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**LTE;**

**5G;**

**NR;**

**Multi-connectivity;**

**Overall description;**

**Stage-2**

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650 Route des Lucioles  
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B  
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# Contents

Intellectual Property Rights .....	2
Legal Notice .....	2
Modal verbs terminology.....	2
Foreword.....	5
1 Scope .....	6
2 References .....	6
3 Definitions, symbols and abbreviations .....	7
3.1 Definitions .....	7
3.2 Abbreviations .....	8
4 Multi-Radio Dual Connectivity .....	8
4.1 General .....	8
4.1.1 Common MR-DC principles .....	8
4.1.2 MR-DC with the EPC .....	8
4.1.3 MR-DC with the 5GC .....	9
4.1.3.1 E-UTRA-NR Dual Connectivity .....	9
4.1.3.2 NR-E-UTRA Dual Connectivity .....	9
4.1.3.3 NR-NR Dual Connectivity .....	9
4.2 Radio Protocol Architecture .....	9
4.2.1 Control Plane .....	9
4.2.2 User Plane .....	10
4.3 Network interfaces .....	12
4.3.1 Control Plane .....	12
4.3.1.1 Common MR-DC principles .....	12
4.3.1.2 MR-DC with EPC .....	13
4.3.1.3 MR-DC with 5GC .....	13
4.3.2 User Plane .....	13
4.3.2.1 Common MR-DC principles .....	13
4.3.2.2 MR-DC with EPC .....	13
4.3.2.3 MR-DC with 5GC .....	13
5 Layer 1 related aspects .....	14
6 Layer 2 related aspects .....	14
6.1 MAC Sublayer .....	14
6.2 RLC Sublayer .....	15
6.3 PDCP Sublayer .....	15
6.4 SDAP Sublayer .....	15
7 RRC related aspects.....	15
7.1 System information handling .....	15
7.2 Measurements.....	15
7.3 UE capability coordination.....	17
7.4 Handling of combined MN/SN RRC messages.....	17
7.5 SRB3 .....	18
7.6 Split SRB.....	18
7.7 SCG/MCG failure handling.....	18
7.8 UE identities .....	19
7.9 Inter-node Resource Coordination .....	19
8 Bearer handling aspects.....	19
8.1 QoS aspects .....	19
8.2 Bearer type selection .....	20
8.3 Bearer type change .....	21
8.4 User data forwarding .....	22
9 Security related aspects .....	22

10	Multi-Connectivity operation related aspects.....	23
10.1	General .....	23
10.2	Secondary Node Addition .....	23
10.2.1	EN-DC .....	23
10.2.2	MR-DC with 5GC.....	25
10.3	Secondary Node Modification (MN/SN initiated) .....	27
10.3.1	EN-DC .....	27
10.3.2	MR-DC with 5GC.....	31
10.4	Secondary Node Release (MN/SN initiated).....	35
10.4.1	EN-DC .....	35
10.4.2	MR-DC with 5GC.....	37
10.5	Secondary Node Change (MN/SN initiated) .....	39
10.5.1	EN-DC .....	39
10.5.2	MR-DC with 5GC.....	41
10.6	PSCell change .....	44
10.7	Inter-Master Node handover with/without Secondary Node change.....	45
10.7.1	EN-DC .....	45
10.7.2	MR-DC with 5GC.....	47
10.8	Master Node to eNB/gNB Change .....	49
10.8.1	EN-DC .....	49
10.8.2	MR-DC with 5GC.....	50
10.9	eNB/gNB to Master Node change.....	51
10.9.1	EN-DC .....	51
10.9.2	MR-DC with 5GC.....	52
10.10	RRC Transfer .....	54
10.10.1	EN-DC .....	54
10.10.2	MR-DC with 5GC.....	55
10.11	Secondary RAT data volume reporting.....	56
10.11.1	EN-DC .....	56
10.11.2	MR-DC with 5GC.....	57
10.12	Activity Notification.....	58
10.12.1	EN-DC .....	58
10.12.2	MR-DC with 5GC.....	60
10.13	Notification Control Indication .....	61
10.13.1	EN-DC .....	61
10.13.2	MR-DC with 5GC.....	62
10.14	PDU Session Split at UPF.....	62
10.14.1	PDU Session Split at UPF during PDU session resource setup.....	62
10.14.2	PDU Session Split at UPF during PDU session resource modify (5GC initiated).....	63
10.14.3	PDU Session Split at UPF (RAN initiated QoS flows offloading from MN to SN).....	63
11	Service related aspects.....	66
11.1	Roaming and Access Restrictions .....	66
11.2	Support of Network Sharing.....	66
12	X2/Xn Interface related aspects .....	66
13	Other aspects .....	66
13.1	Interference avoidance for in-device coexistence.....	66
<b>Annex A (informative):</b>	<b>Layer 2 handling for bearer type change .....</b>	<b>67</b>
<b>Annex B (informative):</b>	<b>Supported MR-DC Handover Scenarios .....</b>	<b>69</b>
<b>Annex C (informative):</b>	<b>Change history .....</b>	<b>70</b>
History .....		74

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# 1 Scope

The present document provides an overview of the multi-connectivity operation using E-UTRA and NR radio access technologies. Details of the network and radio interface protocols are specified in companion specifications of the 36 and 38 series.

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# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
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- [1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
- [2] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2".
- [3] 3GPP TS 38.300: "NR; NR and NG-RAN Overall description; Stage 2".
- [4] 3GPP TS 38.331: "NR; Radio Resource Control (RRC) protocol specification".
- [5] 3GPP TS 38.423: "NG-RAN; Xn application protocol (XnAP)".
- [6] 3GPP TS 38.425: "NG-RAN; NR user plane protocol".
- [7] 3GPP TS 38.401: "NG-RAN; Architecture description".
- [8] 3GPP TS 38.133: "NG-RAN; Requirements for support of radio resource management".
- [9] 3GPP TS 36.423: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)".
- [10] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification".
- [11] 3GPP TS 23.501: "System Architecture for the 5G System; Stage 2".
- [12] 3GPP TS 38.101-1: "User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".
- [13] 3GPP TS 38.101-2: "User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone".
- [14] 3GPP TS 38.101-3: "User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios".
- [15] 3GPP TS 36.323: "Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification".
- [16] 3GPP TS 38.323: "NR; Packet Data Convergence Protocol (PDCP) specification".
- [17] Void
- [18] Void
- [19] Void

- [20] Void
- [21] 3GPP TS 38.213: "NR; Physical layer procedures".

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## 3 Definitions, symbols and abbreviations

### 3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1] and TS 36.300 [2].

**En-gNB:** node providing NR user plane and control plane protocol terminations towards the UE, and acting as Secondary Node in EN-DC.

**Master Cell Group:** in MR-DC, a group of serving cells associated with the Master Node, comprising of the SpCell (PCell) and optionally one or more SCells.

**Master node:** in MR-DC, the radio access node that provides the control plane connection to the core network. It may be a Master eNB (in EN-DC), a Master ng-eNB (in NGEN-DC) or a Master gNB (in NR-DC and NE-DC).

**MCG bearer:** in MR-DC, a radio bearer with an RLC bearer (or two RLC bearers, in case of CA packet duplication) only in the MCG.

**MN terminated bearer:** in MR-DC, a radio bearer for which PDCP is located in the MN.

**MCG SRB:** in MR-DC, a direct SRB between the MN and the UE.

**Multi-Radio Dual Connectivity:** Dual Connectivity between E-UTRA and NR nodes, or between two NR nodes.

**Ng-eNB:** as defined in TS 38.300 [3].

**PCell:** SpCell of a master cell group.

**PSCell:** SpCell of a secondary cell group.

**RLC bearer:** RLC and MAC logical channel configuration of a radio bearer in one cell group.

**Secondary Cell Group:** in MR-DC, a group of serving cells associated with the Secondary Node, comprising of the SpCell (PSCell) and optionally one or more SCells.

**Secondary node:** in MR-DC, the radio access node, with no control plane connection to the core network, providing additional resources to the UE. It may be an en-gNB (in EN-DC), a Secondary ng-eNB (in NE-DC) or a Secondary gNB (in NR-DC and NGEN-DC).

**SCG bearer:** in MR-DC, a radio bearer with an RLC bearer (or two RLC bearers, in case of CA packet duplication) only in the SCG.

**SN terminated bearer:** in MR-DC, a radio bearer for which PDCP is located in the SN.

**SpCell:** primary cell of a master or secondary cell group.

**SRB3:** in EN-DC, NGEN-DC and NR-DC, a direct SRB between the SN and the UE.

**Split bearer:** in MR-DC, a radio bearer with RLC bearers both in MCG and SCG.

**Split PDU Session (or PDU Session split):** a PDU Session whose QoS Flows are served by more than one SDAP entities in the NG-RAN.

**Split SRB:** in MR-DC, a SRB between the MN and the UE with RLC bearers both in MCG and SCG.

**User plane resource configuration:** in MR-DC with 5GC, encompasses radio network resources and radio access resources related to either one or more PDU sessions, one or more QoS flows, one or more DRBs, or any combination thereof.

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1] and TS 36.300 [2].

DC	Intra-E-UTRA Dual Connectivity
EN-DC	E-UTRA-NR Dual Connectivity
MCG	Master Cell Group
MN	Master Node
MR-DC	Multi-Radio Dual Connectivity
NE-DC	NR-E-UTRA Dual Connectivity
NGEN-DC	NG-RAN E-UTRA-NR Dual Connectivity
NR-DC	NR-NR Dual Connectivity
SCG	Secondary Cell Group
SMTC	SS/PBCH block Measurement Timing Configuration
SN	Secondary Node

## 4 Multi-Radio Dual Connectivity

### 4.1 General

#### 4.1.1 Common MR-DC principles

Multi-Radio Dual Connectivity (MR-DC) is a generalization of the Intra-E-UTRA Dual Connectivity (DC) described in TS 36.300 [2], where a multiple Rx/Tx capable UE may be configured to utilise resources provided by two different nodes connected via non-ideal backhaul, one providing NR access and the other one providing either E-UTRA or 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.

NOTE 1: MR-DC is designed based on the assumption of non-ideal backhaul between the different nodes but can also be used in case of ideal backhaul.

NOTE 2: All MR-DC normative text and procedures in this version of the specification show the aggregated node case. The details about non-aggregated node for MR-DC operation are described in TS 38.401 [7].

#### 4.1.2 MR-DC with the EPC

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

The EN-DC architecture is illustrated in Figure 4.1.2-1 below.

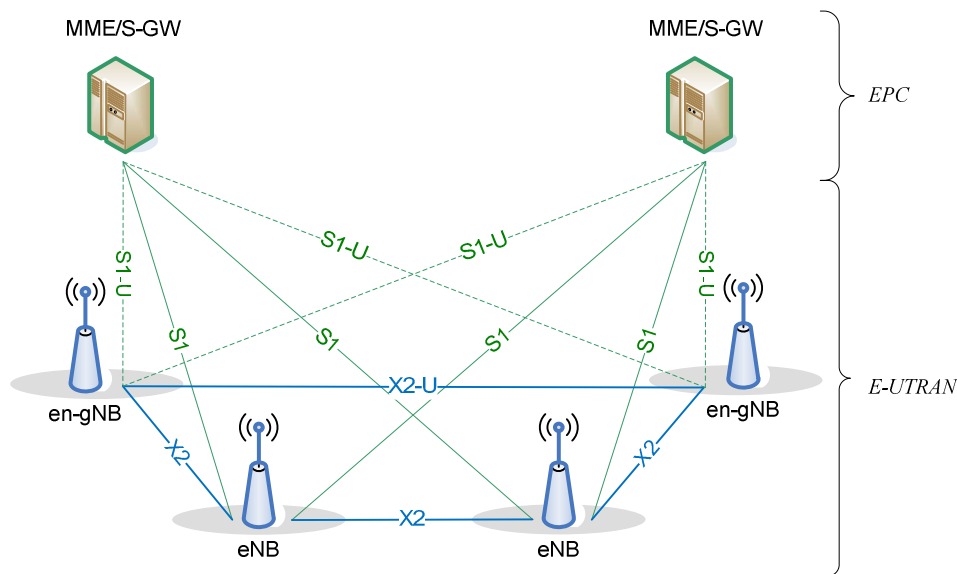


Figure 4.1.2-1: EN-DC Overall Architecture

### 4.1.3 MR-DC with the 5GC

#### 4.1.3.1 E-UTRA-NR Dual Connectivity

NG-RAN supports NG-RAN E-UTRA-NR Dual Connectivity (NGEN-DC), in which a UE is connected to one ng-eNB that acts as a MN and one gNB that acts as a SN.

#### 4.1.3.2 NR-E-UTRA Dual Connectivity

NG-RAN supports NR-E-UTRA Dual Connectivity (NE-DC), in which a UE is connected to one gNB that acts as a MN and one ng-eNB that acts as a SN.

#### 4.1.3.3 NR-NR Dual Connectivity

NG-RAN supports NR-NR Dual Connectivity (NR-DC), in which a UE is connected to one gNB that acts as a MN and another gNB that acts as a SN. In addition, NR-DC can also be used when a UE is connected to two gNB-DUs, one serving the MCG and the other serving the SCG, connected to the same gNB-CU, acting both as a MN and as a SN.

## 4.2 Radio Protocol Architecture

### 4.2.1 Control Plane

In MR-DC, the UE has a single RRC state, based on the MN RRC and a single C-plane connection towards the Core Network. Figure 4.2.1-1 illustrates the Control plane architecture for MR-DC. Each radio node has its own RRC entity (E-UTRA version if the node is an eNB or NR version if the node is a gNB) which can generate RRC PDUs to be sent to the UE.

RRC PDUs generated by the SN can be transported via the MN to the UE. The MN always sends the initial SN RRC configuration via MCG SRB (SRB1), but subsequent reconfigurations may be transported via MN or SN. When transporting RRC PDU from the SN, the MN does not modify the UE configuration provided by the SN.

In E-UTRA connected to EPC, at initial connection establishment SRB1 uses E-UTRA PDCP. If the UE supports EN-DC, regardless whether EN-DC is configured or not, after initial connection establishment, MCG SRBs (SRB1 and SRB2) can be configured by the network to use either E-UTRA PDCP or NR PDCP (either SRB1 and SRB2 are both configured with E-UTRA PDCP, or they are both configured with NR PDCP). Change from E-UTRA PDCP to NR PDCP (or vice-versa) is supported via a handover procedure (reconfiguration with mobility) or, for the initial change of SRB1 from E-UTRA PDCP to NR PDCP, with a reconfiguration without mobility before the initial security activation.

If the SN is a gNB (i.e. for EN-DC, NGEN-DC and NR-DC), the UE can be configured to establish a SRB with the SN (SRB3) to enable RRC PDUs for the SN to be sent directly between the UE and the SN. RRC PDUs for the SN can only be transported directly to the UE for SN RRC reconfiguration not requiring any coordination with the MN. Measurement reporting for mobility within the SN can be done directly from the UE to the SN if SRB3 is configured.

Split SRB is supported for all MR-DC options, allowing duplication of RRC PDUs generated by the MN, via the direct path and via the SN. Split SRB uses NR PDCP. This version of the specification does not support the duplication of RRC PDUs generated by the SN via the MN and SN paths.

In EN-DC, the SCG configuration is kept in the UE during suspension. The UE releases the SCG configuration (but not the radio bearer configuration) during resumption initiation.

In MR-DC with 5GC, the UE stores the PDCP/SDAP configuration when moving to RRC Inactive but it releases the SCG configuration.

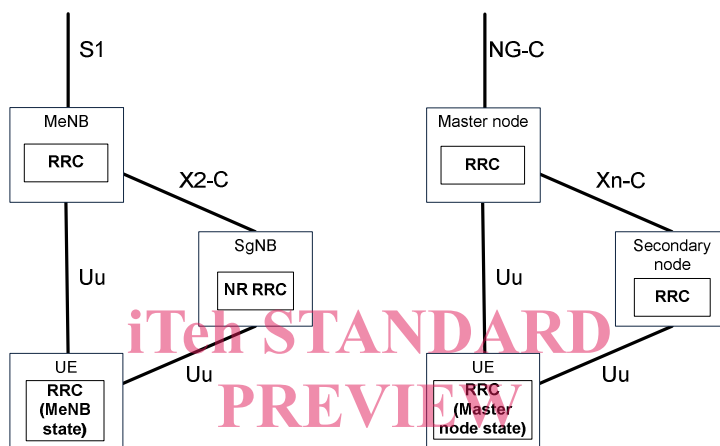


Figure 4.2.1-1: Control plane architecture for EN-DC (left) and MR-DC with 5GC (right).

4.2.2 User Plane [ETSI TS 137 340 V15.16.0 \(2022-05\)](https://standards.iteh.ai/catalog/standards/sist/9e38a1a4-71da-4479-8821-671d17416888/etsi-ts-137-340-v15-16-0-2022-05)

In MR-DC, from a UE perspective, three bearer types exist: MCG bearer, SCG bearer and split bearer. These three bearer types are depicted in Figure 4.2.2-1 for MR-DC with EPC (EN-DC) and in Figure 4.2.2-2 for MR-DC with 5GC (NGEN-DC, NE-DC and NR-DC).

In E-UTRA connected to EPC, if the UE supports EN-DC, regardless whether EN-DC is configured or not, the network can configure either E-UTRA PDCP or NR PDCP for MN terminated MCG bearers while NR PDCP is always used for all other bearers.

In MR-DC with 5GC, NR PDCP is always used for all bearer types. In NGEN-DC, E-UTRA RLC/MAC is used in the MN while NR RLC/MAC is used in the SN. In NE-DC, NR RLC/MAC is used in the MN while E-UTRA RLC/MAC is used in the SN. In NR-DC, NR RLC/MAC is used in both MN and SN.

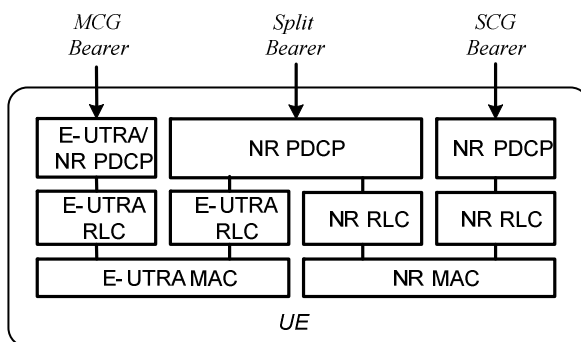
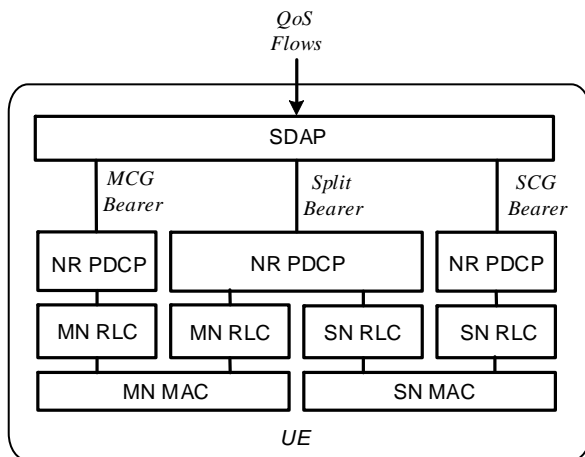


Figure 4.2.2-1: Radio Protocol Architecture for MCG, SCG and split bearers from a UE perspective in MR-DC with EPC (EN-DC)

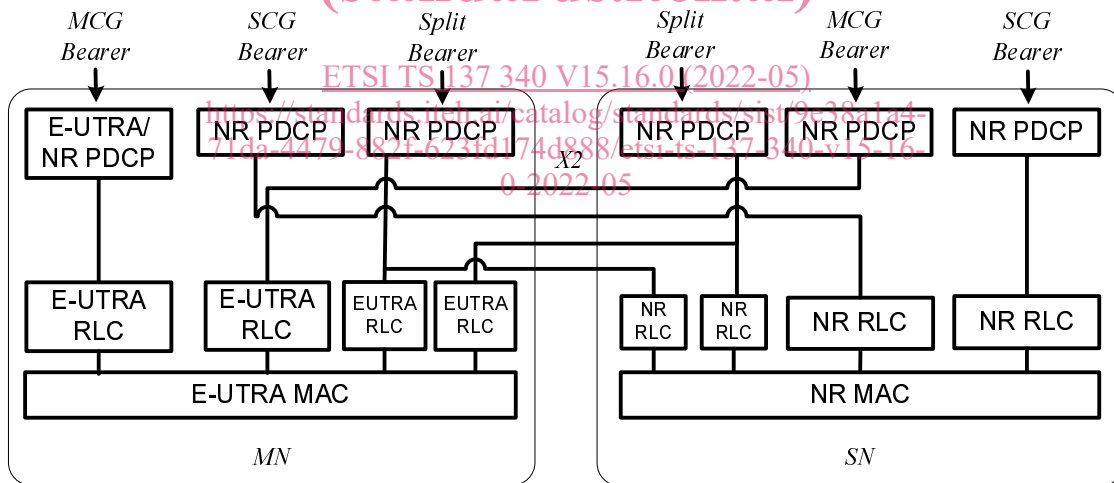


**Figure 4.2.2-2: Radio Protocol Architecture for MCG, SCG and split bearers from a UE perspective in MR-DC with 5GC (NGEN-DC, NE-DC and NR-DC).**

From a network perspective, each bearer (MCG, SCG and split bearer) can be terminated either in MN or in SN. Network side protocol termination options are shown in Figure 4.2.2-3 for MR-DC with EPC (EN-DC) and in Figure 4.2.2-4 for MR-DC with 5GC (NGEN-DC, NE-DC and NR-DC).

NOTE 1: Even if only SCG bearers are configured for a UE, for SRB1 and SRB2 the logical channels are always configured at least in the MCG, i.e. this is still an MR-DC configuration and a PCell always exists.

NOTE 2: If only MCG bearers are configured for a UE, i.e. there is no SCG, this is still considered an MR-DC configuration, as long as at least one of the bearers is terminated in the SN.



**Figure 4.2.2-3: Network side protocol termination options for MCG, SCG and split bearers in MR-DC with EPC (EN-DC).**

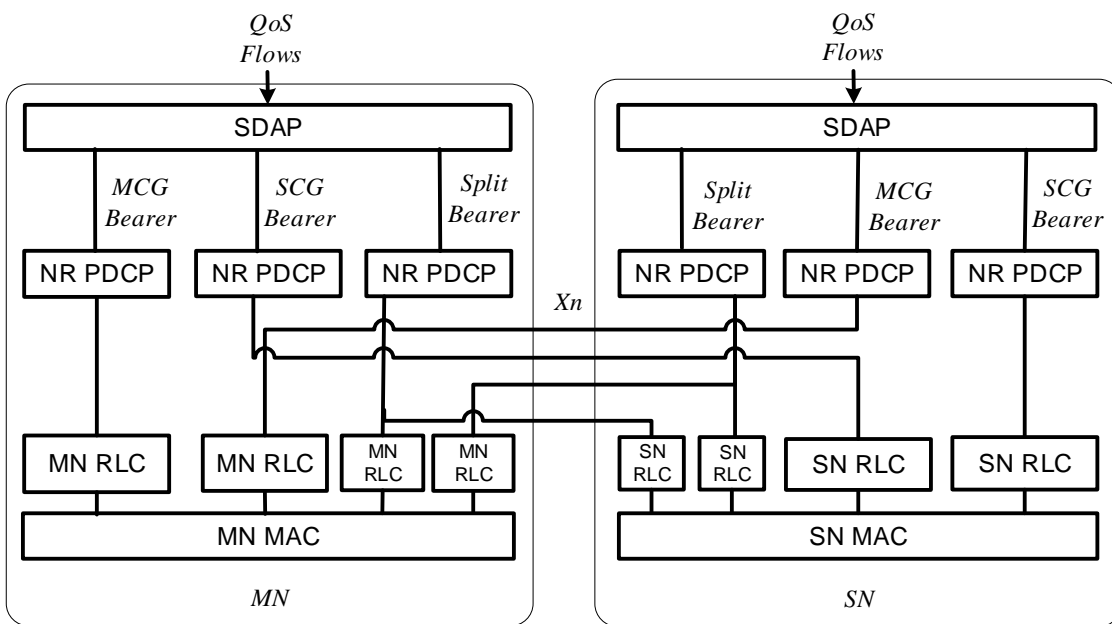


Figure 4.2.2-4: Network side protocol termination options for MCG, SCG and split bearers in MR-DC with 5G (NGEN-DC, NE-DC and NR-DC).

### 4.3 Network interfaces

#### 4.3.1 Control Plane [ETSI TS 137 340 V15.16.0 \(2022-05\)](https://standards.iteh.ai/catalog/standards/sist/9e38a1a4-174d888/etsi-ts-137-340-v15-16-0-2022-05)

##### 4.3.1.1 Common MR-DC principles <https://standards.iteh.ai/catalog/standards/sist/9e38a1a4-174d888/etsi-ts-137-340-v15-16-0-2022-05>

In MR-DC, there is an interface between the MN and the SN for control plane signalling and coordination. For each MR-DC UE, there is also one control plane connection between the MN and a corresponding CN entity. The MN and the SN involved in MR-DC for a certain UE control their radio resources and are primarily responsible for allocating radio resources of their cells.

Figure 4.3.1.1-1 shows C-plane connectivity of MN and SN involved in MR-DC for a certain UE.

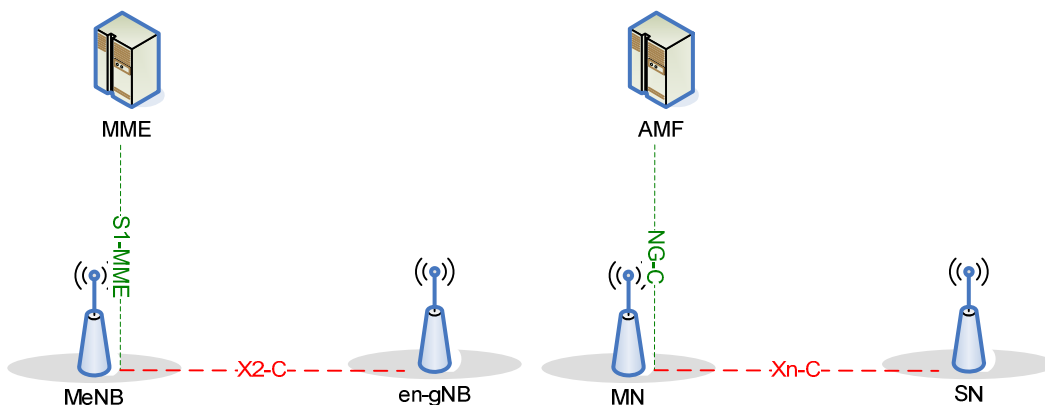


Figure 4.3.1.1-1: C-Plane connectivity for EN-DC (left) and MR-DC with 5GC (right).

### 4.3.1.2 MR-DC with EPC

In MR-DC with EPC (EN-DC), the involved core network entity is the MME. S1-MME is terminated in MN and the MN and the SN are interconnected via X2-C.

### 4.3.1.3 MR-DC with 5GC

In MR-DC with 5GC (NGEN-DC, NE-DC and NR-DC), the involved core network entity is the AMF. NG-C is terminated in the MN and the MN and the SN are interconnected via Xn-C.

## 4.3.2 User Plane

### 4.3.2.1 Common MR-DC principles

There are different U-plane connectivity options of the MN and SN involved in MR-DC for a certain UE, as shown in Figure 4.3.2.1-1. The U-plane connectivity depends on the bearer option configured:

- For *MN terminated bearers*, the user plane connection to the CN entity is terminated in the MN;
- For *SN terminated bearers*, the user plane connection to the CN entity is terminated in the SN;
- The transport of user plane data over the Uu either involves MCG or SCG radio resources or both:
  - For *MCG bearers*, only MCG radio resources are involved;
  - For *SCG bearers*, only SCG radio resources are involved;
  - For *split bearers*, both MCG and SCG radio resources are involved.
- For split bearers, *MN terminated SCG bearers* and *SN terminated MCG bearers*, PDCP data is transferred between the MN and the SN via the MN-SN user plane interface.

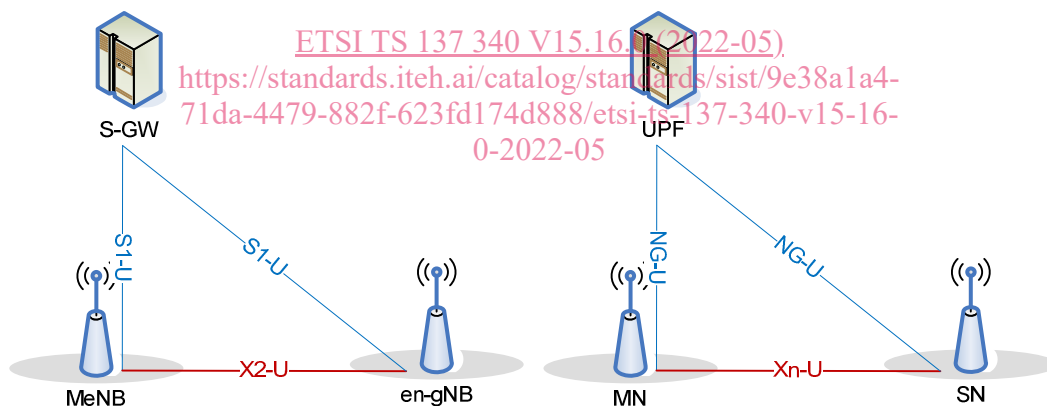


Figure 4.3.2.1-1: U-Plane connectivity for EN-DC (left) and MR-DC with 5GC (right).

### 4.3.2.2 MR-DC with EPC

For MR-DC with EPC (EN-DC), X2-U interface is the user plane interface between MN and SN, and S1-U is the user plane interface between the MN, the SN or both and the S-GW.

### 4.3.2.3 MR-DC with 5GC

For MR-DC with 5GC (NGEN-DC, NE-DC and inter-gNB NR-DC), Xn-U interface is the user plane interface between MN and SN, and NG-U is the user plane interface between the MN, the SN or both and the UPF.

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## 5 Layer 1 related aspects

In MR-DC, two or more Component Carriers (CCs) may be aggregated over two cell groups. A UE may simultaneously receive or transmit on multiple CCs depending on its capabilities. The maximum number of configured CCs for a UE is 32 for DL and UL. Depending on UE's capabilities, up to 31 CCs can be configured for an E-UTRA cell group when the NR cell group is configured. For the NR cell group, the maximum number of configured CCs for a UE is 16 for DL and 16 for UL.

A gNB may configure the same Physical Cell ID (PCI) to more than one NR cell it serves. To avoid PCI confusion for MR-DC, NR PCIs should be allocated in a way that an NR cell is uniquely identifiable by a PCell identifier. This PCell is in the coverage area of an NR cell included in the MR-DC operation. In addition, NR PCIs should only be re-used in NR cells on the same SSB frequency sufficiently distant from each other. X2-C/Xn-C signalling supports disambiguation of NR PCIs by including the CGI of the PCell in respective X2AP/XnAP messages (e.g. SGNB ADDITION REQUEST/S-NODE ADDITION REQUEST) and by providing neighbour cell relationship via non-UE associated signaling (e.g. via the Xn Setup procedure or the NG-RAN node Configuration Update procedure).

In this version of the specification, NR-DC assumes slot-level synchronization between PCell and PSCell, with no assumption on SFN synchronization. However, some UEs may indicate they support NR-DC only if SFN synchronization between PCell and PSCell is also ensured.

In (NG)EN-DC and in NE-DC, power sharing can be performed within a frequency range with either semi-static or dynamic power sharing. With semi-static power sharing, the maximum UE transmission power is semi-statically split between MCG and SCG by RRC configuration. With dynamic power sharing:

- when determining the UL transmission power of an SCG transmission in (NG)EN-DC, the UE takes into account transmission(s) on MCG overlapping with any part of the SCG transmission;
- when determining the UL transmission power of an MCG transmission in NE-DC, the UE takes into account transmission(s) on SCG overlapping with any part of the MCG transmission.

Details are specified in TS38.213 [21].

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## 6 Layer 2 related aspects

### 6.1 MAC Sublayer

In MR-DC, the UE is configured with two MAC entities: one MAC entity for the MCG and one MAC entity for the SCG. The serving cells of the MCG other than the PCell can only be activated/deactivated by the MAC Control Element received on MCG, and the serving cells of the SCG other than PSCell can only be activated/ deactivated by the MAC Control Element received on SCG. The MAC entity applies the bitmap for the associated cells of either MCG or SCG. PSCell in SCG is always activated like the PCell (i.e. deactivation timer is not applied to PSCell). With the exception of PUCCH SCell, one deactivation timer is configured per SCell by RRC.

In MR-DC, semi-persistent scheduling (SPS) resources and configured grant (CG) resources can be configured on serving cells in both MCG and SCG.

In MR-DC, contention based random access (CBRA) procedure is supported on both PCell and PSCell while contention free random access (CFRA) procedure is supported on all serving cells in both MCG and SCG.

In MR-DC, the BSR configuration, triggering and reporting are independently performed per cell group. For split bearers, the PDCP data is considered in BSR in the cell group(s) configured by RRC.

In MR-DC, separate DRX configurations are provided for MCG and SCG.

In MR-DC, PHR is independently configured per cell group. Events in one cell group can trigger power headroom reporting in both MCG and SCG. Power headroom information for one cell group is also included in a PHR transmitted in the other cell group.