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3
5G系統架構：NSA與SA

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Outline

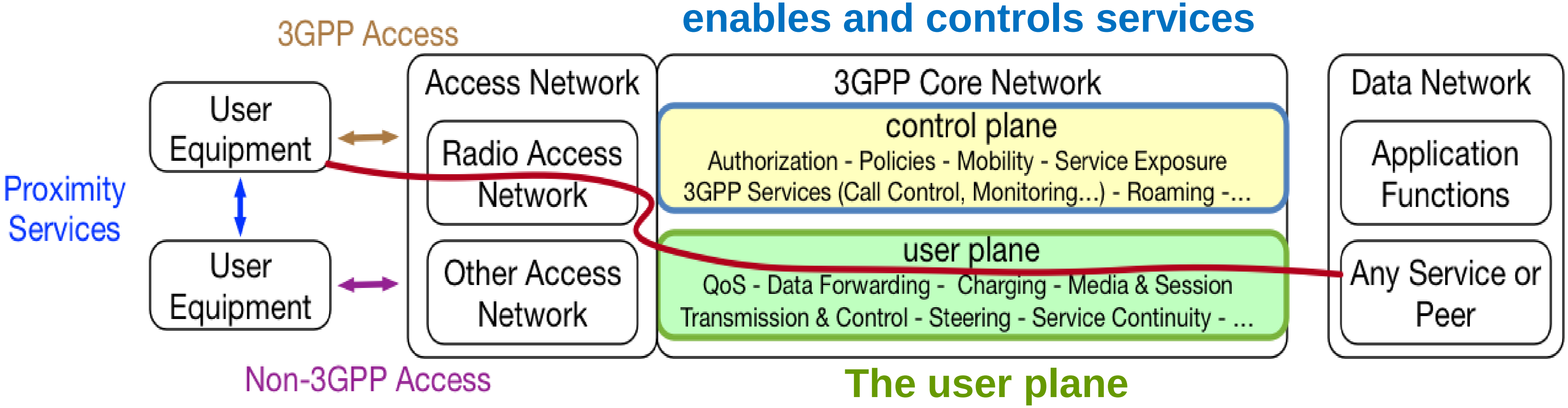
- Overview of 5G System Architecture
  - 3GPP System
  - Architecture Options
- Radio Access Architecture and Interfaces
  - Deployment Scenarios
  - Overall New RAN Architecture
  - RAN Architecture and Interfaces
  - Radio Access Network Procedures
  - RAN Logical Architecture for NR

Reference:

- TR 38.801: Radio Access Architecture and Interfaces

3GPP System

The control plane
enables and controls services

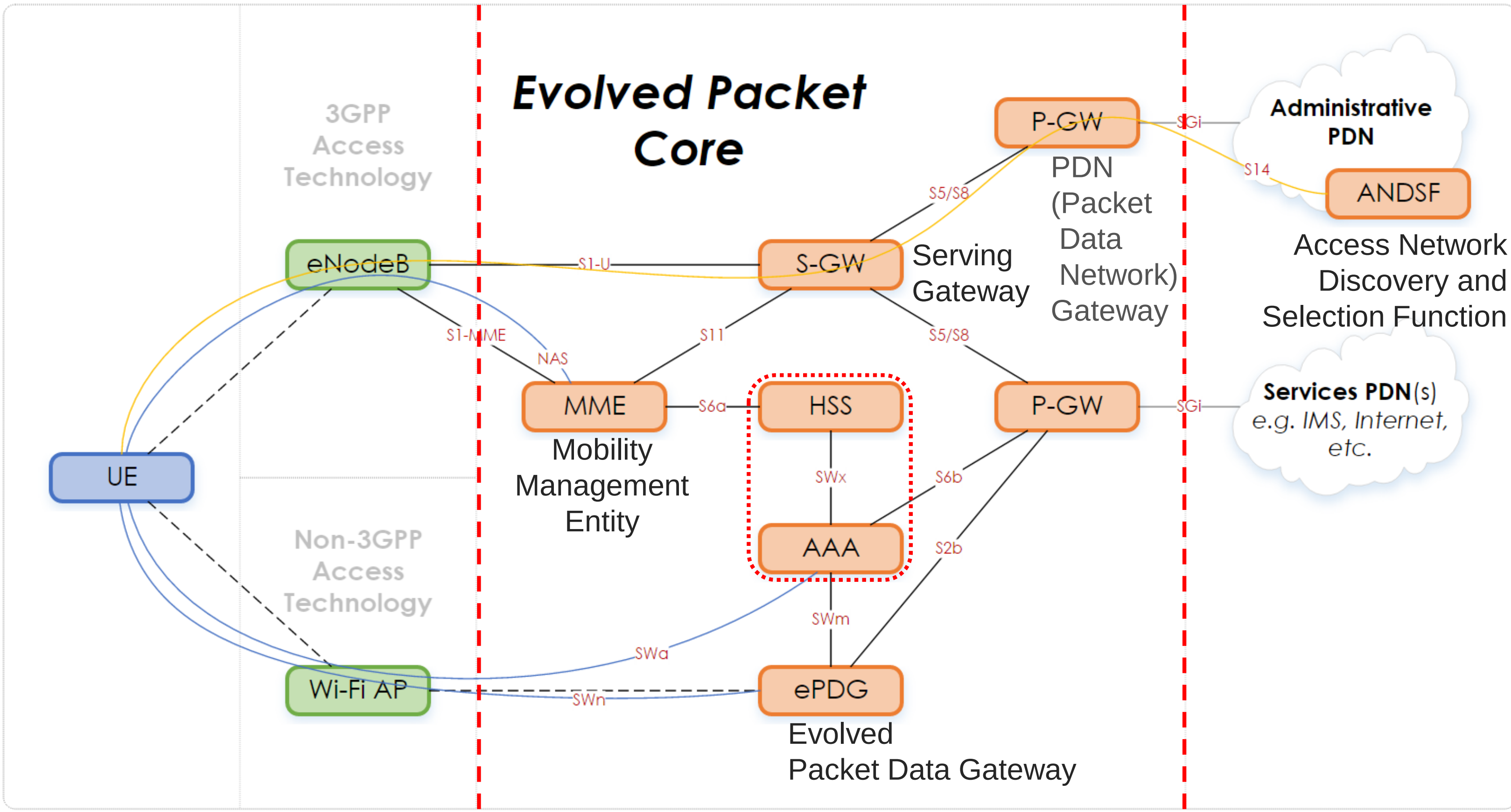


The user plane
carries user data & some service signalling

LTE/eNB	EPC (MME/SGW/PGW)
NR/gNB	5GC (Service Based Architecture)

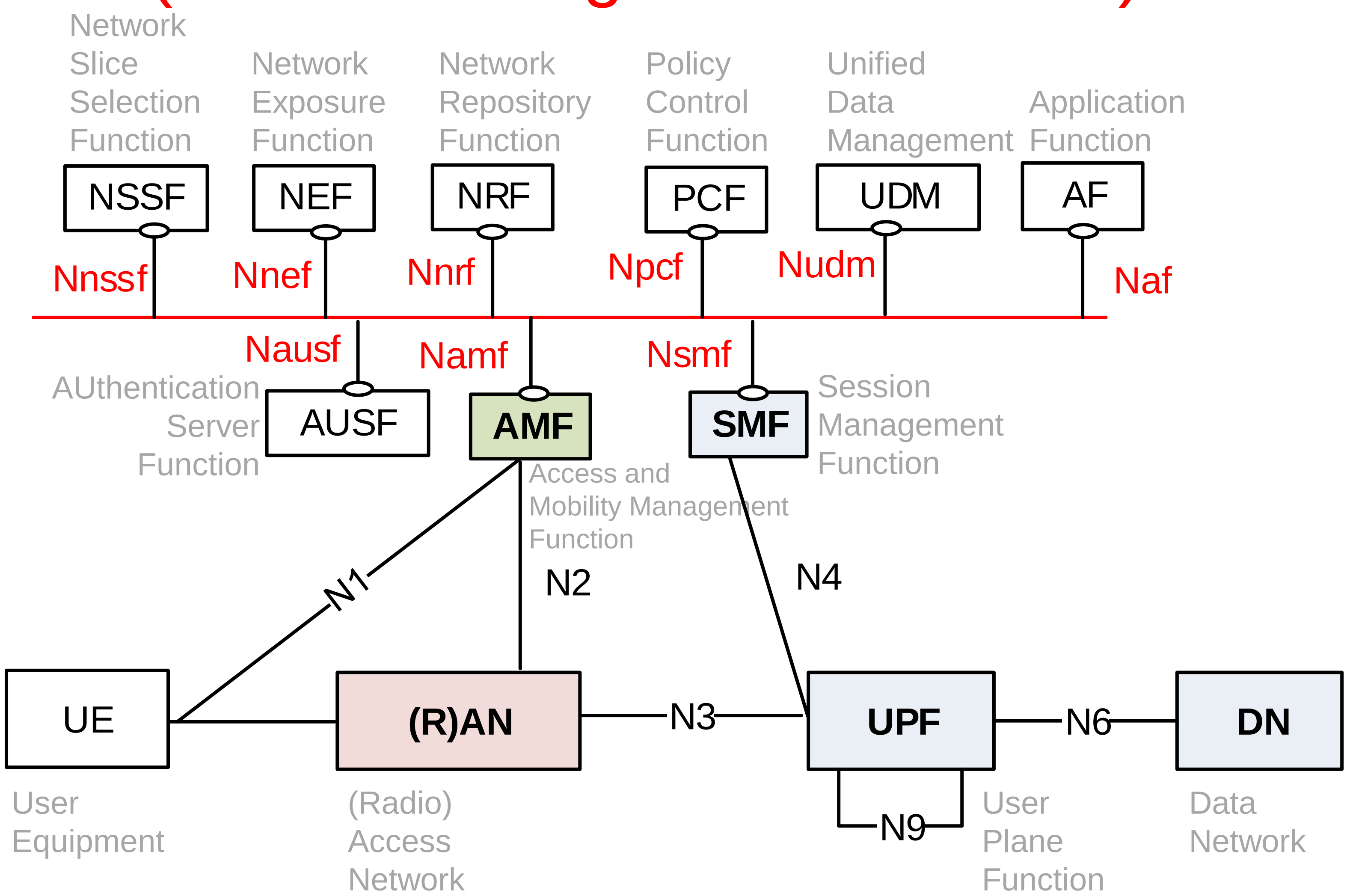
Many services are delivered end-to-end via the user plane

EPS (Evolved Packet System) / SAE



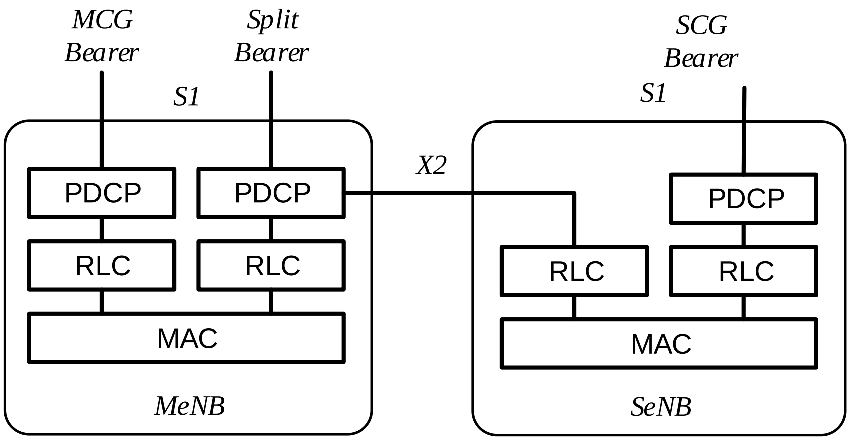
- EPC (Evolved Packet Core): main component of EPS, includes
  - MME: key control-node for LTE – UE paging; chooses S-GW for UE during attach and handover
    - Authenticating the user (by interacting with HSS - Home Subscriber Server)
  - S-GW: manages and stores UE contexts; routes and forwards user data packets
  - P-GW: provides connectivity from the UE to external packet data networks
  - ePDG: secures data transmission with UE connected to EPC over untrusted non-3GPP access
  - ANDSF: provides information to UE to discover available access networks (either 3GPP or not)

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

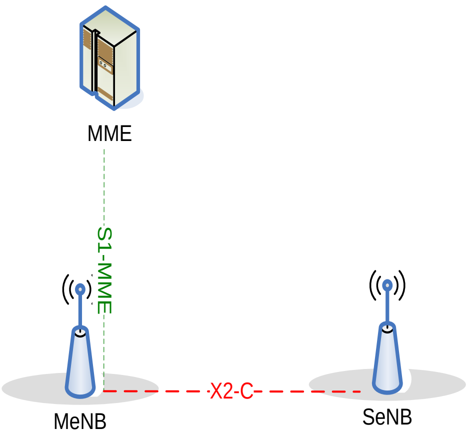


The non-roaming reference architecture with service-based interfaces used within the Control Plane (TS23.501)

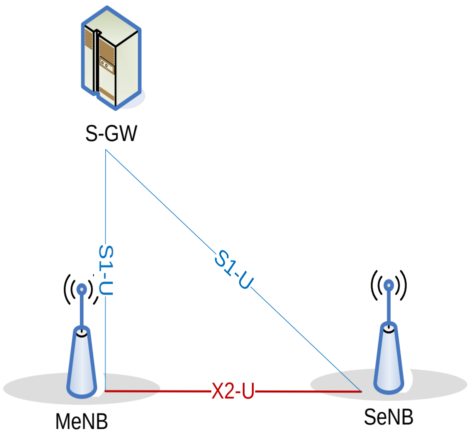
E-UTRAN for Dual Connectivity (DC) (TS36.300)



Radio Protocol Architecture



C-Plane



U-Plane

- Three bearer types exist
  - MCG bearer (Master Cell Group)
  - SCG bearer (Secondary Cell Group) and
  - Split bearer
- Network Interfaces
  - C-Plane: by means of X2 interface signalling
    - There is only one S1-MME connection per DC UE between the MeNB and the MME
  - U-Plane: two different user plane architectures are allowed
    - One in which the S1-U only terminates in the MeNB and the user plane data is transferred from MeNB to SeNB using the X2-U, and
    - A second architecture where the S1-U can terminate in the SeNB

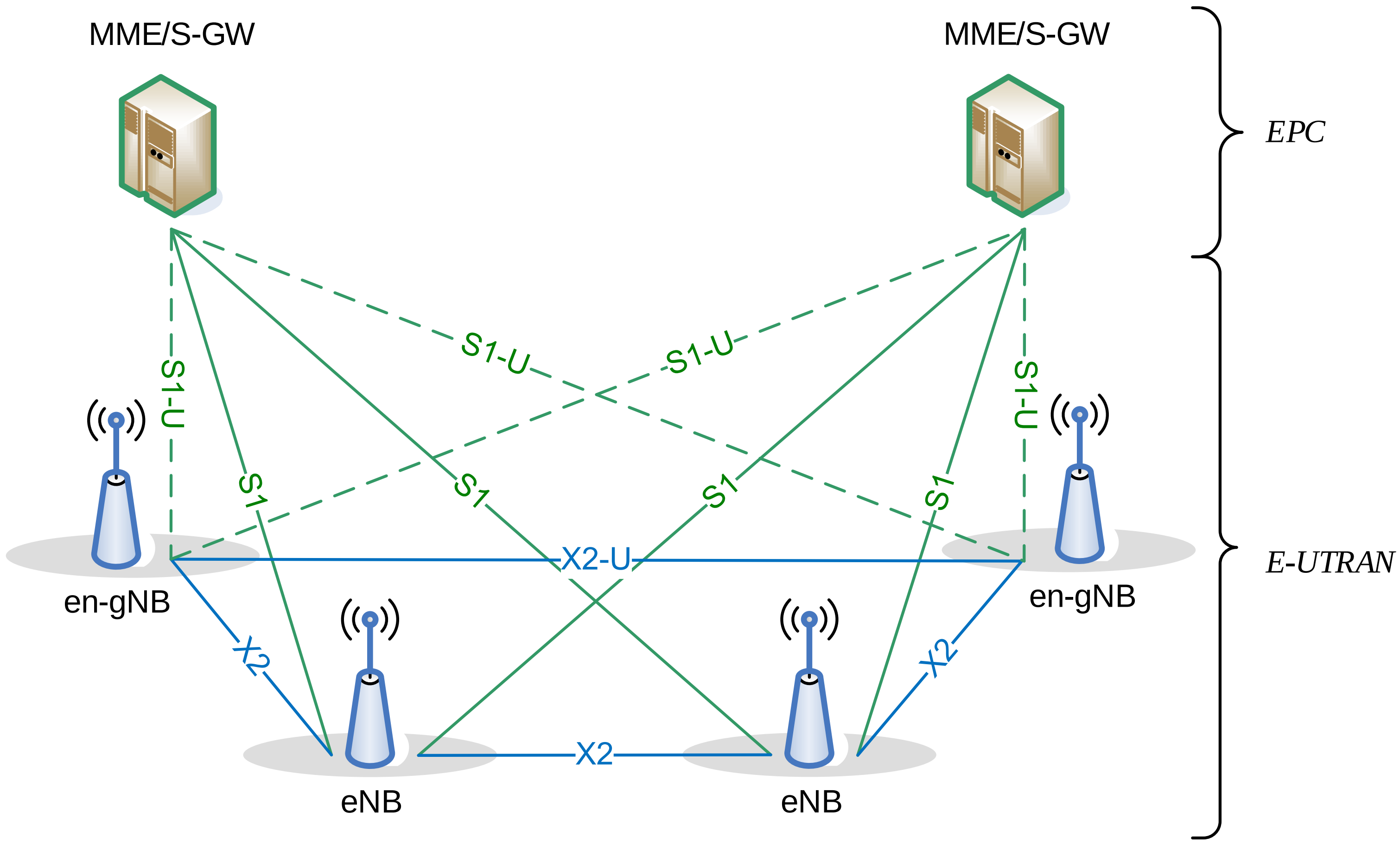
Multi-RAT Dual Connectivity (MR-DC) (TS37.340)

- MR-DC: 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 and the other as the SN
  - The MN and SN are connected via a network interface and at least the MN is connected to the core network
- MR-DC with the **EPC**
  - E-UTRAN supports MR-DC via **E**-UTRA-**N**R Dual Connectivity (EN-DC) [Option 3]
    - 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
- MR-DC with the **5GC**
  - NG-RAN supports **N**R-**E**-UTRA Dual Connectivity (NE-DC) [Option 4]
    - 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 the 5GC and
      - The **ng-eNB** is connected to the gNB via the Xn interface
  - NG-RAN supports **NG**-RAN **E**-UTRA-**N**R Dual Connectivity (NGEN-DC) [Option 7]
    - 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

MR-DC with the 5GC is not complete and is targeted for completion in December 2018

Agreements for MR-DC, V15.4.0 (2018-12)

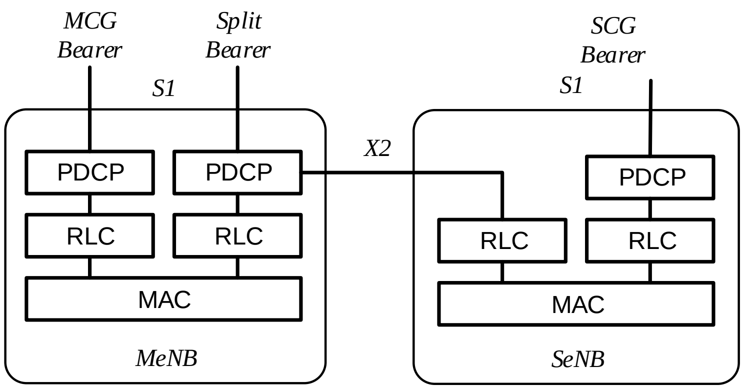
EN-DC Overall Architecture

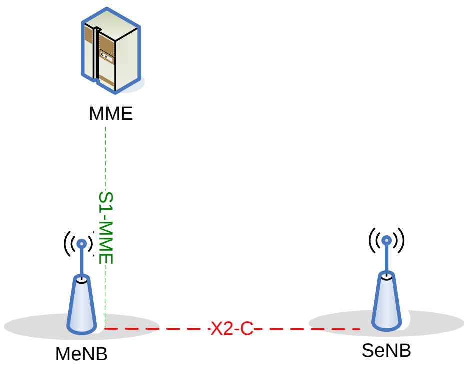


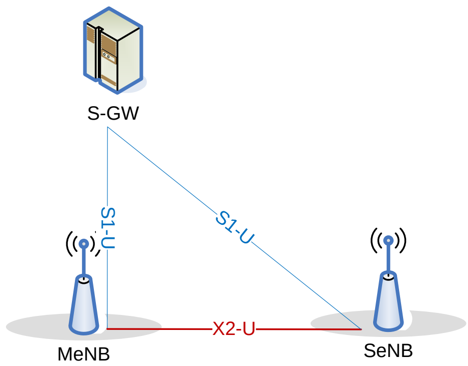
en-gNB: node providing NR user plane and control plane protocol terminations towards the UE, and acting as *Secondary Node* in EN-DC (TS 37.340 Clause 4)

DC and EN-DC

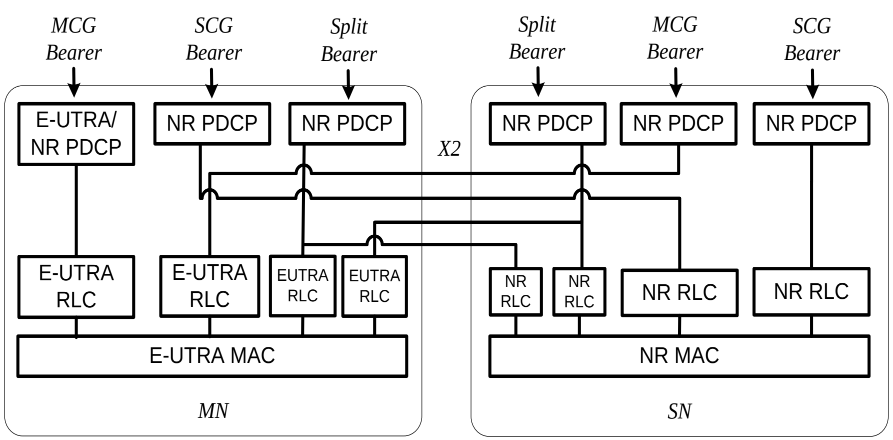
DC

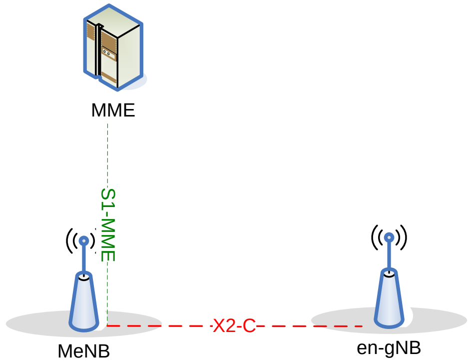


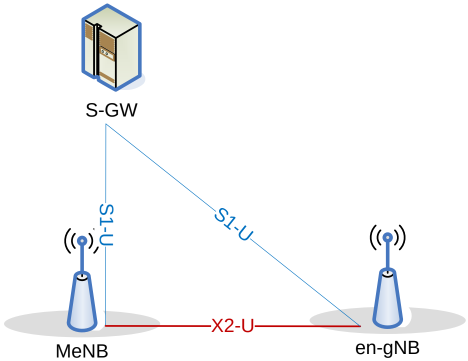




EN-DC

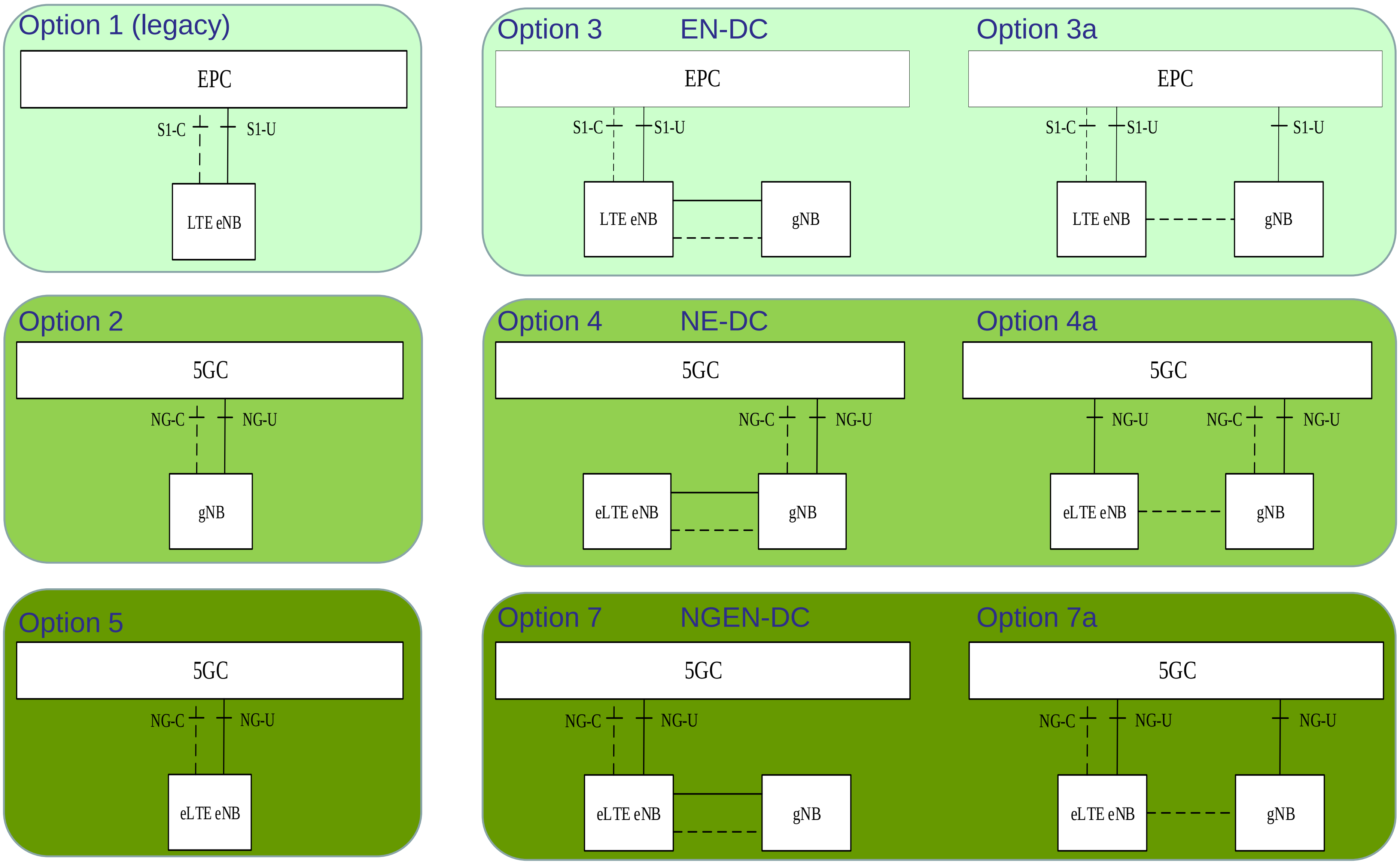






Radio Protocol Architecture C-Plane U-Plane

5G Architecture Options (TR38.801)

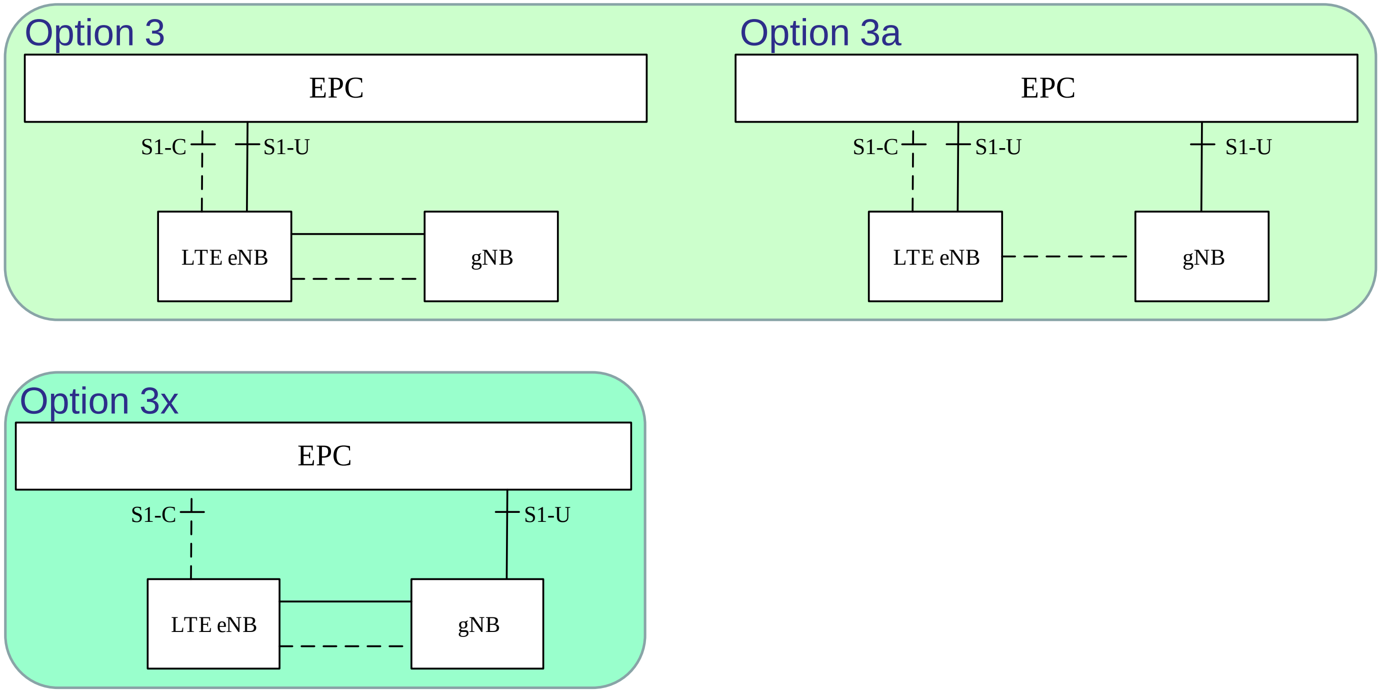


Dual Connectivity

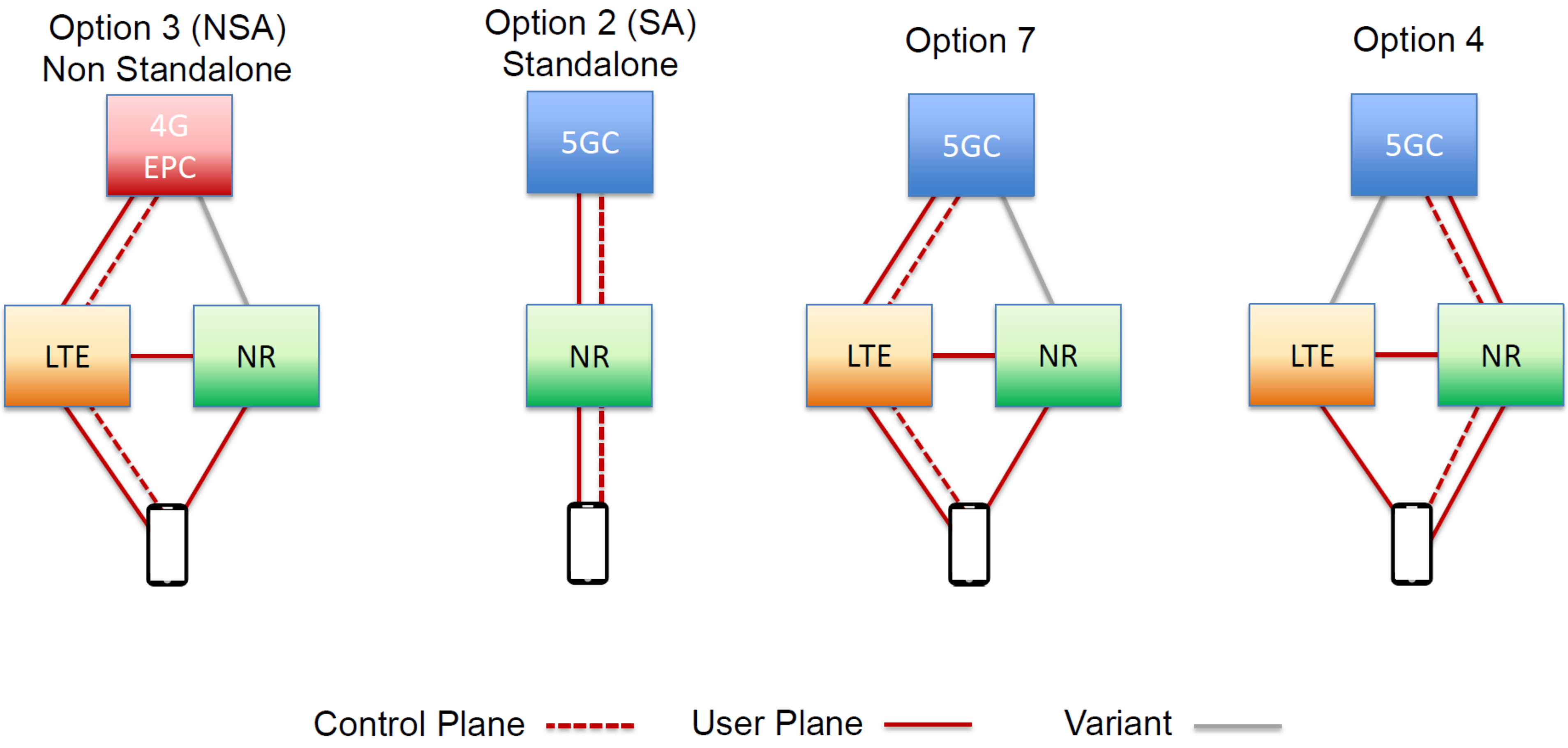
Directly Connected

5G NSA (Release 15)

- Focus on eMBB, and Options 3 and 2
- Three models of NSA with EN-DC
  - Option 3 – Traffic split at eNB
  - Option 3a – Traffic split at S-GW
  - Option 3x – Traffic split at gNB

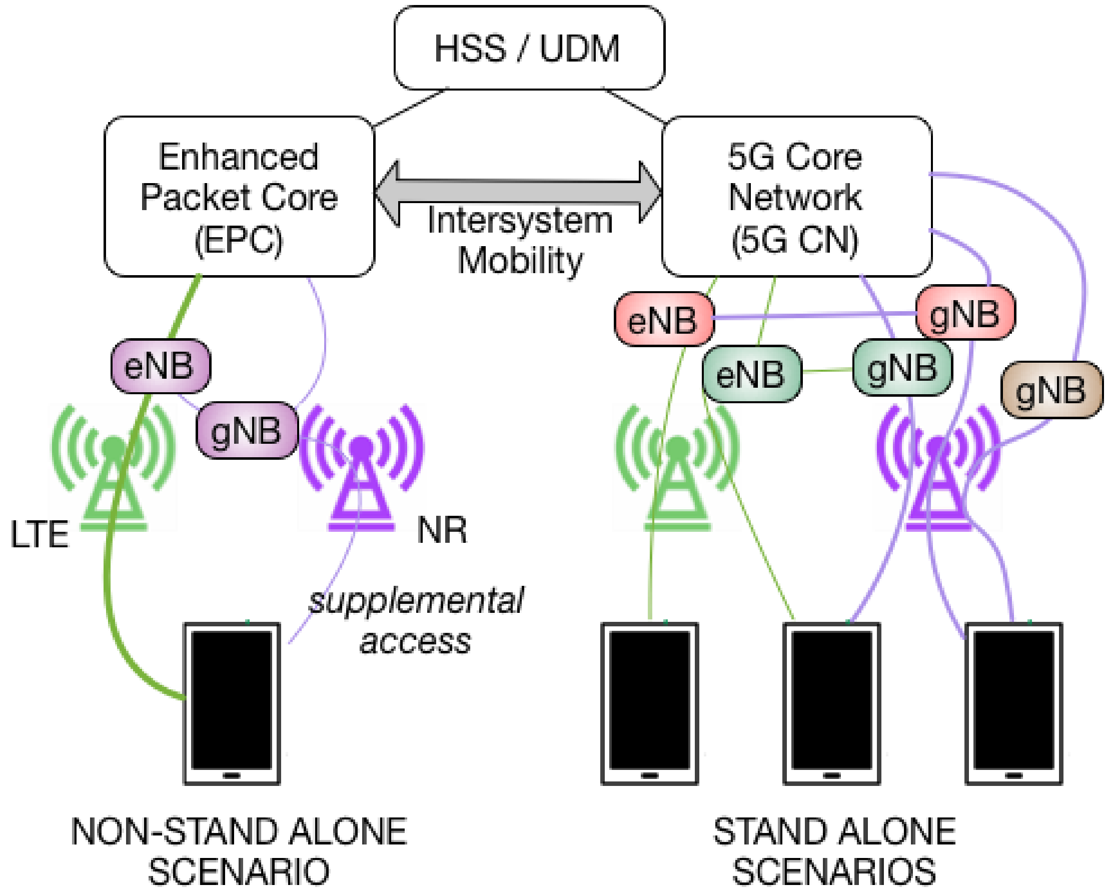


Two Core Networks Support 5G



https://www.atis.org/01_news_events/webinar-pptslides/5g-slides7312019.pdf

5G Deployment Scenarios



See 3GPP TR 38.801, clause 10

Stage 3 freeze:	12.17	12.18	12.18	06.18
Option [see 38.801]:	3	7	4	2

https://www.3gpp.org/ftp/workshop/2018-10-24_25_WS_on_3GPP_subm_tw_IMT2020/Docs/RWS-180006.zip

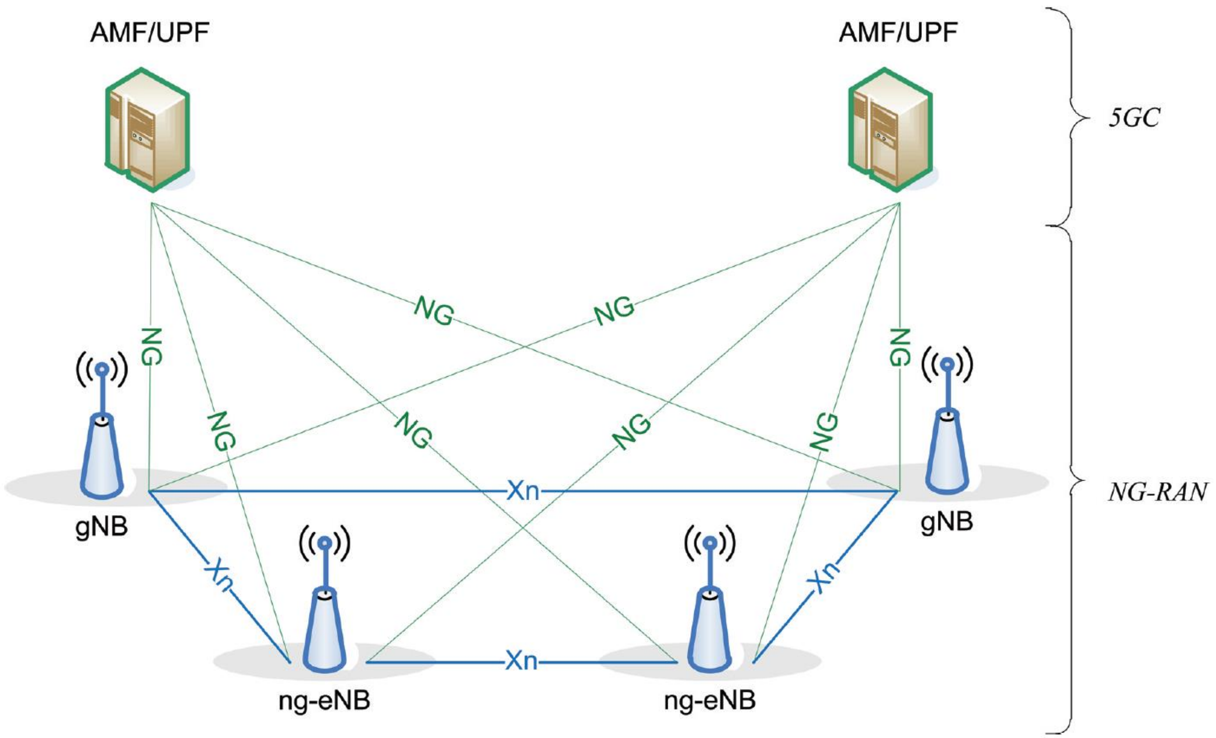
NG-RAN

- The New RAN (Radio Access Network) for 5G
  - Provides both NR and E-UTRA ("LTE") radio access
- An NG-RAN node is *either*
  - **gNB** – ("5G base station", providing NR access) *or*
  - **ng-eNB** ("enhanced 4G base station", providing E-UTRA access)
- NG-RAN nodes are connected
  - To the 5G core network – NG interface
  - To one another – Xn interface

Options 3, 4, and 7

https://www.3gpp.org/ftp/workshop/2018-10-24_25_WS_on_3GPP_subm_tw_IMT2020/Docs/RWS-180009.zip

The NG-RAN



AMF/UPF
AMF/UPF
5GC
NG
NG
NG
NG
NG
NG
NG
NG
Xn
Xn
Xn
Xn
gNB
gNB
NG-RAN
ng-eNB
ng-eNB

Deployment Options

- **Stand-Alone (SA)**: gNB connects to the 5G Core Network (5GC)
- **Non-Stand-Alone (NSA)**: tight interoperation between gNBs and ng-eNBs
  - Connected to the same core network: *either*
    - EPC, the existing LTE core network (NSA within "4G RAN") *or*
    - 5GC, the 5G core network (NSA within NG-RAN)

    Options 3a, 4a and 7a
  - **Dual Connectivity (DC)** toward the terminal
    - A Master Node (MN) and a Secondary Node (SN) concurrently provide radio resources toward the user, for higher bit rate
    - The terminal "sees" a Master Cell Group (MCG) and a Secondary Cell Group (SCG)

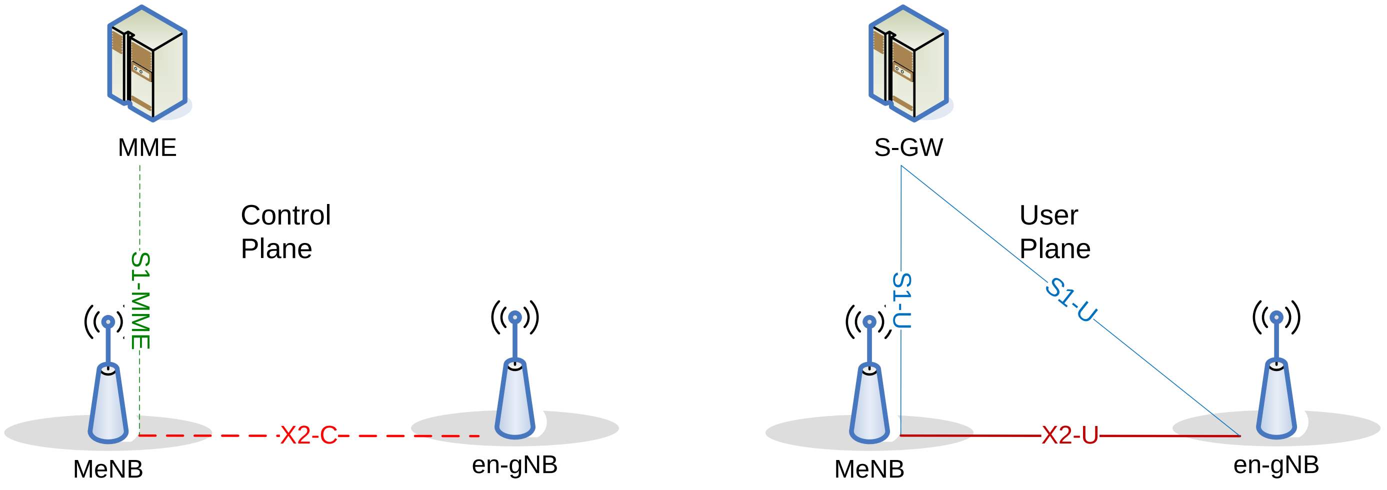
    Options 3 (EN-DC), 4 (NE-DC) and 7 (NGEN-DC)

Architecture “Options”

- Combinations of various alternatives for Master Node (MN), Secondary Node (SN), and core network types
  - (numbering is for reference only)
  - Different migration paths are possible according to operator strategy

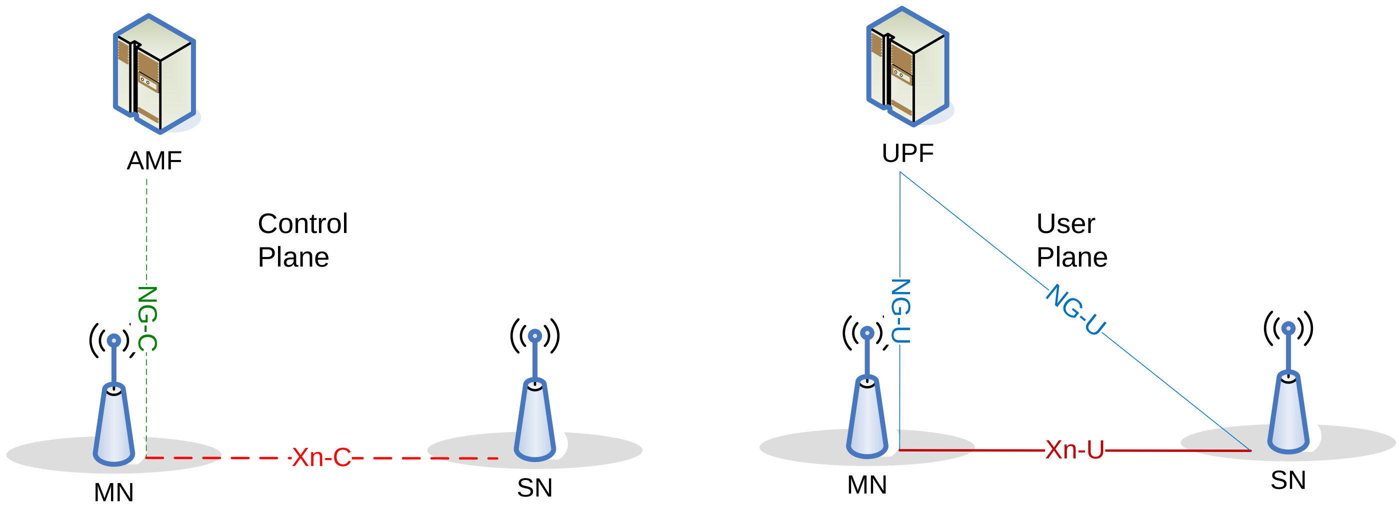
Option 3 ("EN-DC")

- eNB as MN, connected to LTE core network
- "en-gNB" as SN
  - Only a subset of 5G radio functionality is needed for this use



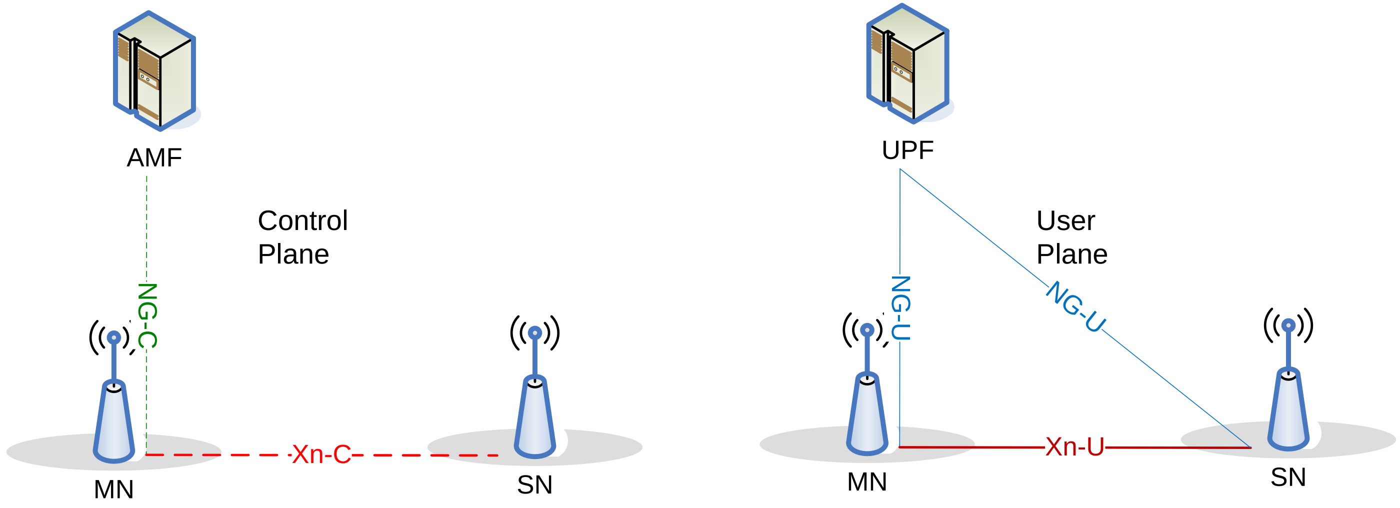
Option 4 ("NE-DC")

- gNB as MN, connected to 5G core network
- ng-eNB as SN



Option 7 (“NGEN-DC”)

- ng-eNB as MN, connected to 5G core network
- gNB as SN



Other Available Options

- Option 2: gNB connected to 5G core network (SA operation)
  - “NR-NR DC” is supported (gNBs as MN and SN)
- Option 5: ng-eNB connected to 5G core network

Migration Considerations

- Migration choice and path depends on:
  - Operator strategy
  - Business decision on when to deploy the 5G core network
  - Availability of new frequencies for NR
  - Existing network density
  - Increase of end-user traffic
  - Availability of terminals with the right feature set / bands

- If initial NR deployments use higher frequencies (e.g. above 6 GHz)
  - Smaller coverage on NR than on LTE
  - **Opt. 3** uses LTE for coverage and NR for higher capacity in busy areas, leveraging existing investments

- When 5G core network is deployed
  - **Opts. 2** (SA) and **4** (NR for coverage, LTE as booster) use NR as basis for coverage
  - **Opts. 5** (ng-eNB for coverage) and **7** (ng-eNB for coverage, NR as booster) use LTE as basis for coverage

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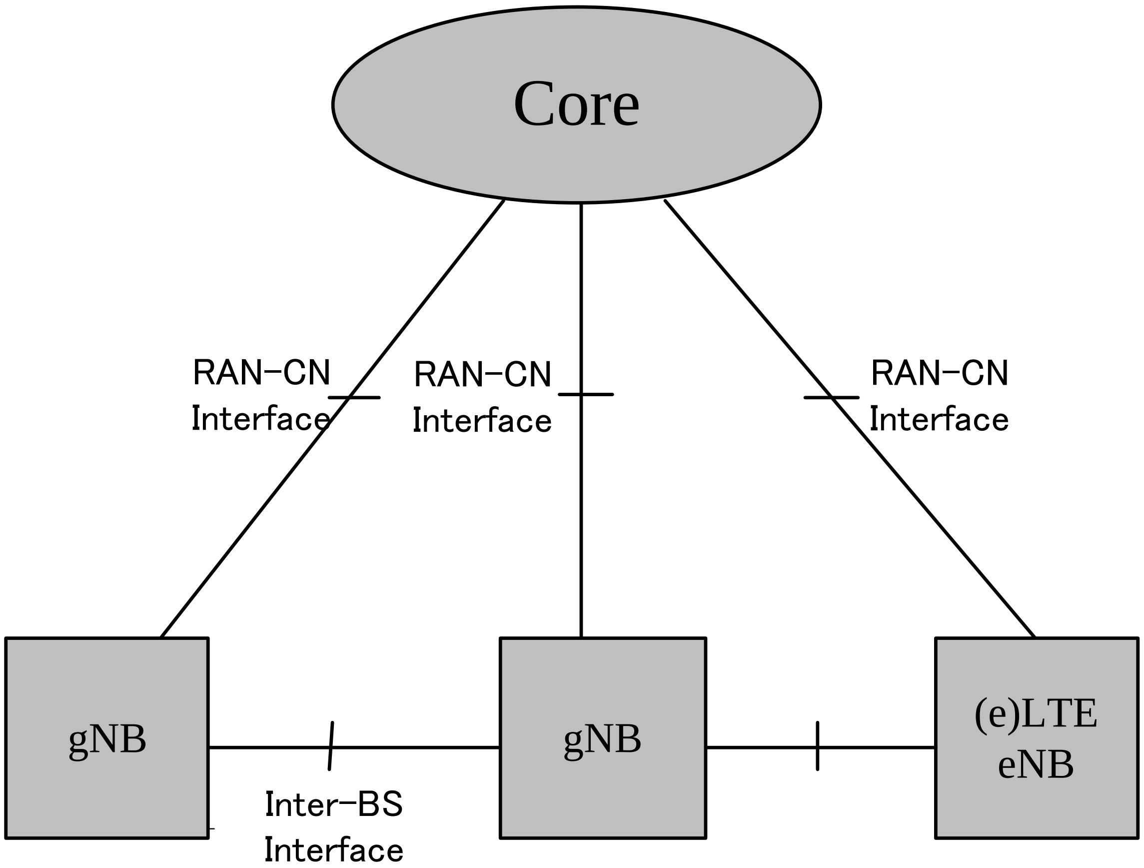
Deployment Scenarios

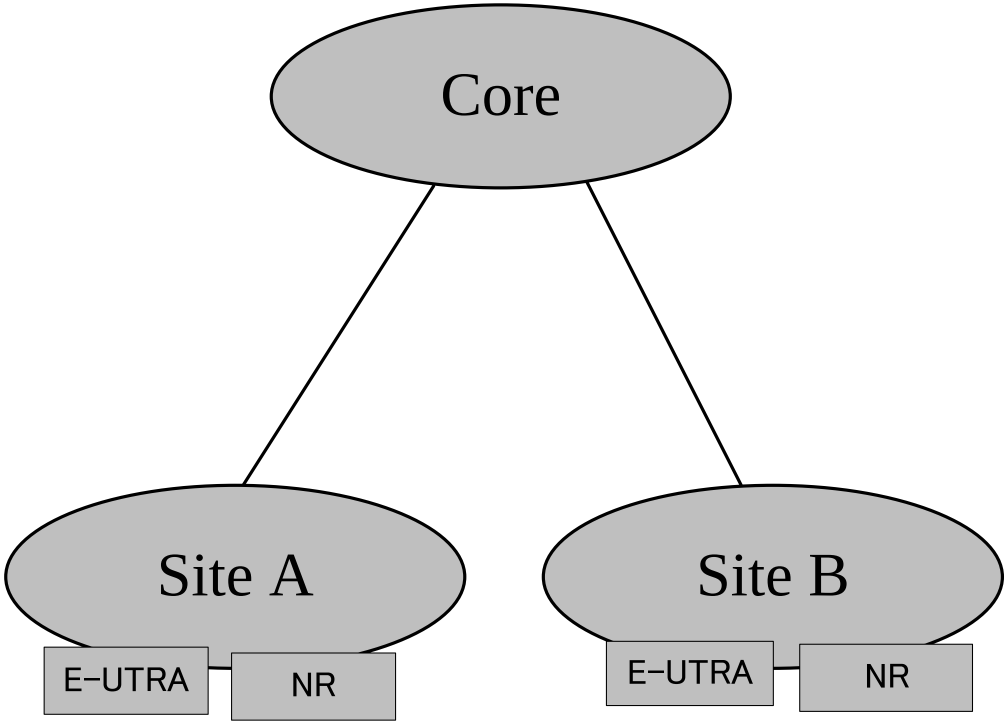
- The following example scenarios should be considered for support by the RAN architecture
  - Non-centralised deployment
  - Co-sited deployment with E-UTRA
  - Centralized deployment
  - Shared RAN deployment
- Although it is not always explicitly specified, it should be assumed that an inter BS interface may be supported between an gNB and other gNBs or (e)LTE eNBs
- The Heterogeneous deployment comprises in the same geographical area two or more deployments as defined in sections 5.2 to 5.5 of the present document

Non-Centralised Deployment



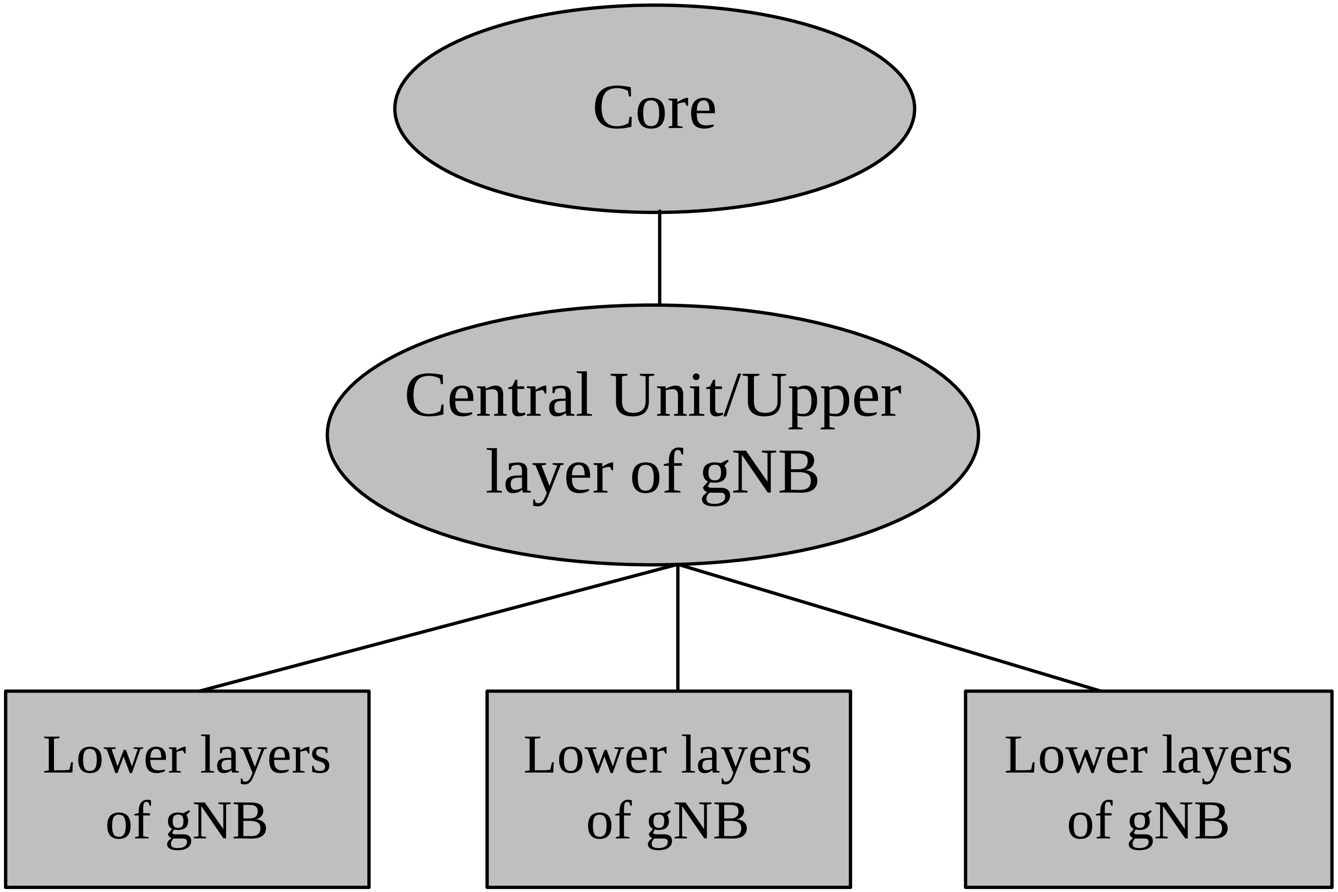
- It is assumed that the gNB is able to connect to other gNBs or (e)LTE eNBs via a RAN interface

Co-Sited Deployment with E-UTRA



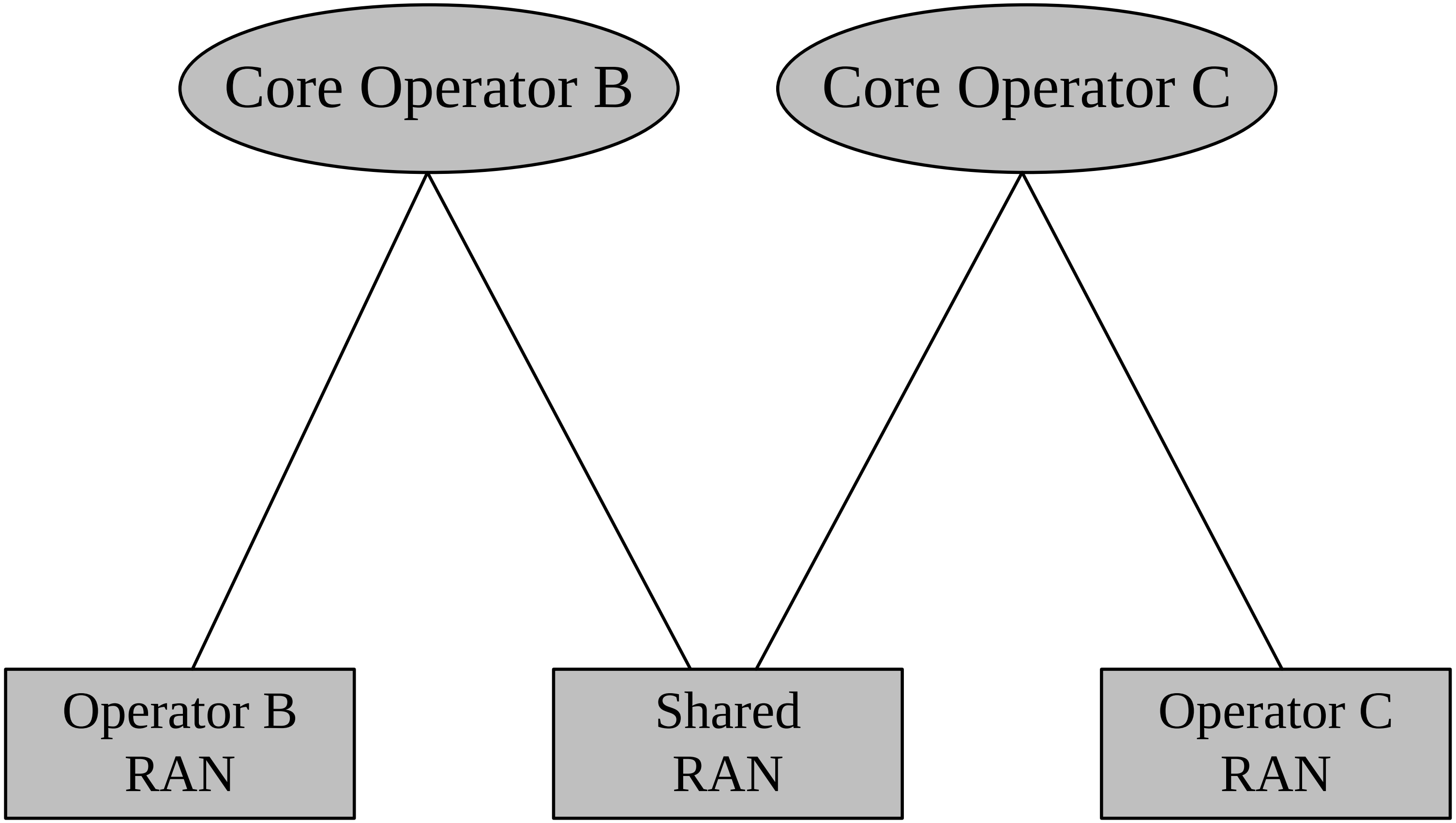
- Co-sited deployment can be applicable in all NR deployment scenarios

Centralized Deployment



- Both non co-sited deployment and co-sited deployment with E-UTRA can be considered for this scenario

Shared RAN Deployment



- The Shared RAN may (as for the case of LTE) operate either on shared spectrum or on the spectrum of each hosted Operator

Overall New RAN architecture

- RAN-CN functional split
  - The general aspects of RAN-CN functional split are captured in TR 23.799
  - The topics still open in TR 23.799 for RAN-CN functional split need to be addressed during normative phase
- RAN functions descriptions
  - Functions similar to E-UTRAN as listed in TS 36.401
  - Functions for new RAN
  - Functions for new RAN which are postponed

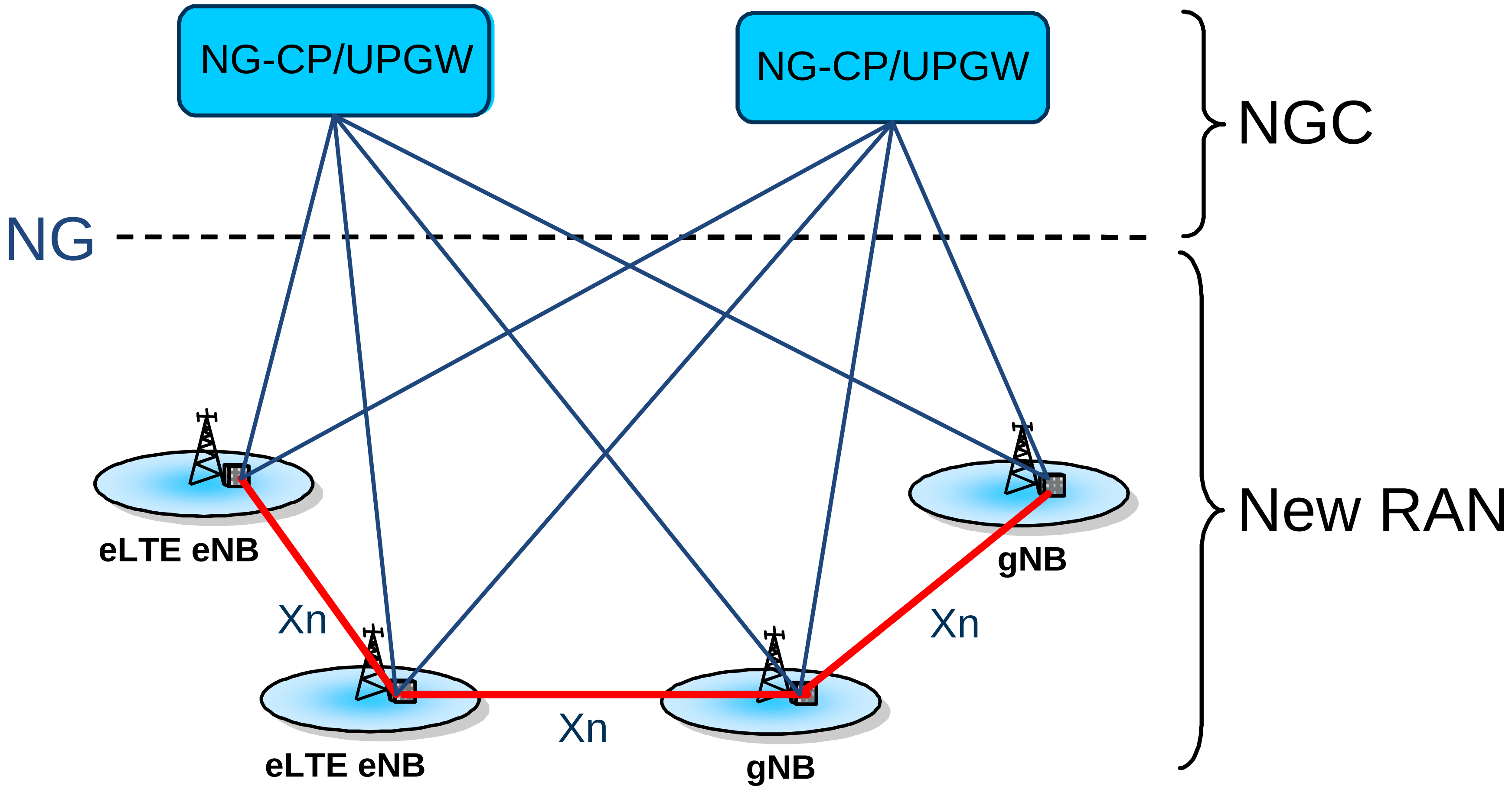
RAN Functions Description

- Functions similar to E-UTRAN as listed in TS 36.401
  - Transfer of user data
  - Radio channel ciphering and deciphering
  - Integrity protection
  - Header compression
  - Mobility control functions : Handover
  - Inter-cell interference coordination
  - Connection setup and release
  - Load balancing
  - Distribution function for NAS messages
  - NAS node selection function
  - Synchronization
  - Radio access network sharing
  - Paging
  - Positioning
- Functions for New RAN
  - Network Slice support
  - Tight Interworking with E-UTRA
  - E-UTRA-NR handover through a New RAN interface
  - E-UTRA - NR handover via CN
  - Session Management
  - Contacting UEs in inactive mode
- Functions for New RAN which are postponed
  - Direct services support
  - Interworking with non-3GPP systems
  - This function provides interworking between NR and Non-3GPP RAT

RAN Architecture and Interfaces

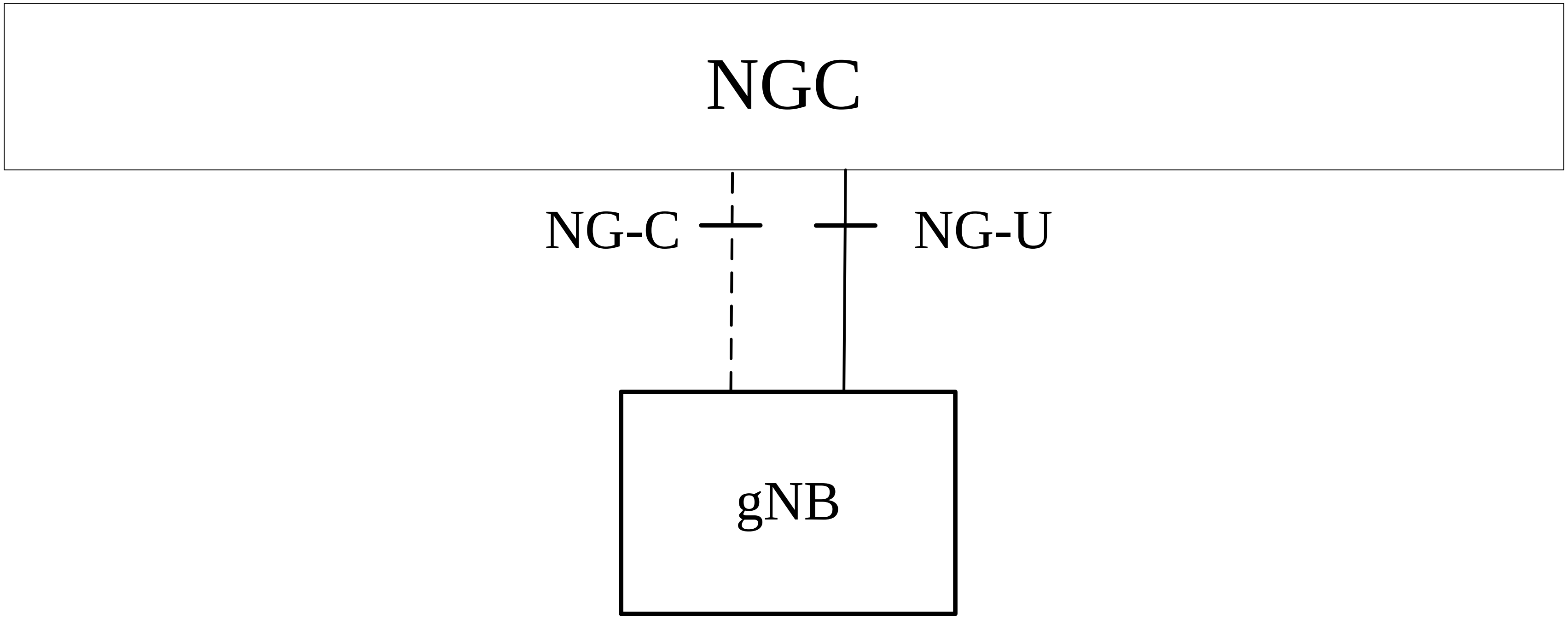
- New RAN Architecture
- 5G Architecture Options
- RAN-CN interface
- RAN internal interface

New RAN Architecture



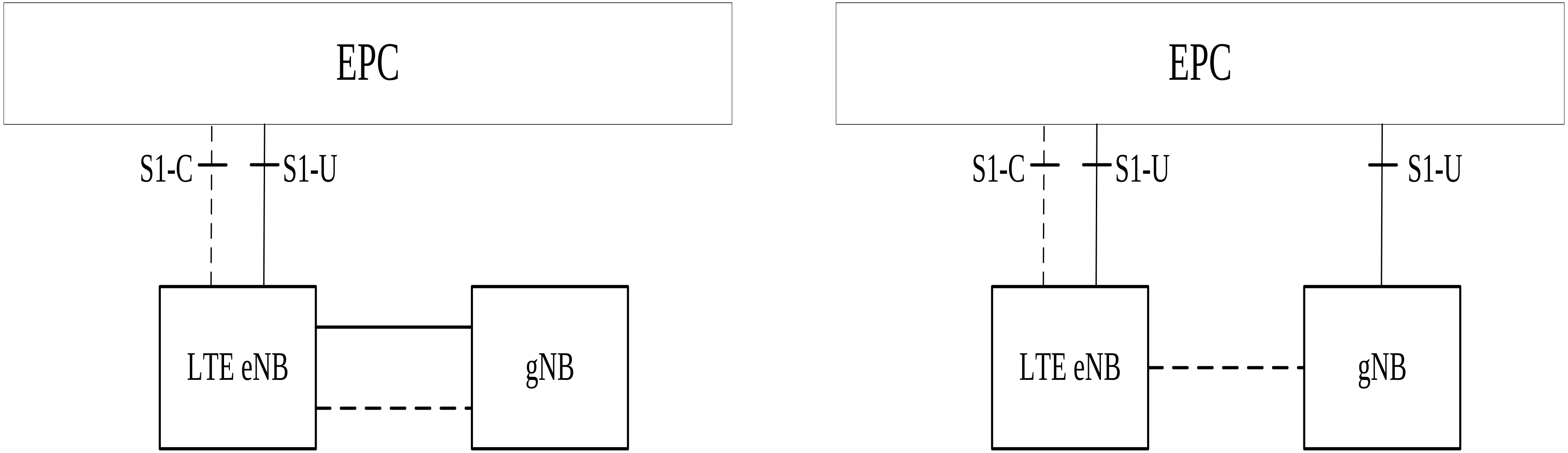
- The NG interface supports a many-to-many relation between NG-CP/UPGWs and the logical nodes in New RAN

Option 2



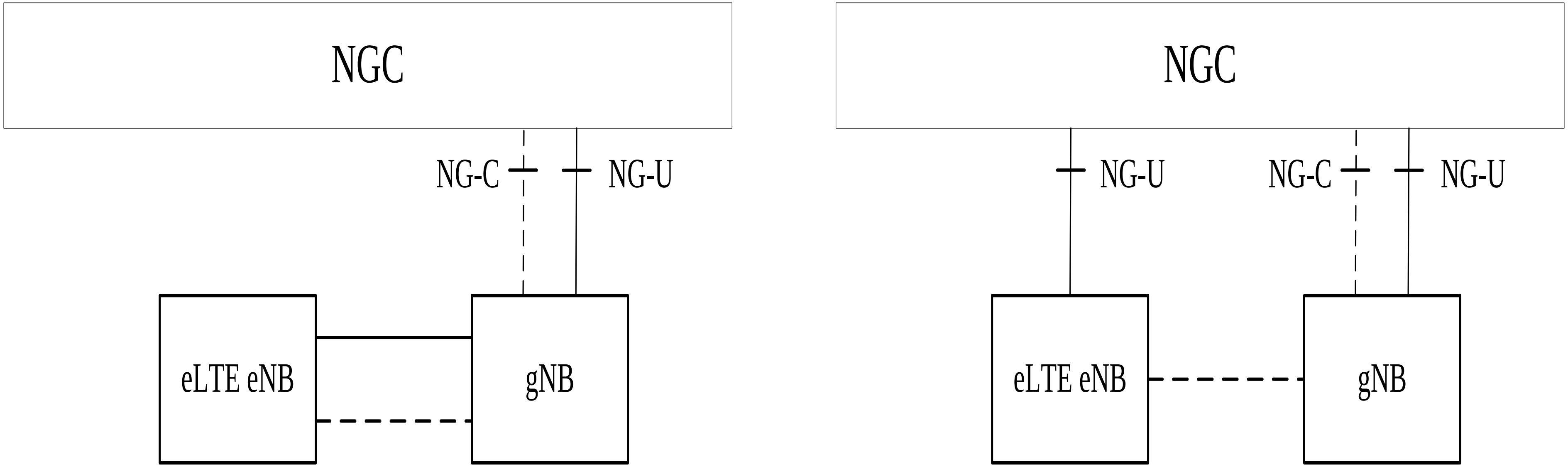
- In Option 2, the gNB is connected to the NGC

Options 3 and 3A



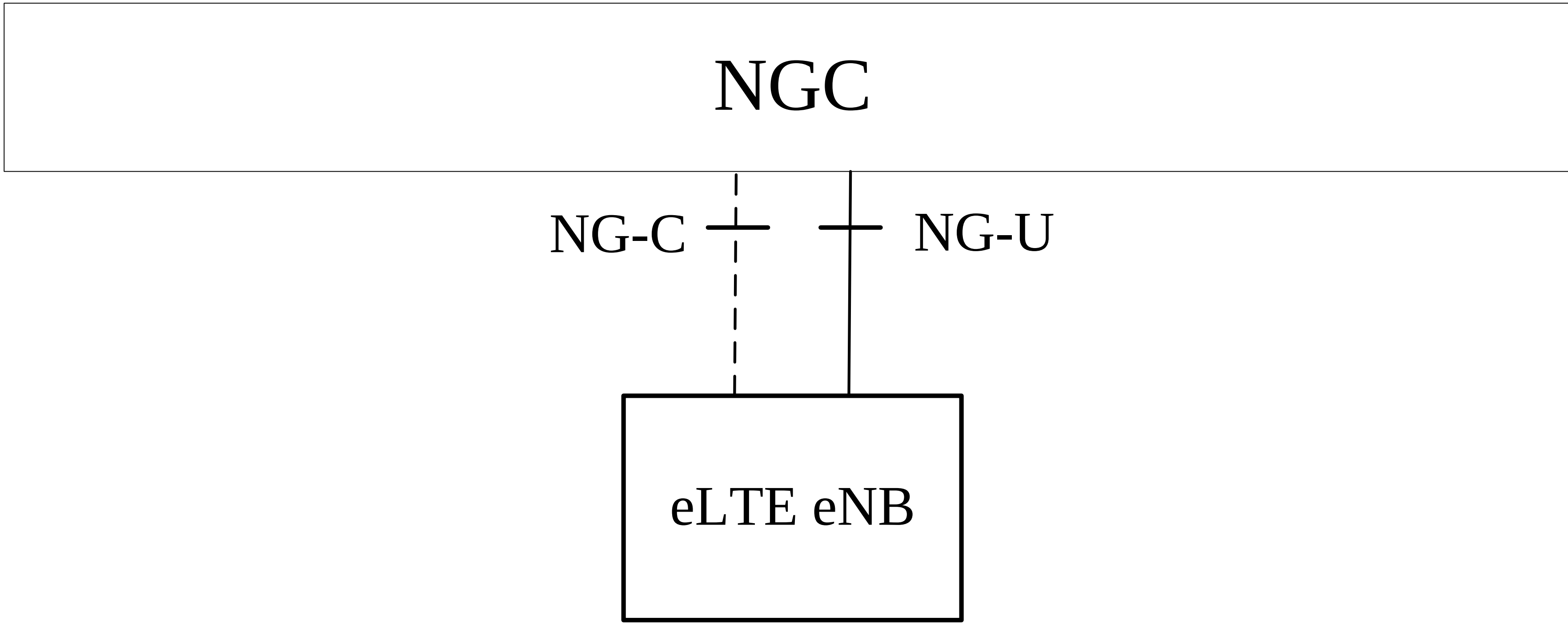
- In Option 3/3A, the LTE eNB is connected to the EPC with Non-standalone NR
- The NR user plane connection to the EPC goes via the LTE eNB (Option 3) or directly (Option 3A)

Options 4 and 4A



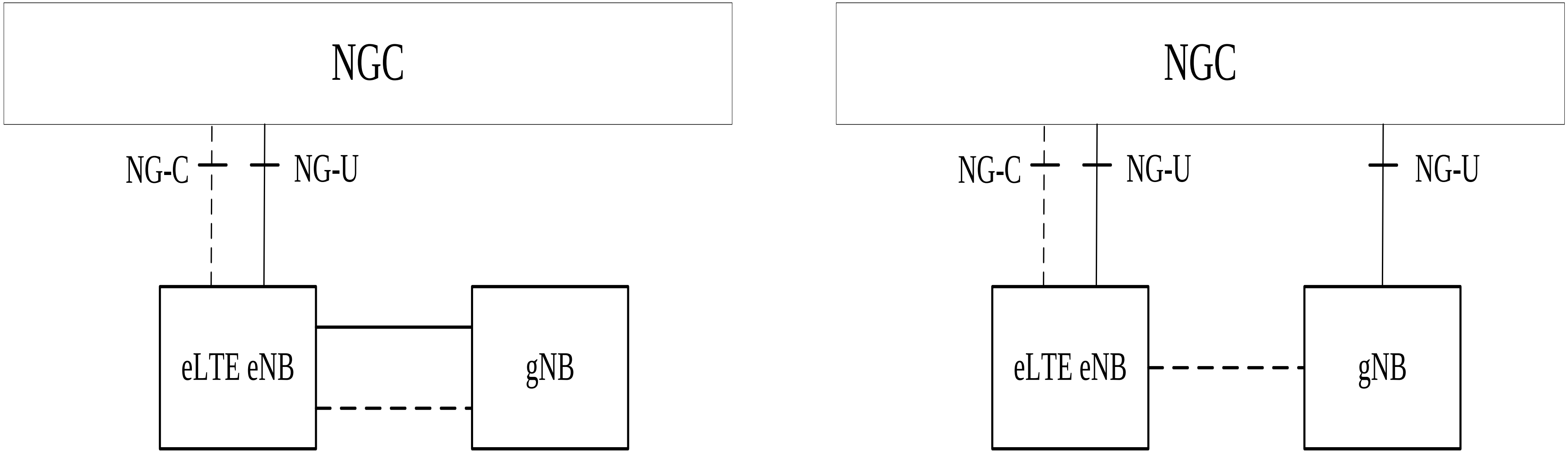
- In Option 4/4A, the gNB is connected to the NGC with Non-standalone E-UTRA
- The E-UTRA user plane connection to the NGC goes via the gNB (Option 4) or directly (Option 4A)

Option 5



- In Option 5, the eLTE eNB is connected to the NGC

Options 7 and 7A

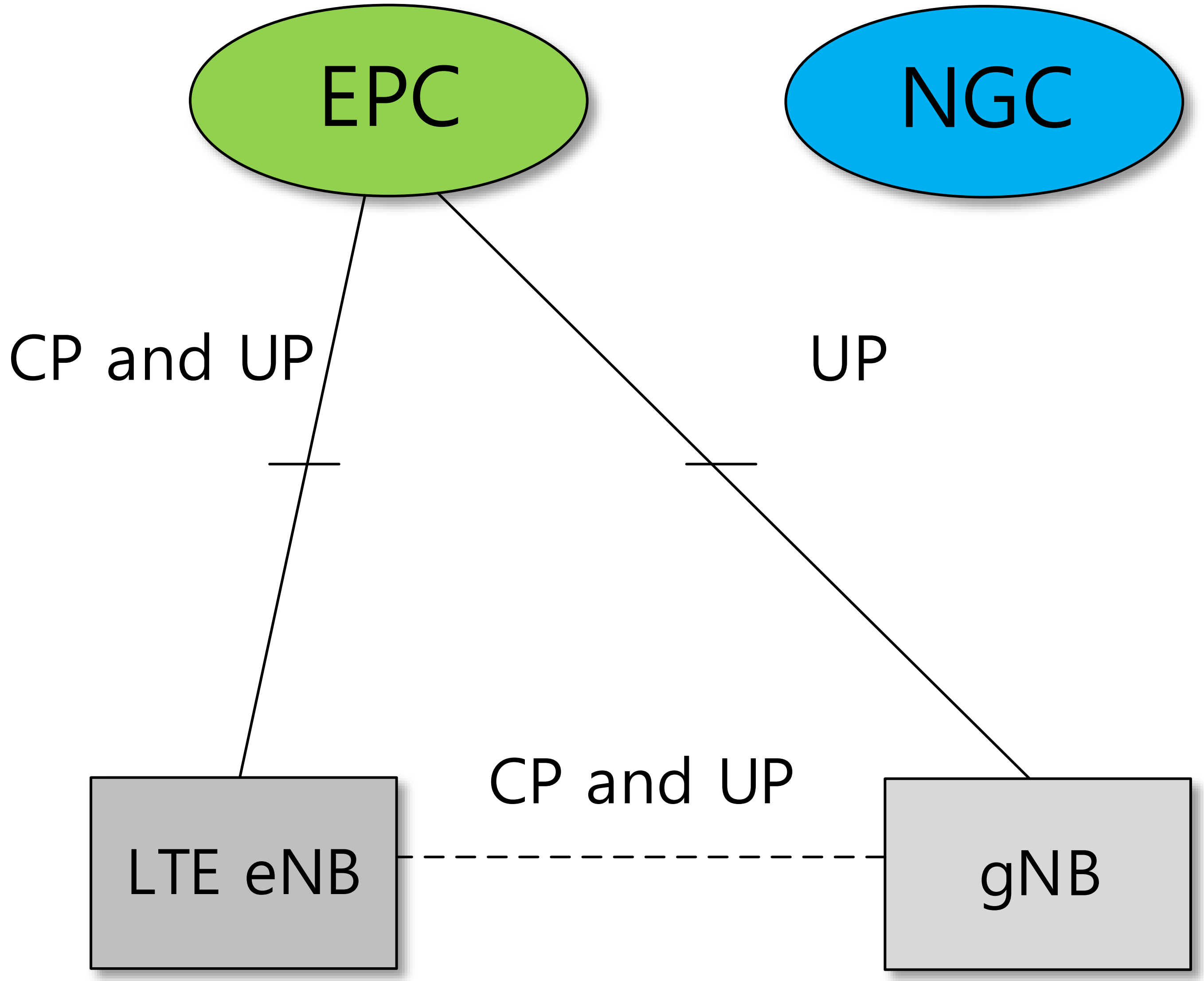


- *In Option 7/7A, the eLTE eNB is connected to the NGC with Non-standalone NR*
- *The NR user plane connection to the NGC goes via the eLTE eNB (Option 7) or directly (Option 7A)*

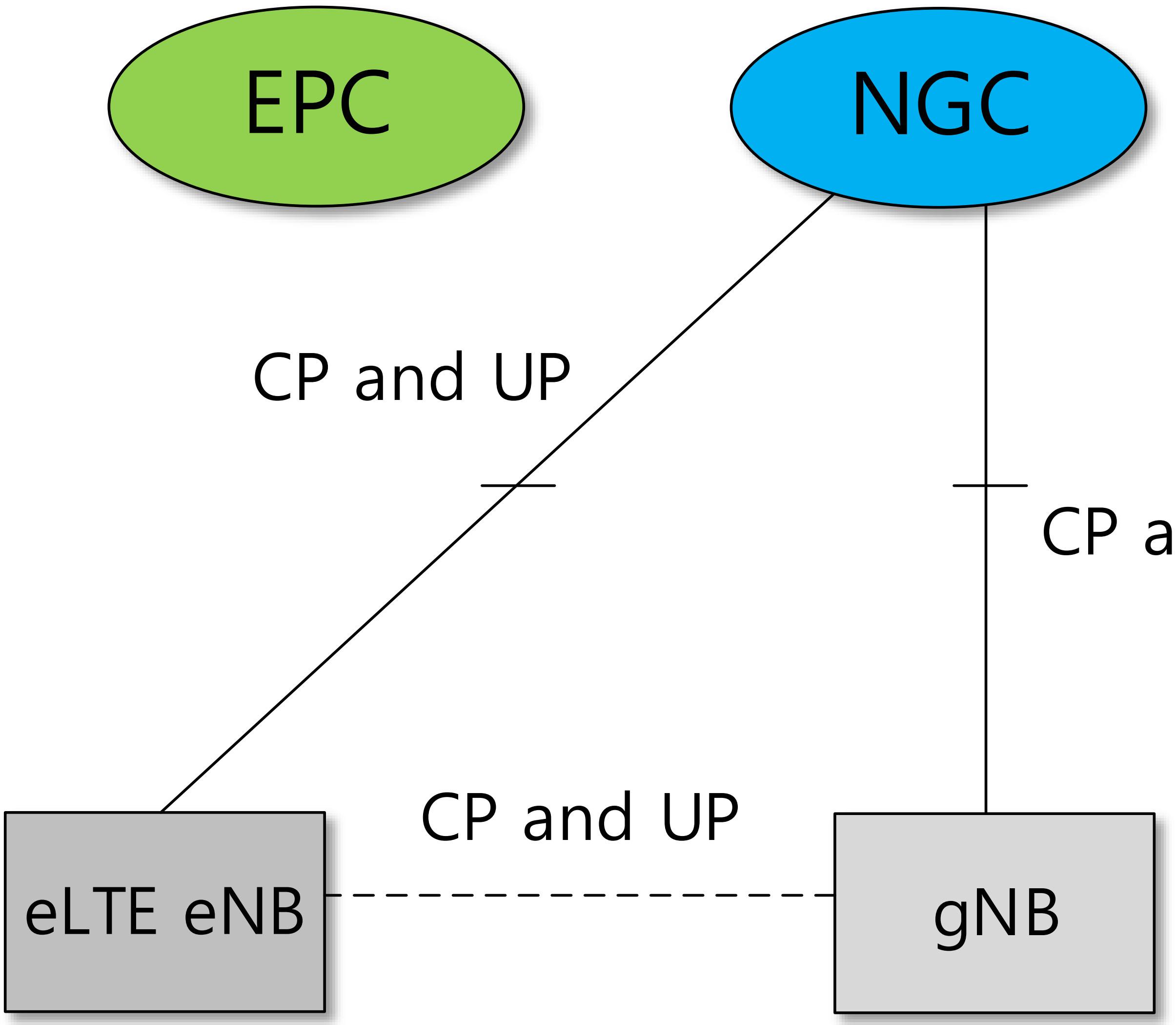
RAN-CN interface

- RAN-CN interface connectivity scenarios
- General principles
- NG Interface Functions
- NG Interface Procedures
- NG interface architecture
- NG Control Plane
- NG User Plane

E-UTRA and NR Connected to the EPC



E-UTRA and NR Connected to the NGC



- In this scenario, eLTE eNB and gNB can be collocated

General Principles

- NG interface shall be open
- NG interface shall support the exchange of signalling information between the New RAN and NGC
- From a logical standpoint, the NG is a point-to-point interface between a New RAN node and an NGC node
- NG interface shall support control plane and user plane separation
- NG interface shall separate Radio Network Layer and Transport Network Layer
- NG interface shall be future proof to fulfil different new requirements and support of new services and new functions
- NG interface shall be decoupled with the possible New RAN deployment variants
- NG Application Protocol shall support modular procedures design and use a syntax allowing optimized encoding /decoding efficiency

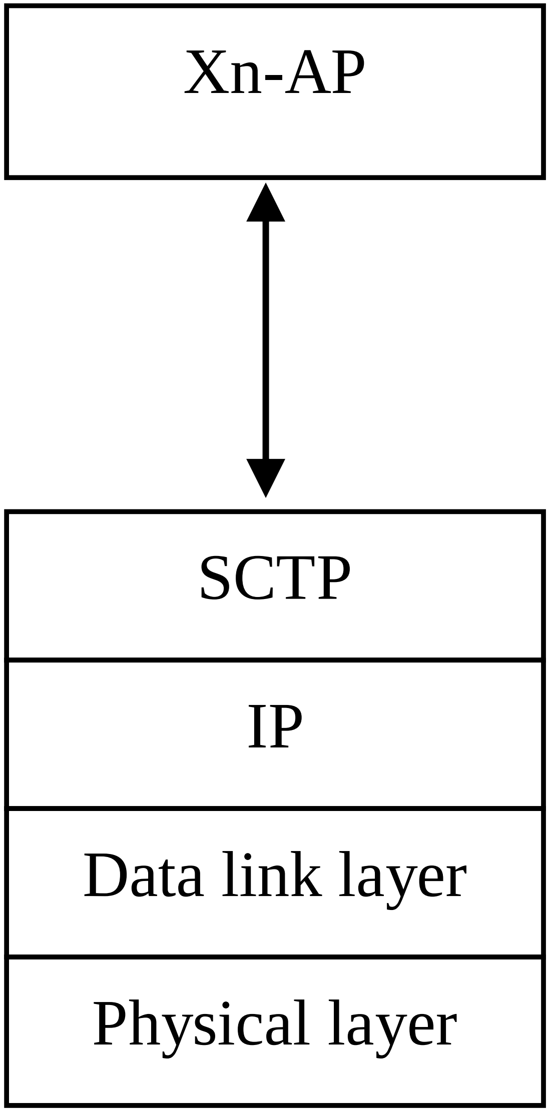
NG Interface Functions

- Interface management: The functionality to manage the NG-C interface
- UE context management: The functionality to manage the UE context between the New RAN and CN
- UE mobility management: The functionality to manage the UE mobility for connected mode between the New RAN and CN
- Transport of NAS messages: procedures to transfer NAS messages between the CN and UE
- Paging: The functionality to enable the CN to generate Paging messages sent to the New RAN and to allow the New RAN to page the UE in RRC_IDLE state
- PDU Session Management: The functionality to establish, manage and remove PDU sessions and respective New RAN resources that are made of data flows carrying UP traffic
- Configuration Transfer: the functionality to transfer the New RAN configuration information between two New RAN nodes via the NGC

Dual Connectivity Procedures

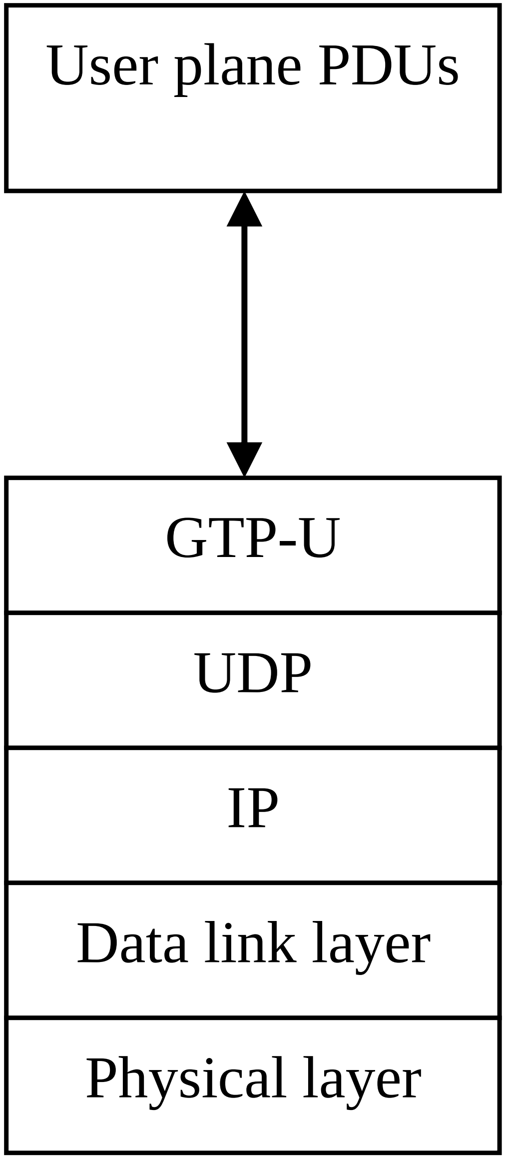
- Secondary Node Addition
- Secondary Node Modification (Master node initiated)
- Secondary Node Modification (Secondary node initiated)
- Secondary Node Release (Master node initiated)
- Secondary Node Release (Secondary node initiated)

Xn Interface Control Plane



- The Xn control plane interface (Xn-C) is defined between two neighbour New RAN nodes
- The transport network layer is built on SCTP on top of IP
- The application layer signalling protocol is referred to as Xn-AP (Xn Application Protocol)

Xn Interface User Plane



- The transport layer for data streams over Xn is an IP based Transport
- The following figure shows the transport protocol stacks over Xn

Radio Access Network Procedures

- Dual Connectivity between NR and LTE
  - General
  - Option 3/3a/3x
  - Option 4/4a
  - Option 7/7a/7x
- New RAN operation
  - Intra-system Mobility
  - Inter-system Mobility
  - PDU Session Management
  - Initial UE Access
  - Intra-NR dual connectivity

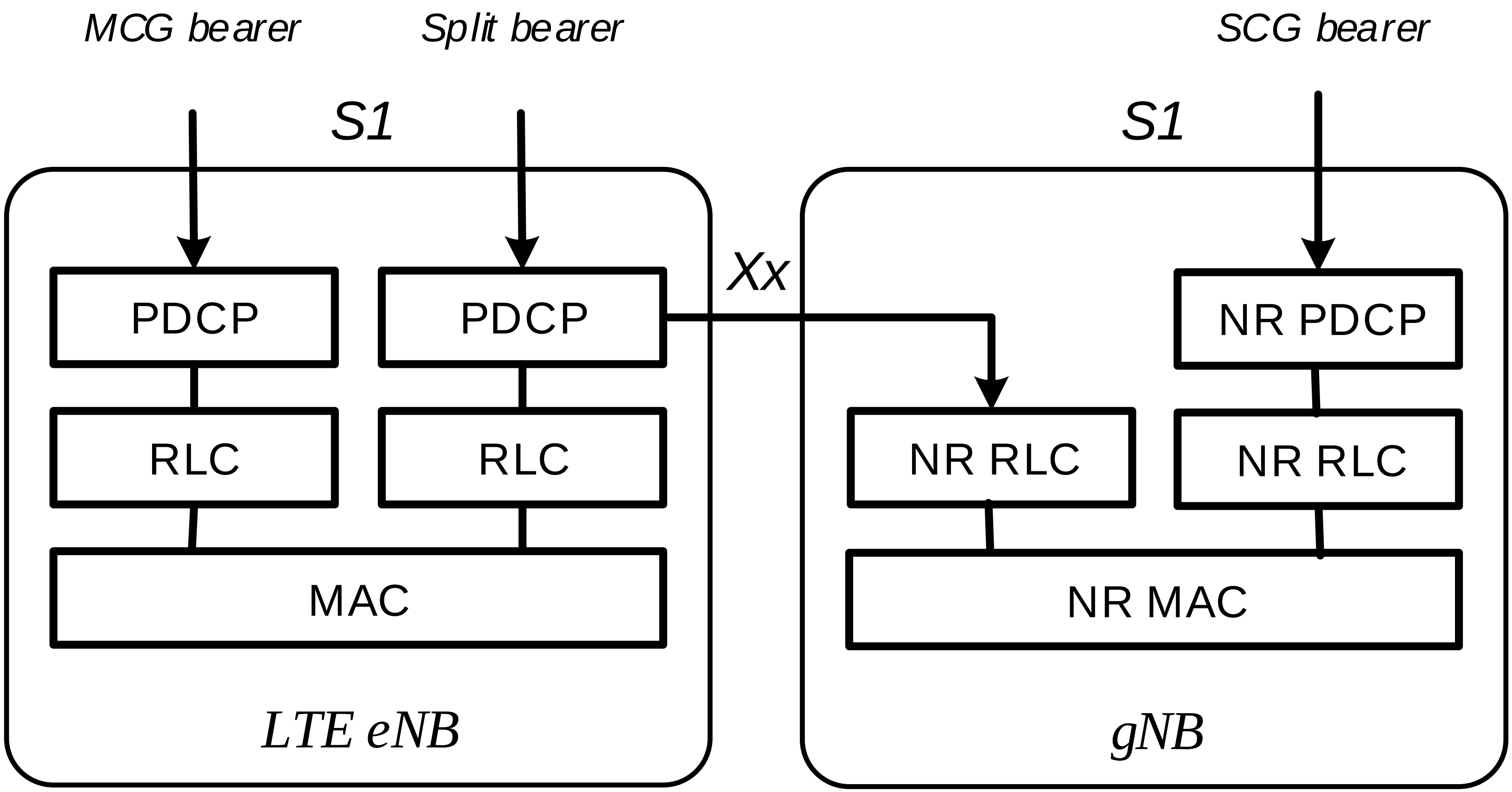
General RAN Procedures

- Option 3/3a/3x, 4/4a and 7/7a/7x of deployment scenarios can be considered as tight interworking between NR and E-UTRA
- In Option 3/3a, Dual Connectivity (DC) specified in TS 36.300 and relevant stage 3 specifications should be reused as baseline considering the fact that EPC should not be impacted
- In Option 4/4a, Dual Connectivity can be realized, in which the gNB is connected to the NGC with Non-standalone E-UTRA
- In Option 7/7a/7x, Dual Connectivity can also be achieved, in which the eLTE eNB is connected to the NGC with Non-standalone NR

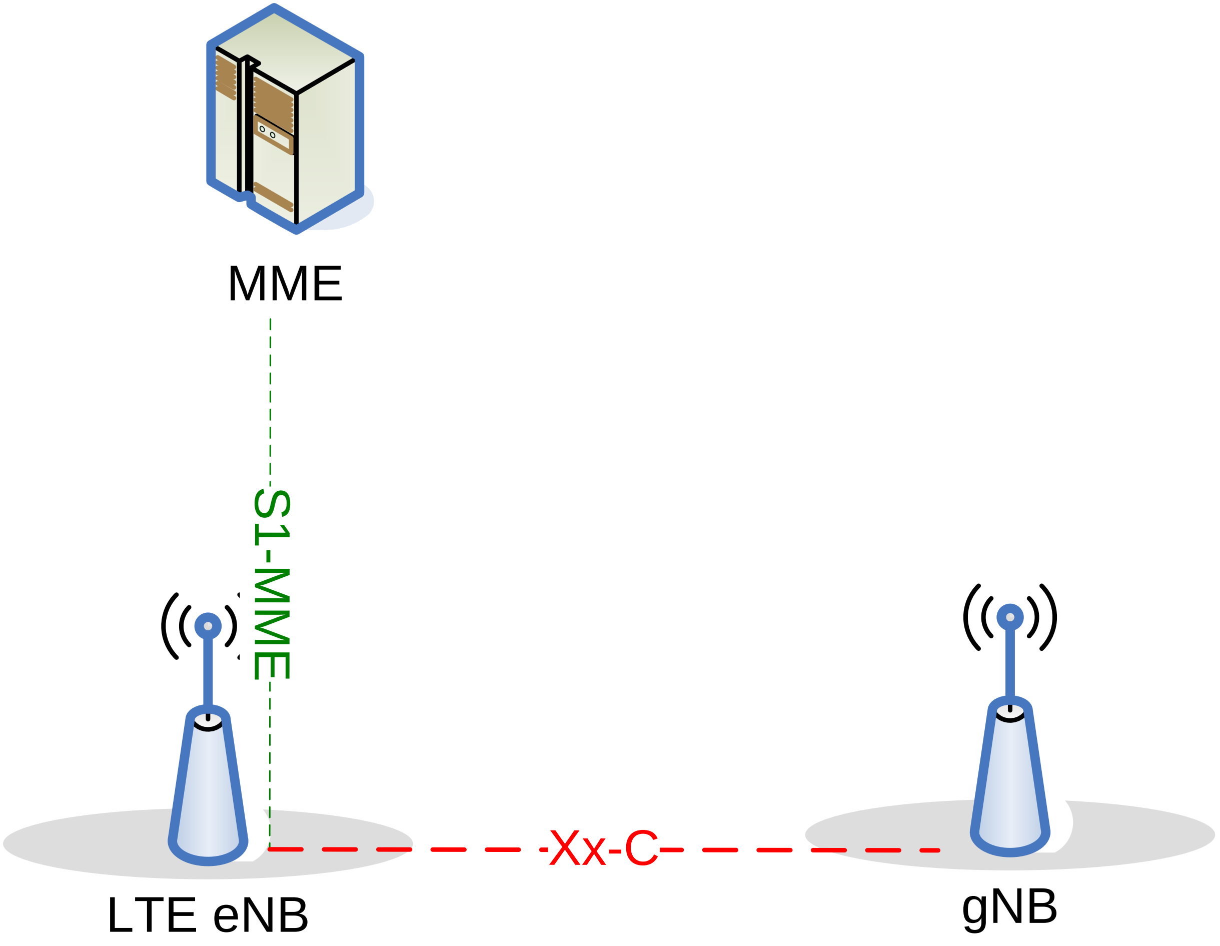
General Principles for Xx Interface

- Xx interface shall be open
- Xx interface shall support the exchange of signalling information between the endpoints
  - The interface shall support data forwarding to the respective endpoints
- From a logical standpoint, the Xx is a point-to-point interface between the endpoints
  - A point-to-point logical interface should be feasible even in the absence of a physical direct connection between the endpoints
- Xx interface shall support control plane and user plane separation
- Xx interface shall separate Radio Network Layer and Transport Network Layer
- Xx interface shall be future proof to fulfil different new requirements, support new services and new functions
- Xx interface shall support LTE based Dual Connectivity operation where LTE eNB is MeNB
- Xx interface shall support flow control functions
- Xx interface does not support handover preparation functions

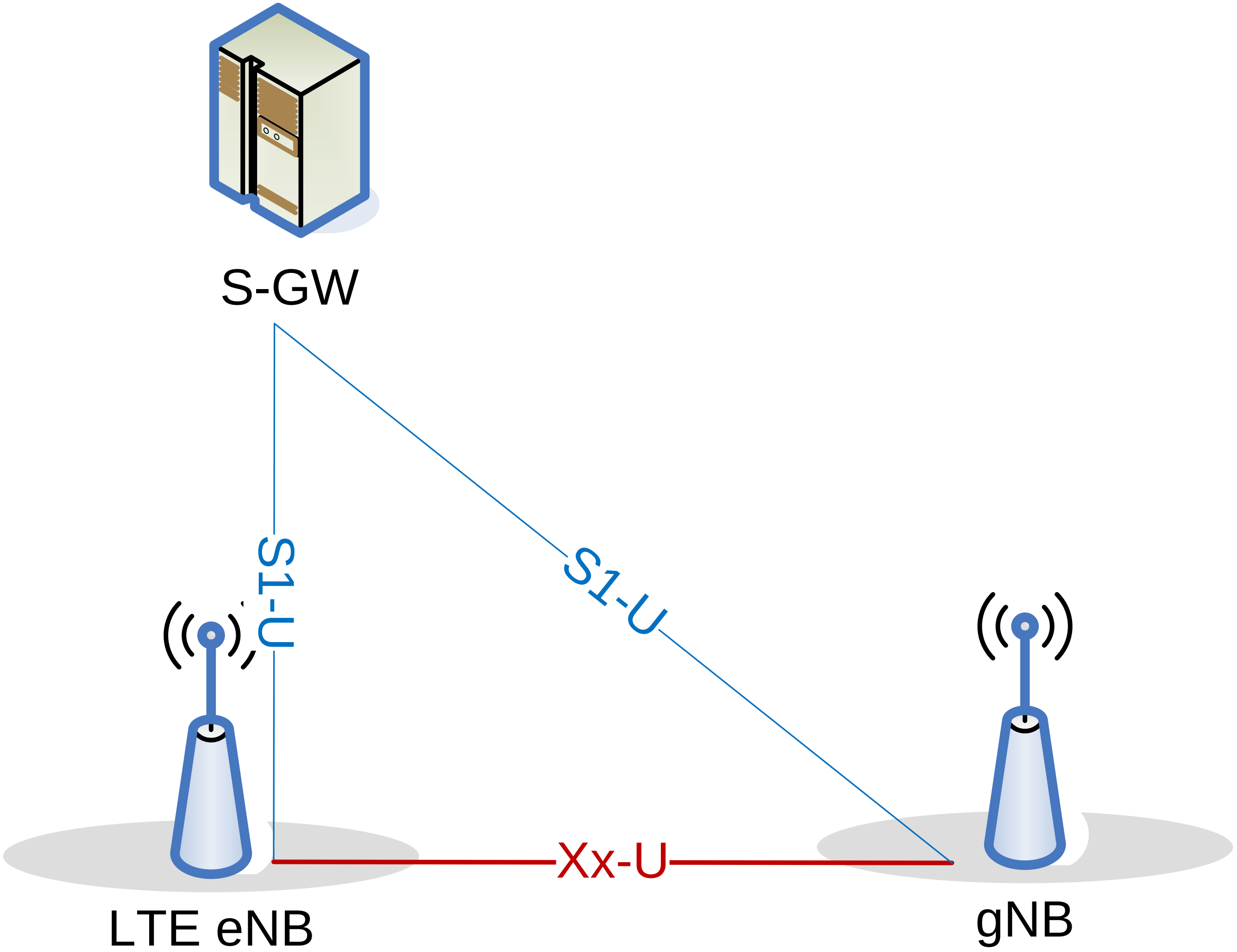
Radio Protocol Architecture for Split Bearer and SCG Bearer in Option 3/3a



C-Plane Connectivity for Option 3/3a/3x



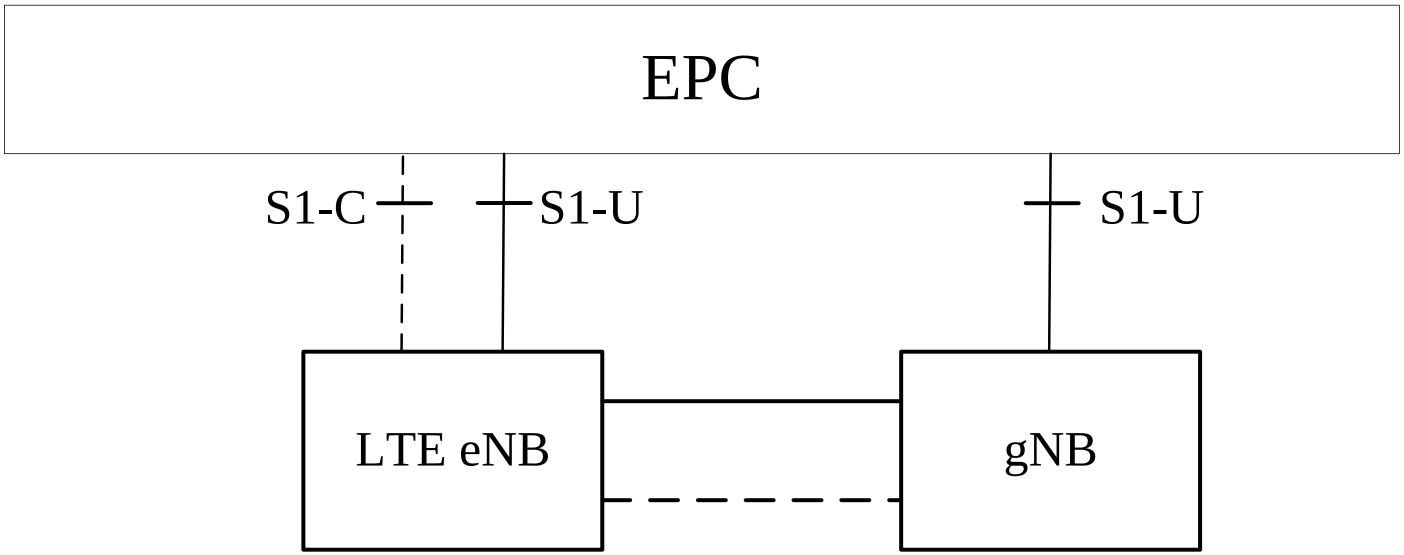
U-Plane Connectivity for Option 3/3a/3x



Procedural Aspects

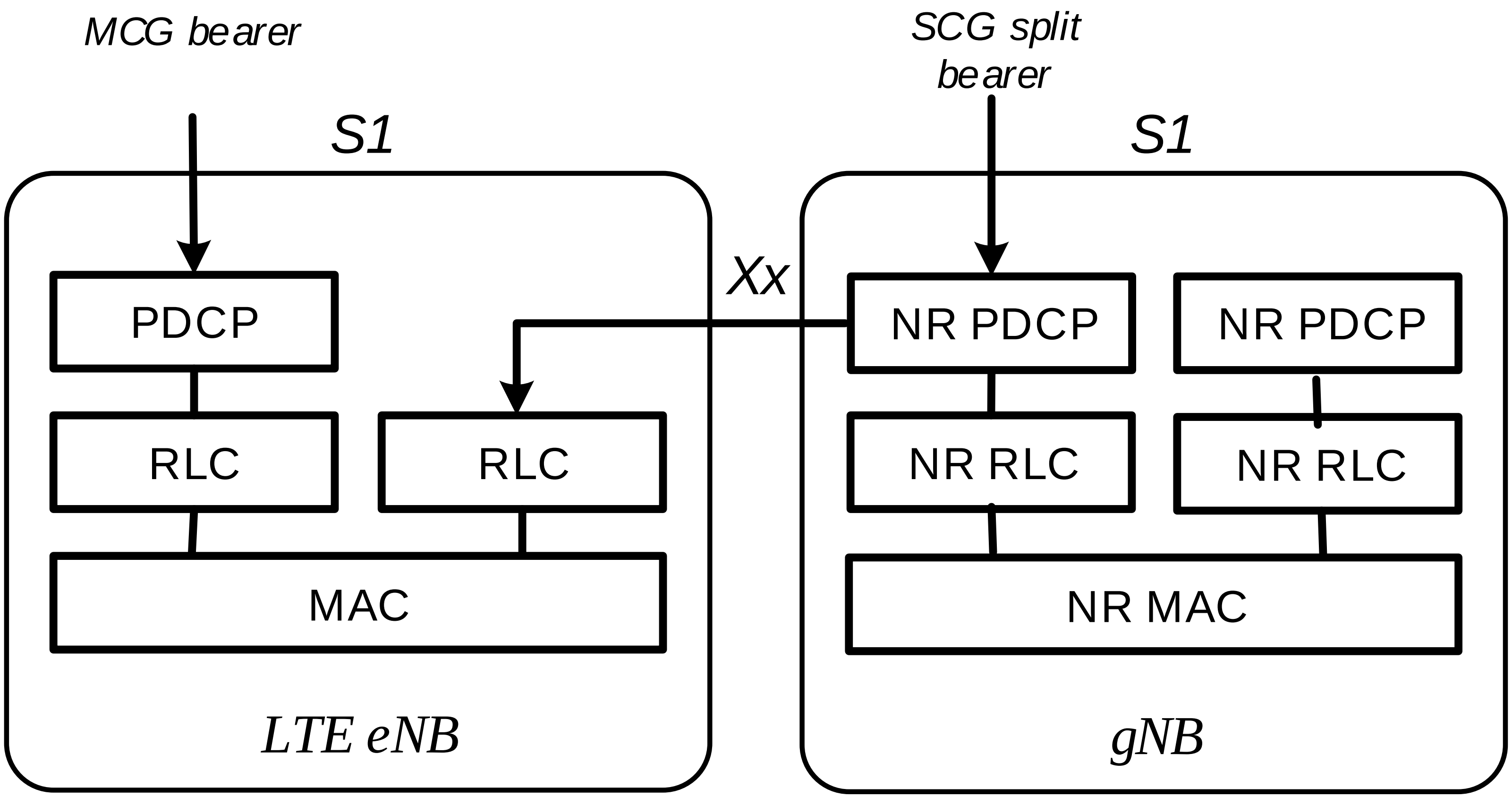
- SeNB Addition
- SeNB Modification (MeNB initiated SeNB Modification)
- SeNB Modification (SeNB initiated SeNB Modification)
- Intra-MeNB handover involving SCG change
- SeNB Release (MeNB initiated SeNB Release)
- SeNB Release (SeNB initiated SeNB Release)
- Change of SeNB
- MeNB to eNB Change
- SCG change
- eNB to MeNB change
- Inter-MeNB handover without SeNB change

Option 3x

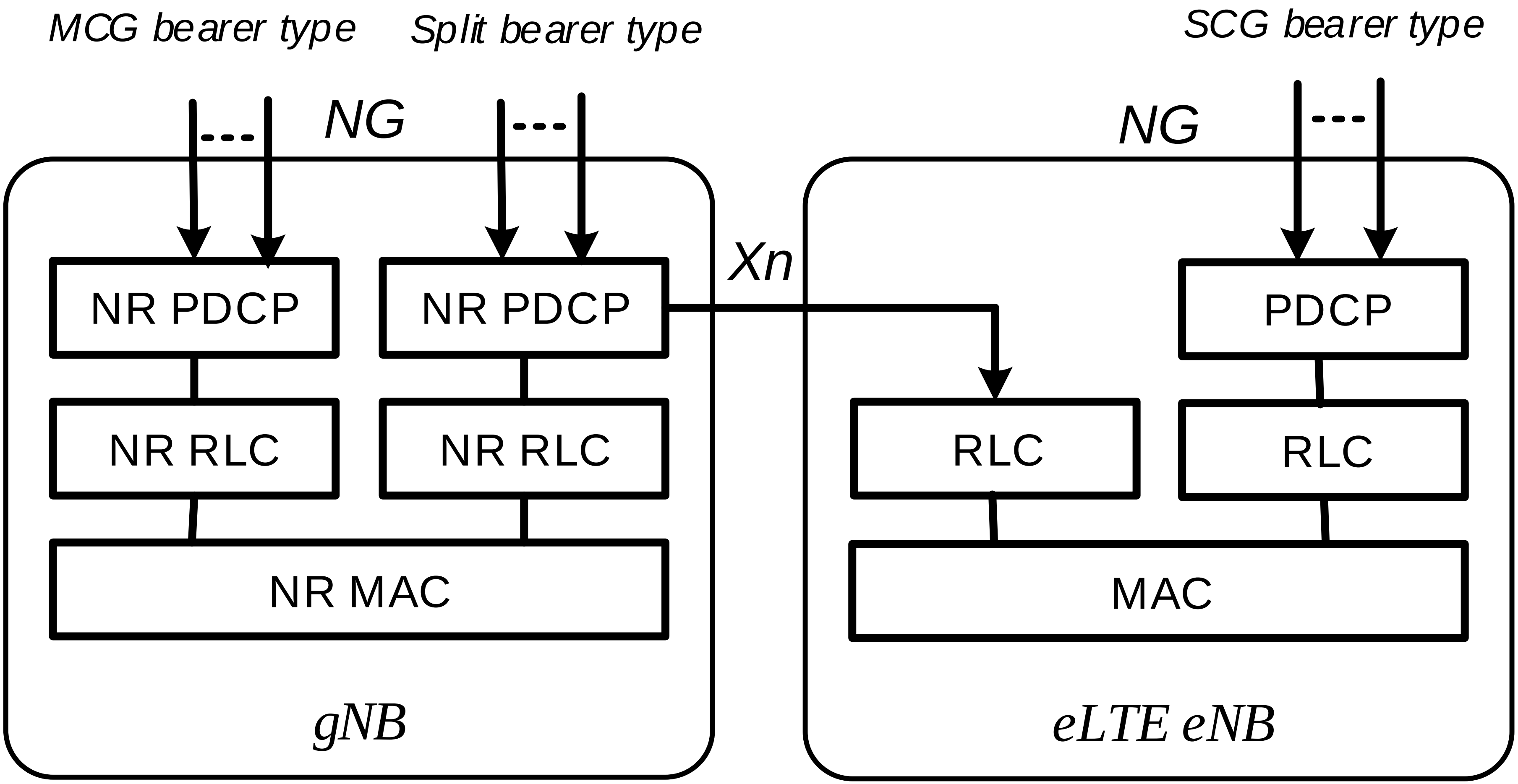


- The solid line shown between LTE eNB and gNB is used for U-plane data transmission terminated at the gNB

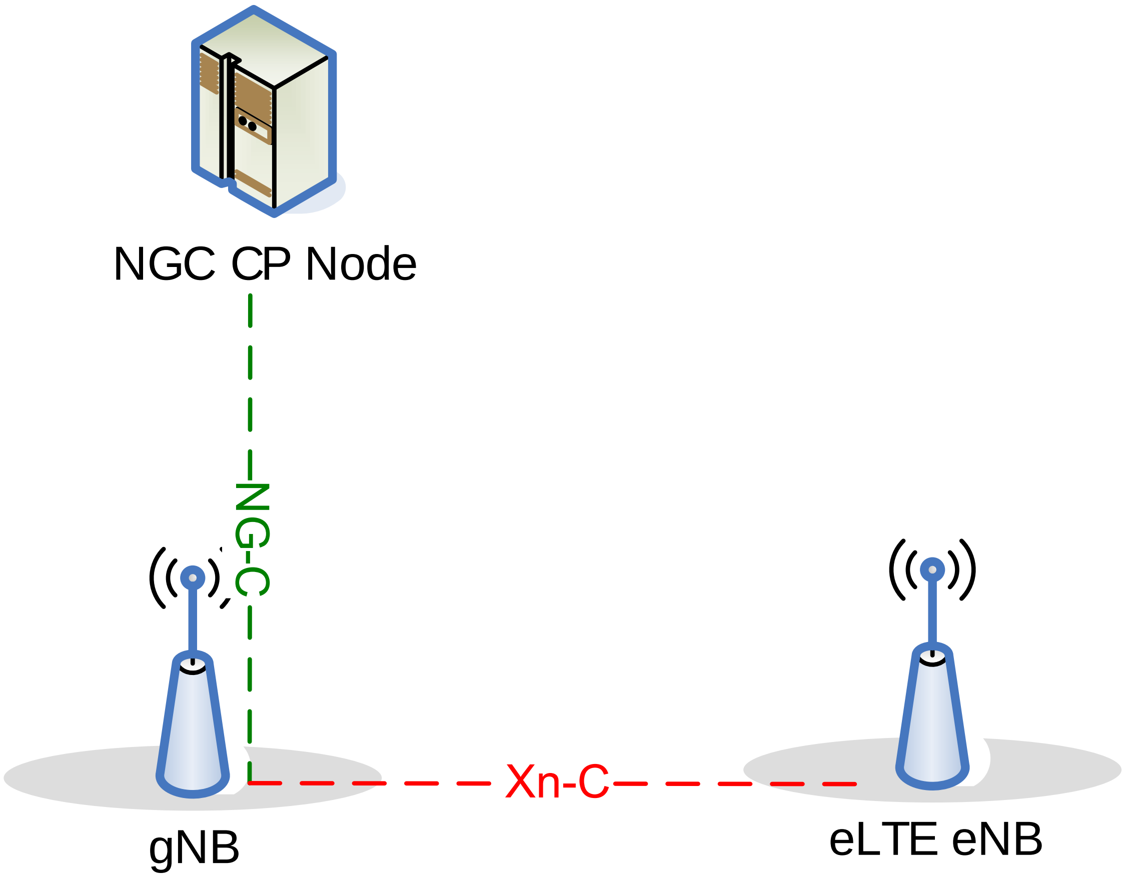
Radio Protocol Architecture for SCG Split Bearer in Option 3x



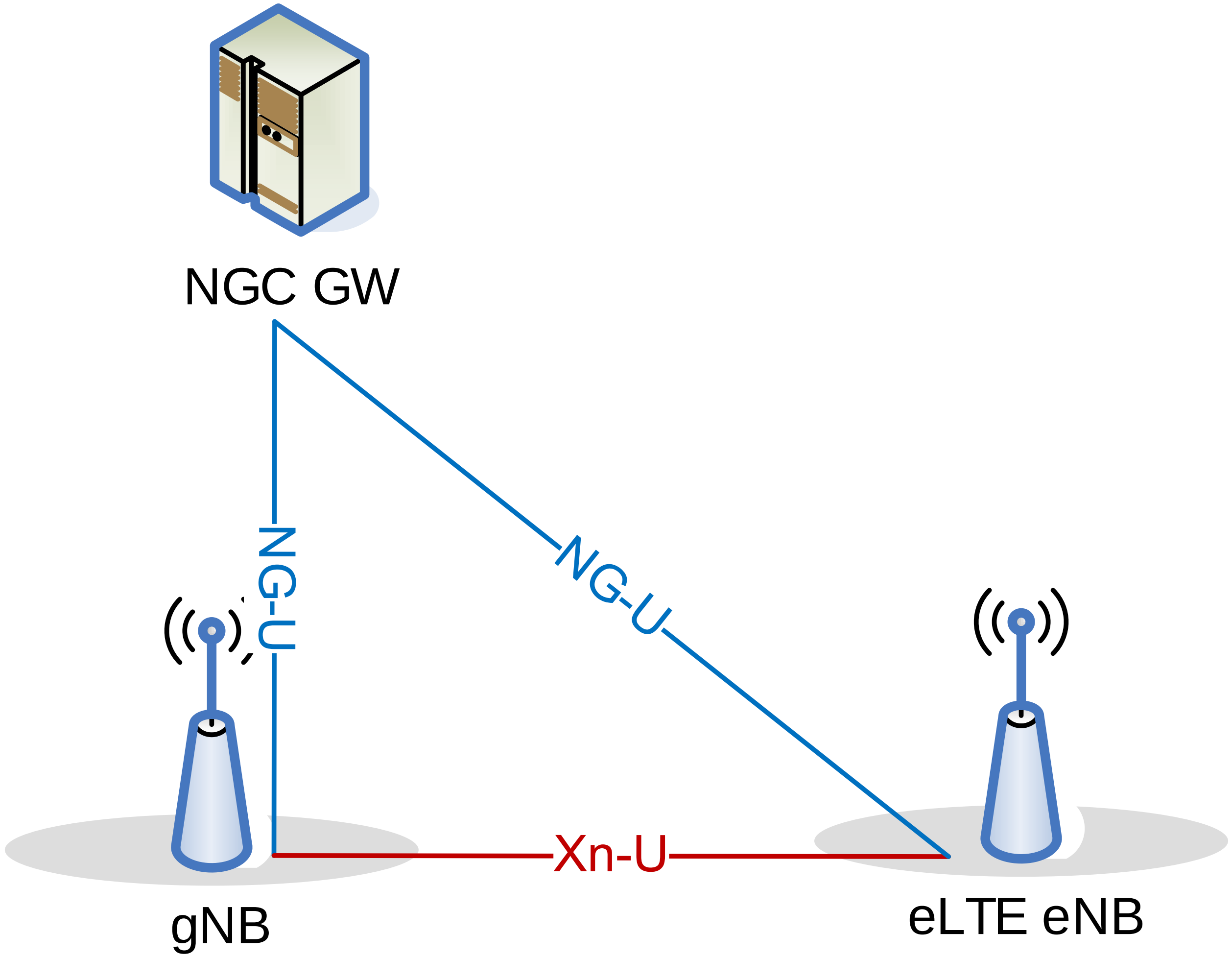
Radio Protocol Architecture for Split Bearer and SCG Bearer in Option 4/4a



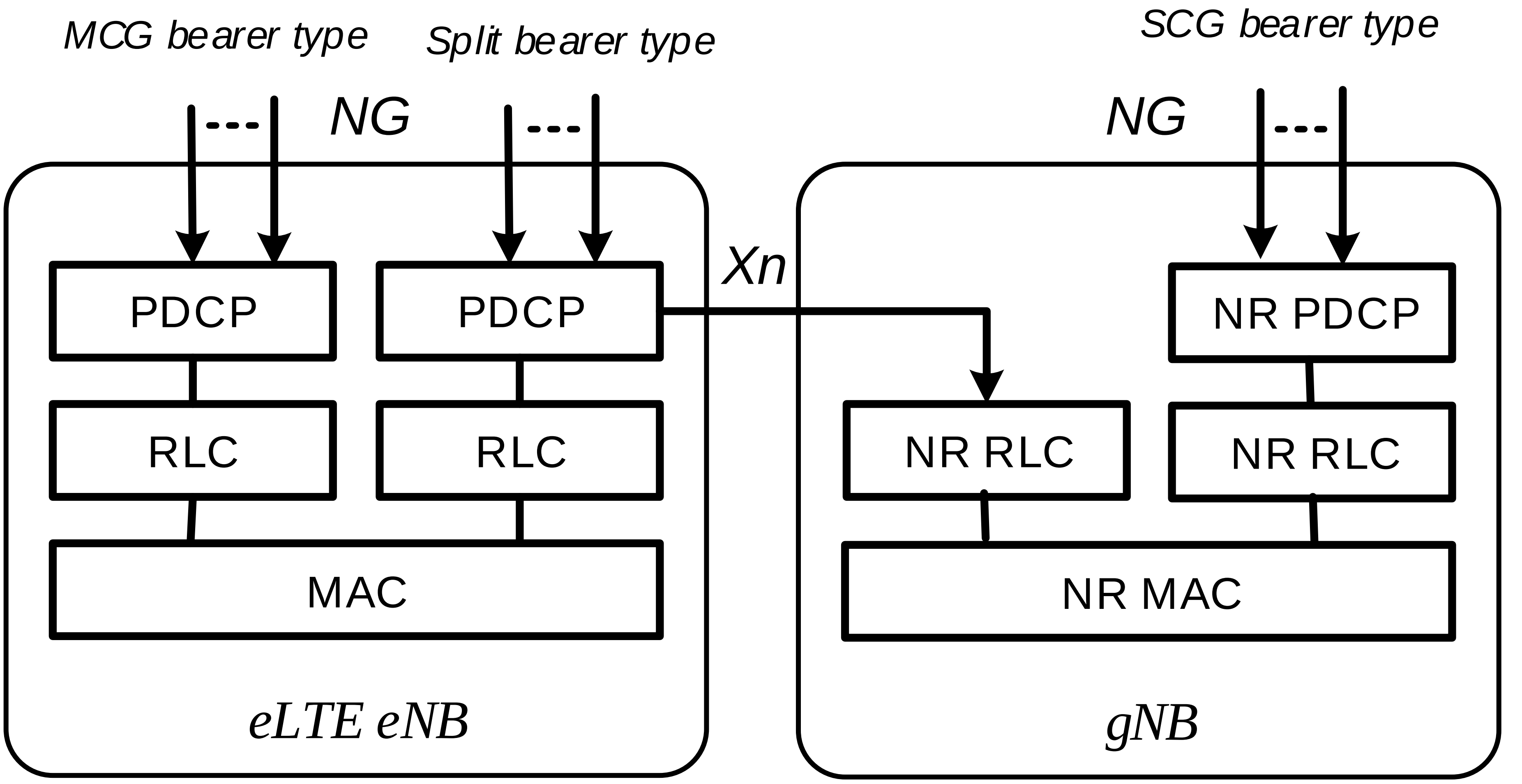
C-Plane Connectivity for Option 4/4a



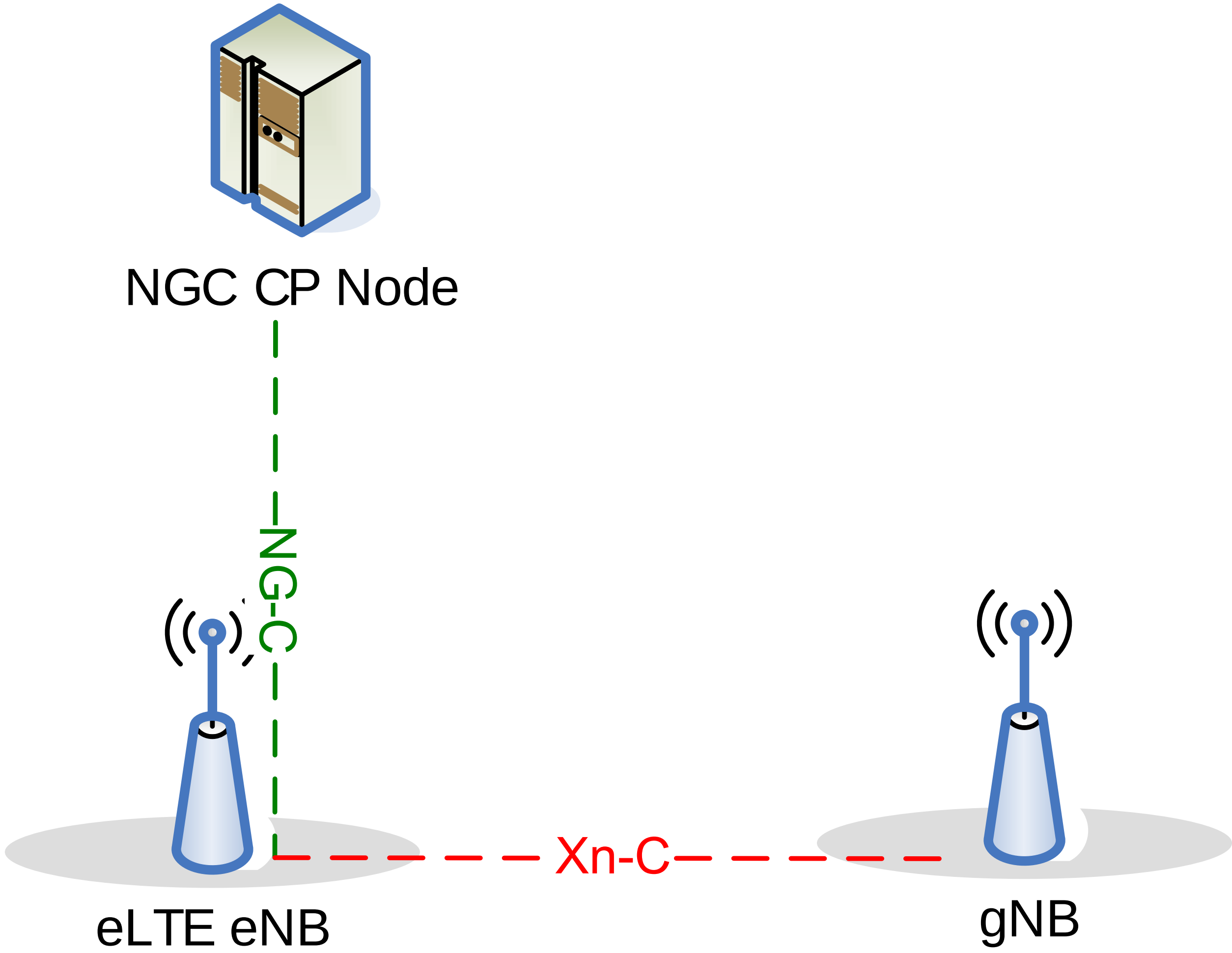
U-Plane Connectivity for Option 4/4a



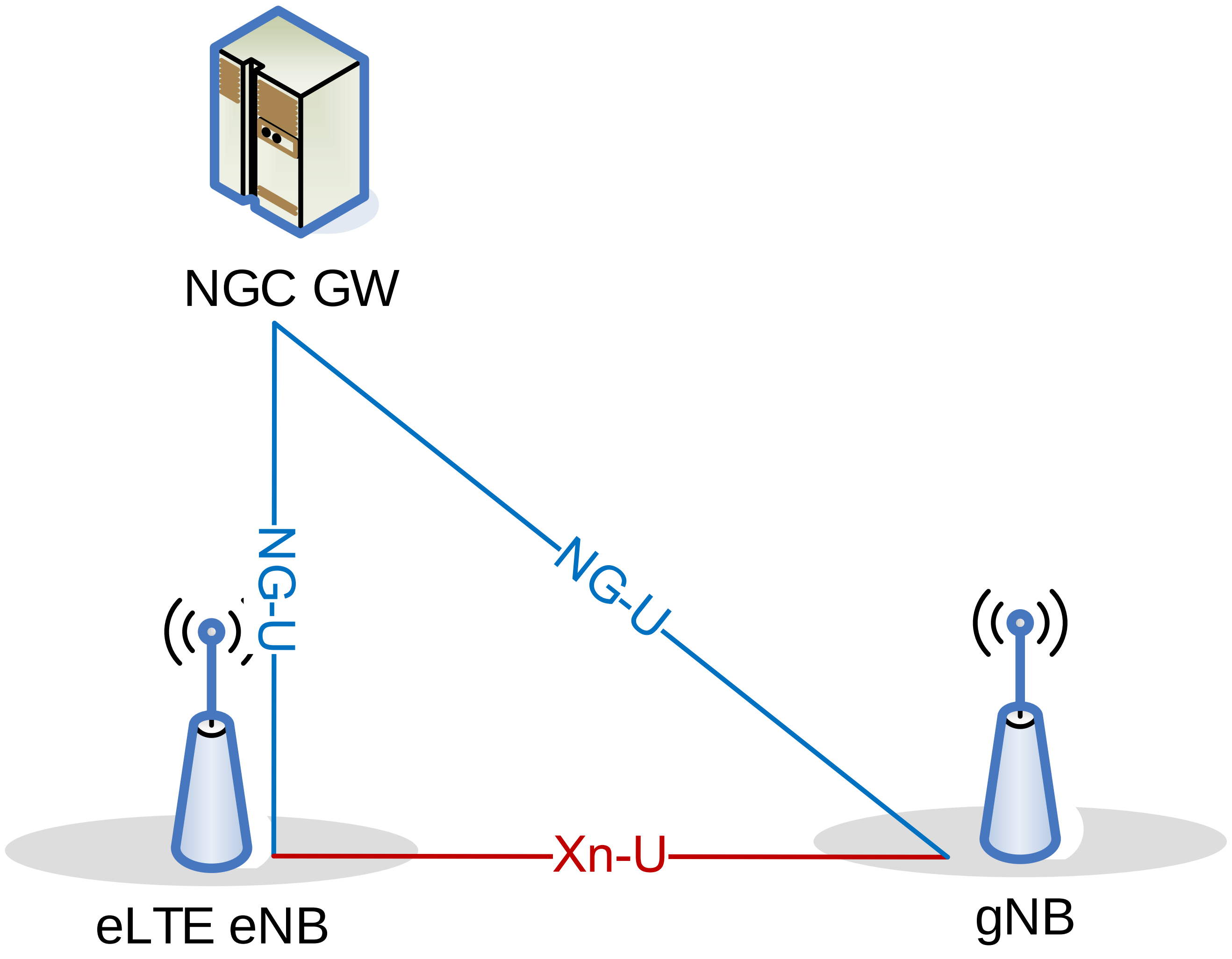
Radio Protocol Architecture for Split Bearer and SCG Bearer in Option 7/7a



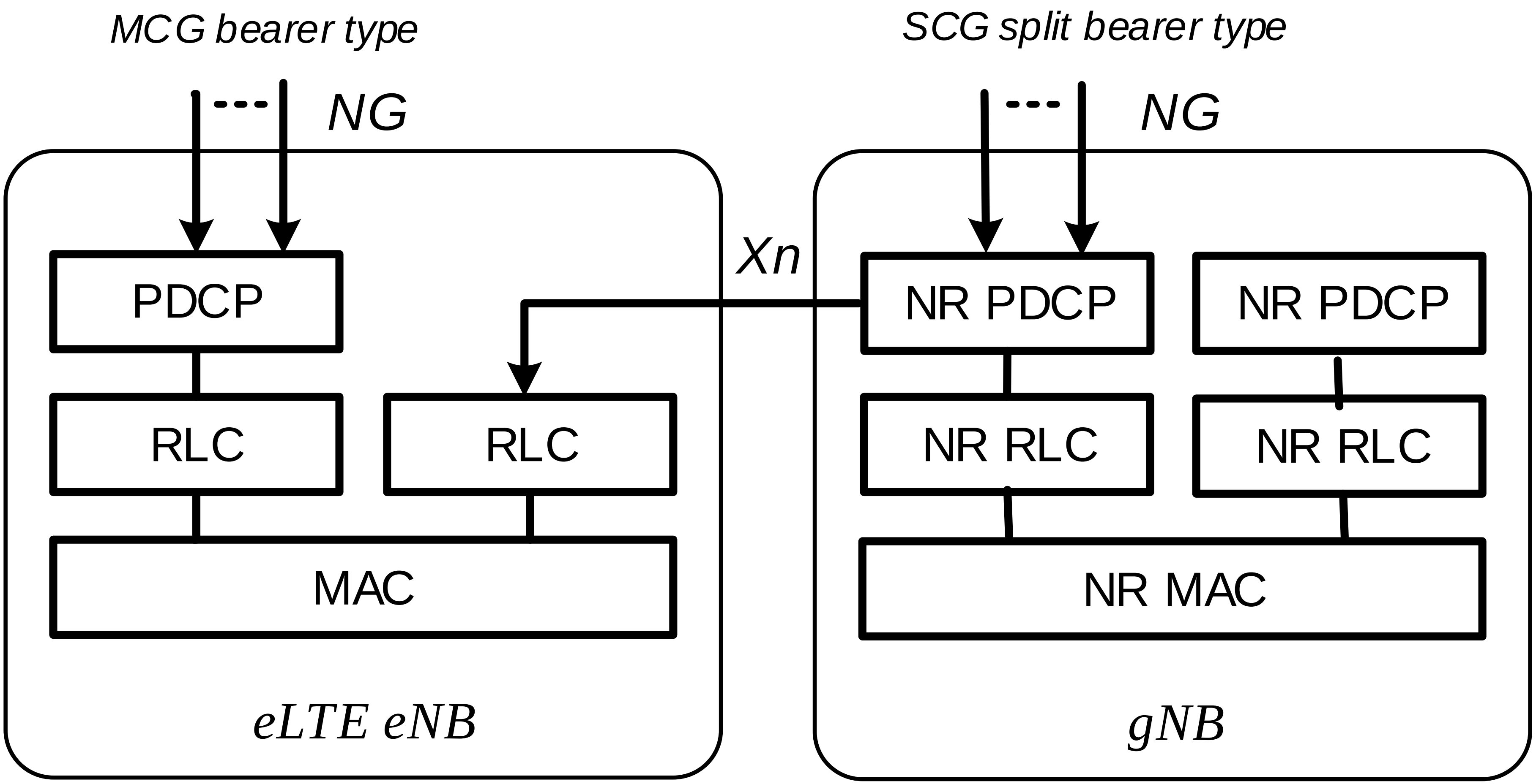
C-Plane Connectivity for Option 7/7a/7x



U-Plane Connectivity for Option 7/7a/7x



Radio Protocol Architecture for SCG Split Bearer in Option 7x



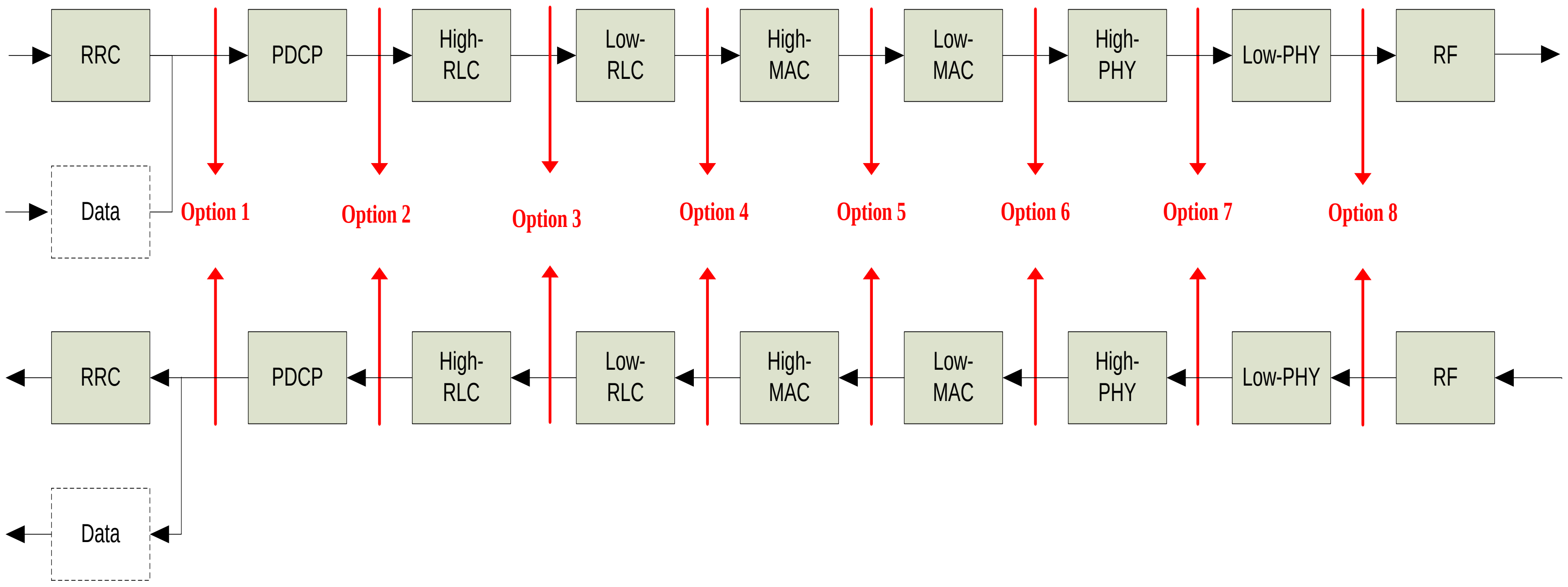
Intra-NR Dual Connectivity

- Unlike NR/LTE Tight Interworking between different RATs, the Intra-NR DC is assumed to be more like legacy LTE DC from RAN3 procedure viewpoint
- The main principles from legacy LTE DC can be inherited by Intra-NR DC with potential enhancement
- The details shall be discussed further in normative phase

RAN Logical Architecture for NR

- Functional split between central and distributed unit
  - General description of split options
  - Detailed Description of Candidate Split Options and Justification
  - Architectural and specification aspects
  - Transport network aspects
- UP-CP Separation
  - General
  - UP and CP Functions Description and Grouping
  - RAN architecture and interfaces for UP-CP Separation
- Realization of RAN Network Functions

Function Split between Central and Distributed Unit



Split Options Description

- Option 1 (1A-like split)
  - The function split in this option is similar as 1A architecture in DC. RRC is in the central unit
- Option 2 (3C-like split)
  - The function split in this option is similar as 3C architecture in DC. RRC, PDCP are in the central unit
- Option 3 (intra RLC split)
  - Low RLC (partial function of RLC), MAC, physical layer and RF are in distributed unit
- Option 4 (RLC-MAC split)
  - MAC, physical layer and RF are in distributed unit
- Option 5 (intra MAC split)
  - RF, physical layer and some part the MAC layer are in the distributed unit. Upper layer is in the central unit
- Option 6 (MAC-PHY split)
  - Physical layer and RF are in the distributed unit
- Option 7 (intra PHY split)
  - Part of physical layer function and RF are in the distributed unit
- Option 8 (PHY-RF split)
  - RF functionality is in the distributed unit and upper layer are in the central unit

Split Option 1

- Description
  - In this split option, RRC is in the central unit. PDCP, RLC, MAC, physical layer and RF are in the distributed unit, thus the entire user plane is in the distributed unit
- Benefits and Justification
  - This option allows a separate U-plane while having a centralised RRC/RRM
  - It may in some circumstances provide benefits in handling some edge computing or low latency use cases where the user data needs to be located close to the transmission point
- Cons
  - Because of the separation of RRC and PDCP, securing the interface in practical deployments may or may not affect performance of this option
  - It needs to be clarified whether and how this option can support aggregation based on alternative 3C

Split Option 2-1

- Description
  - In this split option, RRC, PDCP are in the central unit
- Benefits and Justification
  - This option will allow traffic aggregation from NR and E-UTRA transmission points to be centralized
  - Fundamentals for achieving a PDCP-RLC split have already been standardized for LTE Dual Connectivity

Split Option 2-2

- Description
  - In this split option, RRC, PDCP are in the central unit. RLC, MAC, physical layer and RF are in the distributed unit
- Benefits and Justification
  - This option will allow traffic aggregation from NR and E-UTRA transmission points to be centralized
  - This option enables centralization of the PDCP layer, which may be predominantly affected by UP process and may scale with UP traffic load
  - This option allows a separate U-plane while having a centralised RRC/RRM
- Cons
  - Coordination of security configurations between different PDCP instances for Option 2-2 needs to be ensured.

Option 3-1 Split Based on ARQ

- Description
  - Low RLC may be composed of segmentation functions
  - High RLC may be composed of ARQ and other RLCfunctions
- Benefits and Justification
  - This option will allow traffic aggregation from NR and E-UTRA transmission points to be centralized
  - This split option may also have better flow control across the split
- Cons
  - Comparatively, the split is more latency sensitive than the split with ARQ in DU, since re-transmissions are susceptible to transport network latency over a split transport network

Option 3-2 Split based on TX RLC and RX RLC

- Description
  - Low RLC may be composed of transmitting TM RLC entity, transmitting UM RLC entity, a transmitting side of AM and the routing function of a receiving side of AM, which are related with downlink transmission
- Benefits and Justification
  - This option will allow traffic aggregation from NR and E-UTRA transmission points to be centralized
  - Flow control is in the CU and for that a buffer in the CU is needed
- Cons
  - Compared to the case where RLC is not split, STATUS PDU of AM Rx RLC may lead to additional time delay

Option 4 (RLC-MAC Split)

- Description
  - In this split option, RRC, PDCP and RLC are in the central unit.MAC, physical layer and RF are in the distributed unit
- Benefits and Justification
  - In the context of the LTE protocol stack a benefit is not foreseen for option 4
  - This might be revised with NR protocol stack knowledge

Option 5 (Intra MAC Split)

- Description
  - RF, physical layer and lower part of the MAC layer (Low-MAC) in the Distributed Unit
  - Higher part of the MAC layer (High-MAC), RLC and PDCP in the Central Unit
- Benefits and Justification
  - This option will allow traffic aggregation from NR and E-UTRA transmission points to be centralized
- Cons
  - Complexity of the interface between CU and DU
  - Difficulty in defining scheduling operations over CU and DU

Option 6 (MAC-PHY Split)

- Description
  - The MAC and upper layers are in the central unit (CU)
  - PHY layer and RF are in the DU
- Benefits and Justification
  - This option will allow traffic aggregation from NR and E-UTRA transmission points to be centralized
  - Additionally, it can facilitate the management of traffic load between NR and E-UTRA transmission points
- Cons
  - This split may require subframe-level timing interactions between MAC layer in CU and PHY layers in Dus
  - Round trip fronthaul delay may affect HARQ timing and scheduling

Option 7-1

- Description
  - In the UL, FFT, CP removal and possibly PRACH filtering functions reside in the DU, the rest of PHY functions reside in the CU
  - The details of the meaning of PRACH filtering were not discussed in the study phase
  - In the DL, iFFT and CP addition functions reside in the DU, the rest of PHY functions reside in the CU
- Benefits and Justification
  - Allows the implementation of advanced receivers

Option 7-2

- Description
  - In the UL, FFT, CP removal, resource de-mapping and possibly pre-filtering functions reside in the DU, the rest of PHY functions reside in the CU
  - The details of the meaning of pre-filtering were not discussed in the study phase
  - In the DL, iFFT, CP addition, resource mapping and precoding functions reside in the DU, the rest of PHY functions reside in the CU
  - It is a requirement that both options allow the optimal use of advanced receivers
  - Whether or not these variants meets this requirement was not discussed in the study phase

Option 7-3(Only for DL)

- Description
  - Only the encoder resides in the CU, and the rest of PHY functions reside in the DU
- Benefits and Justification
  - This option is expected to reduce the fronthaul requirements in terms of throughput to the baseband bitrates as the payload for Option 7-3 is encoded data

Option 8 (PHY-RF split)

- Benefits and Justification
  - This option will allow traffic aggregation from NR and E-UTRA transmission points to be centralized
  - Additionally, it can facilitate the management of traffic load between NR and E-UTRA transmission points
  - High levels of centralization and coordination across the whole protocol stack, which may enable a more efficient resource management and radio performance
- Cons
  - High requirements on front-haul latency, which may cause constraints on network deployments with respect to network topology and available transport options

Summary on Characteristics of Different CU-DU Split option

<table>
<tr><th></th><th>Opt. 1</th><th>Opt. 2</th><th>Opt. 3-2</th><th>Opt. 3-1</th><th>Opt. 5</th><th>Opt. 6</th><th>Opt. 7-3 (only for DL)</th><th>Opt. 7-2</th><th>Opt. 7-1</th><th>Opt. 8</th></tr>
<tr><td>Baseline available</td><td>No</td><td>Yes (LTE DC)</td><td colspan="7">No</td><td>Yes (CPRI)</td></tr>
<tr><td>Traffic aggregation</td><td>No</td><td colspan="9">Yes</td></tr>
<tr><td>ARQ location</td><td colspan="3">DU</td><td colspan="7">CU
May be more robust under non-ideal transport conditions</td></tr>
<tr><td rowspan="2">Resource pooling in CU</td><td>Lowest</td><td colspan="8">in between (higher on the right)</td><td>Highest</td></tr>
<tr><td>RRC only</td><td colspan="4">RRC + L2 (partial)</td><td>RRC + L2</td><td colspan="3">RRC + L2 + PHY (partial)</td><td>RRC + L2 + PHY</td></tr>
<tr><td>Transport NW latency requirement</td><td colspan="4">Loose</td><td>NOTE 7</td><td colspan="5">Tight</td></tr>
<tr><td rowspan="3">Transport NW Peak BW requirement</td><td>N/A</td><td>Lowest</td><td colspan="7">in between (higher on the right)</td><td>Highest</td></tr>
<tr><td>No UP req.</td><td colspan="6">baseband bits</td><td colspan="2">Quantized IQ (f)</td><td>Quant. IQ (t)</td></tr>
<tr><td>-</td><td colspan="7">Scales with MIMO layers</td><td colspan="2">Scales with antenna ports</td></tr>
<tr><td>Multi-cell/freq. coordination</td><td colspan="4">multiple schedulers
(independent per DU)</td><td colspan="6">centralized scheduler
(can be common per CU)</td></tr>
<tr><td>UL Adv. Rx</td><td colspan="6">NOTE 7</td><td>NA</td><td>NOTE 7</td><td colspan="2">Yes</td></tr>
<tr><td>Remarks</td><td>NOTE 4</td><td></td><td></td><td></td><td>NOTE 5/6</td><td>NOTE 5</td><td>NOTE 5</td><td>NOTE 5</td><td></td><td></td></tr>
</table>

Number of Split options to be Specified and Supported by Open Interface

- There are transport networks with performances that vary from high transport latency to low transport latency in the real deployment
- 3GPP specifications should try to cater for these types of transport networks
- For transport network with higher transport latency, higher layer splits may be applicable
- For transport network with lower transport latency, lower layer splits can also be applicable and preferable to realize enhanced performance

Implications of LTE/NR Tight Interworking

- LTE <-> NR interworking is mainly based on Dual-Connectivity-like mechanisms
- Such approach does not imply any particular functional split
- The requirement that could be extrapolated by the LTE-NR tight interworking requirement is that of allowing aggregation of PDCP functionalities, in case of split bearers

Granularity of the Functional Split

- Per CU: each CU has a fixed split, and DUs are configured to match this
- Per DU: each DU can be configured with a different split
- Per UE: different UEs may have different service levels, or belong to different categories, that may be best served in different ways by the RAN
- Per bearer: different bearers may have different QOS requirements that may be best supported by different functionality mapping
- Per slice: it is expected that each slice would have at least some distinctive QOS requirements

Reconfiguration Dynamicity of the Functional Split

- Dynamicity implies that the protocol distribution and the interface between the CU and DU need to be reconfigured
- If the switching only occur in CU-DU setup procedure, the interface design will not be influenced largely as the split option will not be changed during operation
- If the switching occurs during operation, there will be impact on complexity of interface

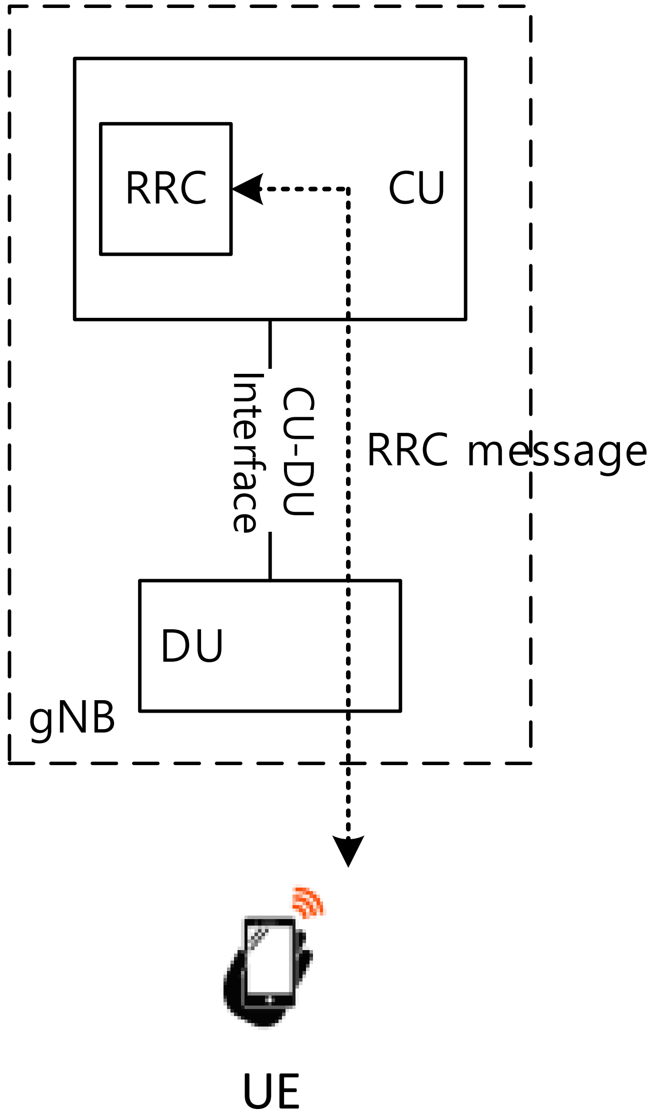
Standardization of Centralized RRM Functions

- Most if not all of the defined functional splits allow for having RRM functions like Call Admission Control and Load balancing in the CU controlling multiple DUs
- However that efficiency can only be realized if the CU can have reliable and accurate understanding of the current environment at the DU which can include issues beyond just radio conditions

Standardization Issues with Centralized Scheduling Options

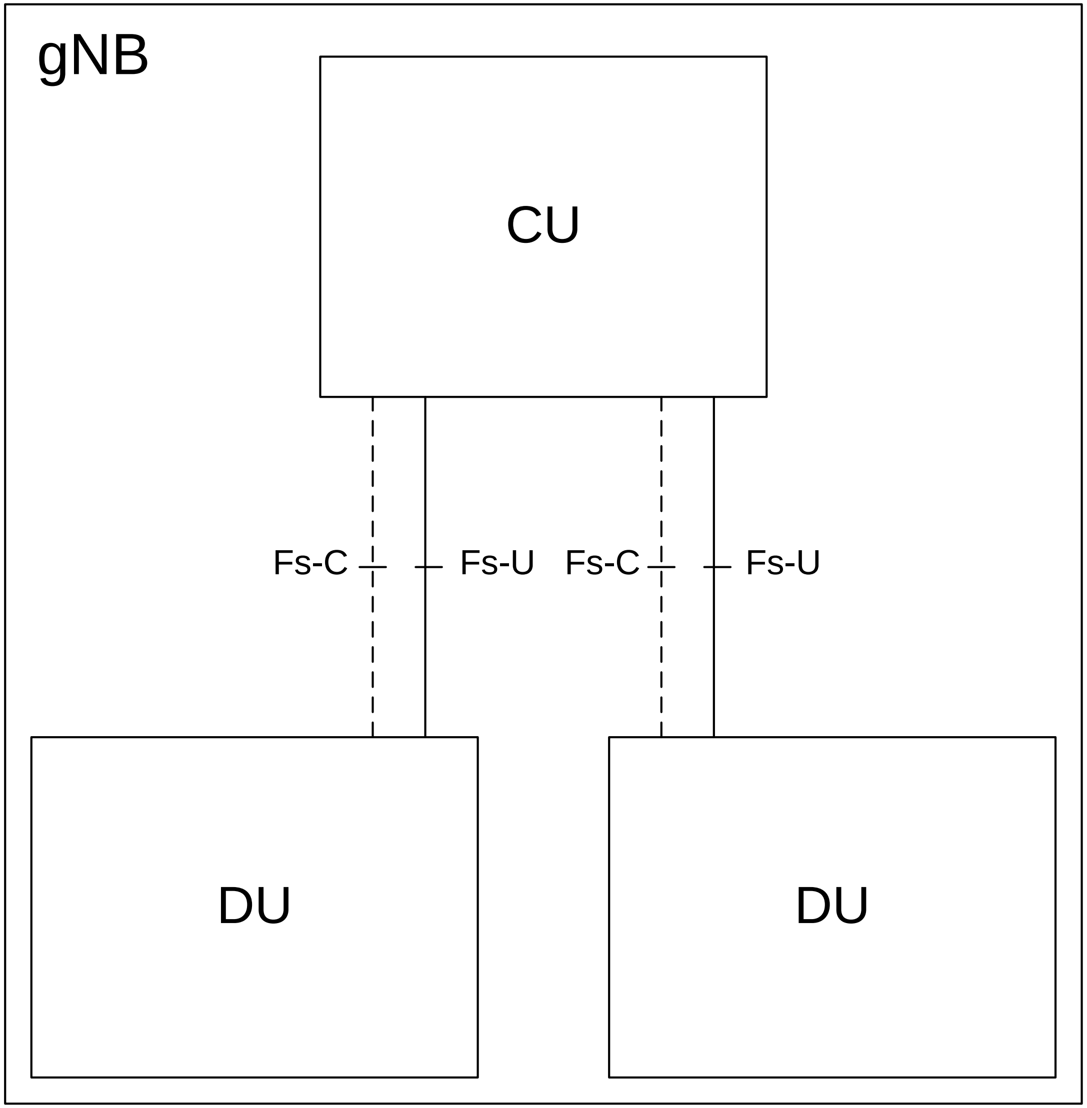
- Functional split Option 5, Option 6, Option 7 and Option 8 allow for scheduling of data transmission in the CU
- Having centralized scheduling can provide benefit particularly for interference management and coordinated transmission in multiple cells
- It also requires either very low latency/jitter transport or sufficiently tight coordination of timing and reception of user plane data

Transmission of RRC Message Between the CU and the UE via the DU



- The RRC related functions should be located in the CU for all functional split options
- The RRC message between the gNB and the UE should be transferred through the interface between the CU and the DU

gNB Architecture with CU and DUs



Max Required Bit-rate on a Transmission Link

Number of Antenna Ports	Frequency System Bandwidth			
	10 MHz	20 MHz	200 MHz	1GHz
2	1Gbps	2Gbps	20Gbps	100Gbps
8	4Gbps	8Gbps	80Gbps	400Gbps
64	32Gbps	64Gbps	640Gbps	3200Gbps
256	128Gbps	256Gbps	2560Gbps	12800Gbps

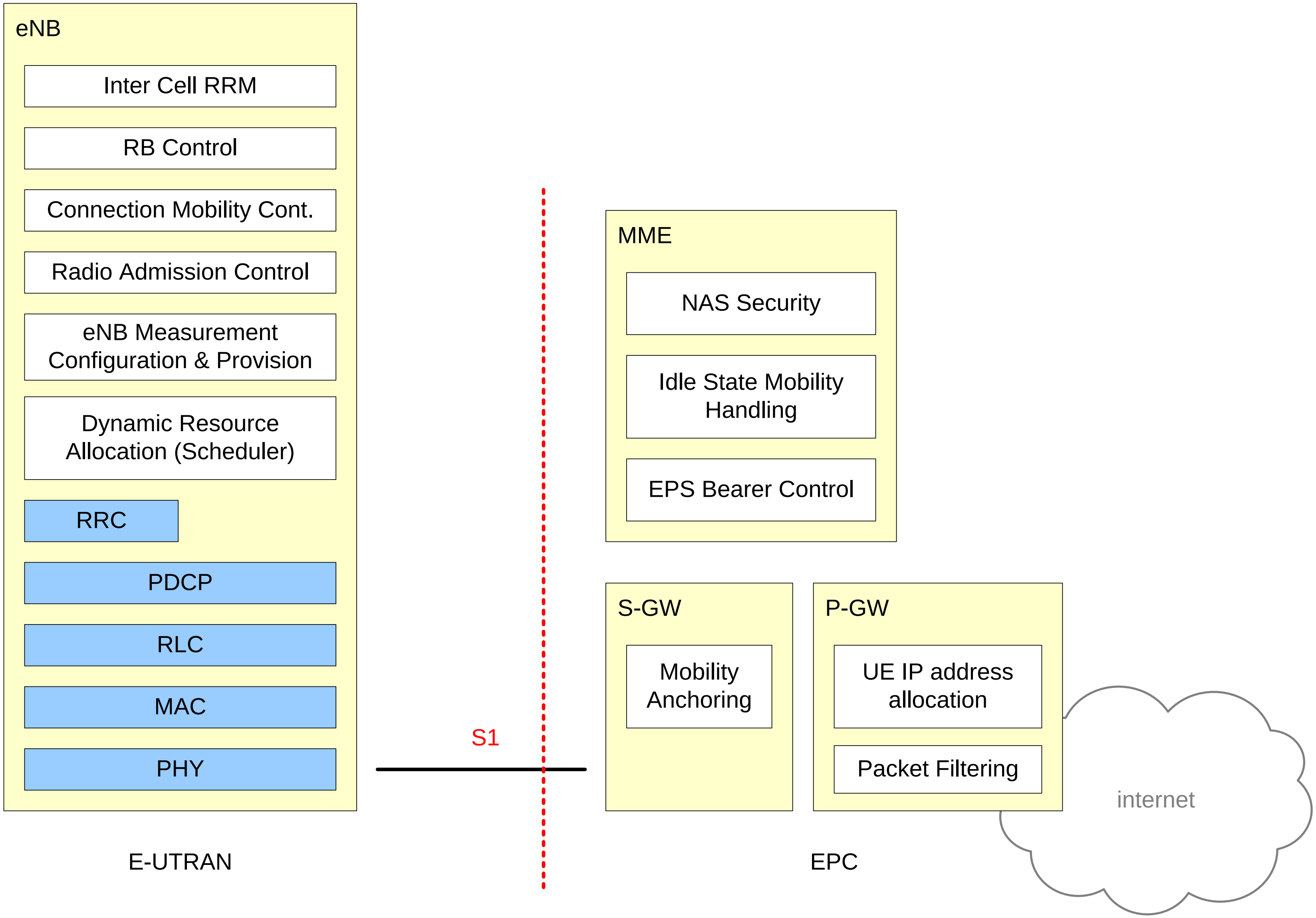
Conclusions on Functional Split

- Higher Layer Split
  - There shall be normative work for a single higher layer split option, i.e. Stage 2 and Stage3
  - In the meantime, if other decisions cannot be made, RAN3 recommends to progress on Option 2 for high layer RAN architecture split
- Lower Layer Split
  - The study on lower layer split RAN architectures is not completed and postponed
  - Further study is required to assess on low layer splits, their feasibility, the selection of options and assess the relative technical benefits

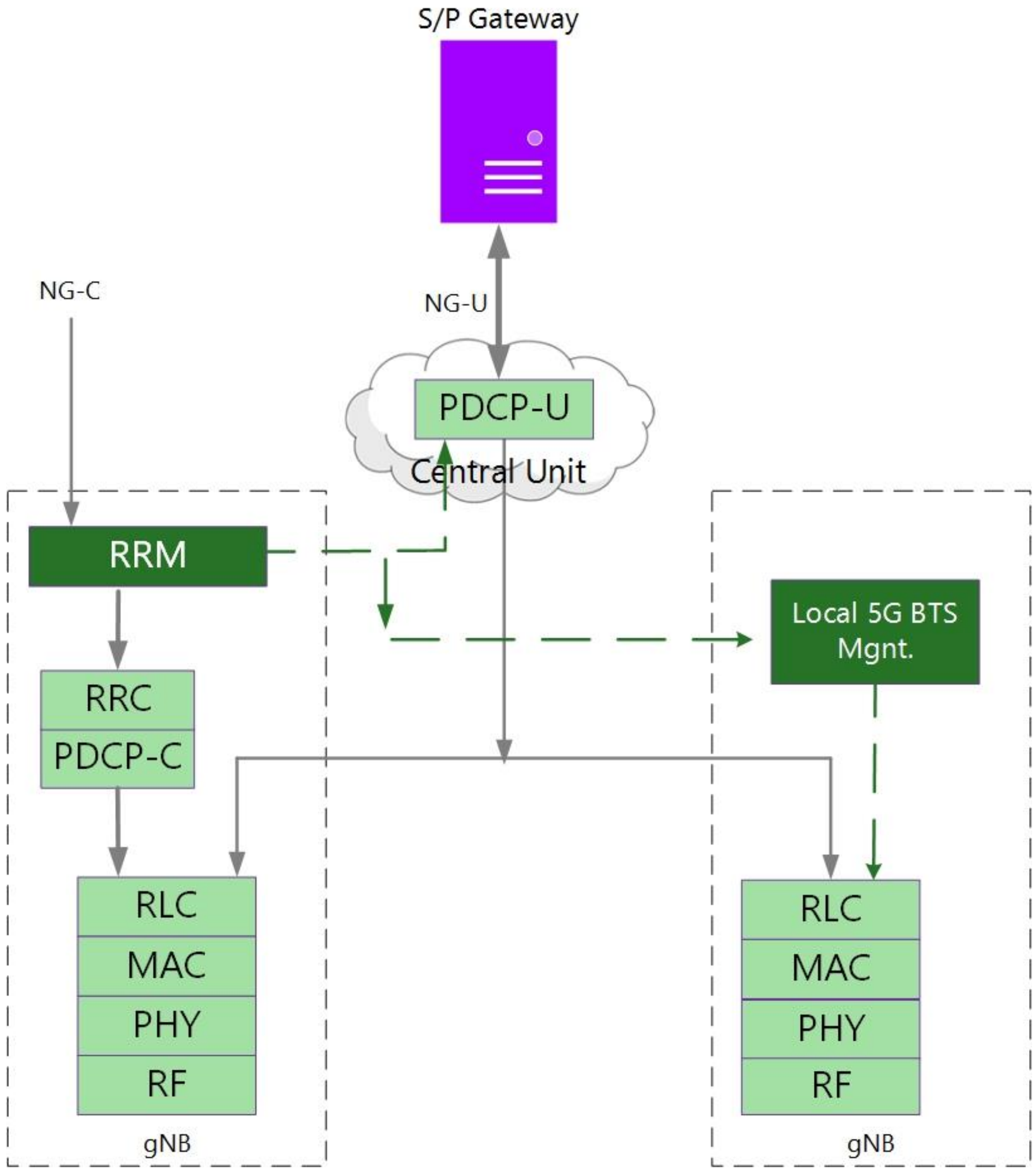
UP-CP Separation General

- A centralization of CP functions, controlling different transmission points, has the potential to achieve enhanced radio performance
- Flexibility to operate and manage complex networks, supporting different network topologies, resources and new service requirements
- Alignment with SDN concept that would result in a functional decomposition of the radio access, based on a partial de-coupled architecture, between user and control plane entities and on network abstractions
- For functions purely handling with CP or UP processes, independent scaling and realization for control and user plane functions operation
- Support of multi-vendor interoperability

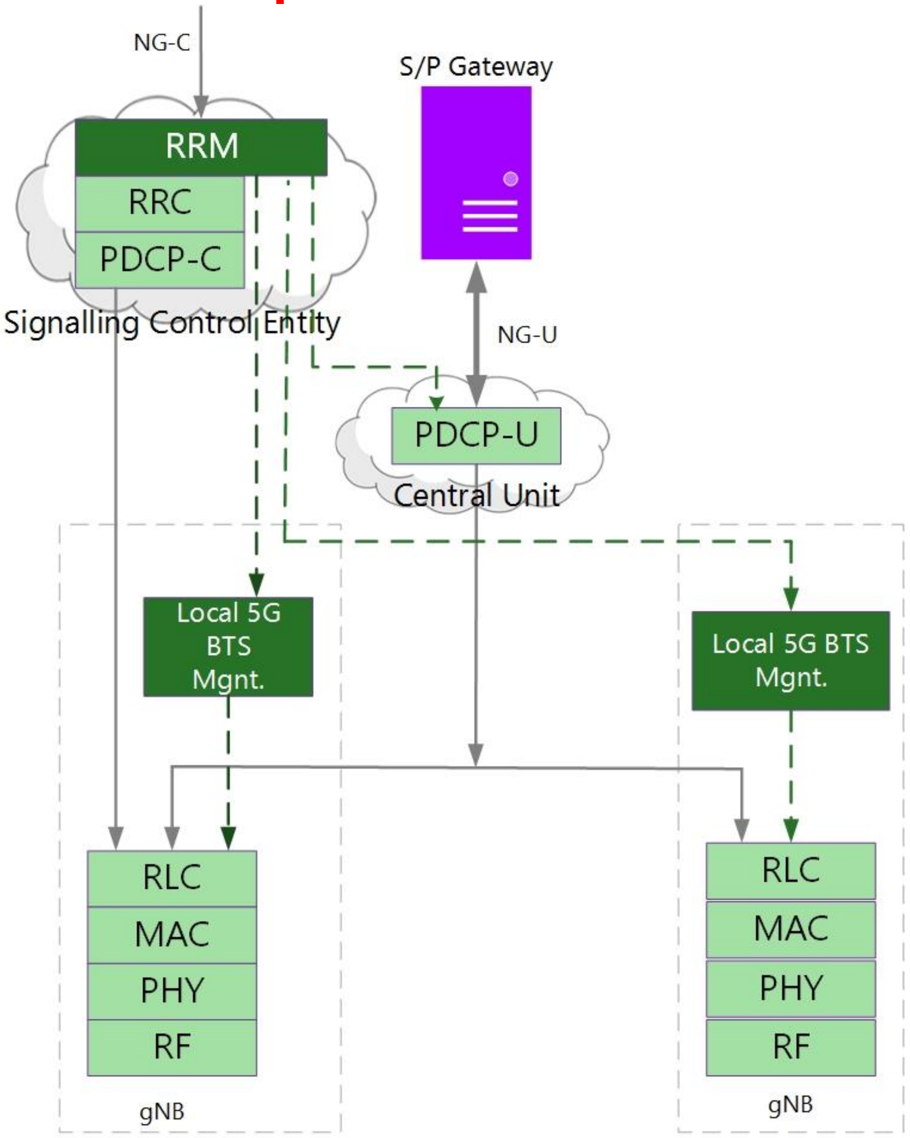
Function Split between E-UTRAN and EPC



Centralised PDCP-U with Local RRM



Centralised PDCP with Centralised RRM in Separate Platforms



Summary

- Several options of 5G System Architecture
  - Non Standalone (NSA)
  - Standalone (SA)
- NG-RAN: New RAN for 5G
  - Directly connected to the same network core
  - Dual connectivity
- Radio Access Architecture and Interfaces
  - Deployment Scenarios
  - RAN Architecture and Interfaces
  - Radio Access Network Procedures
  - RAN Logical Architecture for NR