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4
Dual Connectivity (DC)技術

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Outline

- Support for Dual Connectivity
  - Radio Protocol Architecture
  - Network Interfaces
- Enhancement of Dual Connectivity
  - Requirements and Functionality
  - Location Reporting Enhancement
  - Handover Enhancement
  - Other Enhancement or Optimization

Reference:

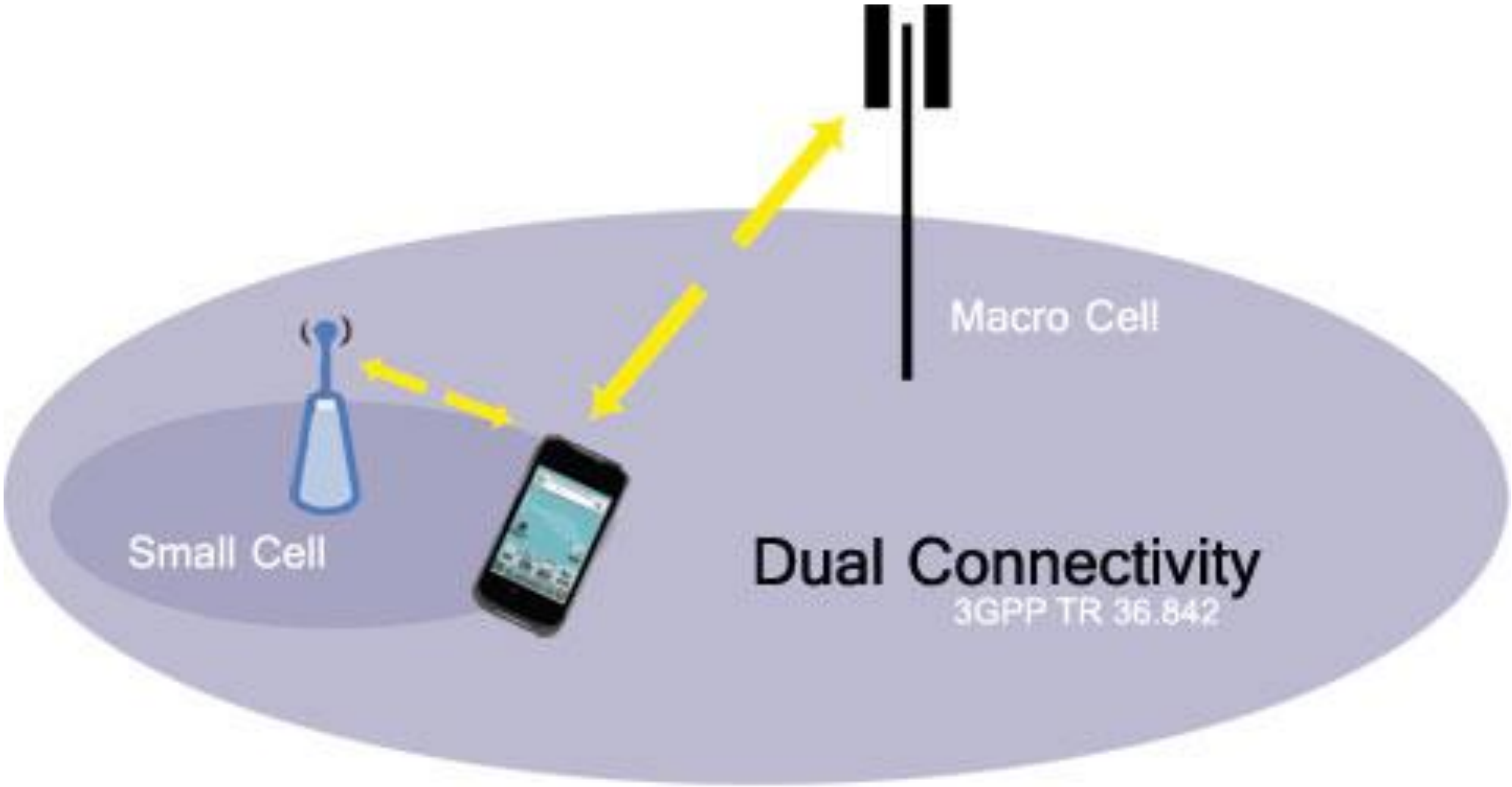
- TS 36.300: E-UTRAN Overall description; Stage 2
- TR 36.875: E-UTRAN Extension of dual connectivity in E-UTRAN

E-UTRAN Dual Connectivity

- E-UTRAN supports Dual Connectivity (DC) operation whereby a multiple Rx/Tx UE in RRC_CONNECTED is configured to utilise radio resources provided by two distinct schedulers
  - Located in two eNBs connected via a non-ideal backhaul over the X2 interface (see TR 36.842 and TR 36.932)
- The overall E-UTRAN architecture as specified in clause 4 is applicable for DC as well
  - eNBs involved in DC for a certain UE may assume two different roles
    - An eNB may either act as an MeNB or as an SeNB
  - In DC a UE is connected to one MeNB and one SeNB

- Dual connectivity between E-UTRAN and NR is specified in TS 37.340

Example: HetNet Dual Connectivity

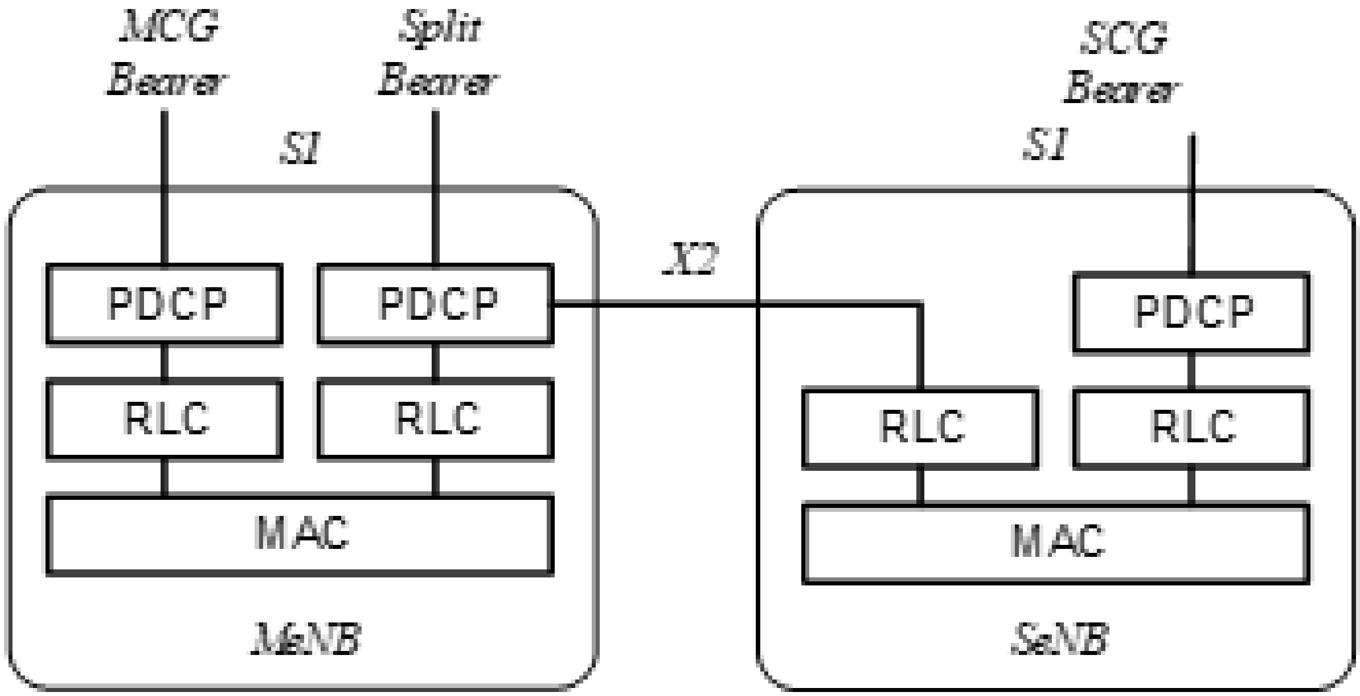


- Simultaneous connection to the macro and low-power layer

DC Radio Protocol Architecture

- In DC, the radio protocol architecture that a particular bearer uses depends on how the bearer is setup
- Three bearer types exist
  - MCG bearer
  - SCG bearer
  - Split bearer
- RRC is located in MeNB and SRBs are always configured as MCG bearer type and therefore only use the radio resources of the MeNB

Radio Protocol Architecture for Dual Connectivity

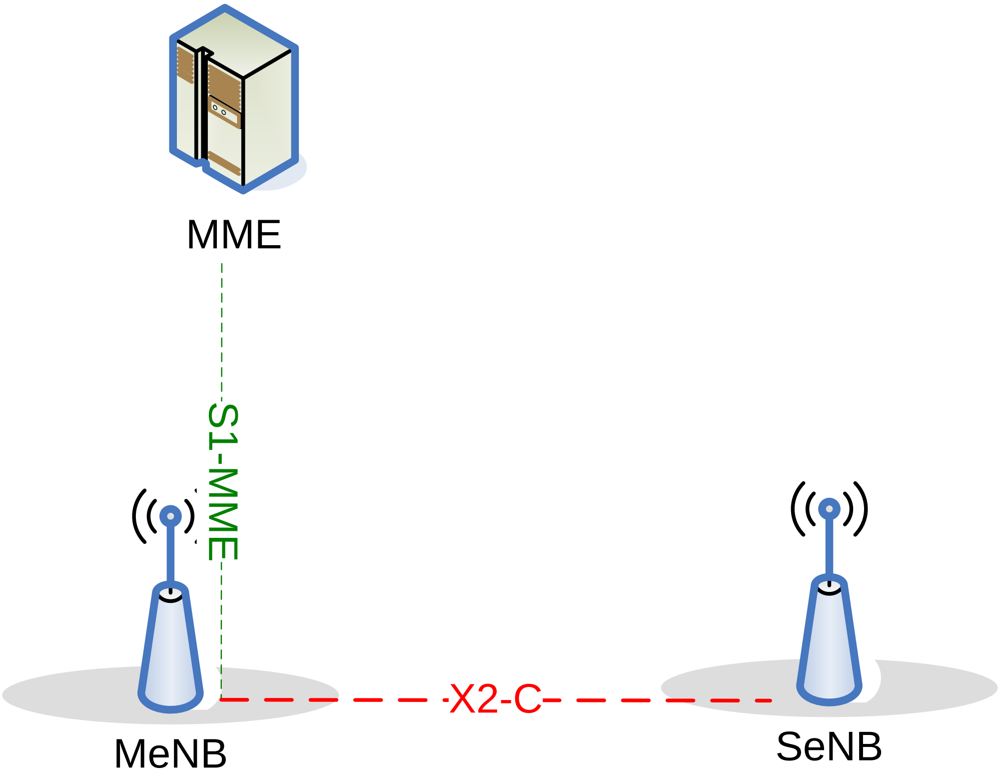


- DC can also be described as having at least one bearer configured to use radio resources provided by the SeNB

E-UTRAN Control Plane for Dual Connectivity

- Inter-eNB control plane signalling for DC is performed by means of X2 interface signaling
  - Control plane signalling towards the MME is performed by means of S1 interface signalling
- There is only one S1-MME connection per DC UE between the MeNB and the MME
  - Each eNB should be able to handle UEs independently, i.e. provide the PCell to some UEs while providing SCell(s) for SCG to others
  - Each eNB involved in DC for a certain UE controls its radio resources and is primarily responsible for allocating radio resources of its cells
  - Respective coordination between MeNB and SeNB is performed by means of X2 interface signalling

C-Plane Connectivity of eNBs Involved in Dual Connectivity



- The S1-MME is terminated in MeNB and the MeNB and the SeNB are interconnected via X2-C

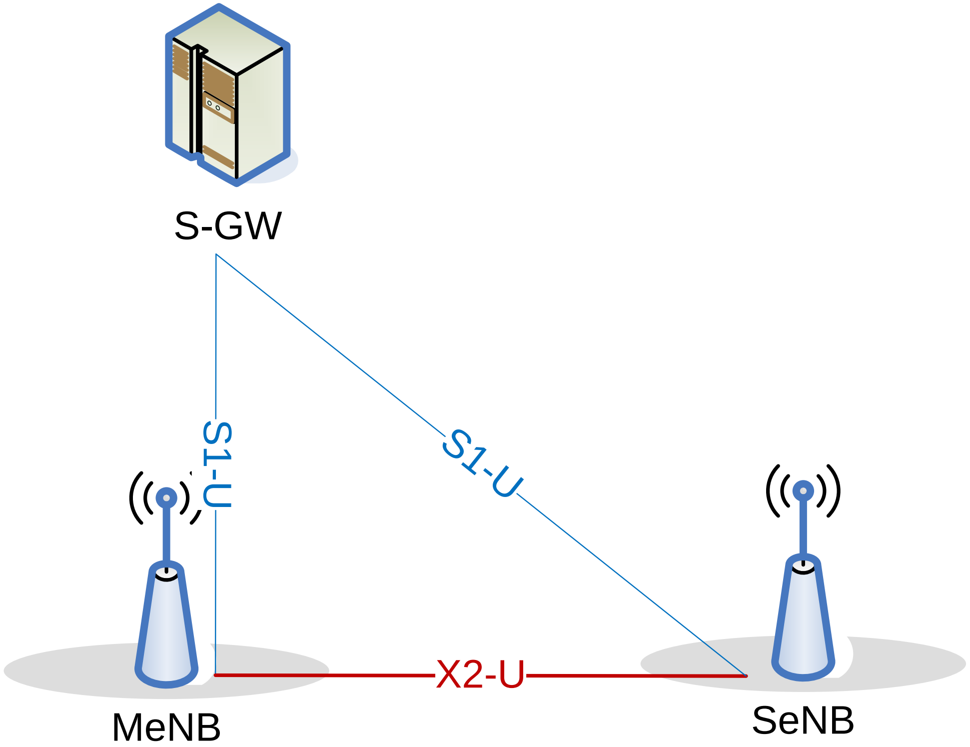
E-UTRAN User Plane for Dual Connectivity

- For dual connectivity 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
  - A second architecture where the S1-U can terminate in the SeNB

Different Bearer Options

- U-plane connectivity depends on the bearer option configured
  - For MCG bearers, the S1-U connection for the corresponding bearer(s) to the S-GW is terminated in the MeNB
    - The SeNB is not involved in the transport of user plane data for this type of bearer(s) over the Uu
  - For split bearers, the S1-U connection to the S-GW is terminated in the MeNB
    - PDCP data is transferred between the MeNB and the SeNB via X2-U
    - The SeNB and MeNB are involved in transmitting data of this bearer type over the Uu.
  - For SCG bearers, the SeNB is directly connected with the S-GW via S1-U
    - The MeNB is not involved in the transport of user plane data for this type of bearer(s) over the Uu

U-Plane Connectivity of eNBs Involved in Dual Connectivity



- If only MCG and split bearers are configured, there is no S1-U termination in the SeNB

Support of HeNBs for Dual Connectivity

- Support of HeNBs for Dual Connectivity

MeNB	SeNB
eNB	open access HeNB
eNB	hybrid access HeNB

- Membership Verification for the hybrid access HeNB is performed between the MeNB and the MME and is based on membership status information reported by the UE and the CSG ID
- The MeNB may re-use the result of the membership verification performed for the first HeNB
  - In case the UE has been admitted with SCG resources configured with the split bearer option from a hybrid HeNB and
  - a SeNB Change is performed within the coverage area of the MeNB towards another hybrid HeNB which has the same CSG ID as the first one

Membership Verification

- If the cell served by the SeNB is a shared hybrid cell
  - The UE reports the subset of the broadcasted PLMN identities passing PLMN ID check and
  - The CSG whitelist of the UE includes an entry comprising of the concerned PLMN identity and the CSG ID broadcast by the cell served by the SeNB
- The MeNB performs PLMN ID check for the PLMNs reported by the UE and selects one if multiple pass the PLMN ID check
- If the cell served by the SeNB belongs to a different PLMN than the PLMN serving for the UE in the MeNB, the information provided to the MME for membership verification needs to contain the PLMN-ID of the hybrid cell served by the SeNB as well
- Finally the MME verifies the CSG membership according to the received CSG ID, the selected PLMN ID and stored subscription CSG information of the UE

Support for Dual Connectivity

- Dual Connectivity involves two RAN nodes, i.e. Master and Secondary RAN nodes, in providing radio resources to a given UE (with active radio bearers), while a single S1-MME termination point exists for an UE between a MME and the E-UTRAN
  - The E-UTRAN architecture and related functions to support Dual Connectivity with E-UTRAN is further described in TS 36.300
  - Dual Connectivity with E-UTRAN as Master RAN node and NR as Secondary RAN node is further described in TS 37.340
- Dual connectivity defines "Master Cell Group (MCG) bearer" and "Secondary Cell Group (SCG) bearer"
  - For E-RABs configured as "MCG bearers" the U-plane termination points are maintained, whereas for E-RABs configured as "SCG bearers" it enables changing the U-plane termination point in the E-UTRAN by means of S1-MME signalling without changing the S1-MME termination point
- Dual Connectivity also defines a "split bearer“
- The "split bearer" in the E-UTRAN is transparent to the core network entities (e.g. MME, S-GW etc.) with the exception of the CSG membership verification by the MME when the Secondary eNB is a hybrid access eNB
- The E-UTRAN uses the per-UE information supplied by the MME and local E-UTRAN configuration data to determine whether or not to use Dual Connectivity for that UE, and, on a per EPS bearer basis the E-UTRAN decides whether to use an MCG bearer or SCG bearer, and, whether or not that bearer is a "split bearer“
  - Typically, the MME and SGW cannot determine whether the RAN termination point(s) for the S1-U interface are located on a Master RAN node that has multiple IP addresses, or, on a Secondary RAN node

MME Support for DC

- If the MME has an Access Restriction for NR for a UE (either signalled from the HSS, or, locally generated by VPLMN policy in the MME) then the MME shall signal this to the E-UTRAN as part of Handover Restriction List and to the UE in Attach and TAU Accept
- An eNB supporting Dual Connectivity with NR checks whether the UE is allowed to use NR
  - If the UE is not allowed to use NR, the eNB shall not establish Dual Connectivity with NR as a secondary RAT
- The MME uses "UE support for dual connectivity with NR" for SGW and PGW selection when the UE indicates support for NR and there is no Access Restriction for NR for the UE
- An E-UTRAN cell, based on operator configuration, broadcasts whether it is capable of supporting dual connectivity with locally available NR secondary cell(s)
- At inter-RAT handover from GERAN/UTRAN, the Access Restriction for NR is either
  - already in the MME's UE context, or,
  - is obtained from the HSS during the subsequent Tracking Area Update procedure
    - (i.e. not from the source SGSN or source RAN)

  In both inter-RAT handover cases, any NR Access Restriction is then signalled to the E-UTRAN
- This signalling of the Access Restriction during the TAU after the inter-RAT handover procedure means that there is a small risk that NR resources are transiently allocated

eNB Support DC

The eNB, at which the S1-MME terminates,

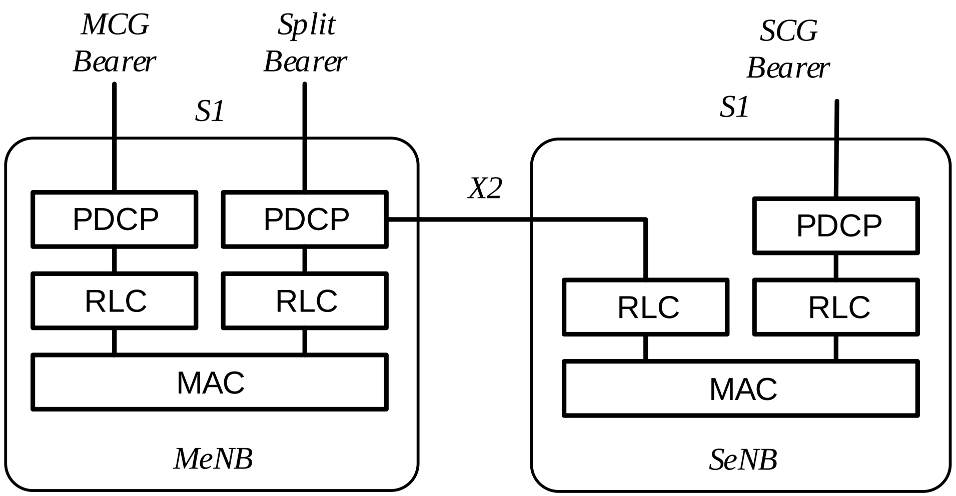
- Merforms all necessary S1-MME related functions (as specified for any serving eNB)
  - Such as mobility management, relaying of NAS signalling, E-RAB handling, etc. and
- Manages the handling of user plane connection of S1-U
  - User location information reporting is based on the identity of the cell that is serving the UE and supported by the eNB terminating S1-MME
  - Path update signalling for E-RABs configured as "SCG bearers" and Serving GW relocation cannot occur at the same time
  - Relaying function is not supported
  - CSG function may be supported in case the Secondary eNB is a hybrid access eNB
    - A HeNB cannot be the Master eNB, i.e. a HeNB cannot initiate the Secondary eNB Addition procedure
    - A HeNB is not allowed to be the Secondary eNB if the HeNB is a closed access eNB
  - When the Secondary eNB is a hybrid access eNB, the Master eNodeB may ask CSG membership verification to the MME using E-RAB Modification Indication message (for SCG bearers) or UE Context Modification Indication (for split bearers) message
    - The MME shall determine the CSG membership based on the CSG Membership Information as specified in TS 36.300 and shall respond to the Master eNodeB using respectively a E-RAB Modification Confirm or a UE Context Modification Confirm, but shall not update the User CSG Information in the Core Network
  - The LIPA function may be supported for the SCG bearer alternative, in the case that the Secondary eNB is a HeNB with a collocated L-GW

eNB Support DC (Cont.)

- "SIPTO at the Local Network with L-GW function collocated with the (H)eNB" function may be supported
- For the MCG and split bearer alternatives, in case the Master eNB is collocated with a L-GW
- For the SCG bearer alternative, in case the Secondary eNB is a (H)eNB with a collocated L-GW
- LIPA or SIPTO at the Local Network PDN connection can be established
  - If the SeNB has already been added before the UE requests establishment of the LIPA or SIPTO at the Local Network PDN connection
  - If the UE is in the coverage of the candidate SeNB when the UE requests establishment of the LIPA or SIPTO at the Local Network PDN connection, but the SeNB has not yet been added
  - In this case, there is a time gap between the moment when the PDN connection establishment is completed and the moment when the SeNB Addition procedure is completed
- "SIPTO at the Local Network with stand-alone GW" function may be supported for the MCG, SCG, and split bearer alternatives if the Master and Secondary eNBs belong to the same LHN

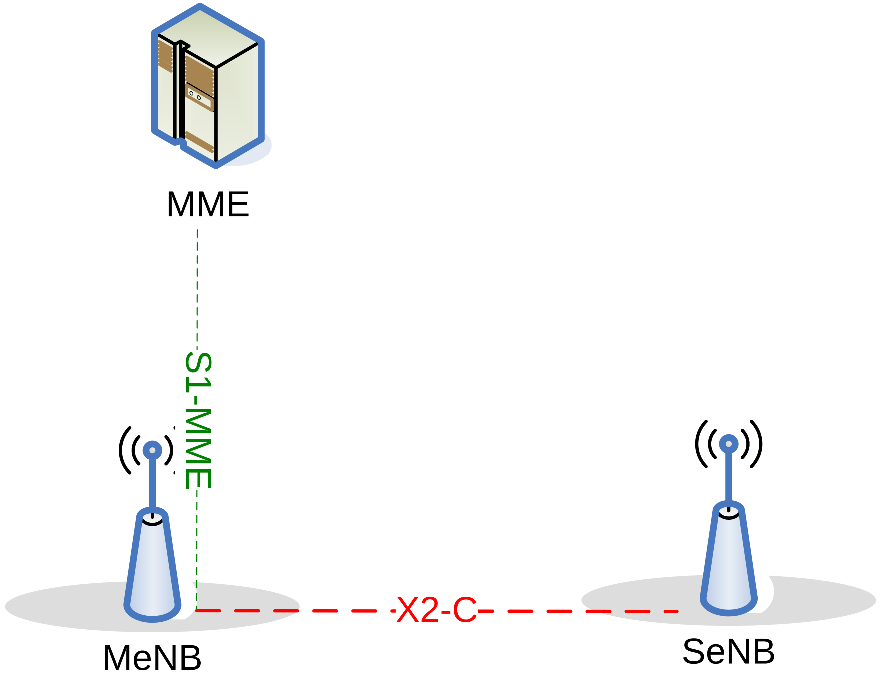
E-UTRAN Supports Dual Connectivity (DC)

- E-UTRAN supports Dual Connectivity (DC) operation whereby a multiple Rx/Tx UE in RRC_CONNECTED is configured to utilise radio resources provided by two distinct schedulers, located in two eNBs connected via a non-ideal backhaul over the X2 interface
  - eNBs involved in DC for a certain UE may assume two different roles: an eNB may either act as an MeNB or as an SeNB
  - In DC a UE is connected to one MeNB and one SeNB
- Radio Protocol Architecture
  - In DC, the radio protocol architecture that a particular bearer uses depends on how the bearer is setup
  - Three bearer types exist: MCG bearer, SCG bearer and split bearer
  - RRC is located in MeNB and SRBs are always configured as MCG bearer type and therefore only use the radio resources of the MeNB
  - DC can also be described as having at least one bearer configured to use radio resources provided by the SeNB



Network Interfaces (E-UTRAN Control Plane for Dual Connectivity)

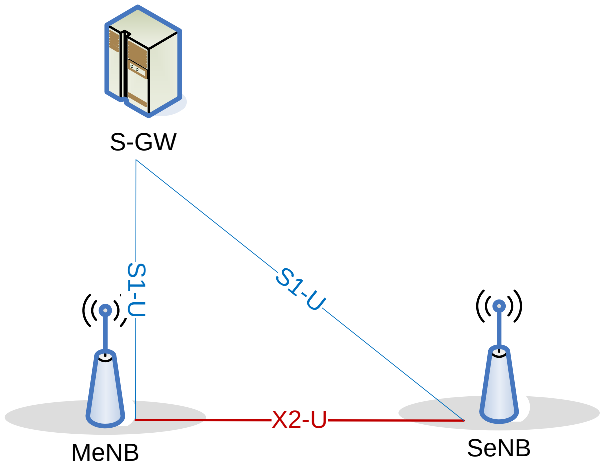
- Inter-eNB control plane signalling for DC is performed by means of X2 interface signalling
  - Control plane signalling towards the MME is performed by means of S1 interface signalling
- There is only one S1-MME connection per DC UE between the MeNB and the MME
  - Each eNB should be able to handle UEs independently, i.e. provide the PCell to some UEs while providing SCell(s) for SCG to others
  - Each eNB involved in DC for a certain UE controls its radio resources and is primarily responsible for allocating radio resources of its cells
  - Respective coordination between MeNB and SeNB is performed by means of X2 interface signalling



The S1-MME is terminated in MeNB and the MeNB and the SeNB are interconnected via X2-C

Network Interfaces (E-UTRAN User Plane for Dual Connectivity)

- For dual connectivity 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
- Different bearer options can be configured with different user plane architectures
- U-plane connectivity depends on the bearer option configured
  - For MCG bearers, the S1-U connection for the corresponding bearer(s) to the S-GW is terminated in the MeNB
    - The SeNB is not involved in the transport of user plane data for this type of bearer(s) over the Uu
  - For split bearers, the S1-U connection to the S-GW is terminated in the MeNB. PDCP data is transferred between the MeNB and the SeNB via X2-U
    - The SeNB and MeNB are involved in transmitting data of this bearer type over the Uu
  - For SCG bearers, the SeNB is directly connected with the S-GW via S1-U
    - The MeNB is not involved in the transport of user plane data for this type of bearer(s) over the Uu



If only MCG and split bearers are configured, there is no S1-U termination in the SeNB

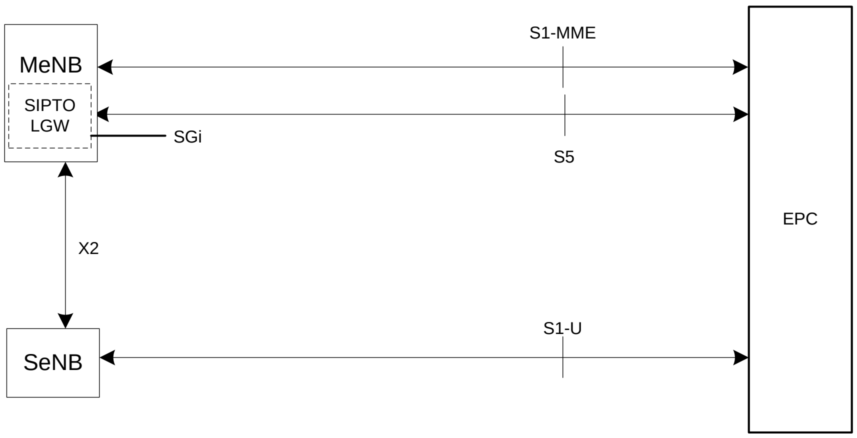
Network Interfaces (Support of HeNBs for Dual Connectivity)

- Membership Verification for the hybrid access HeNB is performed between the MeNB and the MME and is based on membership status information reported by the UE and the CSG ID
- If the cell served by the SeNB is a shared hybrid cell, the UE reports the subset of the broadcasted PLMN identities passing PLMN ID check and the CSG whitelist of the UE includes an entry comprising of the concerned PLMN identity and the CSG ID broadcast by the cell served by the SeNB
  - The MeNB performs PLMN ID check for the PLMNs reported by the UE and selects one if multiple pass the PLMN ID check
  - If the cell served by the SeNB belongs to a different PLMN than the PLMN serving for the UE in the MeNB, the information provided to the MME for membership verification needs to contain the PLMN-ID of the hybrid cell served by the SeNB as well
  - Finally the MME verifies the CSG membership according to the received CSG ID, the selected PLMN ID and stored subscription CSG information of the UE
- In case the UE has been admitted with SCG resources configured with the split bearer option from a hybrid HeNB and a SeNB Change is performed within the coverage area of the MeNB towards another hybrid HeNB which has the same CSG ID as the first one, the MeNB may re-use the result of the membership verification performed for the first HeNB

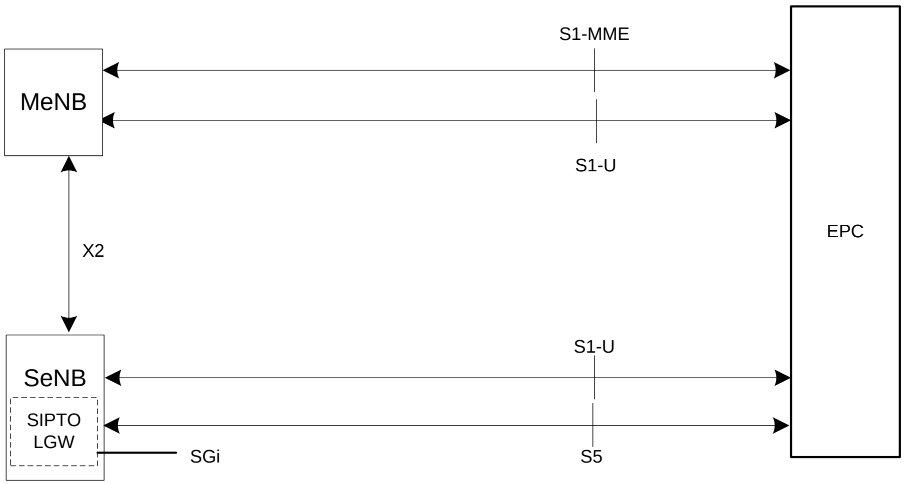
MeNB	**SeNB**
eNB	open access HeNB
eNB	hybrid access HeNB

Network Interfaces (Support of SIPTO@LN and LIPA for Dual Connectivity)

- SIPTO@LN with co-located L-GW in the MeNB
  - For SCG bearer option, the MeNB sets GTP TEID and Transport Layer Address in S1 UL GTP Tunnel Endpoint IE in the SENB ADDITION REQUEST message and SENB MODIFICATION REQUEST messages as the correlation ID received from the MME and the IP address of the collocated L-GW respectively
- SIPTO@LN with co-located L-GW in the SeNB
  - For this scenario, only the SCG bearer option is supported for the SIPTO bearer
  - The SeNB signals its L-GW IP address using the SeNB Addition Preparation procedure, or the MeNB obtains such address via OAM
  - The MeNB signals the "SIPTO correlation id" to the SeNB using the SeNB Addition Preparation and SeNB Modification Preparation procedures



SIPTO@LN with co-located L-GW in MeNB – split and SCG bearer options



SIPTO@LN with co-located L-GW in SeNB

Outline

- Support for Dual Connectivity
  - Radio Protocol Architecture
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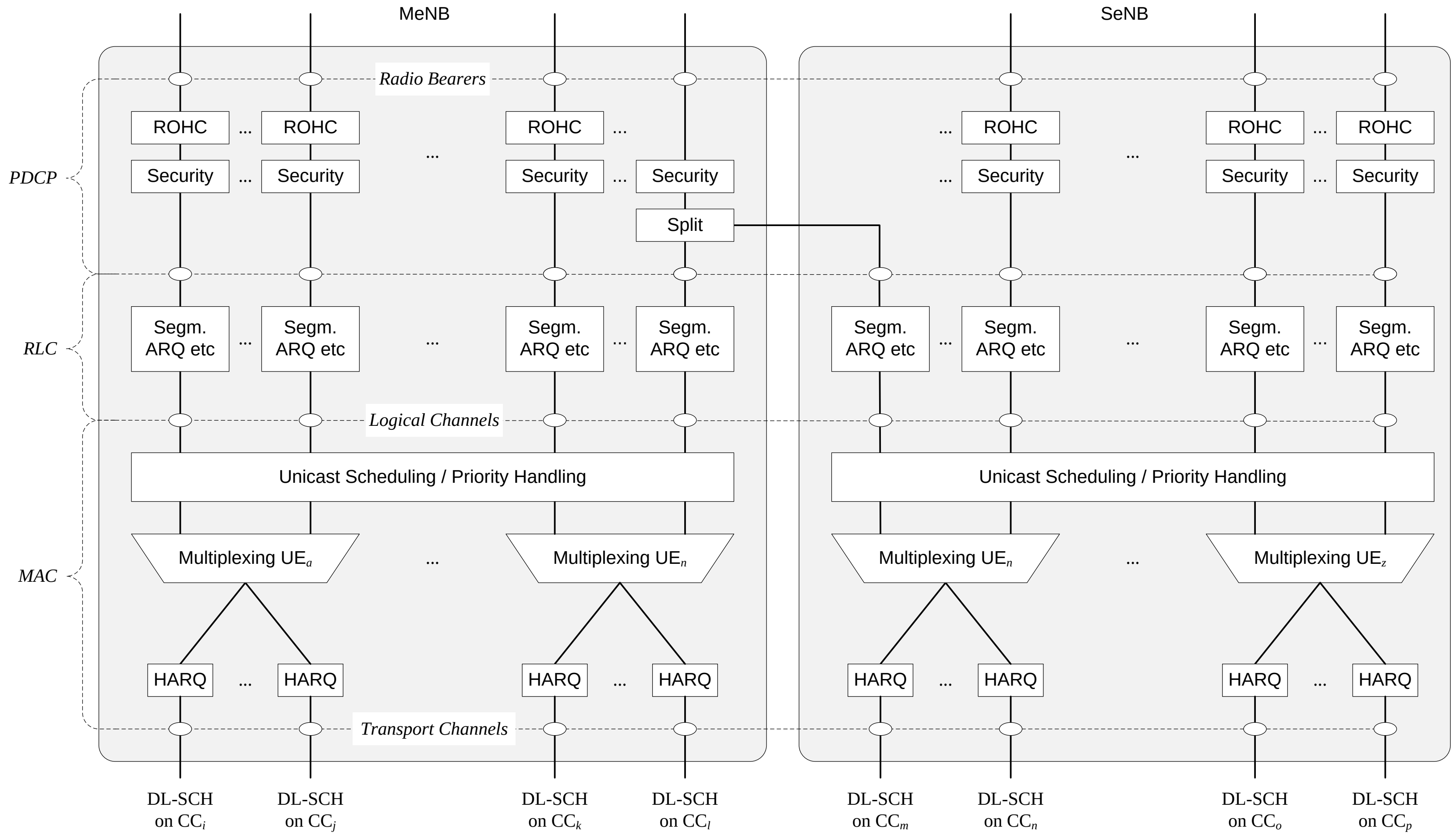
Reference:

- TS 36.300: E-UTRAN Overall description; Stage 2
- TR 36.875: E-UTRAN Extension of dual connectivity in E-UTRAN

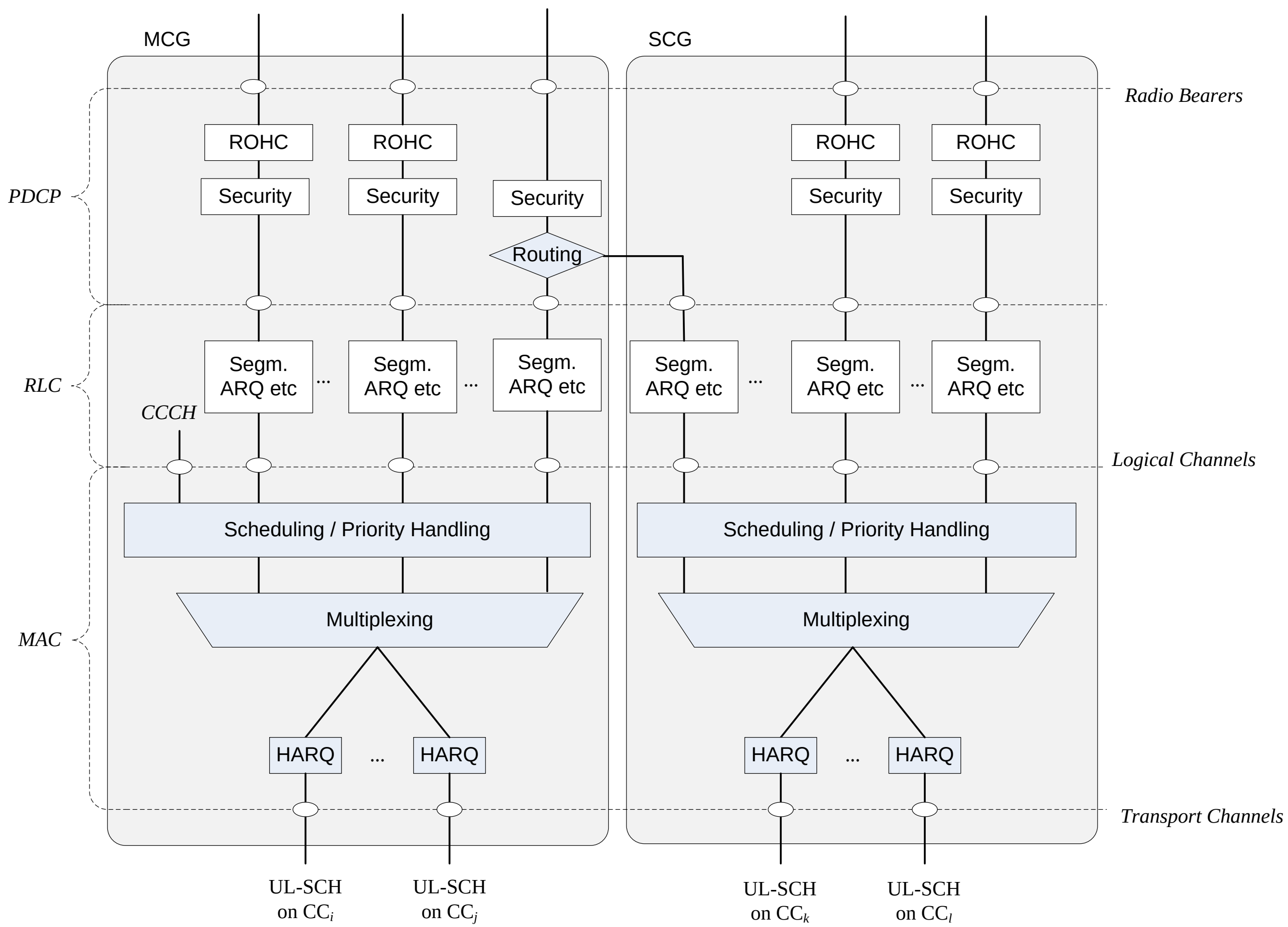
Layer 2 Structure for DL with CA and DC Configured

- In case of DC, the UE is configured with two MAC entities
  - One MAC entity for MeNB
  - One MAC entity for SeNB



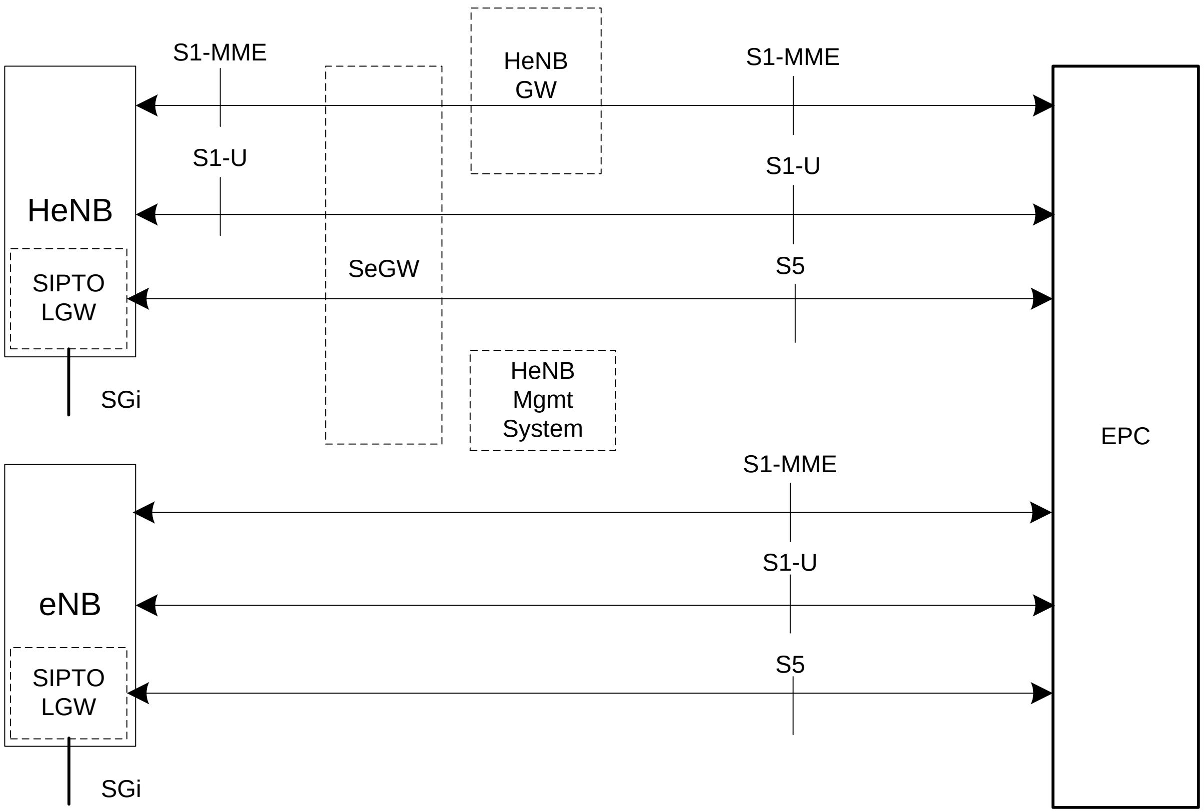
Layer 2 Structure for UL with CA and DC Configured

- SRBs are always handled by the MeNB and as a result, CCCH is only shown for the MeNB
- For a split bearer, UE is configured over which link (or both) the UE transmits UL PDCP PDUs by the MeNB
  - On the link which is not responsible for UL PDCP PDUs transmission, the RLC layer only transmits corresponding ARQ feedback for the downlink data



Support of SIPTO at the Local Network

- E-UTRAN supports SIPTO at the Local Network with a collocated L-GW in the eNB or a standalone GW (with S-GW and L-GW collocated)
- For a SIPTO@LN PDN connection, the eNB sets up and maintains an S5 connection to the EPC
- The mobility of the SIPTO@LN PDN connection is not supported in TS 36.300 V15.3.0
  - The SIPTO@LN PDN connection is released after a handover is performed, and the collocated L-GW in the source eNB triggers the release over the S5 interface



eNB Supports Functions

- In case of SIPTO@LN with collocated L-GW support, the eNB supports the following additional functions
- Transfer of the collocated L-GW IP address of the eNB over S1-MME to the EPC at every idle-active transition
- Transfer of the collocated L-GW IP address of the eNB over S1-MME to the EPC within every Uplink NAS Transport procedure
- Support of basic P-GW functions in the collocated L-GW such as support of the SGi interface corresponding to SIPTO@LN
- Additional support of first packet sending, buffering of subsequent packets, internal direct L-GW-eNB user path management and in sequence packet delivery to the UE
- Support of the necessary restricted set of S5 procedures corresponding to the support of SIPTO@LN function
- Notification to the EPC of the collocated L-GW uplink TEID(s) or GRE key(s) for the SIPTO@LN bearer(s) over S5 interface within the restricted set of procedures to be forwarded over S1-MME and further used by the eNB as "SIPTO correlation id" for correlation purposes between the collocated L-GW and the eNB
- Triggering SIPTO@LN PDN connection release by the collocated L-GW after a handover is performed

MME Supports Functions

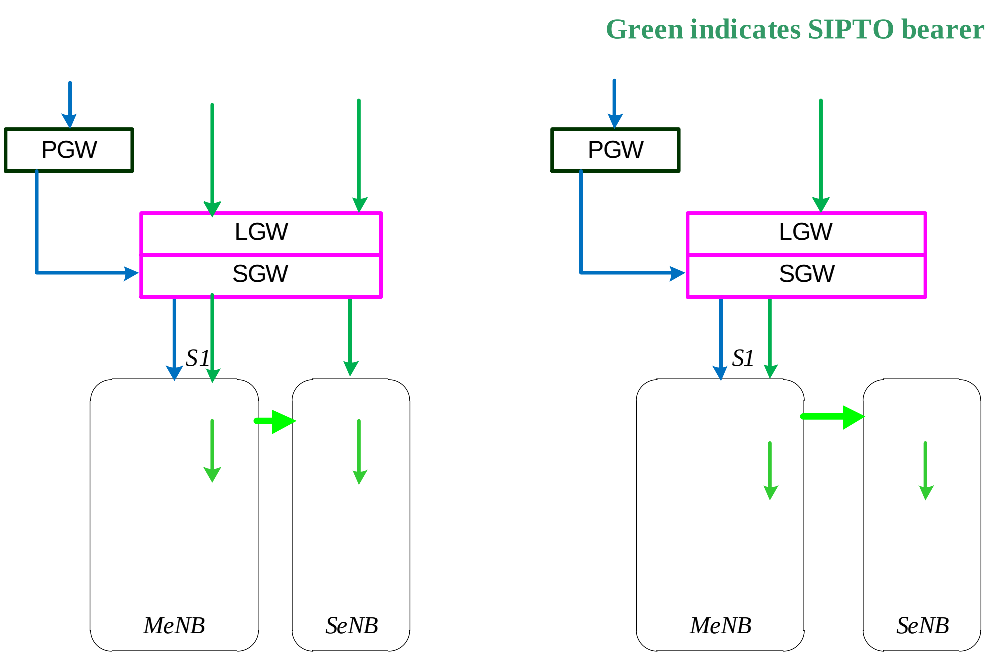
- In case of SIPTO@LN with collocated L-GW support, the MME supports the following additional functions
  - SIPTO@LN activation for the requested APN based on SIPTO permissions in the subscription data and received collocated L-GW IP address
  - Transfer of the "SIPTO correlation id" to the eNB via the initial context setup procedure and E-RAB setup procedure
  - Release of the SIPTO@LN PDN connection of an idle-mode UE when the UE moves away from the coverage area of the eNB

Support for SIPTO@LN with Stand-Alone Gateway

- SIPTO@LN is supported using a stand-alone gateway (with co-located S-GW and L-GW) deployed in the local network
  - The MME may decide to trigger S-GW relocation without UE mobility
  - Mobility for the SIPTO@LN PDN connection is not supported in this release: the SIPTO@LN PDN connection shall be released after handover, unless the source and target eNBs are in the same LHN (i.e. they have the same LHN ID)
- In case of SIPTO@LN support with stand-alone gateway, the eNB supports the following additional functions
  - Signalling of its LHN ID to the MME in the INITIAL UE MESSAGE, UPLINK NAS TRANSPORT, HANDOVER NOTIFY and PATH SWITCH REQUEST messages
  - Support for MME-triggered S-GW relocation without UE mobility through the E-RAB MODIFY REQUEST message
- In case of SIPTO@LN support with stand-alone gateway, the MME supports the following additional functions
  - SIPTO@LN PDN activation for the requested APN based on subscription data and received LHN ID
  - S-GW relocation without UE mobility

SIPTO at the Local Network with stand-alone GW for Dual Connectivity

- SIPTO@LN(Selected IP Traffic Offload at the Local Network) with a stand-alone GW provides the possibility to select the most appropriate GW according to the UE location in a certain neighborhood (LHN, Local Home Network)
- All eNBs in an LHN have IP connectivity for SIPTO@LN via the L-GW
  - All MeNBs and SeNBs in the same LHN have IP connectivity to a stand-alone GW in that LHN



Alternative 1: standalone GW connects to MeNB/SeNB

Alternative 2: standalone GW connects to MeNB

Alternative 1: Standalone GW Connects to both MeNB and the SeNB

- SIPTO bearers can be configured to MeNB and/or SeNB
- For SIPTO bearer in SeNB, it can be SCG(Secondary Cell Group) bearer or split bearer
  - It is the MeNB to decide one bearer is setup in MeNB or the SeNB
- If SIPTO bearer is decided for the UE, the MeNB shall select the SeNB in the local network to configure the SIPTO bearer
  - The MeNB can know the local home network ID of the SeNB by configuration or through X2 procedure
- For SIPTO at local network with standalone architecture, it is the MME to trigger SIPTO bearer deactivation procedure after handover if the UE moves out the source local home network
  - In case of DC, the MeNB can transmit the target LHN ID to the MME with the current Path Switch Request message so that the MME can trigger the bearer deactivation procedure correspondingly
- This alternative is used in the scenario that MeNB and the SeNB belong to the same local home network

Alternative 2: Standalone GW Connects to MeNB

- The bearers in MeNB can be SIPTO bearer
  - Whether split bearer can be setup to SeNB needs to be discussed
  - It is not allowed considering SeNB is not in the local home network
  - There is no reason to block it since there is connectivity between MeNB and SGW/LGW
  - SCG bearer in SeNB is not possible
  - The MeNB shall configure SIPTO bearer in MeNB or split bearer in SeNB
- It is the MME to trigger bearer deactivation procedure after handover if the UE moves out the source local home network
  - To support bearer deactivation, the MeNB need to inform the MME the target local home network during handover procedure.
- This alternative is used in the scenario that MeNB is in the local home network

Summary of the Standalone Architecture Alternatives

- SIPTO@LN is restricted to a single bearer only
  - While in theory both the MeNB and the SeNB might connect to several standalone GWs, only one at a time will ever be used for any given UE
  - Therefore, the architecture forces a single termination point for that particular bearer from the network side
  - The gain of such an arrangement depends on the relative performance of the path from the SeNB through the MeNB and to the GW, with respect to the Uu link from the UE to the SeNB

	Architecture alternative 1	**Architecture alternative 2**
Architecture description	Standalone GW connects to both MeNB and the SeNB. MeNB and the SeNB belong to the same local home network	Standalone GW connects to MeNB. MeNB only is in the local home network
Specification impact	There is minimal specification impact to support this alternative	There is minimal specification impact to support architecture 3C. Only Architecture 3C can be supported

SIPTO at the Local Network with Collocated L-GW for Dual Connectivity

- In the following analysis the 2 alternatives are described on a per-PDN-connection basis
  - Alternative 1: LGW in MeNB
    - SIPTO bearers can be configured to MeNB and/or SeNB
    - For SIPTO bearer in SeNB, it can be SCG bearer or split bearer
    - Service continuity can be assured if MeNB is unchanged
    - Only S1 backhaul can be saved for SCG bearer
    - For SIPTO bearer setup, switch and bearer deactivation procedure, the existing procedure is enough
    - There is no stage 3 (at least ASN.1) impact
    - If SIPTO bearer is configured to SeNB as SCG bearer, the MeNB set the uplink TEID and TNL address as Correlation ID and TNL address of the LGW in X2AP message and transmit to the SeNB
    - This alternative is used in the scenario that MeNB has collocated LGW function
  - Alternative 2: LGW in SeNB
    - The bearers in SeNB can be offloaded
    - Only SCG bearer option can be configured as SIPTO bearer
    - Once there is SeNB change, the bearer should be deactivated
    - For SIPTO bearer setup, the MeNB report the LGW IP in SeNB to the MME
    - The MME transmit the Correlation ID to MeNB when MME decide to setup SIPTO bearer for the UE
    - To configure the local tunnel in SeNB, Correlation ID needs to be transmitted to the SeNB over X2
    - The existing procedure is enough for SIPTO trigger bearer deactivation during handover or during bearer switch
    - This alternative is used in the scenario that SeNB has collocated LGW function

Summary of the Collocated Architecture Alternatives

- The purpose of SIPTO@LN is to select the most appropriate GW according to the UE location information
- Dual Connectivity puts two additional constraints on SIPTO@LN operation
  - The location of the co-located L-GW may be more or less optimal with respect to the location of the UE
  - The choice of MCG, SCG or split bearer may or may not make sense depending on the location of the L-GW

	Architecture alternative 1	**Architecture alternative 2**
Architecture description	LGW in MeNB. MeNB has collocated LGW function	LGW in SeNB. SeNB has collocated LGW function. SIPTO bearer has to be deactivated during SeNB change procedure
Specification impact	No stage 3 impact	The MeNB transmits the IP address of the L-GW co-located with the SeNB to the MME. How to signal such address is to be clarified in the normative phase; MeNB transmits Correlation ID to SeNB for local tunnel setup in SeNB; MeNB obtains the LGW IP through X2 procedure

Possible Combinations of Bearer Type and L-GW Location

- Several combinations of SIPTO@LN bearer type and L-GW location are theoretically possible
- Some combinations seem to always make sense, such as
  - The cases of SIPTO@LN as M/SCG bearer when the L-GW is co-located with the M/SeNB (respectively)
    - In these cases the traffic termination point and the radio anchor are the same, thereby ensuring the most optimized path
- Other combinations seem to never make sense, such as
  - The cases of SIPTO@LN as S/MCG bearer when the L-GW is co-located with the M/SeNB (respectively)
    - In these cases all the packets for the SIPTO bearer terminate in one node and are transferred to the other through X2-U, creating an obvious criticality in the traffic path
- For split bearers, for the case of L-GW in the MeNB the benefit depends on the relative performance of X2-U with respect to Uu toward the SeNB (i.e. there is the risk of "losing" due to transport what is "gained" over the radio)
  - This is similar to the case without SIPTO@LN
  - The case of L-GW in the SeNB is excluded because it is incompatible with the MeNB being in control

	SIPTO bearer = MCG bearer	**SIPTO bearer = SCG bearer**	**SIPTO bearer = split bearer**
L-GW co-located with MeNB	Beneficial	Not beneficial – all SIPTO traffic routed to the MeNB	Beneficial as long as X2-U between MeNB and SeNB is good enough (similar to the case without SIPTO)
L-GW co-located with SeNB	Not beneficial – all SIPTO traffic routed to the SeNB	Beneficial	Excluded

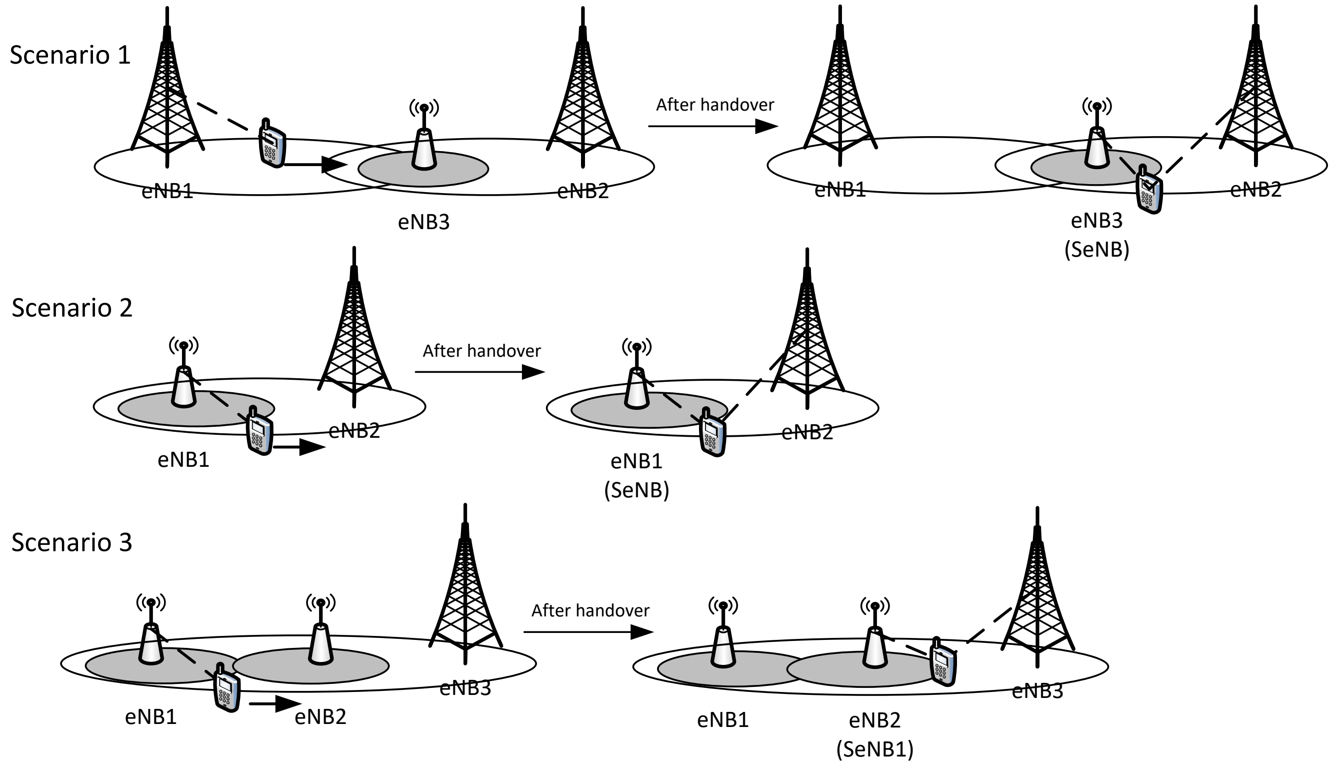
Location Reporting Enhancement

- According to TS 23.401 User location information reporting is based on the identity of the cell that is serving the UE and supported by the eNB terminating S1-MME
- According to TS 36.300, in case of carrier aggregation, the cell that provides the NAS mobility information (e.g. TAI) and the security input at RRC connection establishment, re-establishment and handover is the Primary Cell (PCell)
- Currently there are no clear requirements known to enhance location reporting from a pure accuracy purpose

Handover Enhancement

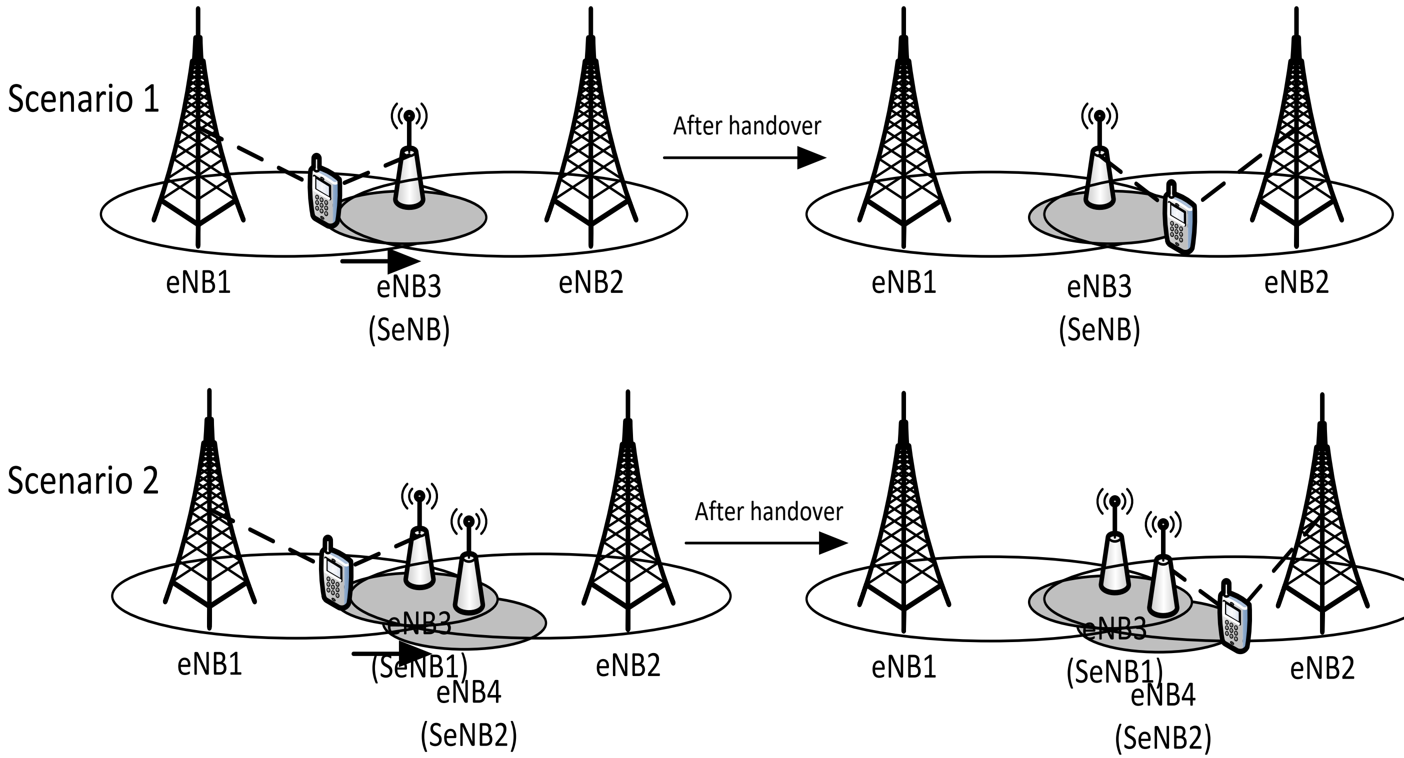
- The handover enhancement includes handover with SeNB addition and inter-MeNB handover without SeNB change
- For handover enhancement in dual connectivity, the following scenarios can be considered
  - Single connectivity to dual connectivity
  - Dual connectivity to Dual connectivity

Scenarios of Single Connectivity to Dual Connectivity Handover



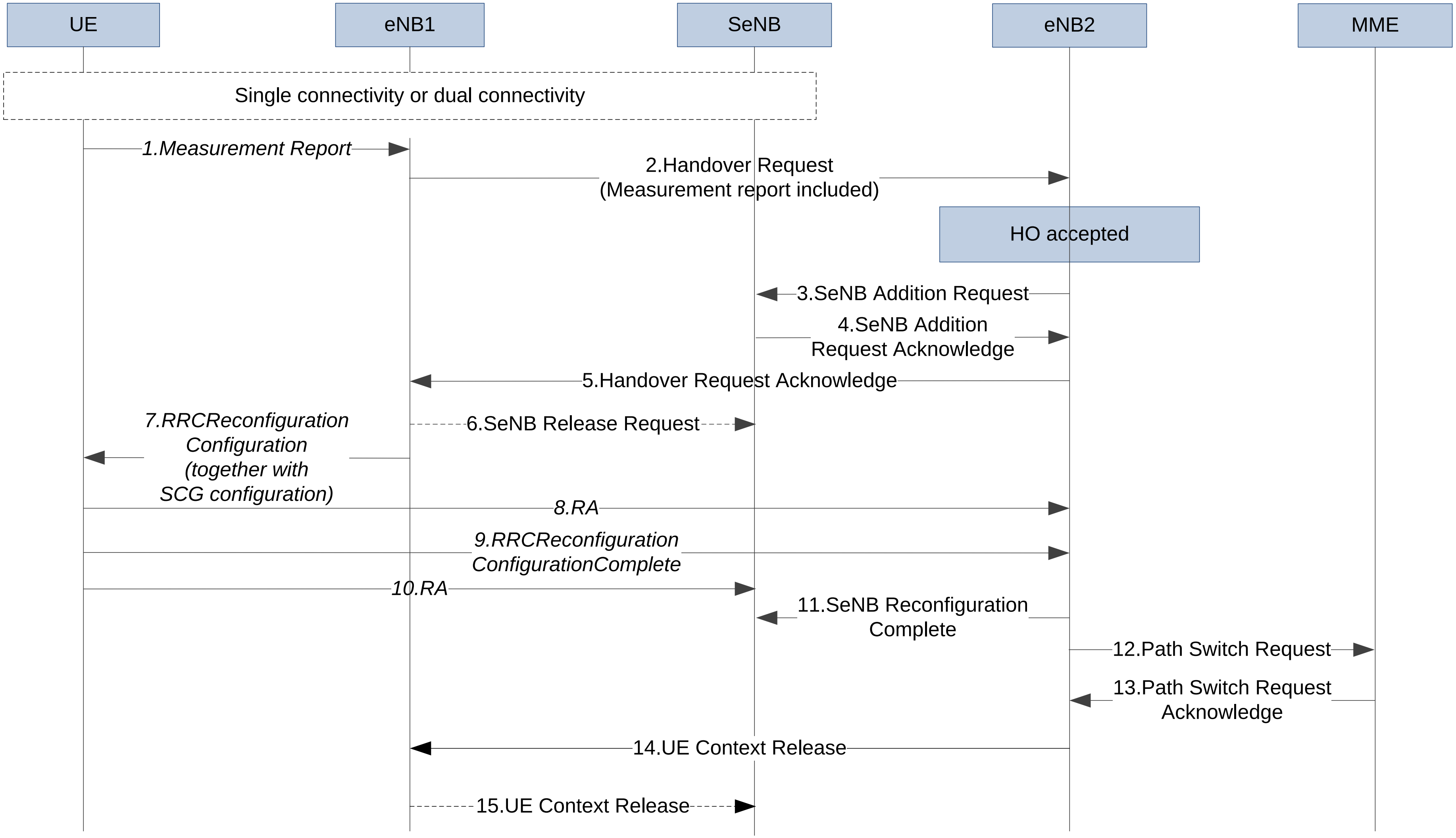
- In scenario 1, UE is handed over from eNB1 to eNB2, and during the handover eNB2 decides to add eNB3 as SeNB for dual connectivity operation
  - After the handover, UE will be configured as dual connectivity with eNB2 and eNB3
- In scenario 2, UE is handed over from eNB1 to eNB2, and during the handover eNB2 decides to add eNB1 as SeNB for dual connectivity operation
  - After the handover, UE will be configured as dual connectivity with eNB1 and eNB2
- In scenario 3, UE is handed over from eNB1 to eNB3, and during the handover eNB3 decides to add eNB2 as SeNB for dual connectivity operation
  - After the handover, UE will be configured as dual connectivity with eNB2 and eNB3

Scenarios of Dual Connectivity to Dual Connectivity Handover



- In scenario 1, UE is in dual connectivity with eNB1 and eNB3 serving as SeNB, and then handed over to eNB2
  - During the handover eNB2 decides to keep eNB3 as SeNB for dual connectivity
  - This scenario is equivalent to inter-MeNB handover without SeNB change
- In scenario 2, UE is in dual connectivity with eNB1 and eNB3 serving as SeNB, and then handed over to eNB2
  - During the handover eNB2 decides to add eNB4 as SeNB for dual connectivity

General Procedure for Enhanced Handover in Dual Connectivity



Signalling Solution Applicable for All Scenarios

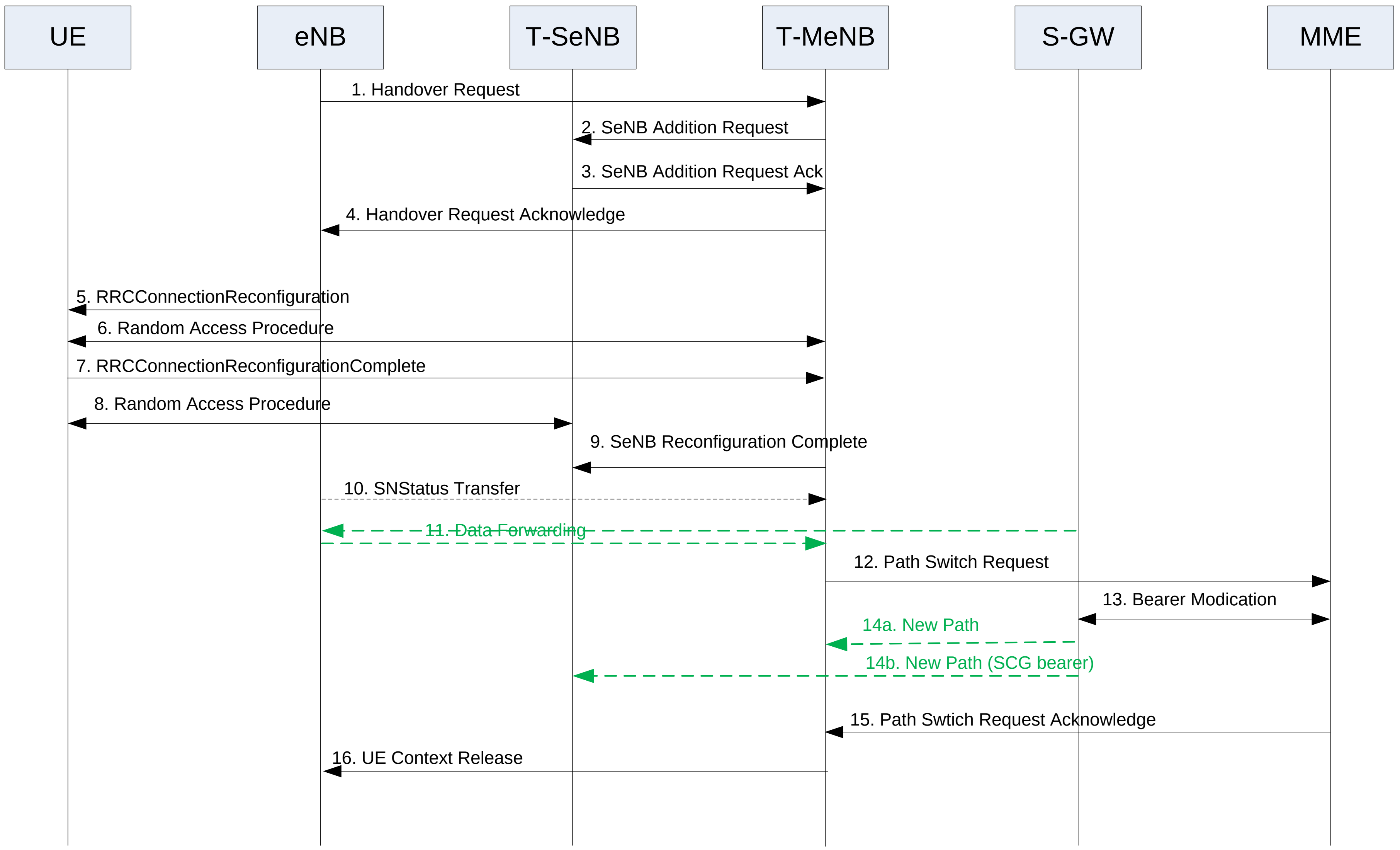
Before the handover UE operates in single connectivity with eNB1 or dual connectivity with eNB1 and SeNB

1. Measurement report is sent to eNB1 and handover is triggered
2. eNB1 sends Handover Request to eNB2 including UE's measurement report, which is used for eNB2 to select an appropriate SeNB to continue dual connectivity, if possible
3. If the eNB2 decides to add or keep the SeNB, the eNB2 sends SeNB Addition Request to SeNB. If UE was in dual connectivity with the SeNB and eNB1 before the handover, the eNB2 includes the SeNB UE X2AP ID as a reference to the UE context in the SeNB that was established by eNB1
4. The SeNB replies with SeNB Addition Request Acknowledge and may also provide forwarding addresses to eNB2
5. eNB2 replies with Handover Request Acknowledge
6. eNB1 sends SeNB Release Request to the SeNB
7. The eNB1 triggers the RRC connection reconfiguration procedure (The RRC message includes SCG configuration)
8. Random Access is performed towards the eNB2
9. UE replies with *RRCConnectionReconfigurationComplete* to the eNB2
10. Random Access is performed towards the SeNB
11. Upon completion of the RRC connection reconfiguration procedure, eNB2 confirms the reconfiguration with the SeNB
12. eNB2 sends Path Switch Request to switch the bearers in both eNB2 and the SeNB. If the SeNB is kept, eNB2 may include the same TEID used for SCG bearer
13. The MME replies with Path Switch Request Acknowledge. If new UL TEIDs at the S-GW are included, eNB2 performs MeNB initiated SeNB Modification procedure to provide them to the SeNB
14. eNB2 sends UE Context Release to eNB1
15. eNB1 sends UE Context Release to the SeNB

Note for General Procedure

- At inter eNB handover without SeNB change data forwarding can be omitted for SCG bearers
- Direct Data Forwarding from eNB1 to SeNB is not possible for split bearer
- Bearer type change during inter-MeNB handover w/o SeNB Change is supported as long as the general restrictions specified in TS 36.300 §7.6 are observed

Handover with SeNB Addition



Signaling Fow for Handover with SeNB Addition

- Handover with SeNB addition is used to transfer context data from a source eNB to a target MeNB that adds an SeNB during the handover

1. The source eNB starts the handover procedure by initiating the X2 Handover Preparation procedure. The source eNB includes the SCG configuration in the HandoverPreparationInformation
2. The target MeNB sends SeNB Addition Request to the target SeNB
3. The target SeNB replies with SeNB Addition Request Acknowledge
4. The target MeNB includes the field in HO command which includes SCG configuration, 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 MeNB and replies with RRCConnectionReconfigurationComplete message

8. The UE synchronizes to the target SeNB
9. If the RRC connection reconfiguration procedure was successful, the target MeNB informs the target SeNB

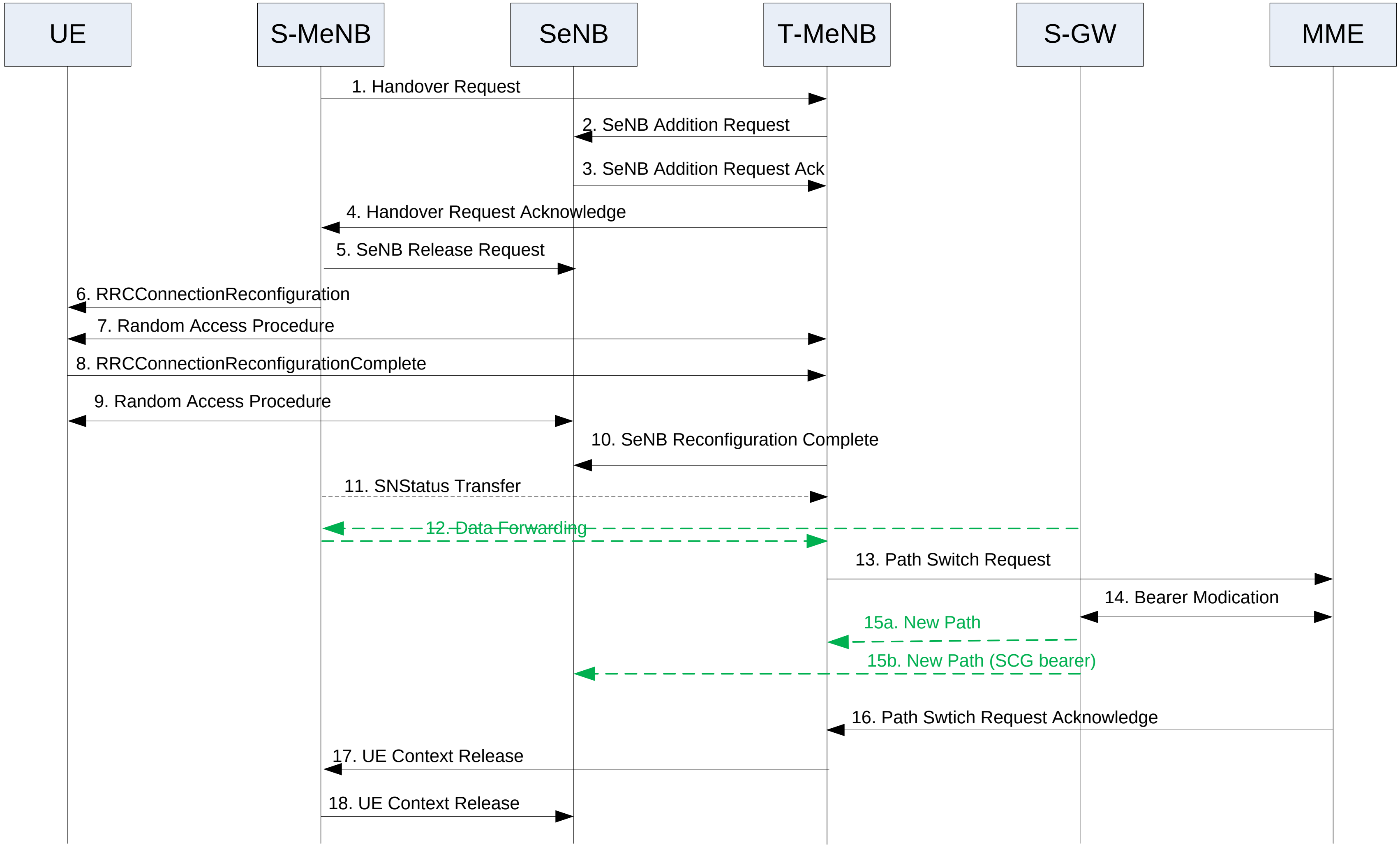
10/11. Data forwarding from the source eNB takes place

- NOTE: Direct Data Forwarding from the eNB to the Target SeNB is possible for SCG bearers

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

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

Inter-MeNB Handover without SeNB Change



Signaling Flow for Inter-MeNB Handover without SeNB Change

Inter-MeNB handover without SeNB change is used to transfer context data from a source MeNB to a target MeNB while the context at the SeNB is kept

1. The source MeNB starts the handover procedure by initiating the X2 Handover Preparation procedure
   - The source MeNB includes the SCG configuration in the *HandoverPreparationInformation*
   - The target MeNB needs to know whether the source MeNB has configured SCG resources in order to decide whether the SeNB can be kept, in which case the target MeNB needs to be able to contact the SeNB.
   - The source MeNB may include the SeNB ID in the Handover Request message or alternatively the target MeNB can detect the identity of the SeNB from the RRC container in Handover Request message
   - Slight preference of RAN3 is to include the SeNB ID in the Handover Request message explicitly
2. The target MeNB sends SeNB Addition Request to the SeNB including the SeNB UE X2AP ID as a reference to the UE context in the SeNB that was established by the Source MeNB
3. The SeNB replies with SeNB Addition Request Acknowledge
4. The target MeNB includes the field in HO command which includes SCG configuration, and may also provide forwarding addresses to the source eNB
5. The source MeNB sends SeNB Release Request to the SeNB
6. The source MeNB triggers the UE to apply the new configuration

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

9. The UE synchronizes to the SeNB
10. If the RRC connection reconfiguration procedure was successful, the target MeNB informs the SeNB

11/12. Data forwarding from the source MeNB takes place

13-16. The target MeNB initiates the S1 Path Switch procedure

17. The target MeNB initiates the UE Context Release procedure towards the source MeNB
18. Upon reception of the UE Context Release message, the SeNB can release C-plane related resource associated to the UE context. Any ongoing data forwarding may continue

Note for Inter-MeNB Handover without SeNB Change

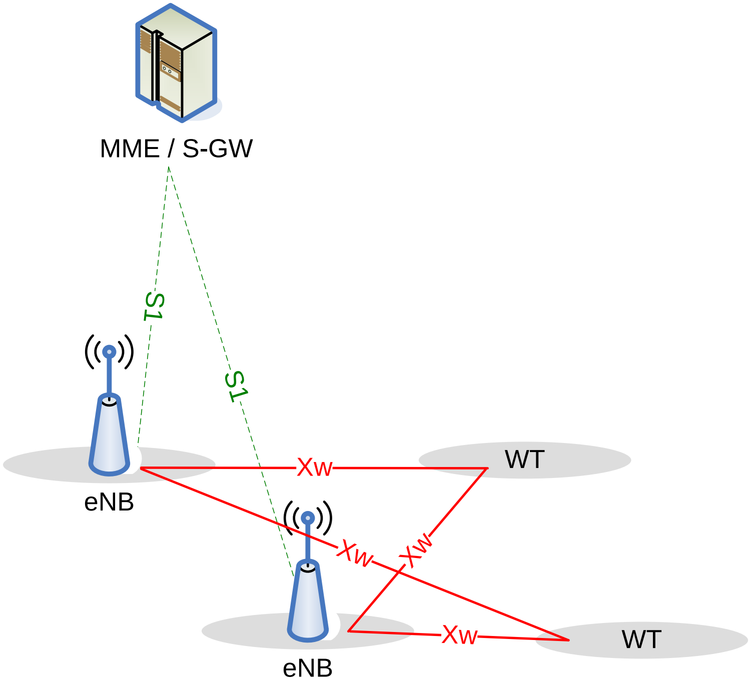
- Three options for the release of the UE-associated signaling connection between the source-MeNB and the SeNB for inter-MeNB handover without SeNB change were discussed
  - Both SeNB Release Request in step 5 and UE Context Release in step 18 are kept without adding a new IE to the messages
    - Specification work for the procedural description in stage 3 is needed
  - An explicit indicator is included in the Handover Request Acknowledge message in case the SeNB keeps unchanged
    - UE Context Release in step 18 is skipped
  - An explicit indicator is included in the Handover Request Acknowledge message, the SeNB Release Request message and the, UE Context Release message
    - Upon receiving this indicator, the SeNB shall only trigger the release of resources related to the UE-associated signalling connection between the source MeNB and the SeNB
- Note
  - Data Forwarding can be omitted for SCG bearers
  - Direct Data Forwarding from Source MeNB to SeNB is not possible for split bearers
  - Bearer type change during inter-MeNB handover w/o SeNB Change is supported as long as the general restrictions specified in TS 36.300 §7.6 are observed

Range of the UE X2AP ID

- It has been discussed and identified that TS 36.401 specifies the UE X2AP IDs to “be unique within the eNB logical node”
- There were concerns that the currently defined range of these IDs (INTEGER (0..4095), see TS 36.423) would be not sufficient to handle the expected higher numbers of UE-associated X2 signalling connections for dual connectivity
- As a solution it was discussed whether it would be possible that during inter-MeNB handover without SeNB change, the source MeNB could provide the MeNB ID to the target MeNB, in which way that an UE X2AP ID would not need to “be unique within the eNB logical node”
  - This would however contradict the statements in TS 36.401
  - Backwards compatibility aspects of this solution would need to be assessed
- As a possible alternative solution it was suggested to extend the currently defined range of the X2AP ID

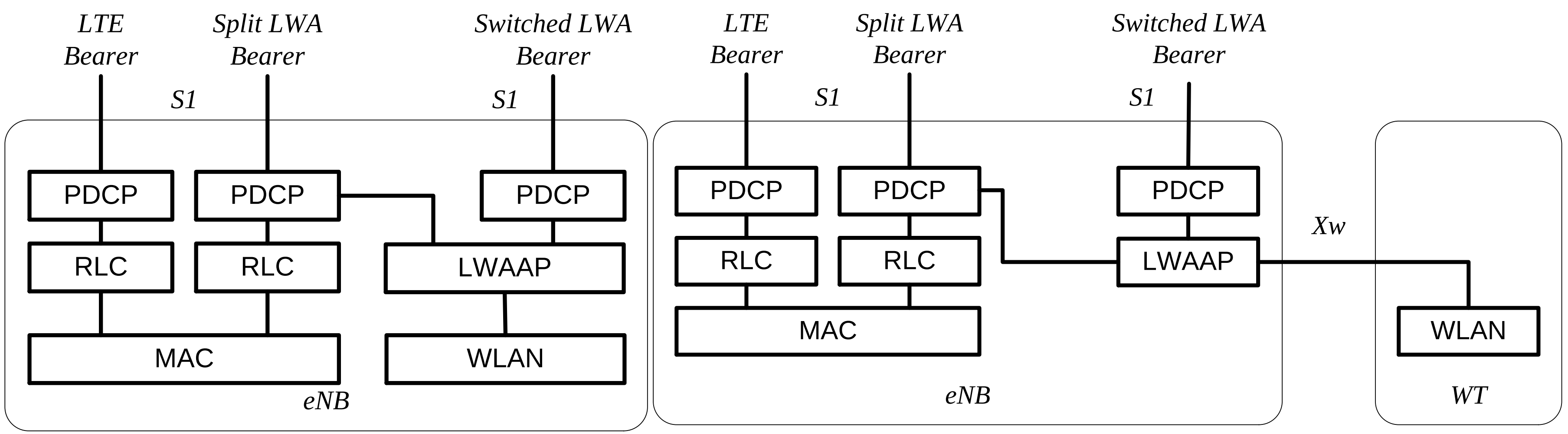
LTE-WLAN Aggregation

- E-UTRAN supports LTE-WLAN aggregation (LWA) operation whereby a UE in RRC_CONNECTED is configured by the eNB to utilize radio resources of LTE and WLAN
- Two scenarios are supported depending on the backhaul connection between LTE and WLAN
  - Non-collocated LWA scenario for a non-ideal backhaul
  - Collocated LWA scenario for an ideal/internal backhaul



LWA Radio Protocol Architecture

- The radio protocol architecture that a particular bearer uses depends on the LWA backhaul scenario and how the bearer is set up
- Two bearer types exist for LWA
  - Split LWA bearer
  - Switched LWA bearer



Collocated Scenario

Non-Collocated Scenario

LWA Radio Protocol Architecture (Cont.)

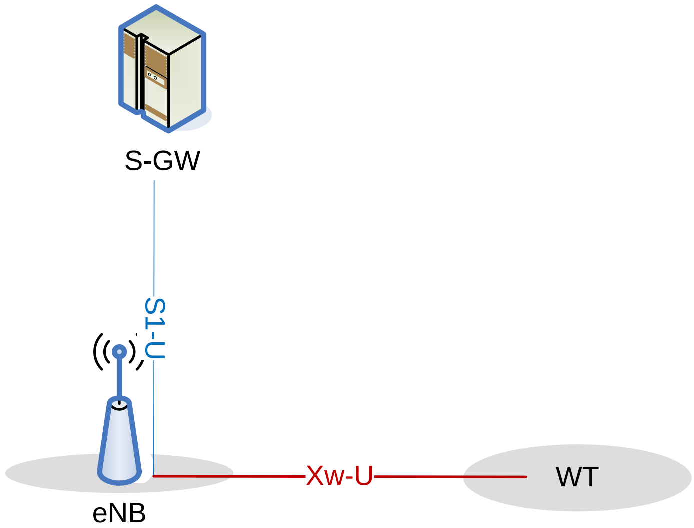
- In the downlink, for PDUs sent over WLAN in LWA operation, the LWAAP entity generates LWAAP PDU containing a DRB identity and the WT uses the LWA EtherType 0x9E65 for forwarding the data to the UE over WLAN
- The UE uses the LWA EtherType to determine that the received PDU belongs to an LWA bearer and uses the DRB identity to determine to which LWA bearer the PDU belongs to
- In the uplink, for PDUs sent over WLAN in LWA operation, the LWAAP entity in the UE generates LWAAP PDU containing a DRB identity and the UE uses the LWA EtherType 0x9E65 for sending the data over WLAN
- LWA supports split bearer operation where the PDCP sublayer supports in-sequence delivery of upper layer PDUs based on the reordering procedure introduced for DC
- The UE supporting LWA may be configured by the eNB to send PDCP status report or LWA status report, in cases where feedback from WT is not available
- Only RLC AM and RLC UM can be configured for an LWA bearer
- E-UTRAN does not configure LWA with DC, LWIP or RCLWI simultaneously for the same UE
- If LWA and RAN assisted WLAN interworking are simultaneously configured for the same UE, in RRC_CONNECTED, the UE only applies LWA
- For LWA bearer, if the data available for transmission is equal to or exceeds the threshold configured by E-UTRAN the UE decides which PDCP PDUs are sent over WLAN or LTE
- If the data available is below the threshold, the UE transmits PDCP PDUs on LTE or WLAN as configured by E-UTRAN
- For each LWA DRB, E-UTRAN may configure the IEEE 802.11 AC value to be used for the PDCP PDUs that are sent over WLAN in the uplink
- For LWA bearer, for routing of UL data over WLAN, the WT MAC address may be provided to the UE by the E-UTRAN or using other WLAN procedure

LWA Network Interfaces

- In the non-collocated LWA scenario, the eNB is connected to one or more WTs via an Xw interface
- In the collocated LWA scenario the interface between LTE and WLAN is up to implementation
- For LWA, the only required interfaces to the Core Network are S1-U and S1-MME which are terminated at the eNB
  - No Core Network interface is required for the WLAN
- WT is a logical node and 3GPP does not specify where it is implemented
- LTE-WLAN aggregation support at a WLAN does not preclude the implementation of legacy WLAN interworking (e.g. S2a, S2b or NSWO) in the same WLAN

LWA Network Interfaces (User Plane)

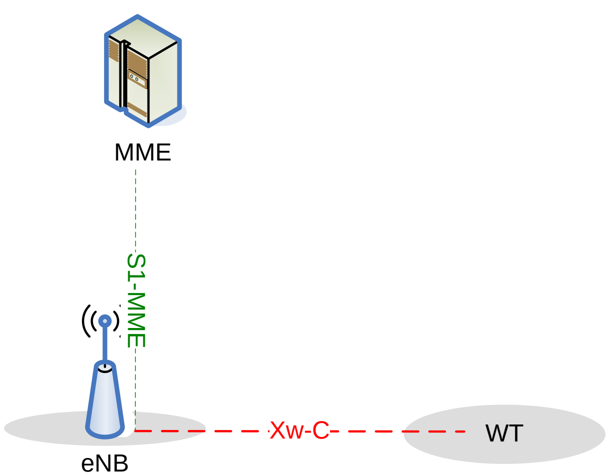
- In the non-collocated LWA scenario, the Xw user plane interface (Xw-U) is defined between eNB and WT
  - The Xw-U interface supports flow control based on feedback from WT
- The Flow Control function is applied in the downlink when an E-RAB is mapped onto an LWA bearer, i.e. the flow control information is provided by the WT to the eNB for the eNB to control the downlink user data flow to the WT for the LWA bearer
- The OAM configures the eNB with the information of whether the Xw DL delivery status provided from a connected WT concerns LWAAP PDUs successfully delivered to the UE or successfully transferred toward the UE
- The Xw-U interface is used to deliver LWAAP PDUs between eNB and WT
- For LWA, the S1-U terminates in the eNB and, if Xw-U user data bearers are associated with E-RABs for which the LWA bearer option is configured, the user plane data is transferred from eNB to WT using the Xw-U interface



The S1-U is terminated at the eNB
The eNB and the WT are interconnected via Xw-U

LWA Network Interfaces (Control Plane)

- In the non-collocated LWA scenario, the Xw control plane interface (Xw-C) is defined between eNB and WT
- The application layer signalling protocol is referred to as Xw-AP (Xw Application Protocol)
- The Xw-AP protocol supports the following functions
  - Transfer of WLAN metrics (e.g. bss load) from WT to eNB
  - Support of LWA for UE in ECM-CONNECTED
    - Establishment, Modification and Release of a UE context at the WT
    - Control of user plane tunnels between eNB and WT for a specific UE for LWA bearers
  - General Xw management and error handling functions
    - Error indication
    - Setting up the Xw
    - Resetting the Xw
    - Updating the WT configuration data
- eNB-WT control plane signalling for LWA is performed by means of Xw-C interface signalling
- There is only one S1-MME connection per LWA UE between the eNB and the MME
  - Respective coordination between eNB and WT is performed by means of Xw interface signalling



The S1-MME is terminated in eNB
The eNB and the WT are interconnected via Xw-C

LWA Mobility

- A WLAN mobility set is a set of one or more WLAN Access Points (APs) identified by one or more BSSID/HESSID/SSIDs, within which WLAN mobility mechanisms apply while the UE is configured with LWA bearer(s), i.e., the UE may perform mobility between WLAN APs belonging to the mobility set without informing the eNB
- The eNB provides the UE with a WLAN mobility set
  - When the UE is configured with a WLAN mobility set, it will attempt to connect to a WLAN whose identifiers match the ones of the configured mobility set
  - UE mobility to WLAN APs not belonging to the UE mobility set is controlled by the eNB e.g. updating the WLAN mobility set based on measurement reports provided by the UE
  - A UE is connected to at most one mobility set at a time
- All APs belonging to a mobility set share a common WT which terminates Xw-C and Xw-U
  - The termination endpoints for Xw-C and Xw-U may differ
  - The WLAN identifiers belonging to a mobility set may be a subset of all WLAN identifiers associated to the WT

RAN Controlled LTE WLAN Interworking

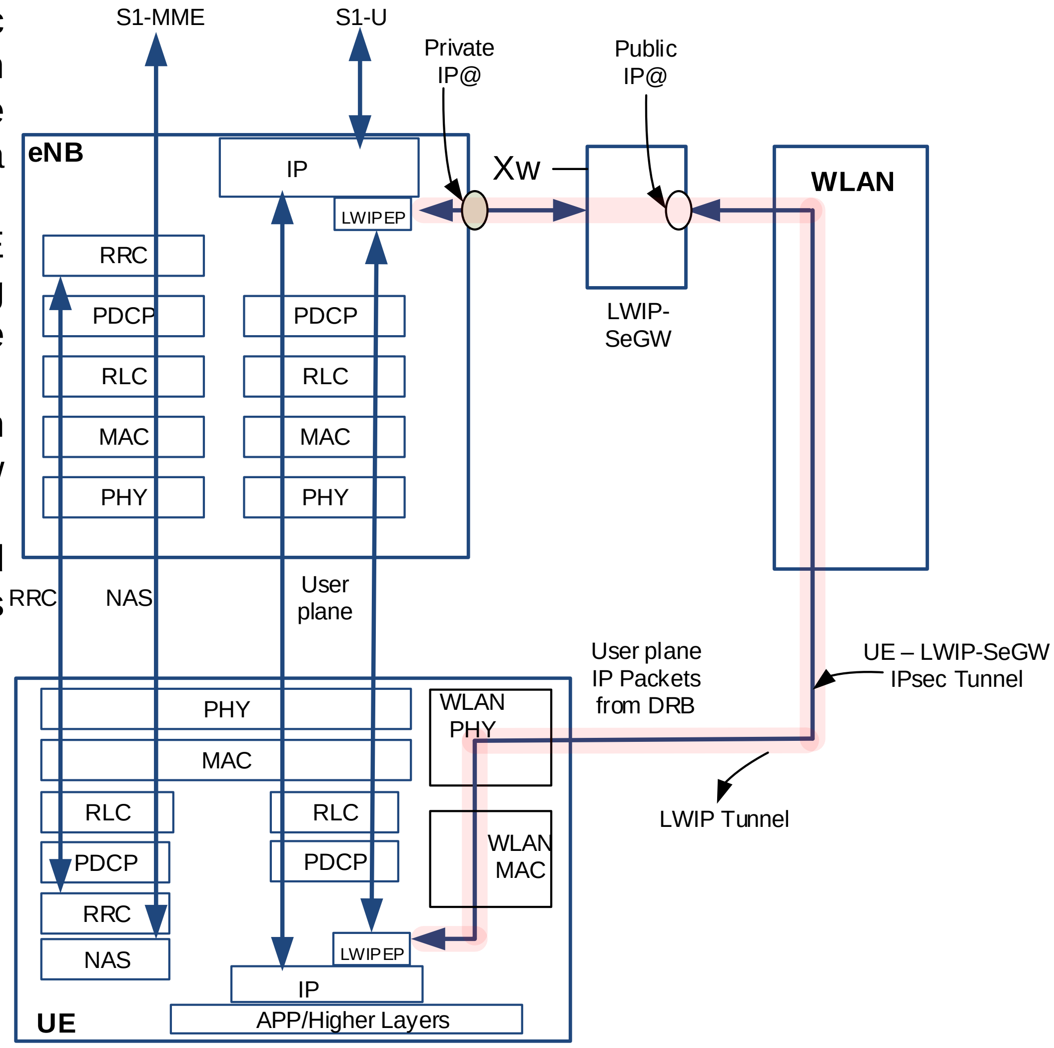
- E-UTRAN supports E-UTRAN controlled bi-directional traffic steering between E-UTRAN and WLAN for UEs in RRC_CONNECTED
  - RAN Controlled WLAN Interworking (RCLWI)
- E-UTRAN may send a steering command to the UE indicating to steer traffic from E-UTRAN to WLAN or from WLAN to E-UTRAN
  - The upper layers in the UE shall be notified upon reception of such a command
  - Upper layers determine which traffic is offloadable to WLAN
- Similarly as for LWA, two scenarios are supported depending on the backhaul connection between LTE and WLAN (non-collocated RCLWI scenario for a non-ideal backhaul and collocated RCLWI scenario for an ideal/internal backhaul), and the overall architecture for the non-collocated RCLWI scenario is the same as illustrated for LWA
- If the UE supporting RCLWI supports access network selection and traffic steering rules, the UE applies the rules in RRC_IDLE using WLAN identifiers provided in WLAN mobility set
- If the UE supporting RCLWI and traffic steering rules, has not been configured with a WLAN mobility set, it applies the broadcasted WLAN identifiers
- If the UE supporting RCLWI does not support the traffic steering rules, it keeps traffic on WLAN within the configured WLAN mobility set (if any) in RRC_IDLE until WLAN connection fails

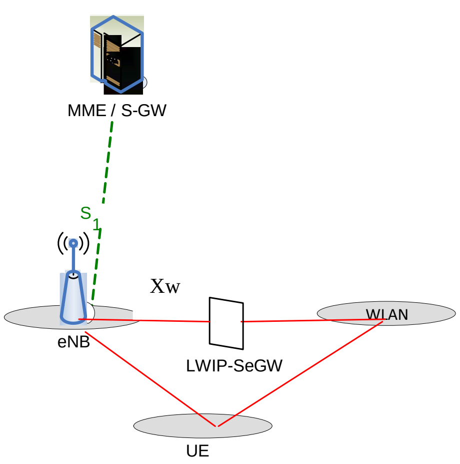
RAN Controlled LTE WLAN Interworking Network Interfaces & Mobility

- Similarly as for LWA, in the non-collocated RCLWI scenario, the eNB is connected to one or more WT logical nodes via an Xw interface and in the collocated RCLWI scenario the interface between LTE and WLAN is up to implementation
- User plane
  - There is no user plane interface defined between the eNB and the WT in RCLWI
- Control plane
  - In the non-collocated RCLWI scenario, the Xw control plane interface (Xw-C) is defined between the eNB and the WT and is similar to what is defined for LWA
  - LWA specific funtions are not part of RCLWI
- Mobility
  - A WLAN mobility set is a set of one or more BSSID/HESSID/SSIDs, within which WLAN mobility mechanisms apply while the UE has moved offloadable traffic to WLAN according to a steering command
  - i.e. the UE may perform mobility between WLAN APs belonging to the mobility set without informing the eNB

LTE/WLAN Radio Level Integration with IPsec Tunnel

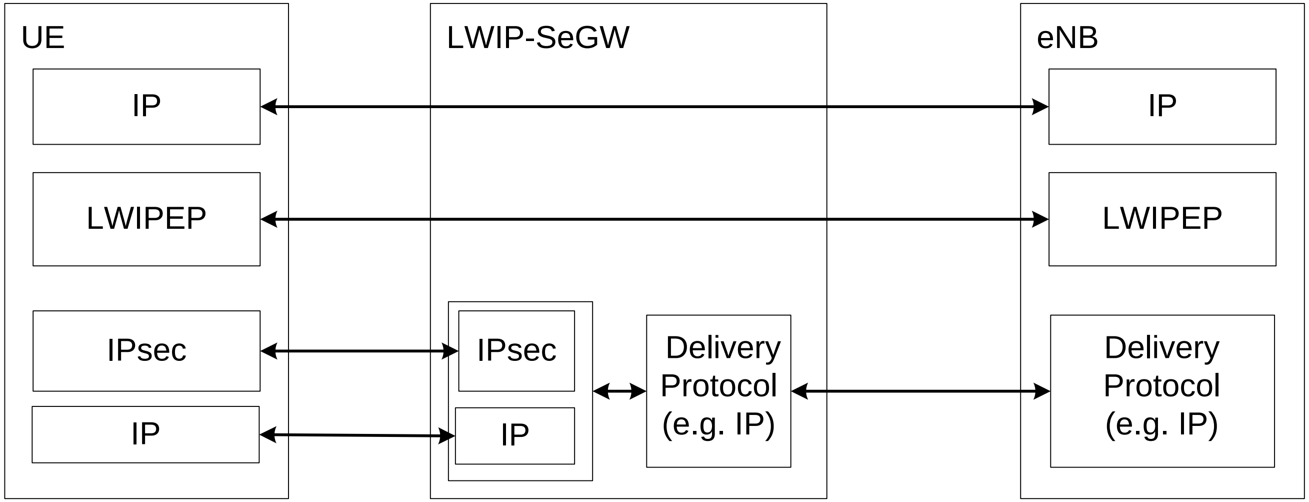
- LTE/WLAN Radio Level Integration with IPsec Tunnel (LWIP) feature allows a UE in RRC_CONNECTED to be configured by the eNB to utilize WLAN radio resources via IPsec tunnelling
- The IP Packets transferred between the UE and LWIP-SeGW are encapsulated using Ipsec in order to provide security to the packets that traverse WLAN
- The IP packets are then transported between the LWIP-SeGW and eNB via the Xw interface
- The end to end path between the UE and eNB via the WLAN network is referred to as the LWIP tunnel





Bearer over LWIP Tunnel - Protocol Stack

- The RRCConnectionReconfiguration message provides the necessary parameters for the UE to initiate the establishment of the IPSec tunnel for the DRB
- When the IPsec tunnel is established a data bearer can be configured to use LWIP resources
- The DRB configuration on the LTE access corresponding to the data bearer using IPsec resources shall not be released
- The data bearer refers to the EPS bearer mapped to the data radio bearer (DRB) which is maintained on the LTE side
- The IPsec tunnel is established following the exchange of security information between the eNB and LWIP-SeGW using the XwAP LWIP Addition Preparation procedure
- A single IPSec tunnel is used per UE for all the data bearers that are configured to send and/ or receive data over WLAN
- The data corresponding to each IPSec Tunnel is transported over the Xw interface on a single GTP-U tunnel
- Each data bearer may be configured so that traffic for that bearer can be routed over the IPsec tunnel in only downlink, only uplink, or both uplink and downlink over WLAN
- SRBs are carried over LTE only. eNB configures specific bearer(s) to use the IPsec tunnel
- If the IPsec tunnel is established then it is expected that eNB routes packets belonging to the data bearer via the LTE access or via the IPSec tunnel
- If eNB implementation routes packets to both LTE Access and the IPSec tunnel simultaneously, then delivery of packets to upper layers at the UE may occur out of order



Bearer over LWIP Tunnel - Protocol Stack (Cont.)

- For the DL of a data bearer, the packets received from the IPsec tunnel are forwarded directly to upper layers
- For the UL, the eNB configures the UE to route the uplink data either via LTE or via WLAN using RRC signalling
  - If routed via WLAN then all UL traffic of the data bearer is offloaded to the WLAN
- UL bearer packets sent over the LWIP tunnel are encapsulated using LWIPEP as specified in TS 36.361 with the 'Key' field in the LWIPEP header populated with the DRB Identity associated with offloaded UL bearer
- If aggregation over LWIP is enabled in UL or DL, the corresponding (UL or DL) packets sent over the LWIP tunnel and LTE are encapsulated using LWIPEP as specified in TS 36.361
  - The LWIPEP layer assigns sequence numbers to all packets and uses this sequence numbers to populate the 'Sequence Number' field in the LWIPEP header
  - The 'Key' field in the LWIPEP header is populated with the DRB Identity of the associated DRB
- The release of the IPsec tunnel is initiated by the eNB
  - Upon receiving the Handover Command or on transition to RRC_IDLE state, the UE shall autonomously release IPsec tunnel configuration and the use of it by the data bearers
- Since, WT node does not exist in LWIP operation, WT related description and procedures does not apply to LWIP
- Mobility Set should be considered as the set of WLAN APs across which UE can perform mobility without informing the eNB, when applying the concept for LWIP operation
- E-UTRAN does not configure LWIP with DC, LWA or RCLWI simultaneously for the same UE
- If LWIP and RAN assisted WLAN interworking are simultaneously configured for the same UE, in RRC_CONNECTED, the UE only applies LWIP

LWIP Network Interfaces

- The eNB is connected to one or more LWIP-SeGWs via an Xw interface
  - LWIP-SeGW supports the subset of WT functionality and additional functionality required to support LWIP
- User Plane
  - The Xw user plane interface (Xw-U) is used between eNB and LWIP-SeGW
  - The Xw-U interface is used to deliver LWIPEP PDUs between eNB and LWIP-SeGW using a single tunnel for all bearers configured for LWIP
  - The Xw-U interface supports flow control based on feedback from LWIP-SeGW
- Control Plane
  - The Xw control plane interface (Xw-C) is used between eNB and LWIP-SeGW
  - The LWIP-SeGW supports the following functions
  - Transfer of WLAN metrics (e.g. bss load) from LWIP-SeGW to eNB
  - Support of LWIP for UE in ECM-CONNECTED
    - Establishment, Modification and Release of a IPSec tunnel between the UE and the LWIP-SeGW
  - General Xw management and error handling functions
    - Error indication
    - Setting up the Xw
    - Resetting the Xw
    - Updating the configuration data

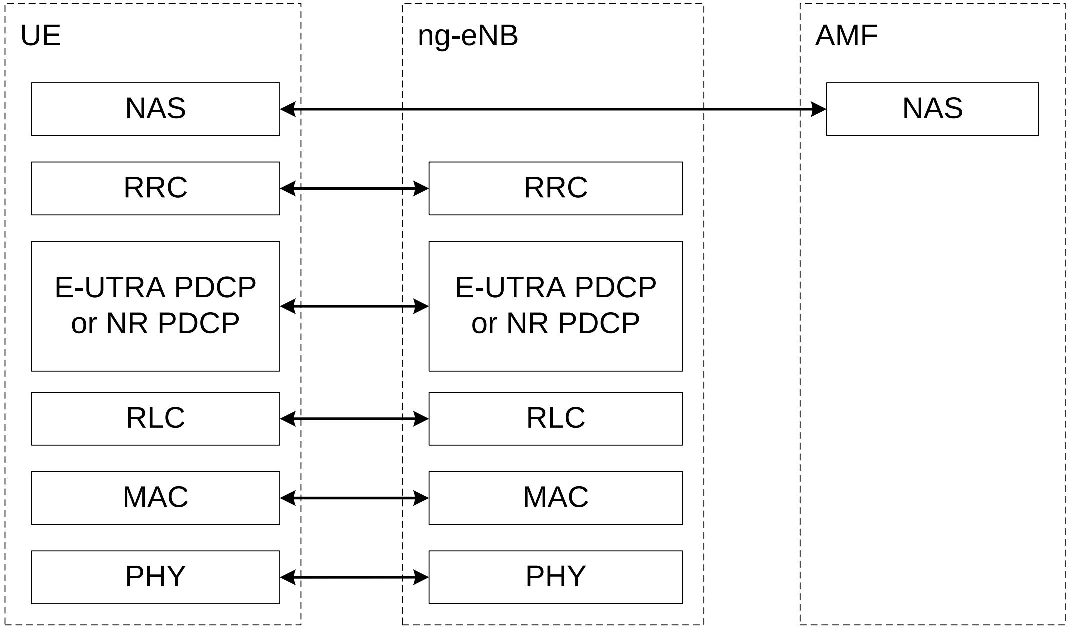
RAN assisted WLAN interworking

- The mechanisms to support traffic steering between E-UTRAN and WLAN
- TS 36.300 V15.3.0 supports E-UTRAN assisted UE based bi-directional traffic steering between E-UTRAN and WLAN for UEs in RRC_IDLE and RRC_CONNECTED
- E-UTRAN provides assistance parameters via broadcast and dedicated RRC signalling to the UE
- The RAN assistance parameters may include E-UTRAN signal strength thresholds, WLAN channel utilization thresholds, WLAN backhaul data rate thresholds, WLAN signal strength thresholds and Offload Preference Indicator (OPI)
- E-UTRAN can also provide a list of WLAN identifiers to the UE via broadcast signalling
- The UE uses the RAN assistance parameters in the evaluation of
  - Access network selection and traffic steering rules defined in TS 36.304
  - ANDSF policies defined in TS 24.312
- For traffic steering decisions between E-UTRAN and WLAN as specified in TS 23.402
- The OPI is only used in ANDSF policies as specified in TS 24.312
- WLAN identifiers are only used in access network selection and traffic steering rules defined in TS 36.304
- If the UE is provisioned with ANDSF policies it shall forward the received RAN assistance parameters to upper layers, otherwise it shall use them in the access network selection and traffic steering rules
- The access network selection and traffic steering rules are applied only to the WLANs of which identifiers are provided by the E-UTRAN
- The UE in RRC_CONNECTED shall apply the parameters obtained via dedicated signalling if such have been received from the serving cell
  - Otherwise, the UE shall apply the parameters obtained via broadcast signalling
- The UE in RRC_IDLE shall keep and apply the parameters obtained via dedicated signalling, until selection/reselection of another cell than the one where these parameters were received or a timer has expired
  - Since the UE entered RRC_IDLE upon which the UE shall apply the parameters obtained via broadcast signalling
- In the case of RAN sharing, each PLMN sharing the RAN can provide independent sets of RAN assistance parameters

Support for 5GC

- The E-UTRA connected to 5GC is supported as part of NG-RAN
  - The E-UTRA can be connected to both EPC and 5GC
- E-UTRA connected to 5GC supports the following functions
  - 5G NAS message transport
  - 5G security framework, except that data integrity protection is not supported
  - Access Control
  - Flow-based QoS
  - Network slicing
  - SDAP
  - NR PDCP
  - Support of UEs in RRC_INACTIVE state

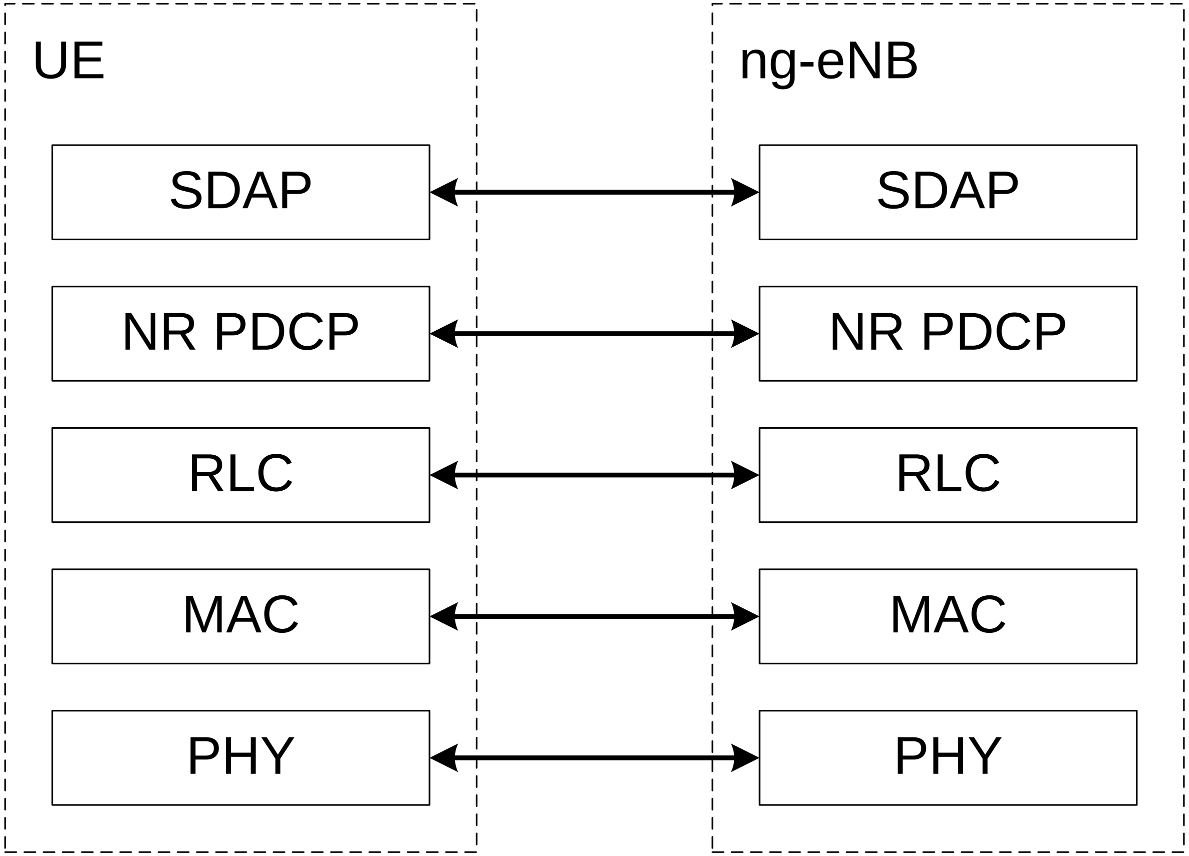
5GC Radio Protocol Architecture (Control Plane)



The protocol stack for the control plane, where

- E-UTRA PDCP sublayer (terminated in ng-eNB on the network side) performs the functions listed for the control plane in subclause 6.3 of TS 36.300, and NR PDCP sublayer (terminated in ng-eNB on the network side) performs the functions listed for the control plane in subclause 6.4 of TS 38.300
  - At initial RRC connection establishment SRB1 uses E-UTRA PDCP
  - After initial RRC connection establishment, SRB1 is reconfigured implicitly to use NR PDCP after the transmission of the RRCConnectionSetupComplete message
  - SRB2 always uses NR PDCP
- RLC and MAC sublayers (terminated in ng-eNB on the network side) perform the functions listed in subclause 6.2 and 6.1 of TS 36.300
- RRC (terminated in ng-eNB on the network side) performs the functions listed in subclause 7 of TS 36.300
- NAS control protocol (terminated in AMF on the network side) performs the functions listed in TS 23.501, for instance: authentication, mobility management, security control

5GC Radio Protocol Architecture (User Plane)



User Plane Protocol Stack

- The protocol stack for the user plane, where SDAP, NR PDCP, RLC and MAC sublayers perform the functions listed in subclause 6.5 of 3GPP TS 38.300, subclause 6.4 of 3GPP TS 38.300, subclause 6.3, and subclause 6.2 respectively

5GC Radio Protocol Architecture (Layer 2 & CN Selection)

- The layer 2 of E-UTRA connected to 5GC is split into the following sublayers: Medium Access Control (MAC), Radio Link Control (RLC), Packet Data Convergence Protocol (PDCP) and Service Data Adaptation Protocol (SDAP)
  - The physical layer offers to the MAC sublayer transport channels
  - The MAC sublayer offers to the RLC sublayer logical channels
  - The RLC sublayer offers to the PDCP sublayer RLC channels
  - The E-UTRA PDCP sublayer offers to the RRC sublayer signalling radio bearers (SRB)
  - The NR PDCP sublayer offers to the SDAP sublayer data radio bearers, and offers to the RRC sublayer signalling radio bearers
  - The SDAP sublayer offers to 5GC QoS flows
- CN Selection
  - For a cell that provides E-UTRA connectivity to both 5GC and EPC within a PLMN, the UE upper layer performs CN selection between EPC and 5GC
  - The UE AS layer indicates available CN type(s) to upper layers for CN type selection
  - The UE NAS layer indicates selected CN type (if available) with selected PLMN during PLMN selection procedure, as defined in 3GPP TS 36.304

5GC Radio Protocol Architecture (Mobility)

- The procedure for the new mobility scenario intra-EUTRA inter-systerm Handover (i.e., handover between E-UTRA connected to 5GC and E-UTRA connected to EPC) is described in section 10.2.2c of 3GPP TS 36.300
- The core network is changed during the procedure, as defined in 3GPP TS 23.502
- Inter-RAT handover to/from GERAN/UTRAN/CDMA2000 and cell change order to GERAN with NACC are not supported, and CS fallback is not applied except for the functionality of release with redirection to GERAN/UTRAN
- The following mobility procedures are supported
  - RRC Connection Release with Redirection to GERAN/UTRAN/CDMA2000/EUTRAN
  - Cell Change Order to GERAN without NACC
- When the UE is connected to E-UTRA/5GC, inter system fallback towards E-UTRAN is performed when 5GC doesnot support emergency services, voice services, for load balancing etc
  - Depending on factors such as CN interface availability, network configuration and radio conditions, the fallback procedure results in either CONNECTED state mobility (handover procedure) or IDLE state mobility (redirection)
- In the N2 signalling procedure, the AMF based on support for emergency services, voice service, any other services or for load balancing etc, may indicate the target CN type as EPC or 5GC to the ng-eNB node
  - When the target CN type is received by ng-eNB, the target CN type is also conveyed to the UE in RRC Connection Release Message
- For E-UTRA connected to 5GC, in RRC_IDLE the UE monitors the PCCH for CN-initiated paging information, in RRC_INACTIVE the UE monitors the PCCH for RAN-initiated and CN-initiated paging information
- NG-RAN and 5GC paging occasions overlap and the same paging mechanism is used in NG-RAN and in 5GC
- The extended DRX (eDRX) is not used for E-UTRA connected to 5GC

5GC Radio Protocol Architecture (Slicing & Access Control)

- Slicing
  - NG-RAN supports network slicing
  - The details of network slicing are specified in 3GPP TS 23.501 and clause 16.3 of TS 3GPP 38.300
- Access Control
  - E-UTRA connected to 5GC supports unified access control functionality
  - The details of unified access control are defined in 3GPP TS 38.300
  - For E-UTRA connected to both EPC and 5GC, E-UTRAN broadcasts the access control information associated with EPC and 5GC separately and the UE AS uses the access control information associated with the core network type selected by NAS

Summary

- Radio protocols and network interfaces are extended to support dual connectivity
- Advanced enhancement of dual connectivity
  - –Location Reporting
  - –Handover/Mobility
  - –WLAN/5GC