TS 36.300
- Xn-C procedures for MR-DC with 5GC are specified in TS 38.423
- X2-U procedures for EN-DC and Xn-U procedures for MR-DC with 5GC are specified in TS 38.425

Outline

- Overall Architecture
- Multi-connectivity
- Non-3GPP Access Architecture
  - Reference Model
  - Network Elements
  - Network Discovery and Selection
  - Charging for Non-3GPP Accesses
- Access to EPC via non-3GPP

Non-3GPP Access

- The EPS supports the use of non-3GPP IP access networks to access the EPC
- The EPS supports
  - Network-based mobility management mechanism based on PMIP or GTP and
  - Host-based mobility management mechanism (e.g., MIP) over S2 reference points

- The EPS supports IETF-based network-based mobility management mechanism (i.e. PMIP) over S5 and S8 reference points

- When host-based mobility protocol (DSMIPv6, RFC 5555) is used within the EPS and the UE camps on a 3GPP access network, in this specification the UE is considered to be on its home link
  - A scenario where the UE in EPS uses a host based mobility protocol with a HA that is outside the EPS is out of the scope of 3GPP specification

Non-3GPP Mobility Management

- The mobility management procedures specified to handle mobility between 3GPP and non 3GPP accesses shall include mechanisms to minimize the handover latency due to authentication and authorization for network access
  - This applies to UEs either supporting simultaneous radio transmission capability or not supporting it
  - EPS-based mobility between GERAN/UTRAN access and non-3GPP access requires S4-based SGSNs
- For multiple PDN-GWs connecting to the same PDN, all the PDN GWs shall support the same mobility protocols

Interworking between E-UTRAN and CDMA2000

- The mobility management procedures specified to handle mobility between E-UTRAN and CDMA2000 accesses shall include mechanisms to minimize the service interruption during handover and where possible support bidirectional service continuity
  - This applies to UEs supporting either single or dual radio capability
  - The mobility management procedures should minimize any performance impacts to the UE and the respective accesses, for example, UE battery consumption and network throughput
  - The mobility management procedures should minimize the coupling between the different accesses allowing independent protocol evolution in each access
- The operator may configure an indicator in HSS which is delivered to the BBERF in HSGW within the Charging Characteristics and used by the BBERF to not establish the Gateway Control Session during the IP-CAN session establishment procedure
- When the Gateway Control Session session is not used, certain functions such as location information report, APN-AMBR update and dedicated bearer establishment are impacted
- The decision to not establish the Gateway Control Session session applies for the life time of the IP-CAN session
- The indicator in the HSS is operator specific, therefore it can only be used in non-roaming cases

Interworking between 3GPP Accesses and WiMAX

- The mobility management procedures specified to handle mobility between 3GPP Accesses and WiMAX shall include mechanisms to minimize the service interruption during handover and where possible support bidirectional service continuity
  - This applies to UEs supporting either single or dual radio capability
  - The mobility management procedures should minimize any performance impacts to the UE and the respective accesses, for example, UE battery consumption and network throughput
  - The mobility management procedures should minimize the coupling between the different accesses allowing independent protocol evolution in each access
- Furthermore, the mobility management procedures specified to handle mobility between 3GPP accesses and WiMAX should minimize the impact on legacy systems (i.e. UTRAN and GERAN)

IP Mobility Management Selection Principles

- The Mobility mechanisms supported between 3GPP and non-3GPP accesses within an operator and its roaming partner's network would depend upon operator choice
- Static Configuration of Inter-technology Mobility Mechanism
  - For networks deploying a single IP mobility management mechanism, the statically configured mobility mechanism can be access type and/or roaming agreement specific
  - The information about the mechanism to be used in such scenario is expected to be provisioned into the terminal (or the UICC) and the network
  - IP session continuity between 3GPP and non-3GPP access types may not be provided in this case if there is a mismatch between what the UE expects and what the network supports
  - For example service continuity may not be possible if the user switches to a terminal supporting a different IP mobility management mechanism than provisioned in the network
  - The mismatch case where a trusted non-3GPP network or ePDG only supports DSMIPv6 and the UE does not, may lead to a situation where the UE receives a local IP address in the trusted non-3GPP access network or ePDG, but gains no PDN connectivity in the EPC
  - Depending on operator policy and roaming agreements, IP connectivity may be provided using this local IP address to access services (e.g. internet access) in the trusted non-3GPP network

IP Mobility Management Selection (IPMS)

- IP Mobility management Selection (IPMS) consist of two components
  - IP MM protocol selection between Network Based Mobility (NBM) and Host based mobility (HBM - MIPv4 orDSMIPv6)
  - Decision on IP address preservation if NBM is selected
- IPMS does not relate to the selection between PMIPv6 and GTP over S5/S8/S2b/S2a

- Upon initial attachment to a 3GPP access, no IPMS is necessary since connectivity to a PDN GW is always established with a network-based mobility mechanism

- Upon initial attachment to a trusted non-3GPP access or ePDG and upon handover from 3GPP to a trusted non-3GPP access or ePDG, IPMS is performed before an IP address is allocated and provided to the UE

Network Based Mobility (NBM)

- The UE support for a specific IP Mobility Management protocol and/or IP address preservation mechanism for inter-access mobility may be known by the network-based on explicit indication from the UE
- Upon attachment to a trusted non-3GPP access or ePDG, if the access network (supporting at least NBM) is not aware of the UE capabilities and the home and access network's policies allow the usage of NBM, then NBM is used for establishing connectivity for the UE to the EPC
- When a NBM mechanism is used for establishing connectivity in the target access upon inter-access mobility, IP address preservation for session continuity
  - based on NBM may take place as per PMIPv6 specification (RFC 5213) or according to clause 8.6 for GTP, and
  - additionally based on the knowledge in the network of UE's capability (if available) to support NBM

  Such knowledge may be based on an explicit indication from the UE upon handover that IP address preservation based on NBM management can be provided

IP Address Preservation of HBM

IP address preservation for session continuity based on HBM may take place if the network is aware of the UE capability to support DSMIPv6 or MIPv4

- Such knowledge may be based on an indication to the target trusted non-3GPP access or ePDG from the HSS/AAA (e.g. in case of DSMIPv6, the UE performed S2c bootstrap before moving to the target trusted non-3GPP access or ePDG)
- In such a case, the trusted non-3GPP access network or ePDG provides the UE with a new IP address, local to the access network if IP mobility management protocol selected is DSMIPv6
- In that case, in order to get IP address preservation for session continuity, the UE shall use DSMIPv6 over S2c reference point
- This IP address shall be used as a care-of address for DSMIPv6
- If the IP mobility management protocol selected is MIPv4, the address provided to the UE by the non-3GPP access network is a FACoA and IP address preservation is performed over S2a using MIPv4 FACoA procedures

Mobility Management Mechanism

- The final decision on the mobility management mechanism is made by the HSS/AAA upon UE authentication in the trusted non-3GPP access system or ePDG (both at initial attachment and handover), based on the information it has regarding the UE, local/home network capabilities and local/home network policies
  - If the UE provided an explicit indication of the supported mobility mechanisms, the network shall provide an indication to the UE identifying the selected mobility management mechanism
- Support of different IP mobility management protocols at local/home network is known by the AAA/HSS in one of the following ways
  - Through static pre-configuration
  - Through indication of the supported IP mobility management protocols (NBM and/or MIPv4 FA CoA mode) by the trusted non-3GPP access system or ePDG as part of the AAA exchange for UE authentication

IP Mobility management Selection (IPMS)

- Upon selecting a mobility management mechanism, as part of the AAA exchange for UE authentication in the trusted non-3GPP access system or ePDG
  - The HSS/AAA returns to the trusted non-3GPP access system or ePDG an indication on whether a local IP address shall be allocated to the UE, or if instead NBM shall be used to establish the connectivity, or
  - The HSS/AAA returns to the trusted non-3GPP access system an indication that the address of the MIPv4 Foreign Agent shall be provided to the UE
- IPMS is performed in the following scenarios
  - Upon initial attach to a trusted non-3GPP access or ePDG, the IPMS is performed to decide how to establish IP connectivity for the UE
  - Upon handover without optimization from a 3GPP access to a non-3GPP access, the IPMS is performed to decide how to establish IP connectivity for the UE over the trusted non-3GPP access or ePDG
  - Upon change of access between a non-3GPP access and a 3GPP access or between two non-3GPP accesses,
    - if the IP MM protocol used to provide connectivity to the UE over the trusted non-3GPP access or ePDG is a NBM protocol,
    - then a decision is performed on whether IP address preservation is provided or not as per PMIPv6 specification, (RFC 5213) or according to 3GPP TS 23.402 clause 8.6 for GTP and additionally based on the knowledge in the network of UE's capability (if available) to support NBM

IP Mobility Management Selection During Initial Attach to a Non-3GPP Access

- The IPMS decision is performed as described in the following
  - If the UE indicates DSMIPv6 support only, and the network supports and selects DSMIPv6, the trusted non-3GPP access network or ePDG provides a local IP address to the UE to be used as CoA for DSMIPv6/S2c
  - If the UE indicates MIPv4 support only, and the network supports and selects MIPv4, then the trusted non-3GPP access network provides a FACoA to the UE
  - If the UE indicates DSMIPv6 or MIPv4 support only, and the network selects NBM for providing connectivity, then NBM is used for providing connectivity
  - If the UE does not indicate any capabilities, it is assumed that the UE is not able to support DSMIPv6 or MIPv4, and NBM is used for providing connectivity if the network supports NBM

IPMS Solutions

- On handover to 3GPP access, UE shall request for IP address preservation by setting Request Type flag to "handover" during the attach procedure
  - UE requests for address preservation if S2c is used over source access network or MIPv4 FACoA is used to connect over source access network or UE is capable of Network address preservation
- When the UE provides an indication of its supported mobility modes either during initial attach or on handover, the UE provides such information to the entity performing IPMS during network access authentication, for trusted non-3GPP accesses, or during authentication for tunnel establishment with ePDG, for untrusted non-3GPP accesses
- The network then makes the decision on what mobility protocol to be used for connectivity as described in further clauses depending on the scenario

IPMS on Handover between Accesses

- On handover to non-3GPP accesses, the IPMS decision is performed as described in the following

a. If the UE only indicates NBM support between the two access technologies involved in the handover and the network supports NBM between those two access technologies involved in the handover, then NBM is used for providing connectivity, and IP address preservation is provided with S2a or S2b procedures

b. If the UE indicates DSMIPv6 support and the network supports and selects DSMIPv6, the trusted non-3GPP access network or ePDG provides a local IP address to the UE to be used as CoA for DSMIPv6, and IP address preservation is provided with S2c procedures

c. If the UE indicates DSMIPv6 support only and the network does not support DSMIPv6, then NBM is used for providing basic connectivity to the existing PDN GW if NBM is supported by the trusted non-3GPP access network or ePDG

   a. In this case, the decision for IP address preservation is made as per PMIPv6 specification, (RFC 5213 [8]) or according to clause 8.6 in 3GPP TS 23.402 for GTP

d. If the UE indicates support for both NBM and DSMIPv6, and the network based on policies selects NBM to establish the connectivity, then NBM is used to establish connectivity, and IP address preservation is provided with S2a or S2b procedures

e. If the UE indicates support for both NBM and DSMIPv6, and the network based on policies selects DSMIPv6 to establish the connectivity, then the trusted non-3GPP access network or ePDG provides a local IP address to the UE to be used as CoA for DSMIPv6, and IP address preservation is provided with S2c procedures

f. If the UE does not indicate any capabilities, then NBM is used for establishing connectivity if NBM is supported by the trusted non-3GPP access network or ePDG. In this case, the decision for IP address preservation is made as per PMIPv6 specification, (RFC 5213) or according to clause 8.6 in 3GPP TS 23.402 for GTP

IPMS on Handover between Accesses (Cont.)

- In case of bullet c and f, PMIPv6 specification allows two options
  - Preserve the IP address based on a timer
    - If the connection through the old access system is not torn down before the timer expires then a new prefix is assigned
  - Immediately assign a new prefix
    - This decision can be based on operator's policies
- If prior to the handover, the UE was attached to a non-3GPP access with DSMIPv6, bullets a. and c. are considered not to apply
- The PDN GW capability of supporting NBM or DSMIPv6 or MIPv4 should be considered in IP Mobility Mode Selection
- The UE indication of DSMIPv6 support may be implicit, e.g. having bootstrapped a security association via the old access network
- The same applies to NBM, since the network can collect information about NBM support from other sources
- On handover to 3GPP access, the only decision that needs to be made is whether IP address preservation needs to be provided or not

Trusted/Untrusted Non-3GPP Access Network Detection

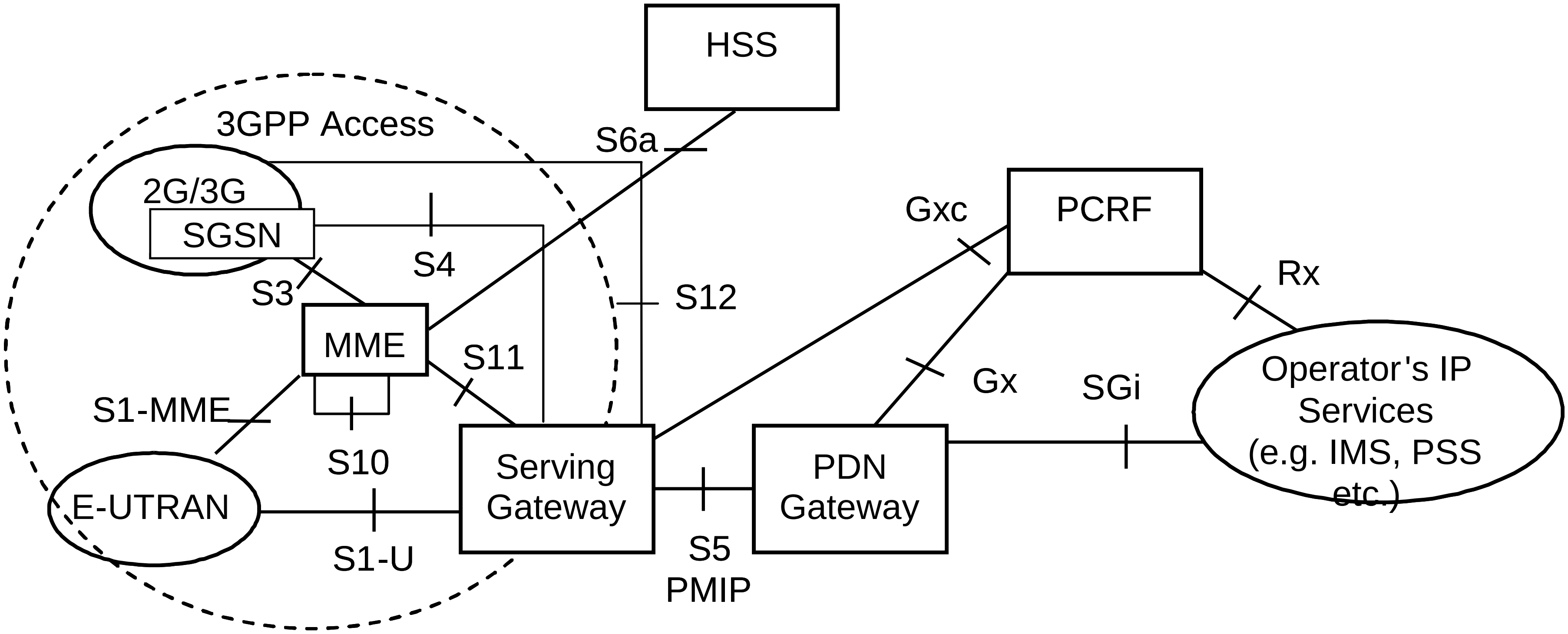
- During initial attach or handover attach a UE needs to discover the trust relationship (whether it is a Trusted or Untrusted Non-3GPP Access Network) of the non-3GPP access network in order to know which non-3GPP IP access procedure to initiate
- The trust relationship of a non-3GPP access network is made known to the UE with one of the following options
  - If the non-3GPP access supports 3GPP-based access authentication, the UE discovers the trust relationship during the 3GPP-based access authentication
  - The UE operates on the basis of pre-configured policy in the UE

Non-seamless WLAN Offload

- Non-seamless WLAN offload is an optional capability of a UE supporting WLAN radio access in addition to 3GPP radio access
- A UE supporting non-seamless WLAN offload may, while connected to WLAN access, route specific IP flows via the WLAN access without traversing the EPC
  - These IP flows are identified via user preferences, the Local Operating Environment Information defined in TS 23.261, and via policies that may be statically pre-configured by the operator on the UE, or dynamically set by the operator via the ANDSF
  - For such IP flows the UE uses the local IP address allocated by the WLAN access network and no IP address preservation is provided between WLAN and 3GPP accesses
- For performing the non-seamless WLAN offload, the UE needs to acquire a local IP address on WLAN access, and it is not required to connect to an ePDG
- Also, in the case the WLAN access is EPC connected, it is possible for a UE which also supports seamless WLAN offload to perfom seamless WLAN offload for some IP flows and non seamless WLAN offload for some other IP flows simultaneously

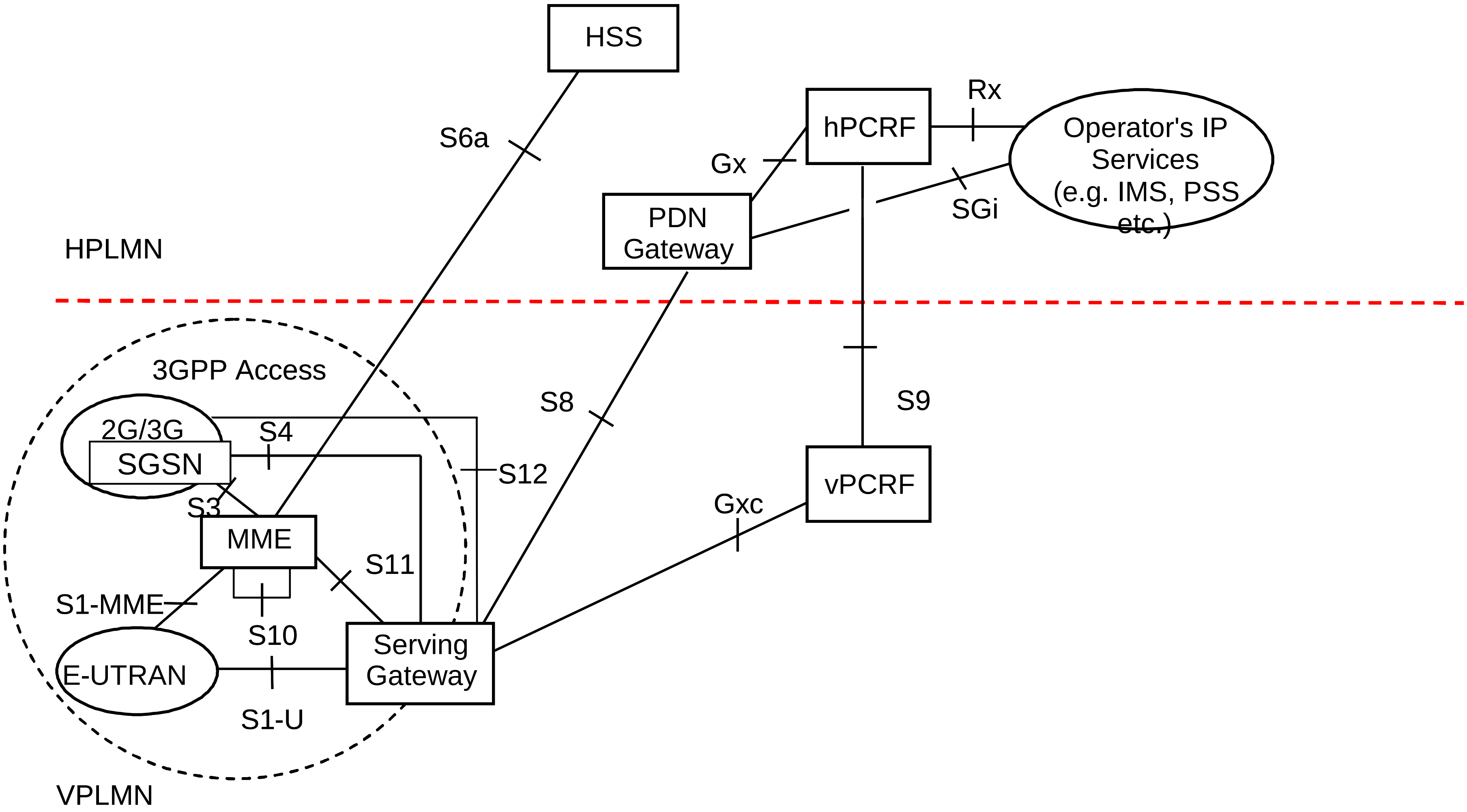
Architecture Reference Model

- The "3GPP Access" bubble represents a collection of functional entities and interfaces for the purpose of pictorial simplification of the architectural models presented below



Non-Roaming Architecture for 3GPP Accesses within EPS using PMIP-based S5

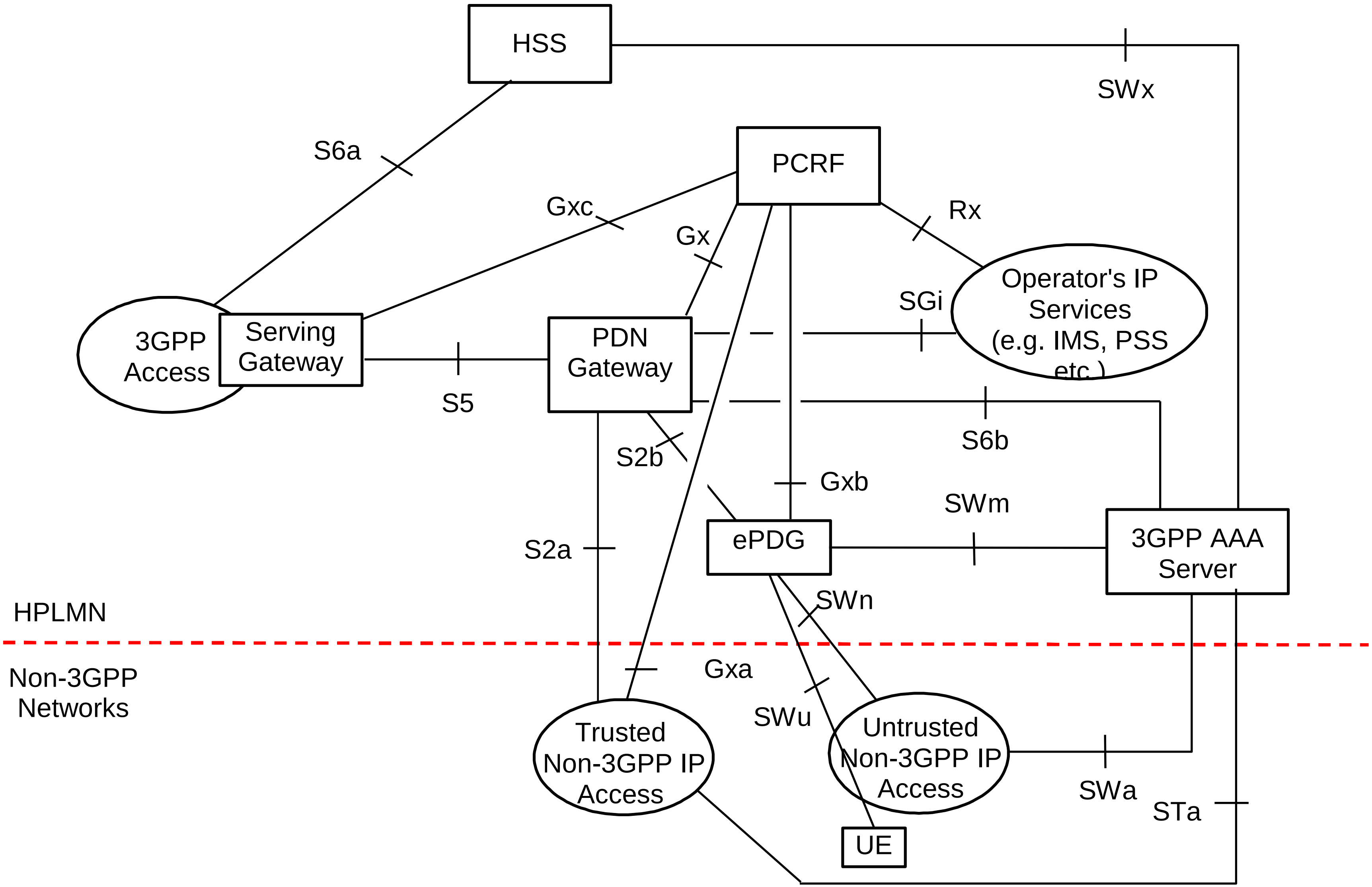
Roaming Architecture for 3GPP Accesses within EPS using PMIP-based S8



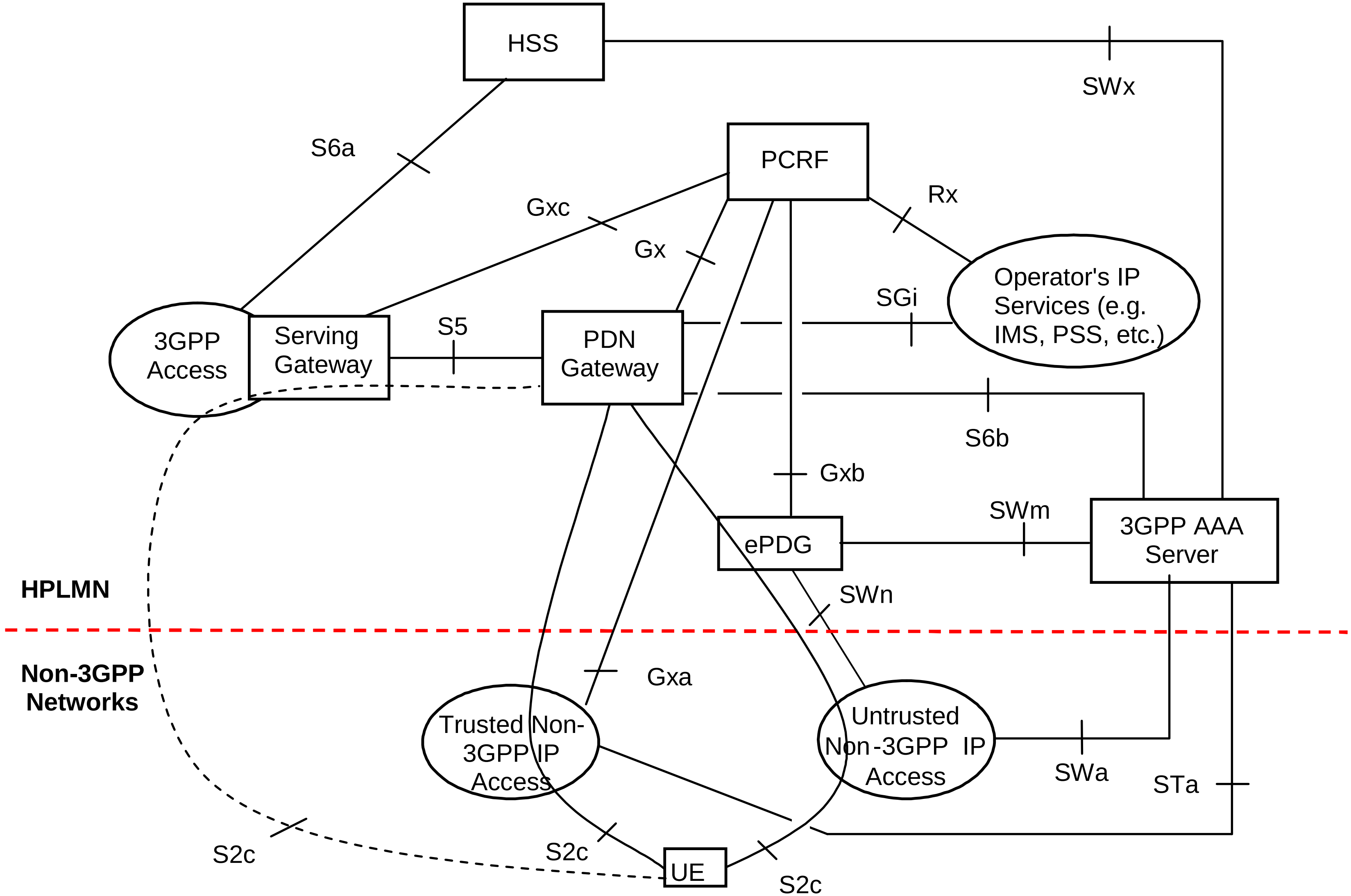
Non-roaming Architectures for EPS

- The following considerations apply to interfaces where they occur in figures
  - S5, S2a and S2b can be GTP-based or PMIP-based
  - Gxc is used only in the case of PMIP variant of S5 or S8
  - Gxa is used when the Trusted non-3GPP Access network is owned by the same operator
  - Gxb is used only in the case of PMIP variant of S2b
  - S9 is used instead of Gxa to the Trusted non-3GPP Access network not owned by the same operator
  - Gxa or S9 are terminated in the Trusted non-3GPP Accesses if supported
  - S2c is used only for DSMIPv6 bootstrapping and DSMIPv6 De-Registration (Binding Update with Lifetime equals zero) when the UE is connected via 3GPP access

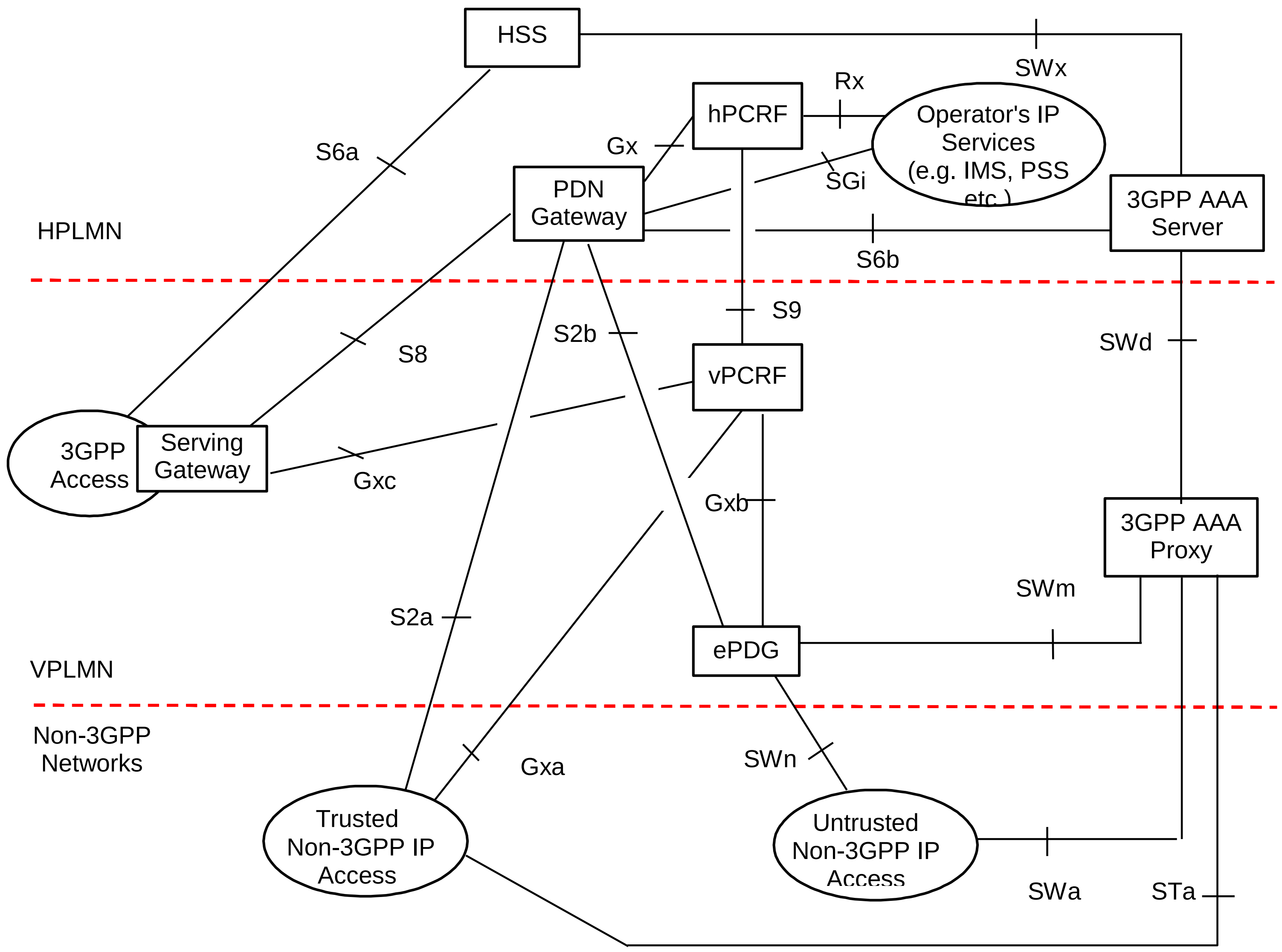
Non-Roaming Architecture within EPS using S5, S2a, S2b



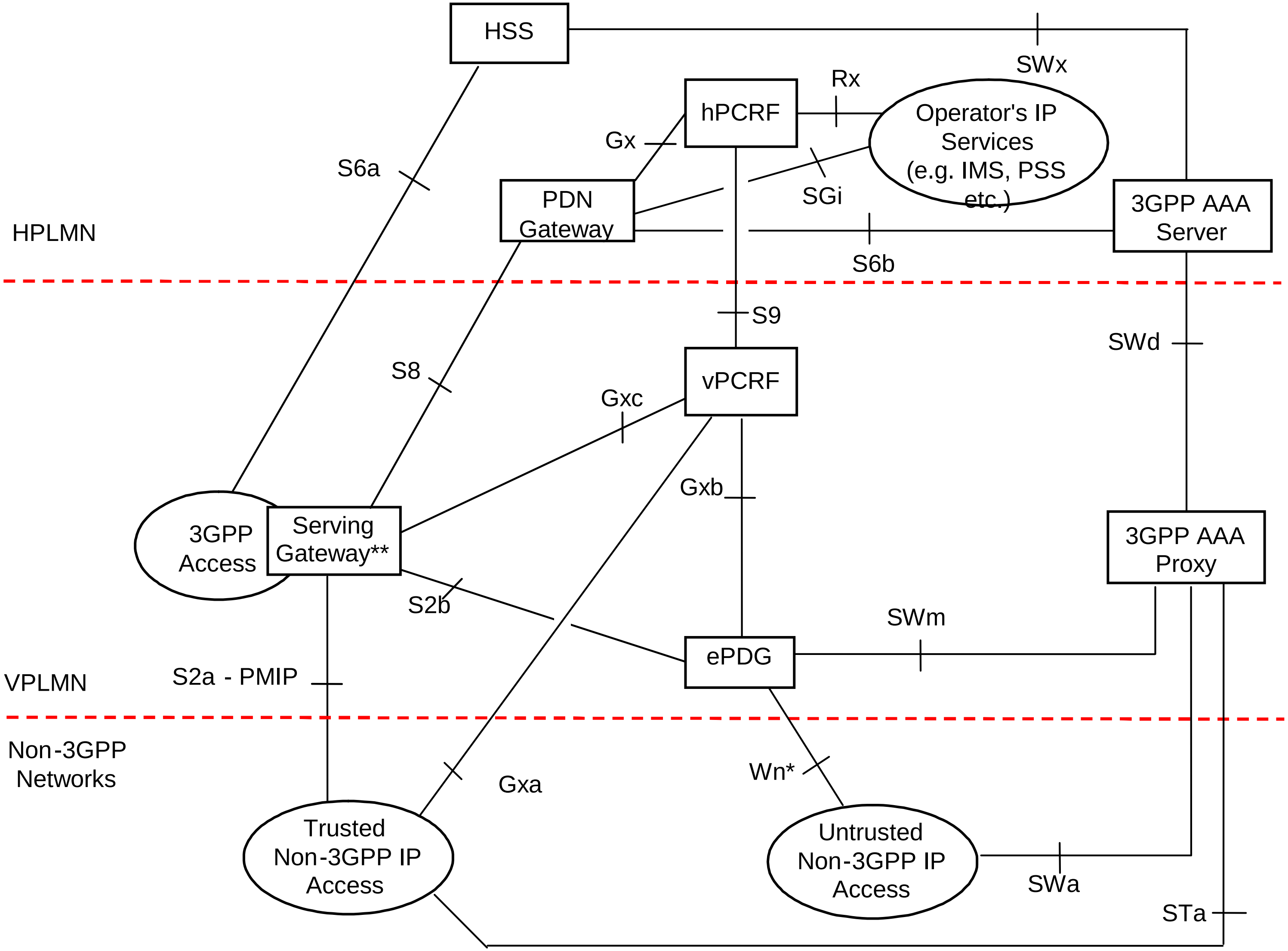
Non-Roaming Architecture within EPS using S5, S2c



Roaming Architecture for EPS using S8, S2a– S2b - Home Routed



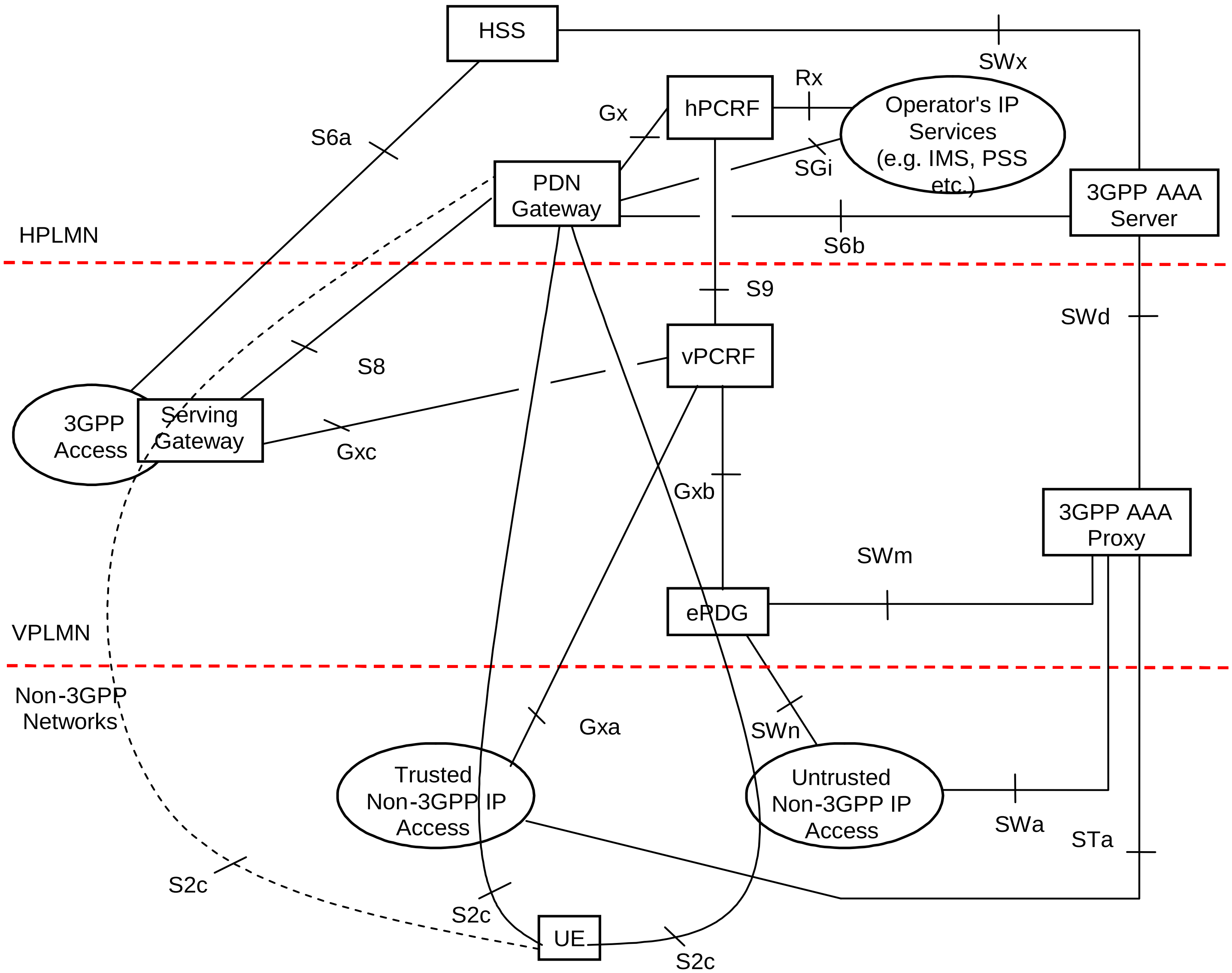
Roaming Architecture for EPS using PMIP-based S8, S2a, S2b (Chained PMIP-based S8-S2a/b) - Home Routed



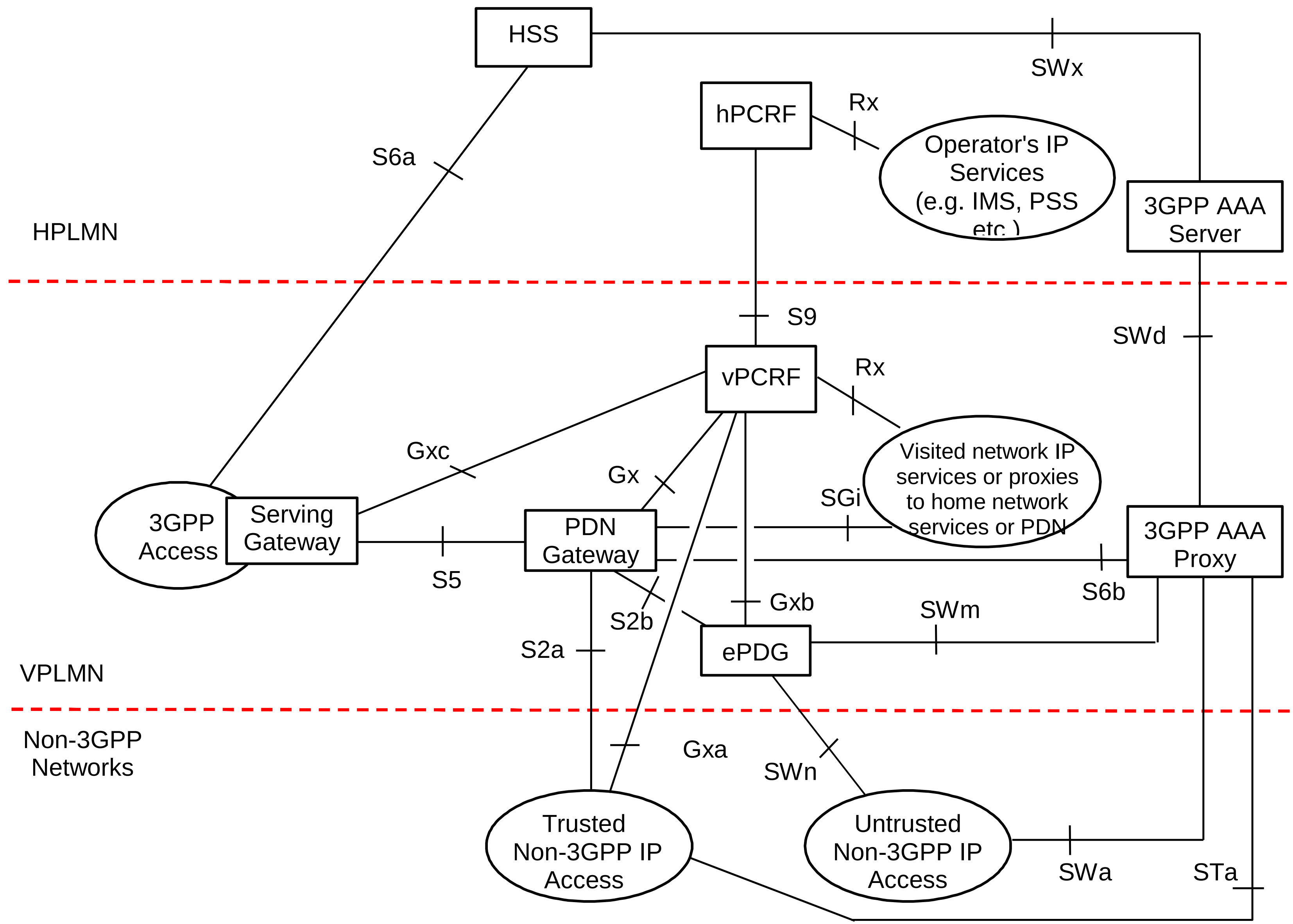
Some Additional Considerations in Roaming Architecture for EPS using PMIP-based S8, S2a, S2b (Chained PMIP-based S8-S2a/b) - Home Routed

- Gxc is used only in the case of PMIP-based S8 and for 3GPP access
  - If QoS enforcement on PMIP-based S8 is required by the Serving Gateway for Un-trusted Non-3GPP IP Accesses, static policies will be used
- Gxc is not required for Trusted Non-3GPP IP Access
- Gxa is used instead to signal the QoS policy and event reporting

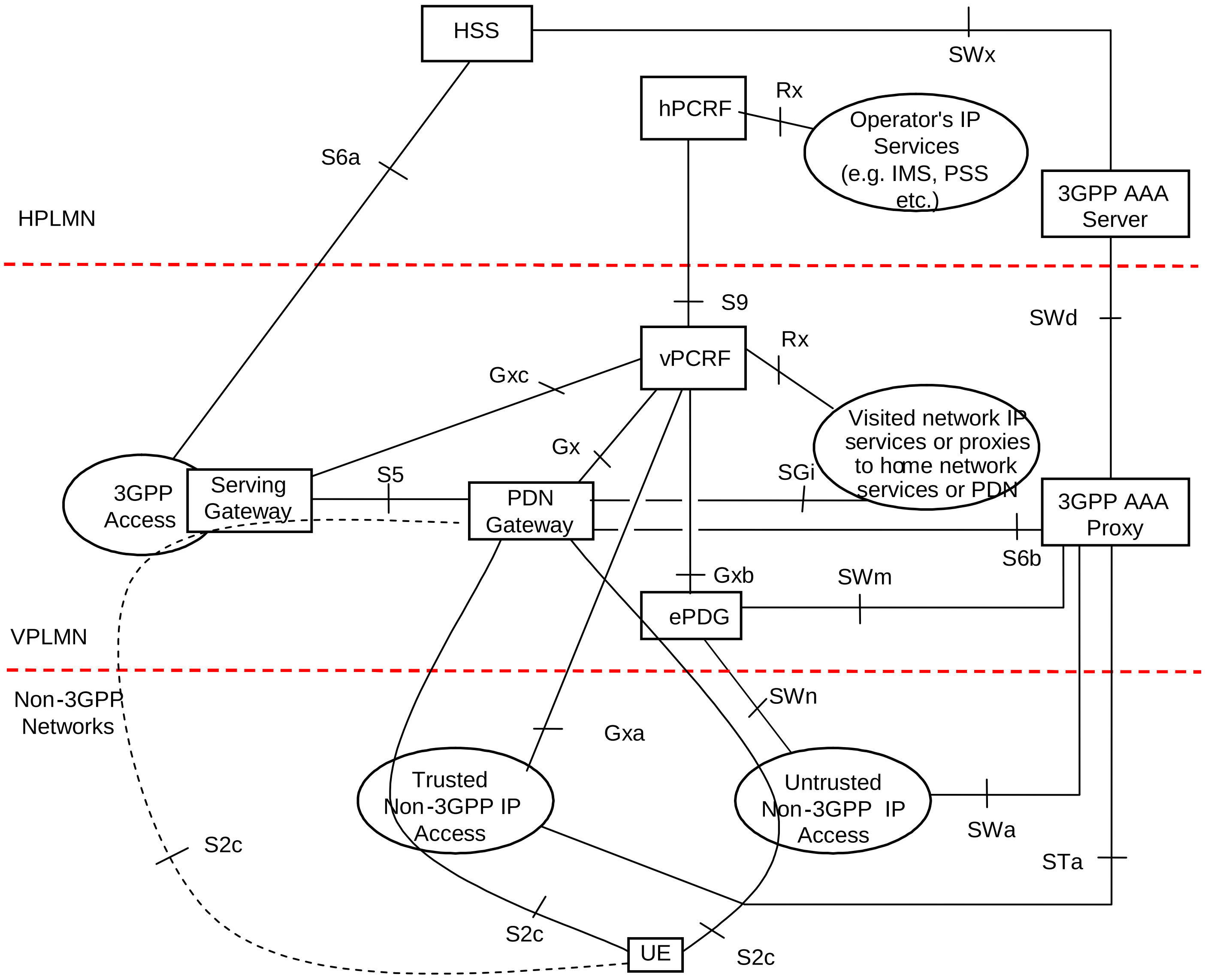
Roaming Architecture for EPS using S8 – S2c - Home Routed



Roaming Architecture for EPS using S5, S2a, S2b – Local Breakout



Roaming Architecture for EPS using S5, S2c – Local Breakout



Network Elements

- E-UTRAN is described in detail in TS 36.300 with additional functions listed in TS 23.401
- Trusted and Untrusted Non-3GPP Access Network
  - Trusted and Untrusted Non-3GPP Access Networks are IP access networks that use access technology whose specification is out of the scope of 3GPP
  - Whether a Non-3GPP IP access network is Trusted or Untrusted is not a characteristic of the access network
  - In non-roaming scenario it is the HPLMN's operator decision if a Non-3GPP IP access network is used as Trusted or Untrusted Non-3GPP Access Network
  - In roaming scenario, the HSS/3GPP AAA Server in HPLMN makes the final decision of whether a Non-3GPP IP access network is used as Trusted or Untrusted non-3GPP Access Network
    - The HSS/3GPP AAA Server may take the VPLMN's policy and capability returned from the 3GPP AAA Proxy or roaming agreement into account
  - For supporting multiple PDNs, the same trust relationship shall apply to all the PDNs the UE connects to from a certain Non-3GPP Access Network, i.e. it shall not be possible to access one PDN using the non-3GPP access network as Trusted, while access to another PDN using the same non-3GPP access network as Untrusted

Network Elements (MME)

- The details of functionality of MME are described TS 23.401
- The following are additional MME functions
  - HRPD access node (terminating S101 reference point) selection and maintenance for handovers to HRPD
  - Transparent transfer of HRPD signalling messages and transfer of status information between E-UTRAN and HRPD access, as specified in the pre-registration and handover flows
  - Forwarding the GRE key for uplink traffic to the target S-GW in case of CN node relocation
  - Transparent transfer of SON Information between E-UTRAN and HRPD access

Network Elements (Gateway)

- The functional split of PDN GW and Serving GW is described in TS 23.401
- Serving GW
  - A local non-3GPP anchor for the case of roaming when the non-3GPP IP accesses connected to the VPLMN
  - Event reporting (change of RAT, etc.) to the PCRF
  - Uplink and downlink bearer binding towards 3GPP accesses as defined in TS 23.203
  - Uplink bearer binding verification with packet dropping of "misbehaving UL traffic"
  - Mobile Access Gateway (MAG) according to PMIPv6 specification, RFC 5213, if PMIP-based S5 or S8 is used. The MAG function shall be able to send UL packets before sending the PBU or before receiving the PBA
  - Decide if packets are to be forwarded (uplink towards PDN or downlink towards UE) or if they are locally destined to the S-GW (e.g. Router Solicitation)
  - DHCPv4 (relay agent) and DHCPv6 (relay agent) functions if PMIP-based S5 or S8 is used
  - Handling of Router Solicitation and Router Advertisement messages as defined in RFC 4861, if PMIP based S5 and S8 is used
  - Handling of Neighbour Solicitation and Neighbor Advertisement messages as defined in RFC 4861, if PMIP based S5 and S8 is used

Network Elements (Gateway) (Cont.)

- Allocation of downlink GRE key for each PDN connection within the Serving GW, which is used by the PDN GW to encapsulate downlink traffic to the Serving GW on the PMIP-based S5/S8 interface
- If PMIP-based S8-S2a/b chaining is used
  - The Serving GW acts as a LMA towards the MAG function of the Trusted Non-3GPP IP Access or the ePDG
  - The Serving GW allocates uplink GRE key for each PDN connection within the Serving GW, which is used to encapsulate uplink traffic on PMIPv6-based S2a/S2b interface
  - The Serving GW does not require full MAG and full LMA functionally
  - The Serving GW includes functionality to interwork the PMIPv6 signalling towards the PDN GW and PMIPv6 signalling towards the MAG function of the Trusted Non-3GPP IP Access or the ePDG
    - In this case the Serving GW also acts as a MAG towards the PDN GW
  - The Serving GW includes functionality to link the user-plane of the PMIPv6 tunnel towards the PDN GW and the user-plane of the PMIPv6 tunnel towards the MAG function of the Trusted Non-3GPP IP Access or the ePDG

Network Elements (PDN GW)

- PDN GW functionality is described in TS 23.401 for 3GPP accesses connected to the EPC via GTP-based and PMIP-based S5/S8 interface
- The PDN GW supports functionality specified in TS 23.401 that is common to both PMIP-based and GTP-based S5/S8 interfaces also for access to EPC via non-3GPP accesses
- The PDN GW is the user plane anchor for mobility between 3GPP access and non-3GPP access
  - A LMA according to the PMIPv6 specification, RFC 5213, if PMIP-based S5 or S8, or if PMIP-based S2a or PMIP-based S2b is used
  - The LMA function shall be able to accept UL packets from any trusted MAG without enforcing that the source IP address must match the CoA in the MN BCE
  - A DSMIPv6 Home Agent, as described in RFC 5555, if S2c is used
  - Allocation of uplink GRE key for each PDN connection within the PDN GW, which is used to encapsulate uplink traffic to the PDN GW on the PMIP-based S5/S8, or PMIP-based S2a or PMIP based S2b interface
  - A MIPV4 Home Agent, if S2a with MIPv4 FA CoA mode is used
  - GPRS Tunnelling Protocol for the control plane and the user plane to provide PDN connectivity to UEs using non-3GPP accesses, if GTP-based S2a or GTP-based S2b is used

Network Elements (ePDG)

- Allocation of a remote IP address as an IP address local to the ePDG which is used as CoA when S2c is used
- Functionality for transportation of a remote IP address as an IP address specific to a PDN when S2b is used
- Routing of packets from/to PDN GW (and from/to Serving GW if it is used as local anchor in VPLMN) to/from UE
  - If GTP based S2b is used and if a single IPSec SA is established for the PDN connection, this includes routing of uplink packets based on the uplink packet filters in the TFTs assigned to the S2b bearers of the PDN connection
  - If multiple IPsec SA are established for the PDN connection, routing of uplink packet is based on the mapping between the IPsec SA and the corresponding S2b bearer
- Routing of downlink packets towards the IPsec SA associated to the PDN connection, if a single IPsec SA is used for the PDN connection
- Routing of downlink packets towards the IPsec SA associated to the S2b bearer, if a separate IPsec SA per S2b bearer is used
- De-capsulation/Encapsulation of packets for IPSec and, if network based mobility (S2b) is used, for GTP or PMIPv6 tunnels
- Mobile Access Gateway (MAG) according to the PMIPv6 specification, RFC 5213, if PMIP based S2b is used

Network Elements (ePDG) (Cont.)

- Tunnel authentication and authorization (termination of IKEv2 signalling and relay via AAA messages)
- Local mobility anchor within untrusted non-3GPP access networks using MOBIKE (if needed)
- Transport level packet marking in the uplink
- Enforcement of QoS policies based on information received via AAA infrastructure
- Lawful Interception
- Allocation of downlink GRE key for each PDN connection within the ePDG, which is used to encapsulate downlink traffic to the ePDG on the PMIPv6-based S2b interface
- Accounting for inter-operator charging according to charging principles specified in TS 32.240
- Interfacing OFCS through reference points TS 32.251 for EPC nodes
- When the UE and the ePDG supports the establishment of a separate IPsec SA per S2b bearer
  - Establishing, where applicable, a new IPsec SA between ePDG and UE over SWu for every new dedicated bearer if the UE supports multiple IPsec SAs per PDN connection
  - Maintaining binding between EPC bearer ID and IPsec SA, where applicable
  - The default bearer maps to the initial IPsec SA

Network Elements (PCRF)

- The functionality of PCRF is described in TS 23.203 with additional functionality listed in TS 23.401
- In the non-roaming scenario, additionally, the PCRF terminates the Gxa, Gxb and Gxc reference points with the appropriate IP-CANs
- In roaming scenarios, the difference from TS 23.401, is that the vPCRF exists for the UE for the scenario of roaming with home-routed traffic in addition to the scenario in TS 23.401 of roaming with local breakout
- Home PCRF
  - Terminates the Gx reference point for roaming with home routed traffic
  - Terminates the Gxa, Gxb or Gxc/S9 reference points as appropriate for the IP-CAN type
- Visited PCRF
  - Terminates the Gxa, Gxb or Gxc reference points as appropriate for the IP-CAN type
  - Terminates the S9 reference point

Reference Points

- S2a
  - It provides the user plane with related control and mobility support between trusted non 3GPP IP access and the Gateway
- S2b
  - It provides the user plane with related control and mobility support between ePDG and the Gateway
- S2c
  - It provides the user plane with related control and mobility support between UE and the Gateway
  - This reference point is implemented over trusted and/or untrusted non-3GPP Access and/or 3GPP access
- S5
  - It provides user plane tunnelling and tunnel management between Serving GW and PDN GW
  - It is used for Serving GW relocation due to UE mobility and in case the Serving GW needs to connect to a non collocated PDN GW for the required PDN connectivity
- S6a
  - This interface is defined between MME and HSS for authentication and authorization
  - It is defined in TS 23.401

Reference Points (Cont.)

- S6b
  - It is the reference point between PDN Gateway and 3GPP AAA server/proxy for mobility related authentication if needed
  - This reference point may also be used to retrieve and request storage of mobility parameters
  - This reference point may also be used to retrieve static QoS profile for a UE for non-3GPP access in case dynamic PCC is not supported
- PMIP-based S8
  - It is the roaming interface in case of roaming with home routed traffic. It provides the user plane with related control between Gateways in the VPLMN and HPLMN
- S9
  - It provides transfer of (QoS) policy and charging control information between the Home PCRF and the Visited PCRF in order to support local breakout function
  - In all other roaming scenarios, S9 has functionality to provide dynamic QoS control policies from the HPLMN
- Gx
  - It provides transfer of (QoS) policy and charging rules from PCRF to Policy and Charging Enforcement Function (PCEF) in the PDN GW
- Gxa
  - It provides transfer of (QoS) policy information from PCRF to the Trusted Non-3GPP accesses

Reference Points (Cont.)

- Gxb
  - This interface is not specified within this Release of the specification
- Gxc
  - It provides transfer of (QoS) policy information from PCRF to the Serving Gateway
- SGi
  - It is the reference point between the PDN Gateway and the packet data network
  - Packet data network may be an operator external public or private packet data network or an intra operator packet data network, e.g. for provision of IMS services
  - This reference point corresponds to Gi for 3GPP accesses
- Sta
  - It connects the Trusted non-3GPP IP Access with the 3GPP AAA Server/Proxy and transports access authentication, authorization, mobility parameters and charging-related information in a secure manner
- SWa
  - It connects the Untrusted non-3GPP IP Access with the 3GPP AAA Server/Proxy and transports access authentication, authorization and charging-related information in a secure manner
- SWd
  - It connects the 3GPP AAA Proxy, possibly via intermediate networks, to the 3GPP AAA Server

Reference Points (Cont.)

- SWm
  - This reference point is located between 3GPP AAA Server/Proxy and ePDG and is used for AAA signalling (transport of mobility parameters, tunnel authentication and authorization data)
  - This reference point also includes the MAG-AAA interface functionality, RFC 5779 and Mobile IPv6 NAS-AAA interface functionality, RFC 5447
- SWn
  - This is the reference point between the Untrusted Non-3GPP IP Access and the ePDG
  - Traffic on this interface for a UE-initiated tunnel has to be forced towards ePDG
- SWu
  - This is the reference point between the UE and the ePDG and supports handling of IPSec tunnels
  - The functionality of SWu includes UE-initiated tunnel establishment, user data packet transmission within the IPSec tunnel and tear down of the tunnel and support for fast update of IPSec tunnels during handover between two untrusted non-3GPP IP accesses
- SWx
  - This reference point is located between 3GPP AAA Server and HSS and is used for transport of authentication, subscription and PDN connection related data

Protocol Assumption

- S2a interface is based on current or future IETF RFCs
- S2a is based on Proxy Mobile IP version 6
- For Trusted WLAN, S2a may also be based on GTP
- To enable access via Trusted Non 3GPP IP accesses that do not support GTP and PMIPv6, S2a also supports Client Mobile IPv4 FA mode
- S2b interface is based on GTP or Proxy Mobile IP version 6
- S2c is based on DSMIPv6, RFC 5555
- The PMIP-based S5, PMIP-based S8, PMIP-based S2a and PMIP-based S2b interfaces are based on the same protocols and differences shall be minimized
  - The S5 interface is based on the PMIPv6 specification, RFC 5213
- The GTP-based S5/S8, GTP-based S2a and GTP based S2b interfaces are based on the GTP protocol (TS 29.274)
  - The GTP variant of S5 interface is described in TS 23.401
- PMIPv6-based S8 interface is based on the PMIPv6 specification, RFC 5213
  - The GTP variant interface is described in TS 23.401

Protocol Assumption (Cont.)

- The PMIPv6-based interfaces (S5, S8, S2a, and S2b) shall support Generic Routing Encapsulation (GRE) RFC 2784 including the Key field extension RFC 2890
  - The Key field value of each GRE packet header should enable the unique identification of the UE PDN connection that the GRE packet payload is associated with
  - These keys are exchanged using GRE Options extension to PMIPv6 Proxy Binding Update and Proxy Binding Ack messages on PMIPv6-based interfaces
- In case of CN node relocation, the GRE key for uplink traffic is forwarded to the target S-GW over S10/S11 reference point
- SWu interface is based on IKEv2, RFC 5996 and MOBIKE, RFC 4555
- The EPS shall allow the operator to configure a type of access (3GPP or non-3GPP) as the "home link" for Client Mobile IP purposes
- Redundancy support on reference points PMIP-based S5 and PMIP-based S8 should be taken into account

S5 Reference Point Requirements

- Both the GTP and PMIP variants of the S5 reference point shall satisfy the following architectural principles
  - There shall be only one radio interface protocol stack defined, common for both S5 variants, including both radio layer and Non-Access Stratum protocols
  - There shall be only one S6a interface defined common to both S5 variants
  - There may be a need for different information elements specific to PMIP-based or GTP-based variants of S5 but differences due to the S5 variants should be minimized
  - In the non-roaming case, there shall be only one Gx interface defined for transfer of policy and charging rules, common to both S5 variants
  - There may be a need for different information elements specific to PMIP-based or GTP-based variants of S5 but differences due to the S5 variants should be minimized
  - Differences between S5 variants in terms of functional split between the endpoints should be minimized

S5 Reference Point Requirements (Cont.)

- The S5 reference point shall fulfil the following requirements
  - S5 shall allow access to multiple PDNs. It shall be possible to allow an UE to connect to different packet data networks
    - It shall also be possible to support a UE with concurrent connections to several packet data networks
  - S5 shall allow multiple PDN connections for a given APN and UE
  - S5 shall be able to transport both IPv4 and IPv6 user plane traffic independent of IP version of the underlying IP transport network
  - S5 shall support fault handling. There should be mechanisms to identify and signal faults for groups of mobiles – e.g., if a large node handling millions of terminals goes down
  - As further development of the architecture takes place as well as when additional functionality such as MBMS, LCS etc. are addressed, further requirements will be needed

PDN GW Selection Function for Non-3GPP Accesses for S2a and S2b

- PDN Gateway selection for non-3GPP accesses uses similar mechanisms as defined in TS 23.401, with the following modification
  - The PDN Gateway selection function interacts with the 3GPP AAA Server or 3GPP AAA Proxy and uses subscriber information provided by the HSS to the 3GPP AAA Server
  - The HSS shall include the UE Usage Type in the UE's subscription information if any and, if included, the ePDG/TWAN shall select the PDN GW as described in TS 23.401
  - To support separate PDN GW addresses at a PDN GW for different mobility protocols (PMIP, MIPv4 or GTP), the PDN GW Selection function takes mobility protocol type into account when deriving PDN GW address by using the Domain Name Service function
- During the initial authorization, PDN Gateway selection information for each of the subscribed PDNs is returned to the ePDG or the Trusted Non-3GPP Access Network
- The PDN Gateway selection information includes
  - The PDN GW identity, which is a logical name (FQDN) or IP address and an APN
  - An APN and an indication whether the allocation of a PDN GW from the visited PLMN is allowed or a PDN GW from the home PLMN shall be allocated

PDN GW Selection Function for Non-3GPP Accesses for S2a and S2b (Cont.)

- This enables the entity requiring the IP address of the PDN Gateway to proceed with selection as per the procedures defined in TS 23.401
- Once the selection has occurred, the PDN Gateway registers its association with a UE and the APN with the AAA/HSS by sending PDN GW identity, that is either its IP address (e.g. if it has a single IP address for all the mobility protocols it supports or if it only supports one mobility protocol) or its FQDN (e.g. if it has multiple IP addresses for the mobility protocols it supports), as well as information that identifies the PLMN in which the PDN GW is located, to the 3GPP AAA Server or AAA Proxy only when the Access Technology Type is non-3GPP
- For 3GPP access types, the MME/S4-SGSN updates the HSS with the selected PDN GW identity, as well as information that identifies the PLMN in which the PDN GW is located, according to TS 23.401/TS 23.060
- This permits the HSS and 3GPP AAA Server or Proxy to provide the association of the PDN Gateway identity and the related APN for the UE subsequently
- The format of the information that identifies the PLMN in which the PDN GW is located is defined in stage 3 specifications

PDN GW Selection Function for S2c

For the S2c reference point, the UE needs to know the IP address of the PDN Gateway for the PDN the UE wants to connect to.

This address is made known to the UE using one of the following methods

1. Via PCO at the attach procedure or UE requested PDN Connectivity procedure, for 3GPP access (as defined in TS 23.401) or trusted non-3GPP access (if supported)
2. Via IKEv2 during tunnel setup to ePDG
   - For a UE's initial Attach, during the IKEv2 tunnel establishment procedure on the SWu interface (between UE and ePDG)
     - For non-roaming case, the 3GPP AAA Server selects the HA (PDN GW) which is close to the ePDG and sends the HA (PDN GW) FQDN or IP address to the ePDG
     - For roaming with local breakout case, the 3GPP AAA Proxy selects the HA (PDN GW) which is close to the ePDG and sends the HA (PDN GW) FQDN or IP address to the ePDG
   - The HA (PDN GW) FQDN or IP address are then forwarded to the UE by the ePDG
   - Whether the selected PDN GW is closer to the UE than other PDN GW depends on the network configurations and operations, it may be geographically/topologically closer or less IP hops

PDN GW Selection Function for S2c (Cont.)

3. If the IP address of the PDN GW is not received using options 1-2 above and if the UE knows that the HA is in the PDN where the UE is attached to then the UE shall request a PDN Gateway address via DHCP IETF RFC 6611
4. If the IP address of the PDN GW is not delivered using options 1-3 above the UE can interact directly with the Domain Name Service function by composing a FQDN corresponding to the PDN

Serving GW Selection Function for Non-3GPP Accesses

- The S-GW selection function allocates an S-GW that acts as a local anchor for non-3GPP access in the case of S8-S2a/b chained roaming
- Whether S8-S2a/b chaining should be used is decided by 3GPP AAA Proxy based on per-HPLMN configuration
- The Serving GW selection function is located in 3GPP AAA Proxy. If an S-GW is needed for non-3GPP access in the visited network, the 3GPP AAA proxy will select an S-GW for the UE during initial attach or handover attach
- The 3GPP AAA proxy shall send the selected S-GW address to the MAG function of the Trusted non-3GPP IP access or ePDG in the chained S8-S2a/b scenarios
- There is no mechanism standardized for S-GW address preservation for handover between 3GPP and non-3GPP in S2/S8 chained case within this Release of the specification

Outline

- Overall Architecture
- Multi-connectivity
- Non-3GPP Access Architecture
- Access to EPC via non-3GPP
  - Trusted and Untrusted Accesses
  - Network Discovery and Selection
  - UE – EPC Network Protocols
  - Tunnel Management Procedures

Trusted and Untrusted Accesses

The HPLMN operator of the EPC selects whether a connected non-3GPP IP access network is a trusted or untrusted IP access network

- For a trusted non-3GPP IP access network the communication between the UE and the EPC is secure.
  - For an untrusted non-3GPP IP access network the communication between the UE and the EPC is not trusted to be secure.
- For a trusted non-3GPP IP access network, all communication between the access network and the EPC is transferred over pre-established secure links.
  - For an untrusted non-3GPP IP access network, to secure communication between the UE and the EPC:
    - A single IPSec tunnel needs to be established to the ePDG for all PDN connections when the UE accesses EPC via S2c is used; or
    - An IPSec tunnel needs to be established with the same ePDG for each PDN connection when the UE accesses EPC via S2b is used

WLAN Access

- WLAN is an access network developed under the auspices of IEEE Computer Society. WLAN is compliant with IEEE Std 802.11, which define air interface aspects
- IEEE Std 802.11 defines Access Network Query Protocol (ANQP)
  - A UE can receive from an AP ANQP-elements in response to an ANQP query
  - The ANQP query response is received in a generic advertisement service response frame or a protected management frame
- Where needed, the current specification further describes the structure and contents of payload of ANQP-elements specified in IEEE Std 802.11

User Identities

- The user identification shall be either the root NAI, or the decorated NAI, when the UE accesses the EPC via non-3GPP access networks, and gets authentication, authorization and accounting services from the EPC
- For emergency services over WLAN
  - if IMSI is not available (i.e. a UE without USIM), the IMEI shall be used for the identification, as user part of the emergency NAI and the UE shall use a specific domain in the realm part of the NAI as specified TS 23.003; or
  - if the UE has an IMSI, it shall use the IMSI for the identification, as user part of the emergency NAI
  - If the IMSI is unauthenticated on the network side and the network supports emergency session for unauthenticated IMSI, the IMEI is used for the identification on the network side

User Identities - Handover

- For handover of an emergency session from E-UTRAN to a S2a based cdma2000 HRPD access network, if IMSI is not available (i.e. a UE without USIM) or IMSI is unauthenticated, the IMEI shall be used for the identification, as part of the emergency NAI as defined
- The UE's Mobile Identity IMEI or IMEISV is conveyed to the network and used to enable consistent services for the UE accessing the network via non-3GPP access or to support the emergency services over WLAN for the unauthenticated UEs
- IMEI and IMEISV are untrusted identities stored on the UE

Additional Identities

- User identification in non-3GPP accesses may require additional identities that are out of the scope of 3GPP
- IETF RFC 4187 and 3GPP TS 23.003 provide definitions for UE and user identities although they use slightly different terms. Similar terms are also used in 3GPP TS 33.402
- The following list provides term equivalencies and describes the relation between various user identities
  - The Root NAI is to be used as the permanent identity as specified in 3GPP TS 33.402
  - The Fast-Reauthentication NAI is to be used as the Fast-Reauthentication Identity or the re-authentication ID as specified in 3GPP TS 33.402
  - The Pseudonym Identity is to be used as the Pseudonym as specified in 3GPP TS 33.402

Identification of IP Services/PDN Connections

- For access to EPC the Access Point Name (APN) is used for identifying IP services/PDN connections
- The detailed definition of APN as used for access to EPC is specified in 3GPP TS 23.003
- APN is conveyed in the IKEv2 signaling during tunnel establishment when S2b interface is used for UE to access EPC
- When UE accesses EPC via S2a using trusted WLAN access network, APN is conveyed in EAP-AKA' signaling for single-connection mode (SCM) or in WLAN Control Protocol (WLCP) signaling (see 3GPP TS 24.244) for multi-connection mode (MCM)

Fixed Broadband Access System

- The fixed broadband access system is a type of high-speed Internet access for multi-service broadband packet networking
  - The fixed broadband access system is specified by the Broadband Forum, including addressing interoperability, architecture and management
- For support of fixed broadband access interworking, the EPC network procedures are specified in 3GPP TS 24.139
- The UE procedures for support of fixed broadband access are specified in 3GPP TS 24.139 and can be used when the EPC network uses the fixed broadband access interworking or the fixed broadband access convergence
- The architecture of the fixed broadband access convergence is specified in 3GPP TS 23.203

EPC Network Selection over Non-3GPP Access

EPC network selection procedures over non-3GPP access are defined:

1. WiMAX specific

2. EPC network selection via cdma2000 HRPD access is given in 3GPP TS 23.122 with any exceptions

3. WLAN specific procedures
   - The procedures detail selecting one or more WLANs and (subsequently) selecting one service provider offering services via the WLAN
   - When the operator of the WLAN requires authentication and the authentication succeeds, the UE follows the procedures defined for connecting with the EPC
   - When the UE is connected to EPC through WLAN access, the tunnel is set-up with the ePDG using a root NAI as defined in 3GPP TS 23.003 or with the HA

4. Generic EPC network selection for other access technologies not listed above

Generic EPC Network Selection Procedure over Non-3GPP Access

1. Identification of the EPC
   - The identification of EPC shall be based on
     - PLMN-Id (i.e. pair of MCC+MNC), as specified in 3GPP TS 23.003; or
     - Home/Visited Network Realm/Domain, as specified in 3GPP TS 23.003
2. EPC network selection
   - Two modes of EPC network selection are defined, manual and automatic
     - Manual EPC network selection
       - The UE shall present the list of available EPC networks, to which connectivity is provided through the selected non-3GPP access network, to the user
       - If UE's HPLMN or PLMNs equivalent to it are in this list, they shall be shown in the highest ranking order. The ordering of the rest of entries in the list is implementation dependent
       - If available, the UE should display names and/or realms/domains.
     - Automatic EPC network selection
       - The UE may use locally stored data for selecting between EPC networks available for connectivity via the currently selected non-3GPP access network
       - The UE shall select a PLMN according to the PLMN selection procedures of the selected non-3GPP access network

EPC Network Selection Procedures for WLAN

- Two UE selection modes: manual service provider selection and automatic service provider selection
- The service provider selected in accordance with these procedures determines the WLAN that is selected
  - When the selected WLAN is a trusted WLAN IP access and the UE decides to access EPC via S2a using trusted WLAN IP access, the UE shall derive a NAI from the identity of the selected service provider and use the NAI as the identity for authentication and authorization with the service provider and usage of the WLAN

Service Provider Solicitation

The UE shall determine which service providers are available from the available list of WLANs as constructed using the WLAN selection procedure using following procedures

1. The UE selects a WLAN from the list of selected WLAN(s) constructed using the WLAN selection procedure
2. If the WLAN selected above
   a. Supports ANQP specified in IEEE Std 802.11 and if the UE did not obtain a list of realms using ANQP, the UE sends an ANQP request for a list of realms (i.e. ANQP-elements "NAI Realm") and/or PLMN identities (i.e. ANQP-element "3GPP Cellular Network"); and
   b. Does not support ANQP (see IEEE Std 802.11) or the UE does not receive a list of realms in item a), an EAP-Request/Identity is received and the EAP-request/Identity does not include one or more of realms and/or PLMN identities of service providers (encoded in accordance with IETF RFC 4284), the UE supports IEEE 802.1x authentication (see IEEE Std 802.1X™-2010),
      - The UE shall request a list of realms and/or PLMN identities of service providers interworking with that WLAN by sending the EAP-Response/Identity message including as identity the alternative NAI; and
3. the UE repeats this procedure for all WLANs from the available list of WLANs as constructed using the WLAN selection procedure

Manual Mode
Service Provider Selection Procedure

- The UE indicates to the user the service providers which are available for WLAN
- The UE may obtain the service providers available for WLAN using procedures
- The UE will select the service provider based on the user preference

Automatic Mode
Service Provider Selection Procedure

- If the ANDSF rules control the WLAN access selection and traffic routing, a service provider is the highest priority service provider if the service provider is available via a WLAN from the selected WLAN(s) constructed using the WLAN selection procedure and if
  1) the service provider is selected in item 3; or
  2) the conditions in item 3 are not met, and
     - the service provider is the HPLMN
     - the service provider is an equivalent home service provider (i.e. the service provider's realm matches a realm in the EquivalentHomeSPs as specified in 3GPP TS 24.312); or
     - no WLAN of the selected WLAN(s) provides access to a higher priority service provider

UE – EPC Network Protocols

- For a UE, the trust relationship of a non-3GPP IP access network is determined by the home PLMN operator. That trust relationship is indicated to the UE via the following methods
  - Pre-configured policies in the UE by the home PLMN operator
  - Dynamic indication during 3GPP-based access authentication
- If the dynamic trust relationship indication is received during 3GPP-based access authentication, the UE shall rely on the dynamic trust relationship indication
  - Otherwise the UE shall follow the pre-configured policies for a specific non-3GPP access network

Authentication and Authorization for Accessing EPC via a Trusted non-3GPP Access Network

- Access authentication signalling for access to the EPC shall be executed between the UE and 3GPP AAA server to ensure mutual authentication of the user and the EPC, with the exception of UEs without IMSI or UEs initiating emergency session but whose IMSI authentication cannot proceed. Such authentication is based on IETF protocols as specified in 3GPP TS 33.402
- EAP-AKA' is used for access authentication in the trusted access network, according to 3GPP TS 33.402
  - EAP-AKA' can be skipped if conditions of 3GPP TS 33.402 are met
- If the access network does not support EAP-AKA or EAP-AKA' and the UE considers the access network as trusted, the UE shall access to the EPC only via S2c and any authentication method (EAP-based or otherwise) can be used for access authentication as long as the criteria set in 3GPP TS 33.402 are met
- When the UE decides to access EPC via S2c using non-3GPP IP access, EAP-AKA authentication is performed between the UE and the PDN-GW as in TS 24.303 and TS 33.402
- The UE may support ERP as described in IETF RFC 6696 and 3GPP TS 33.402
  - In this release, only the ERP Implicit Bootstrapping mode defined in IETF RFC 6696 is supported
- After a UE successfully completes authentication and authorization for accessing EPC via the trusted non-3GPP access network, the UE may receive as part of an ANQP query to the access point, an ANQP-element in a protected frame with management frame protection enabled
  - If the ANQP-element is an Emergency Call Number ANQP-element encoded in accordance with Annex I, the UE considers the content of the Emergency Call Number field valid

Tunnel Management Procedures

- Define the procedures for establishment or disconnection of an end-to-end tunnel between the UE and the ePDG
  - The tunnel establishment procedure is always initiated by the UE
  - The tunnel disconnection procedure can be initiated by the UE or the ePDG
- The tunnel is an IPsec tunnel (IETF RFC 4301) established via an IKEv2 protocol exchange IETF RFC 5996 between the UE and the ePDG
  - The UE may indicate support for IETF RFC 4555
  - The security mechanisms for tunnel setup using IPsec and IKEv2 are specified in 3GPP TS 33.402

Selection of the ePDG

- If the UE does not supports ePDG selection according to 3GPP TS 24.502, the UE performs ePDG selection based on the ePDG configuration information configured by the home operator in the UE either via H-ANDSF or via USIM or via implementation specific means
  - Implementation specific means apply only if the configurations via H-ANDSF and USIM are not present
- The ePDG configuration information may consist of home ePDG identifier or ePDG selection information or both:
  - When available in ANDSF MO, the ePDG configuration information is provisioned in ePDG node under Home Network Preference as specified in 3GPP TS 24.312
  - When available in USIM, the ePDG configuration information is provisioned in EFePDGId and EFePDGSelection files as specified in 3GPP TS 31.102

Tunnel Establishment

- Once the ePDG has been selected, the UE shall initiate the IPsec tunnel establishment procedure using the IKEv2 protocol as defined in IETF RFC 5996 and 3GPP TS 33.402
- The UE shall send an IKE_SA_INIT request message to the selected ePDG in order to setup an IKEv2 security association
- Upon receipt of an IKE_SA_INIT response, the UE shall send an IKE_AUTH request message to the ePDG, including:
  - The type of IP address (IPv4 address or IPv6 prefix or both) that needs to be configured in an IKEv2 CFG_REQUEST Configuration Payload
    - If the UE requests for both IPv4 address and IPv6 prefix, the UE shall send two configuration attributes in the CFG_REQUEST Configuration Payload: one for the IPv4 address and the other for the IPv6 prefix
  - The "IDr" payload, containing the APN in the Identification Data, for non-emergency session establishment
    - The UE shall set ID Type field of "IDr" payload to ID_FQDN as defined in IETF RFC 5996
    - The UE indicates a request for the default APN by omitting the "IDr" payload, which is in accordance with IKEv2 protocol as defined in IETF RFC 5996
  - The "IDi" payload containing the NAI

Tunnel Disconnection

- The UE shall use the procedures defined in the IKEv2 protocol (see IETF RFC 5996) to disconnect one or more IPsec tunnels to the ePDG
- The UE shall close the incoming security associations associated with the tunnel and instruct the ePDG to do the same by sending the INFORMATIONAL request message including a "DELETE" payload
- The DELETE payload shall contain either:

1. Protocol ID set to "1" and no subsequent Security Parameters Indexes (SPIs) in the payload
   - This indicates closing of IKE security association, and implies the deletion of all IPsec ESP security associations that were negotiated within the IKE security association
2. If the IKEv2 multiple bearer PDN connectivity is not supported or not used in the PDN connection as determined in subclause 7.2.7, Protocol ID set to "3" for ESP
   - The Security Parameters Indexes included in the payload shall correspond to the particular incoming ESP security associations at the UE for the given tunnel in question
3. If the IKEv2 multiple bearer PDN connectivity is used in the PDN connection as determined in subclause 7.2.7, the Protocol ID field of the DELETE payload is set to "3" for ESP and the SPI field of the DELETE payload includes UE's ESP SPIs of all bearer contexts of the PDN connection

Summary

- Overall architecture of NG-RAN for 4G/5G access
  - Network functional split
  - Network interfaces
  - Radio protocols
- Support for multi-connectivity with 4G and 5G networks
  - Multi-RAT dual connectivity
  - RAN/NAS related aspects
  - Operation and service related aspects
  - X2/Xn interface related aspects
- Trusted and untrusted non-3GPP access
  - Several reference model defined
  - Tens of reference points to support non-3GPP access
- Support for non-3GPP
  - Discovery and selection of network elements
    - Fixed broadband access system, WLAN and 5G
  - Tunnel Management Procedures
    - Selection, connection and disconnection