5G NR Protocols: Layer 3 (Radio Resource Control)

TP00005-V-1701 V0 - S02M03 Ed1

Learning objectives

Upon completion of this module, you should be able to:

- Describe NR RRC Protocol
- Explain RRC Functions and Procedures
- Describe RRC Connection Control
- Describe Measurement Configuration and Reporting
- Explain Inter-RAT Mobility
- Describe NR RRC Connection Setup

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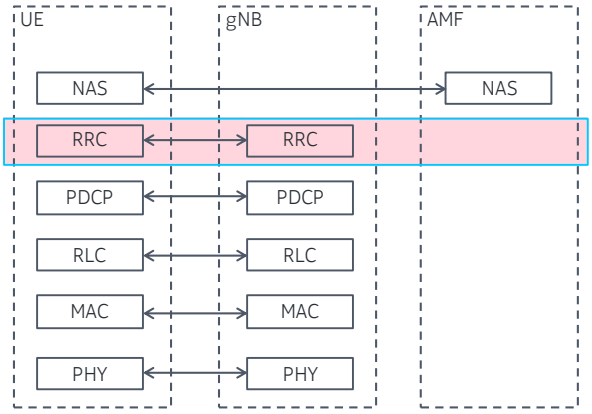
NOKIA

NR RRC Protocol

NR RRC Protocol
Radio Resource Control

Functions

- Enables the message exchange over Uu interface (gNB → UE)
- Defines associated procedures
- Responsible for:
  - SystemInformation broadcast,
  - Paging initiated by 5GC or NG-RAN
  - Connectioncontrol
  - Mobility and Measurements
  - NAS message transfer



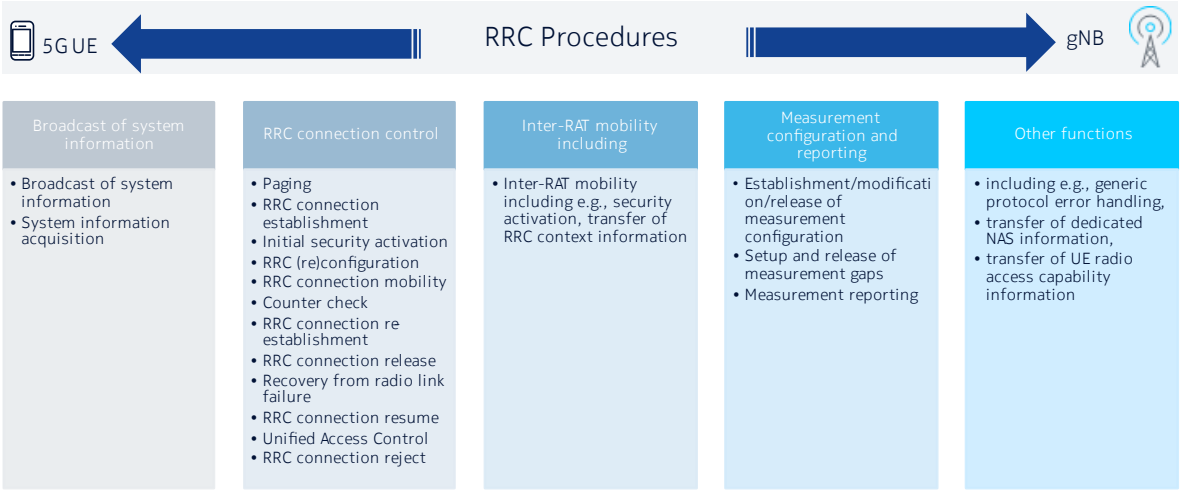
The main services and functions of the RRC sublayer include:

- Broadcast of System Information related to AS and NAS;
- Paging initiated by 5GC or NG-RAN;
- Establishment, maintenance and release of an RRC connection between the UE and NG-RAN including:
  - Addition, modification and release of carrier aggregation;
  - Addition, modification and release of Dual Connectivity in NR or between E-UTRA and NR.
- Security functions including key management;
- Establishment, configuration, maintenance and release of Signaling Radio Bearers (SRBs) and Data Radio Bearers (DRBs);
- Mobility functions including:
  - Handover and context transfer;
  - UE cell selection and reselection and control of cell selection and reselection;
  - Inter-RAT mobility.
- QoS management functions;
- UE measurement reporting and control of the reporting;
- Detection of and recovery from radio link failure;
- NAS message transfer to/from NAS from/to UE.

Main differences with LTE:

- On demand system information
- RRC Inactive State
- Beam handling.

NR RRC Protocol
RRC Functions and Procedures



The RRC protocol includes the following main functions:

Broadcast of system information:

- Including NAS common information;
- Information applicable for UEs in RRC_IDLE and RRC_INACTIVE (e.g., cell (re)selection parameters, neighboring cell information) and information (also) applicable for UEs in RRC_CONNECTED (e.g., common channel configuration information);
- Including ETWS notification, CMAS notification.

RRC connection control:

- Paging;
- Establishment/modification/suspension/resumption/release of RRC connection, including e.g., assignment/modification of UE identity (C-RNTI, I-RNTI, etc.), establishment/modification/suspension/resumption/release of SRBs (except for SRB0);
- Access barring;
- Initial security activation, i.e., initial configuration of AS integrity protection (SRBs, DRBs) and AS ciphering (SRBs, DRBs);
- RRC connection mobility including e.g., intra-frequency and inter-frequency handover, associated security handling, i.e., key/algorithm change, specification of RRC context information transferred between network nodes;
- Establishment/modification/suspension/resumption/release of RBs carrying user data (DRBs);
- Radio configuration control including e.g., assignment/modification of ARQ configuration, HARQ configuration, DRX configuration;
- In case of DC, cell management including e.g., change of PSCell, addition/modification/release of SCG cell(s);
- In case of CA, cell management including e.g., addition/modification/release of SCell(s);
- QoS control including assignment/ modification of semi-persistent scheduling (SPS) configuration and configured grant configuration for DL and UL respectively, assignment/ modification of parameters for UL rate control in the UE, i.e., allocation of a priority and a prioritized bit rate (PBR) for each RB.
- Recovery from radio link failure.

Inter-RAT mobility including e.g., security activation, transfer of RRC context information;

Measurement configuration and reporting:

- Establishment/modification/release of measurement configuration (e.g., intra-frequency, inter-frequency and inter-RAT measurements);
- Setup and release of measurement gaps;
- Measurement reporting.

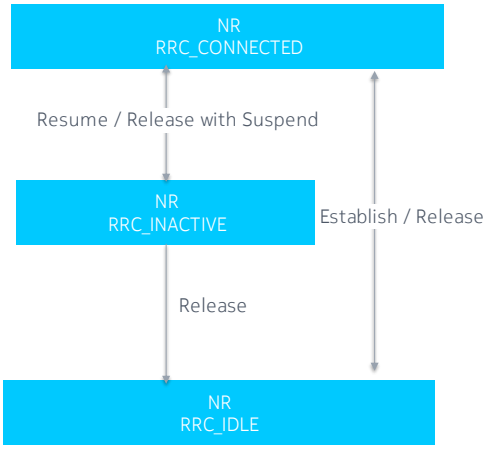
Other functions including e.g., generic protocol error handling, transfer of dedicated NAS information, transfer of UE radio access capability information.

NR RRC Protocol
RRC States

- A UE is either in RRC_CONNECTED state or in RRC_INACTIVE state when an RRC connection has been established.
- If this is not the case, i.e., no RRC connection is established, the UE is in RRC_IDLE state

The introduction of RRC-inactive state to the RRC state machine allows for the UE to maintain RRC connection in an inactive state while having the battery saving characteristics of the Idle mod

This allows for maintaining the RRC connection also when the UE is inactive for longer time durations, and avoid the signaling overhead and related energy consumption needed when the RRC connection re-established from Idle mode



RRC_IDLE:

- The UE NAS layer identifies a selected PLMN and equivalent PLMNs;
- UE controlled cell (re-)selection mobility based on network configuration and neighboring cell measurements;
- The UE AS context is not stored in any gNB nor in the UE;
- A UE specific DRX may be configured by upper layers;
- The UE monitors a Paging channel for CN paging using 5G-S-TMSI;
- Acquires system information and can send SI request.

RRC_CONNECTED:

- The UE has an NR RRC connection;
- Network controlled mobility, i.e., handover within NR and to/from E-UTRAN based on neighboring cell measurements and measurement reporting;.
- The UE stores the AS context;
- Transfer of unicast data to/from the UE with channel quality and feedback information;
- At lower layers, the UE may be configured with a UE specific DRX;
- For UEs supporting CA, use of one or more SCells, aggregated with the SpCell;
- For UEs supporting DC, use of one SCG, aggregated with the MCG;
- The UE monitors a Paging channel and control channels associated with the shared data channel;
- Acquires system information.

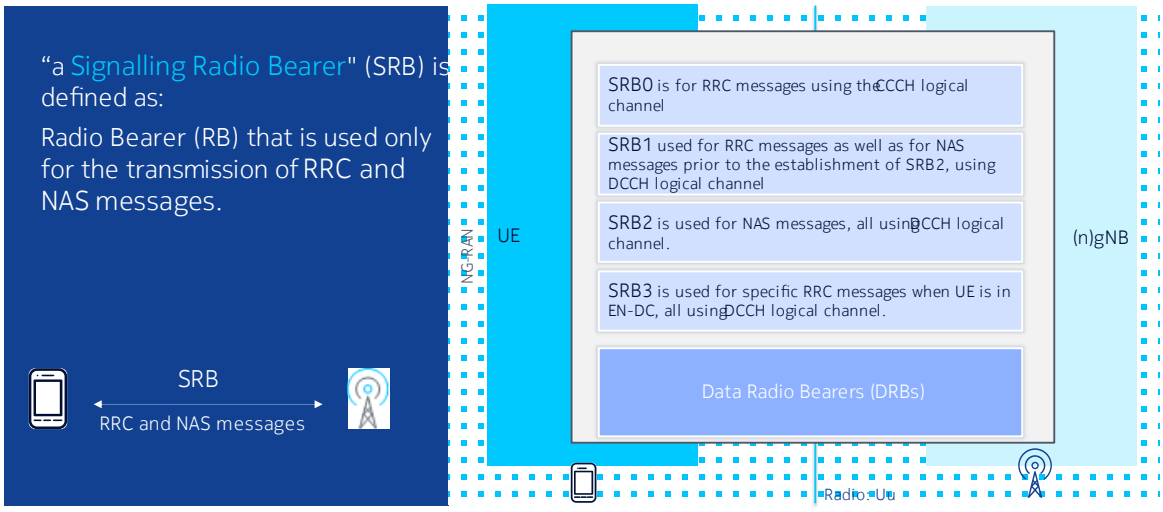
RRC_INACTIVE:

- The UE has an NR RRC connection;
- UE controlled cell re-selection mobility based on network configuration and neighboring cell measurements;
- The UE AS context is stored in at least one gNB and the UE;
- A UE specific DRX may be configured by upper layers or by RRC layer;
- The UE monitors a Paging channel for CN paging using 5G-S-TMSI and RAN paging using I-RNTI;
- A RAN-based notification area (RNA) is configured by RRC layer and UE performs RNA updates periodically and when moving outside the RNA;
- Acquires system information and can send SI request.

NR RRC Protocol
RRC States

RRC_IDLE	RRC_INACTIVE	RRC_CONNECTED
UE controlled mobility based on network configuration (cell reselection)		Network controlled mobility within NR and to/from E-UTRAN
DRX configured by NAS	DRX configured by NAS or gNB	DRX configured by gNB
Broadcast of system information		Neighbour cell measurements
Paging (CN-initiated)	Paging (CN-initiated or NG-RAN-initiated)	Network can transmit and/or receive data to/from UE
UE has an CN ID that uniquely identifies it w/in a tracking area	NG-RAN knows the RNA which the UE belongs to	NG-RAN knows the cell which the UE belongs to
No RRC context stored in gNB	UE and NG RAN have the UE AS context stored, and the 5GC - NG-RAN connection (both C/U planes) is established for UE	

NR RRC Protocol
Signaling Radio Bearers



"Signaling Radio Bearers" (SRBs) are defined as Radio Bearers (RBs) that are used only for the transmission of RRC and NAS messages. More specifically, the following SRBs are defined:

- SRB0 is used for RRC messages using the CCCH logical channel;
- SRB1 is used for RRC messages (which may include a piggybacked NAS message) as well as for NAS messages prior to the establishment of SRB2, all using DCCH logical channel;
    - In downlink piggybacking of NAS messages is used only for bearer establishment/modification/release. In uplink piggybacking of NAS message is used only for transferring the initial NAS message during connection setup and connection resume.
- SRB2 is used for NAS messages, all using DCCH logical channel.
    - SRB2 has a lower-priority than SRB1 and is always configured by the network after security activation.
- SRB3 is used for specific RRC messages when UE is in EN-DC, all using DCCH logical channel.

Note that the NAS messages transferred via SRB2 are also contained in RRC messages, which however do not include any RRC protocol control information.

Also, it is noteworthy that once security is activated, all RRC messages on SRB1, SRB2 and SRB3, including those containing NAS messages, are integrity protected and ciphered by PDCP. NAS independently applies integrity protection and ciphering to the NAS messages.

NR RRC Protocol
UE Identities

For NR connected to 5GC, the following UE identities are used at cell level

C-RNTI:	• unique identification, which is used as an identifier of the RRC Connection and for scheduling
Temporary C-RNTI:	• identification used for the random access procedure
Random value for contention resolution:	• during some transient states, the UE is temporarily identified with a random value used for contention resolution purposes

For NR connected to 5GC, the following UE identities are used at NG-RAN level:

I-RNTI	• unique identification used to identify the UE context for RRC_INACTIVE

The identities used by NR connected to 5GC :
For scheduling at cell level, the following identities are used:
- C-RNTI: unique UE identification used as an identifier of the RRC Connection and for scheduling;
- CS-RNTI: unique UE identification used for Semi-Persistent Scheduling in the downlink or configured grant in the uplink;
- INT-RNTI: identification of pre-emption in the downlink;
- P-RNTI: identification of Paging and System Information change notification in the downlink;
- SI-RNTI: identification of Broadcast and System Information in the downlink;
- SP-CSI-RNTI: unique UE identification used for semi-persistent CSI reporting on PUSCH;

For power and slot format control, the following identities are used:
- SFI-RNTI: identification of slot format;
- TPC-PUCCH-RNTI: unique UE identification to control the power of PUCCH;
- TPC-PUSCH-RNTI: unique UE identification to control the power of PUSCH;
- TPC-SRS-RNTI: unique UE identification to control the power of SRS;

During the random access procedure, the following identities are also used:
- RA-RNTI: identification of the Random Access Response in the downlink;
- Temporary C-RNTI: UE identification temporarily used for scheduling during the random access procedure;
- Random value for contention resolution: UE identification temporarily used for contention resolution purposes during the random access procedure.

For NR connected to 5GC, the following UE identities are used at NG-RAN level:
- I-RNTI: used to identify the UE context in RRC_INACTIVE.

For UE power saving purpose during DRX, the following identity is used:

- PS-RNTI: used to determine if the UE needs to monitor PDCCH on the next occurrence of the connected mode DRX on-duration.

For IAB the following identity is used:

- AI-RNTI: identification of the DCI carrying availability indication for soft symbols of an IAB-DU.

For MBS, the following identities are used:

- G-RNTI: Identifies dynamically scheduled PTM transmissions of MTCH(s);
- G-CS-RNTI: Identifies configured scheduled PTM transmissions of MTCH(s);
- MCCH-RNTI: Identifies transmissions of MCCH and MCCH change notification.

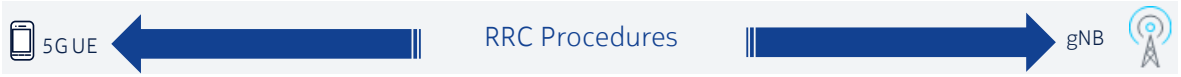
Source: TS 38.300

NR RRC Protocol
Quiz 1

1. What is the UE identifier used to identify the UE context in RRC_INACTIVE?
   a. C-RNTI
   b. I-RNTI
   c. CS-RNTI
   d. 5G-S-TMSI
2. Which of the following apply to RRC_INACTIVE state?
   a. The UE has an NR RRC connection
   b. The UE has no NR RRC connection
   c. NG-RAN knows the cell which the UE belongs to
   d. The UE monitors a Paging channel for RAN paging using P-RNTI
3. Which Signaling Radio Bearer is used for specific RRC messages when UE is in Dual Connectivity (EN_DC)?
   a. SRB0
   b. SRB1
   c. SRB2
   d. SRB3

System Information Messaging

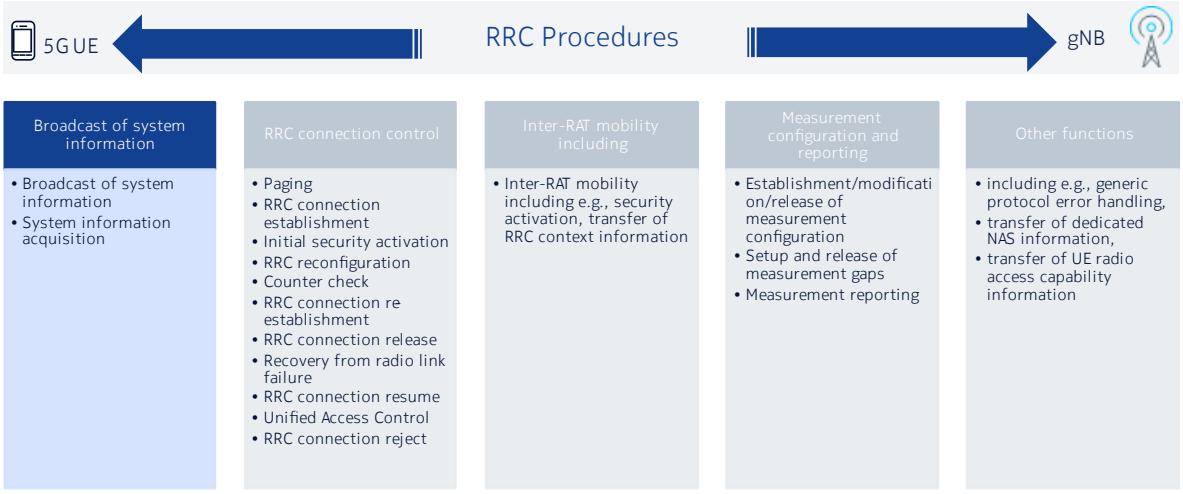
System Information Messaging
Broadcast of System Information



Broadcast of system information	RRC connection control	Inter-RAT mobility including	Measurement configuration and reporting	Other functions
• Broadcast of system information • System information acquisition	• Paging • RRC connection establishment • Initial security activation • RRC reconfiguration • Counter check • RRC connection re establishment • RRC connection release • Recovery from radio link failure • RRC connection resume • Unified Access Control • RRC connection reject	• Inter-RAT mobility including e.g., security activation, transfer of RRC context information	• Establishment/modification/release of measurement configuration • Setup and release of measurement gaps • Measurement reporting	• including e.g., generic protocol error handling, • transfer of dedicated NAS information, • transfer of UE radio access capability information

Categorization of the different Radio Resource Control procedures.

System Information Messaging
Broadcast of System Information



Broadcast of system information:

- Including NAS common information;
- Information applicable for UEs in RRC_IDLE and RRC_INACTIVE (e.g., cell (re-)selection parameters, neighboring cell information) and information (also) applicable for UEs in RRC_CONNECTED (e.g., common channel configuration information);
- Including ETWS notification, CMAS notification.

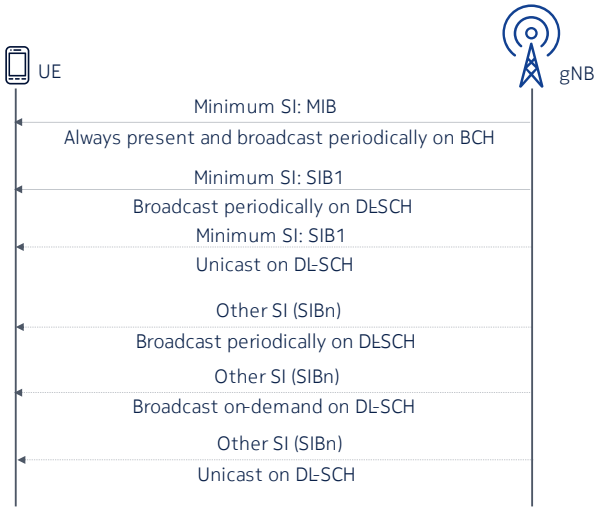
System Information Messaging
5G System Information

5G system information is classified into 2 groups:

Minimum System Information (MinSI):
- MIB and SIB1

Other System Information (OSI):
- SIB2 onwards

- For NSA mode of operation NR NodeB needs to broadcast only MIB, other parameters are signaled via dedicated Radio Resource Control message to the UE



The RRC takes care of system information broadcast, in NR, System Information (SI) is divided into Minimum SI and Other SI. Minimum SI is periodically broadcast and comprises basic information required for initial access and information for acquiring any other SI broadcast periodically or provisioned on-demand, i.e., scheduling information.

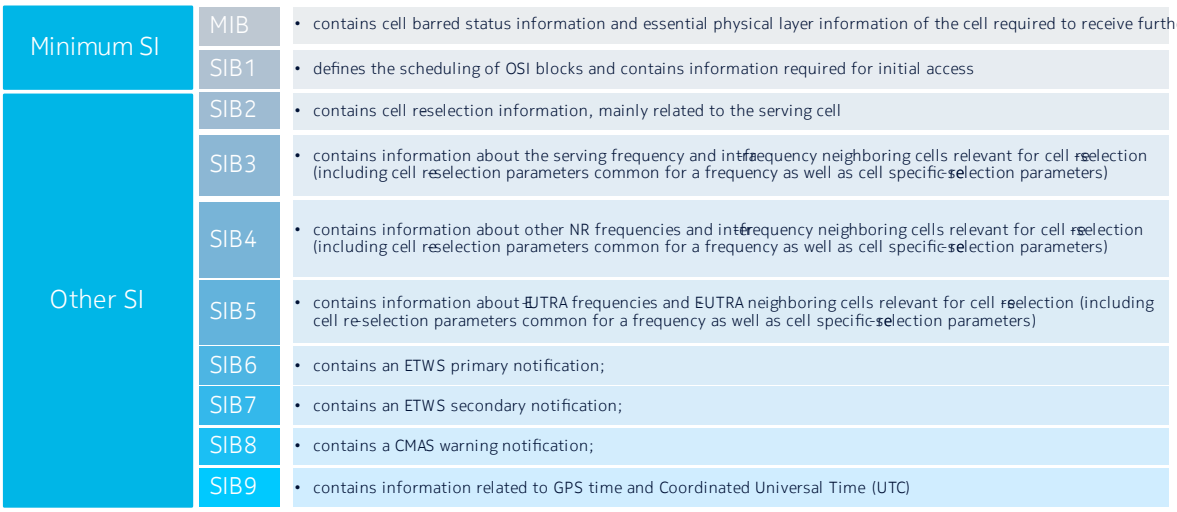
Minimum SI is transmitted over two different downlink channels using different messages (MIB and SIB1).

The Other SI encompasses everything not broadcast in the Minimum SI and may either be broadcast, or provisioned in a dedicated manner, either triggered by the network or upon request from the UE.

Other SI is transmitted in System Information messages (SIB2 and above).

For NSA mode of operation NR NodeB needs to broadcast only MIB, other parameters are signaled via dedicated Radio Resource Control message to the UE.

System Information Messaging
Minimum System Information and Other System Information



More other SI are introduced in Release 16 & 17 (see note).

Minimum SI comprises basic information required for initial access and information for acquiring any other SI. Minimum SI consists of:

- MIB contains cell barred status information and essential physical layer information of the cell required to receive further system information, e.g., CORESET#0 configuration. MIB is periodically broadcast on BCH.
- SIB1 defines the scheduling of other system information blocks and contains information required for initial access. SIB1 is also referred to as Remaining Minimum SI (RMSI) and is periodically broadcast on DL-SCH or sent in a dedicated manner on DL-SCH to UEs in RRC_CONNECTED.
- Other SI encompasses all SIBs not broadcast in the Minimum SI. Those SIBs can either be periodically broadcast on DL-SCH, broadcast on-demand on DL-SCH (i.e., upon request from UEs in RRC_IDLE or RRC_INACTIVE) or sent in a dedicated manner on DL-SCH to UEs in RRC_CONNECTED.

MSI and OSI content is shown on the slide.

More other SI are introduced in Release 16 & 17:

- *SIB10* contains the Human-Readable Network Names (HRNN) of the NPNs listed in SIB1;
- *SIB11* contains information related to idle/inactive measurements;
- *SIB15* contains information related to disaster roaming;
- *SIB16* contains slice specific cell reselection information;
- *SIB17* contains information related to TRS configuration for UEs in RRC_IDLE/RRC_INACTIVE;
- *SIBpos* contains positioning assistance data as defined in TS 37.355 and TS 38.331.
- *SIB18* contains information related to the Group IDs for Network selection (GINs) associated with SNPNs listed in SIB1.

For sidelink, Other SI also includes:

- *SIB12* contains information related to NR sidelink communication;
- *SIB13* contains information related to *SystemInformationBlockType21* for V2X sidelink communication as specified in TS 36.331 clause 5.2.2.28;
- *SIB14* contains information related to *SystemInformationBlockType26* for V2X sidelink communication as specified in TS 36.331 clause 5.2.2.33.

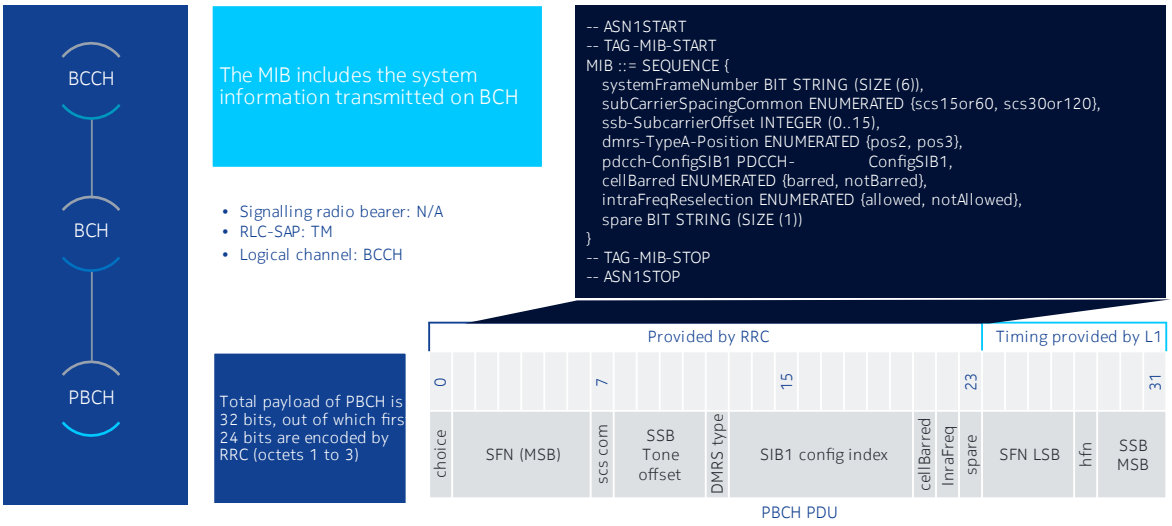
For non-terrestrial network, Other SI also includes:

- *SIB19* contains NTN-specific parameters for serving cell and/or neighbour cells as defined in TS 38.331.

For MBS broadcast, Other SI also includes:

- *SIB20* contains MCCH configuration;
- *SIB21* contains information related to service continuity for MBS broadcast reception.

System Information Messaging
Physical Broadcast Channel

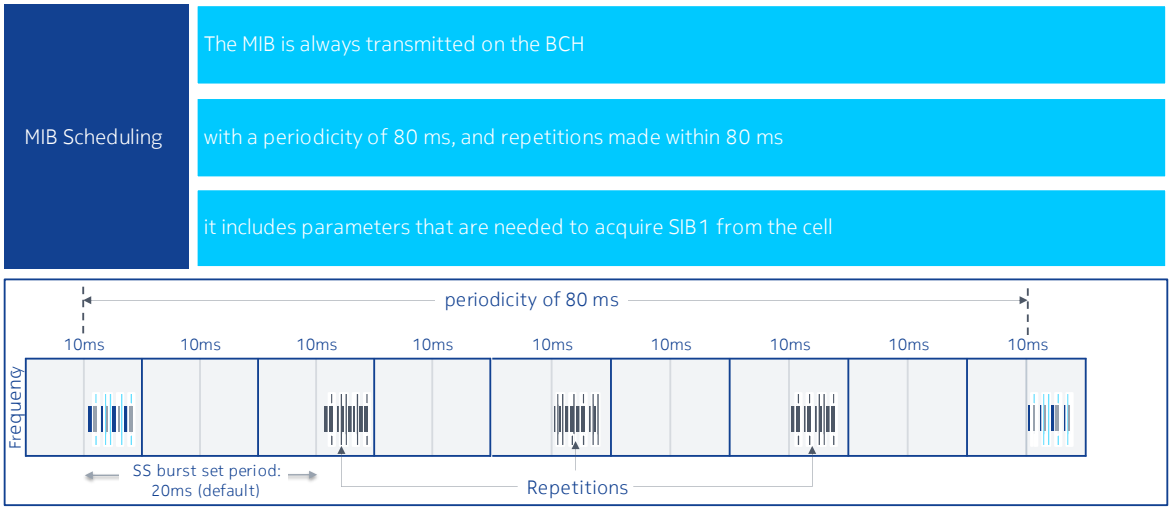


Total payload of Physical Broadcast Channel (PBCH) is 32 bits, out of which first 24 bits are encoded by L3 (octets 1 to 3). Last octet called as L1 signal value is not encoded by L3.

MIB field descriptions:

- cellBarred: Barred means the cell is barred
- dmrs-TypeA-Position: Position of (first) DM-RS for and uplink.
- intraFreqReselection: Controls cell selection/reselection to intra-frequency cells when the highest ranked cell is barred or treated as barred by the UE.
- pdcch-ConfigSIB1: Determines a common ControlResourceSet (CORESET) a common search space and necessary PDCCH parameters. If the field ssb-SubcarrierOffset indicates that SIB1 is not present, the field pdcch-ConfigSIB1 indicate the frequency positions where the UE may find SS/PBCH block with SIB1 or the frequency range where the network does not provide SS/PBCH block with SIB1.
- ssb-SubcarrierOffset: Corresponds to kSSB, which is the frequency domain offset between SSB and the overall resource block grid in number of subcarriers. The value range of this field may be extended by an additional most significant bit encoded within PBCH. This field may indicate that this cell does not provide SIB1 and that there is hence no CORESET#0 configured in MIB. In this case, the field pdcch-ConfigSIB1 may indicate the frequency positions where the UE may (not) find a SS/PBCH with a control resource set and search space for SIB1.
- subCarrierSpacingCommon: Subcarrier spacing for SIB1, Msg.2/4 for initial access, paging and broadcast SI-messages. If the UE acquires this MIB on a carrier frequency <6GHz, the value scs15or60 corresponds to 15 kHz and the value scs30or120 corresponds to 30 kHz. If the UE acquires this MIB on a carrier frequency >6GHz, the value scs15or60 corresponds to 60 kHz and the value scs30or120 corresponds to 120 kHz.
- systemFrameNumber: The 6 most significant bit (MSB) of the 10-bit System Frame Number. The 4 LSB of the SFN are conveyed in the PBCH transport block as part of channel coding (i.e., outside the MIB encoding).

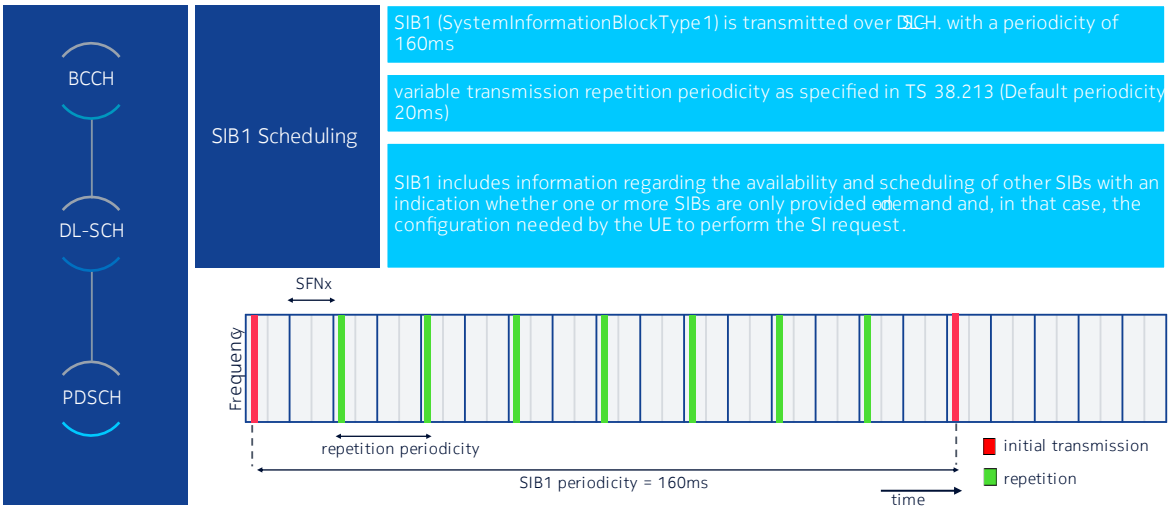
System Information Messaging
MIB Scheduling



The MIB is mapped on the BCCH and carried on BCH while all other SI messages are mapped on the BCCH, where they are dynamically carried on DL-SCH. The scheduling of SI messages part of Other SI is indicated by SIB1.

The MIB is mapped on the BCCH and it is always transmitted on the BCH with a periodicity of 80 ms (Data arrives to the coding unit in the form of a maximum of one transport block every 80ms) and repetitions made within 80 ms and it includes parameters that are needed to acquire SIB1 from the cell. The first transmission of the MIB is scheduled in subframes defined by [TS 38.211, 7.4.3.2] and repetitions are scheduled according to the period of SSB.

System Information Messaging
Physical Downlink Shared Channel

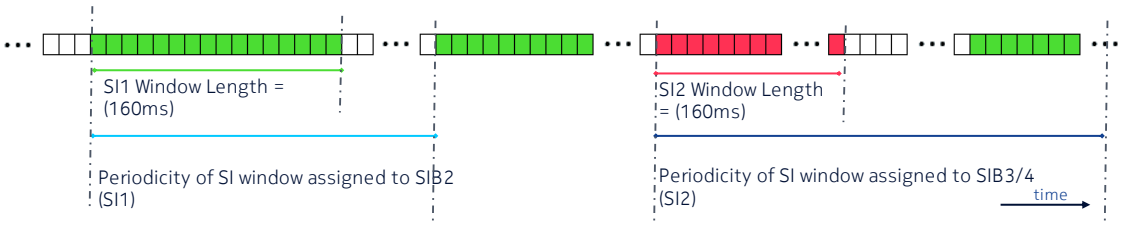


The SIB1 is transmitted on the DL-SCH with a periodicity of 160ms and variable transmission repetition periodicity (more details can be found in TS 38.213). The default transmission repetition periodicity of SIB1 is 20ms. For SSB and CORESET multiplexing pattern 1, SIB1 repetition transmission period is 20ms. For SSB and CORESET multiplexing pattern 2/3, SIB1 transmission repetition period is the same as the SSB period [3GPP TS 38.213].

SIB1 includes information regarding the availability and scheduling (e.g., mapping of SIBs to SI message, periodicity, SI-window size) of other SIBs with an indication whether one or more SIBs are provided on-demand only, where, in that case, the configuration needed by the UE to perform the SI request. SIB1 is cell-specific SIB.

System Information Messaging
Other System Information Scheduling

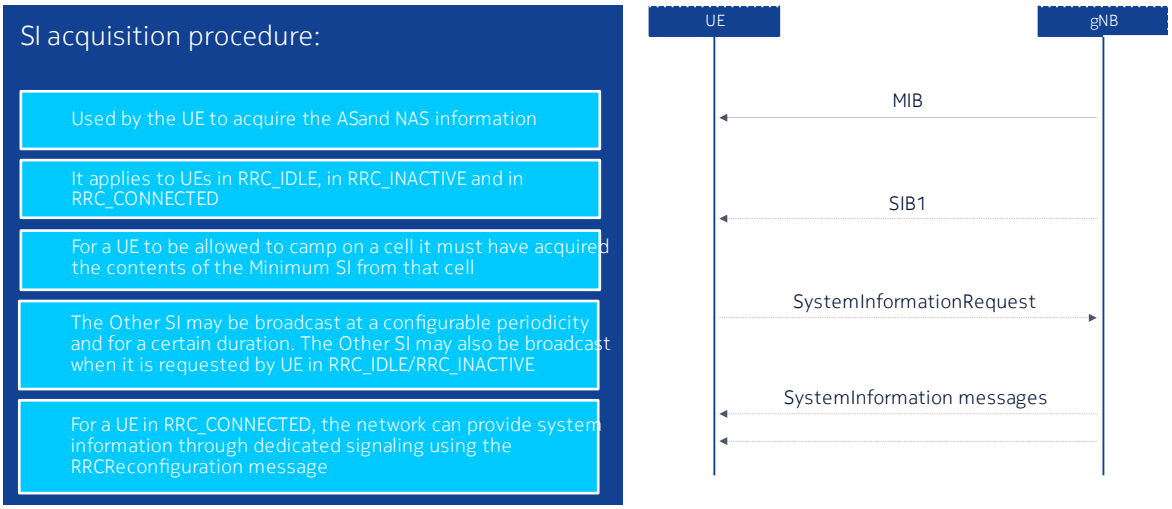
Other SI Scheduling	
	SystemInformation (SI) messages are used to carry SIBs other than SIB1
	Each SI message is transmitted (on the DL -SCH) within SI-window
	Each SI message is associated with a SI -window and the SI-windows of different SI messages do not overlap



SystemInformation (SI) messages are used to carry SIBs other than SIB1. SI messages are transmitted on the DL-SCH. Only SIBs having the same periodicity can be mapped to the same SI message.

Each SI message is transmitted within periodically occurring time domain windows (referred to as SI-windows with same length for all SI messages). Each SI message is associated with a SI-window and the SI-windows of different SI messages do not overlap. That is, within one SI-window only the corresponding SI message is transmitted.

System Information Messaging
System Information Acquisition Procedure



The UE applies the SI acquisition procedure to acquire the AS- and NAS information. The procedure applies to UEs in RRC_IDLE, in RRC_INACTIVE and in RRC_CONNECTED.

The UE in RRC_IDLE and RRC_INACTIVE shall ensure having a valid version of (at least) the MIB, SIB1 through SIB4 and SIB5 (if the UE supports E-UTRA).

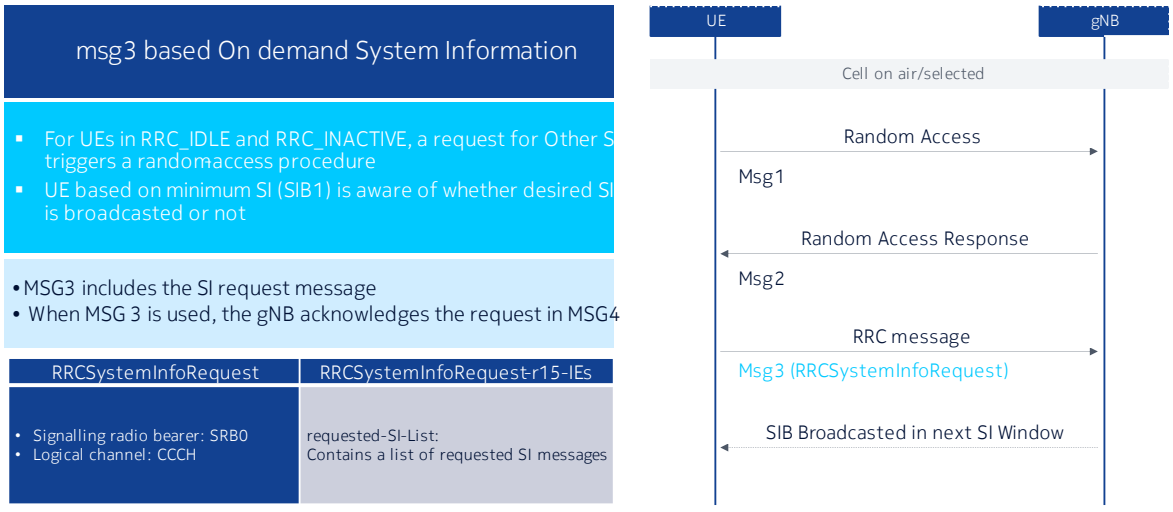
The UE shall apply the SI acquisition procedure upon cell selection (e.g., upon power on), cell-reselection, return from out of coverage, after reconfiguration with sync completion, after entering the network from another RAT, upon receiving an indication that the system information has changed, upon receiving a PWS notification; and whenever the UE does not have a valid version of a stored SIB.

The Other SI may be broadcast at a configurable periodicity and for a certain duration. The Other SI may also be broadcast when it is requested by UE in RRC_IDLE/RRC_INACTIVE.

For a UE to be allowed to camp on a cell it must have acquired the contents of the Minimum SI from that cell. There may be cells in the system that do not broadcast the Minimum SI and where the UE therefore cannot camp.

For a UE in RRC_CONNECTED, the network can provide system information through dedicated signaling using the RRCReconfiguration message, e.g., if the UE has an active BWP with no common search space configured to monitor system information or paging.

System Information Messaging
On demand System Information



For UEs in RRC_IDLE and RRC_INACTIVE, a request for Other SI triggers a random-access procedure where MSG3 includes the SI request message unless the requested SI is associated to a subset of the PRACH resources, in which case MSG1 is used for indication of the requested Other SI. When MSG1 is used, the minimum granularity of the request is one SI message (i.e., a set of SIBs), one RACH preamble and/or PRACH resource can be used to request multiple SI messages and the gNB acknowledges the request in MSG2. When MSG 3 is used, the gNB acknowledges the request in MSG4.

The RRCSystemInfoRequest message is used to request SI message(s) required by the UE, for which si-BroadcastStatus in si-SchedulingInfo in SIB1 is set to notBroadcasting, when no si-RequestConfig or si-RequestConfigSUL is included in the si-SchedulingInfo.

SIB1:

si-SchedulingInfo:

si-Request-Config: if present, then other SI is broadcasted by on-demand way otherwise periodically broadcasted.

msg1-Request: if present, then msg1 based ODSI otherwise msg3 based ODSI.

si-PRACH-Preamble: Step1, fixed to 63.

requested-SI-List:

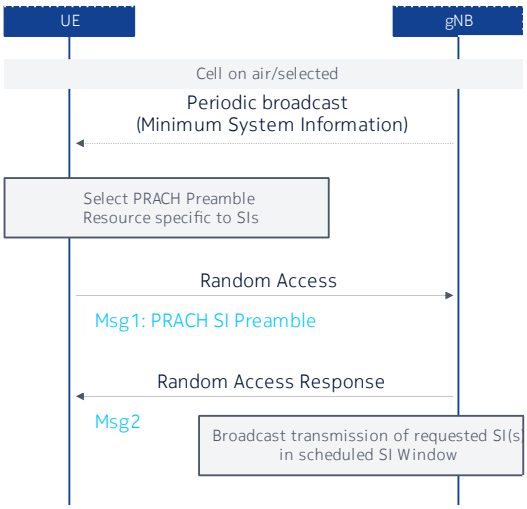
Contains a list of requested SI messages. According to the order of entry in the list of SI messages configured by schedulingInfoList in si-SchedulingInfo in SIB1, first bit corresponds to first/left most listed SI message, second to second listed SI message, and so on.

System Information Messaging
On demand System Information

msg1 based On demand System Information

- The requested SI is associated to a subset of the PRACH resources, in which case MSG1 is used for indication of the requested Other SI
- The gNB acknowledges the request in MSG2

- Other IEs such as Timing Alignment Information, UL grant and Temporary C-RNTI are not included in Msg2.



General concept of MSG 1 based On demand System Information is as follows:

- UE based on minimum SI is aware of whether desired SI is broadcasted or not (refer to SIB1 content below)
- one RACH preamble (fixed to 63) can be reserved/used to request for multiple SI
- RAPID is included in Msg2 for acknowledging the SI requests, other IEs such as Timing Alignment Information, UL grant and Temporary C-RNTI are not included in Msg2.
- UE retransmits RACH preamble using increased power (depending on the NR RACH procedure design), if Msg2 for SI request is not received. Preamble re-transmission is continued until reaching max preamble transmissions (preambleTransMax).

SIB1:

si-SchedulingInfo

si-Request-Config: if present, then other SI is broadcasted by on-demand way otherwise periodically broadcasted.

msg1-Request: if present, then msg1 based ODSI otherwise msg3 based ODSI.

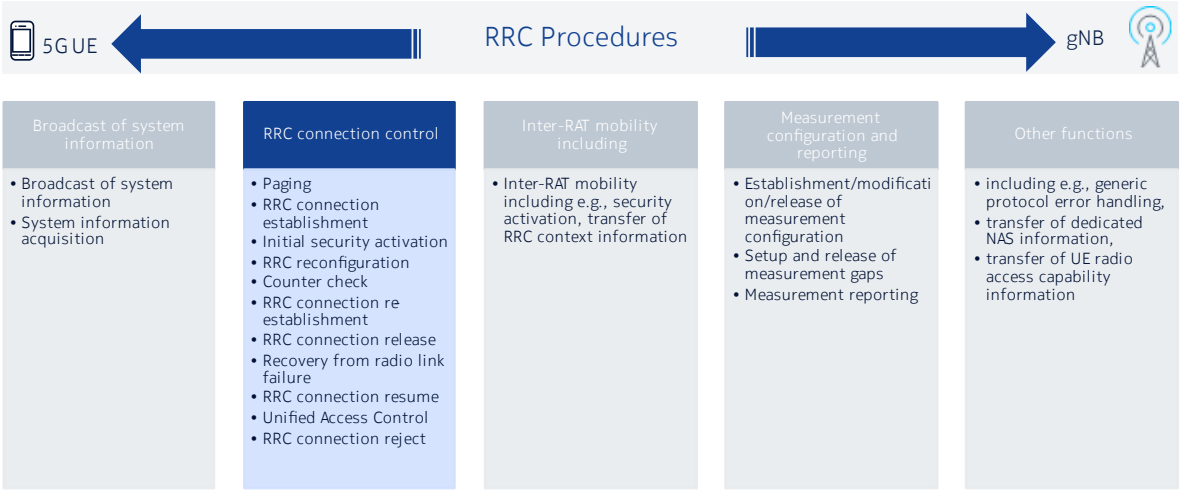
si-PRACH-Preamble: Step1, fixed to 63.

System Information Messaging
Quiz 2

1. Which System information is mapped on the BCCH and carried on BCH/PBCH?
   a. MIB
   b. SIB1
   c. All other SI messages
2. Which SIB defines the scheduling of Other System Info blocks and contains information required for initial access?
   a. MIB
   b. SIB1
   c. SIB2
   d. SIB3

RRC Connection Control

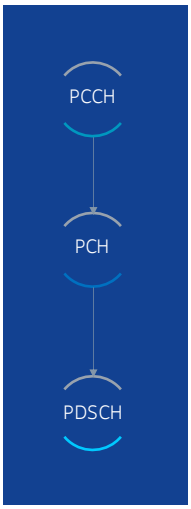
RRC Connection Control
RRC Connection Control



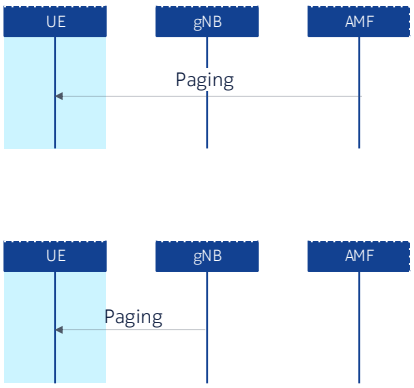
RRC connection control:

- Paging;
- Establishment/modification/suspension/resumption/release of RRC connection, including e.g., assignment/modification of UE identity (C-RNTI, I-RNTI, etc.), establishment/modification/suspension/resumption/release of SRBs (except for SRB0);
- Access barring;
- Initial security activation, i.e., initial configuration of AS integrity protection (SRBs, DRBs) and AS ciphering (SRBs, DRBs);
- RRC connection mobility including e.g., intra-frequency and inter-frequency handover, associated security handling, i.e., key/algorithm change, specification of RRC context information transferred between network nodes;
- Establishment/modification/suspension/resumption/release of RBs carrying user data (DRBs);
- Radio configuration control including e.g., assignment/modification of ARQ configuration, HARQ configuration, DRX configuration;
- In case of DC, cell management including e.g., change of PSCell, addition/modification/release of SCG cell(s);
- In case of CA, cell management including e.g., addition/modification/release of SCell(s);
- QoS control including assignment/ modification of semi-persistent scheduling (SPS) configuration and configured grant configuration for DL and UL respectively, assignment/ modification of parameters for UL rate control in the UE, i.e., allocation of a priority and a prioritized bit rate (PBR) for each RB.
- Recovery from radio link failure.

RRC Connection Control
Paging Procedure



RRC State	Allowed mode for DL channel monitoring	UE location known on	Paging
RRC Idle	Discontinuous with DRX	Tracking area list level	CN paging using 5G-S-TMSI
RRC Inactive	Discontinuous with DRX	RAN Notification Area level	Paging channel for CN paging using 5G-S-TMSI and RAN paging using I-RNTI;
RRC Connected	Both continuous and discontinuous with DRX	Cell level	Paging channel associated with the shared data channel



Paging procedure is used to transmit paging information to a UE in RRC_IDLE or RRC_INACTIVE. It is used also to notify UEs in RRC_IDLE, RRC_INACTIVE and RRC_CONNECTED state of system information change and ETWS/CMAS indications.

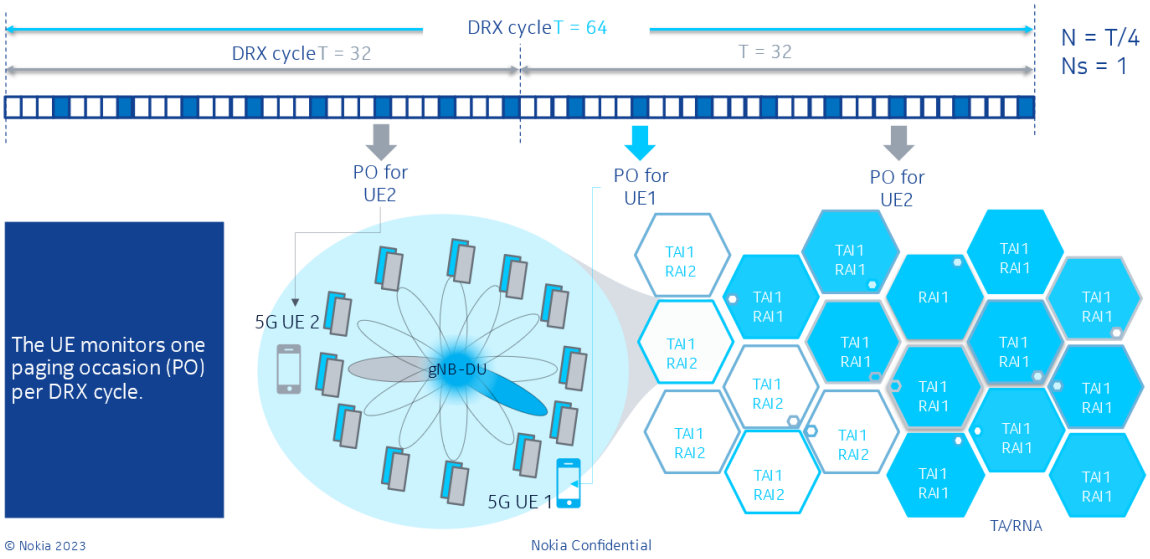
At the reception of the PAGING message, the NG-RAN node shall perform paging of the UE in cells which belong to tracking areas as indicated in the List of TAIs IE.

For each cell that belongs to any of the tracking areas indicated in the List of TAIs IE, the NG-RAN node shall generate one page on the radio interface.

Paging messages are sent over the PCCH logical channel. PCCH is mapped onto the PCH transport channel, which itself is carried on the PDSCH physical channel. Transport format and resource allocation for the PCH channel is signaled on the PDCCH channel, using the dedicated P-RNTI (defined as 0xFFFE).

PCCH uses RLC and MAC Transparent Mode.

RRC Connection Control
Paging Occasions



While in RRC_IDLE the UE monitors the paging channels for Core Network-initiated paging; in RRC_INACTIVE the UE also monitors paging channels for RAN-initiated paging.

When in RRC_CONNECTED, the UE monitors the paging channels in any PO signaled in system information for SI change indication and PWS notification.

In case of Bandwidth Part Adaptation, a UE in RRC_CONNECTED only monitors paging channels on the active BWP with common search space configured.

Paging DRX is defined where the UE in RRC_IDLE or RRC_INACTIVE is only required to monitor paging channels during one Paging Occasions (PO) per DRX cycle. The Paging DRX cycles are configured by the network:

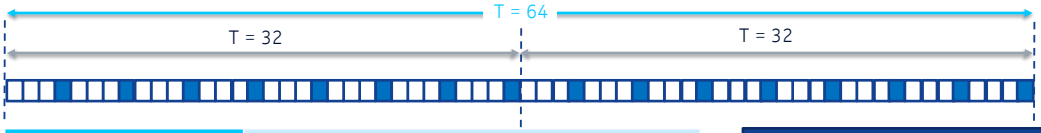
- For CN-initiated paging, a default cycle is broadcast in system information;
- For CN-initiated paging, a UE specific cycle can be configured via NAS signaling;
- For RAN-initiated paging, a UE-specific cycle is configured via RRC signaling;

The UE uses the shortest of the DRX cycles applicable i.e., a UE in RRC_IDLE uses the shortest of the first two cycles above, while a UE in RRC_INACTIVE uses the shortest of the three.

The POs of a UE for CN-initiated and RAN-initiated paging are based on the same UE ID, resulting in overlapping POs for both. The number of different POs in a DRX cycle is configurable via system information and a network may distribute UEs to those POs based on their IDs.

The network may address multiple UEs within a Paging message by including one Paging Record for each UE.

RRC Connection Control
Paging Occasions



$T \in \{32, 64, 128, 256\}$	• DRX cycle of the UE
$N \in \{T,\ T/2,\ T/4,\ T/8,\ T/16\}$	• number of total paging frames in T (given UE based on its ID is assigned one PF if)
$PF\_offset \in \{0, \ldots, T/N - 1\}$	• offset used for PF determination, the offset is needed for UE to align its paging frame with SSB-carrying frame
$N\_s \in \{1, 2, 4\}$	• number of paging occasions for a PF
UE_ID	• Refers to UE Identity Index value sent by AMF in the NGAP:PAGING message and it is calculated as: • 5G-S-TMSI mod 1024

SFN (System Frame Number= 0,...,1023) for the PF (Paging Frame) is determined by:

$$(SFN + PF_{offset}) \bmod T = (T/N) \cdot (UE_{ID} \bmod N)$$

Index i_s, indicating the start of a set of PDCCH monitoring occasions for the paging DCI (i.e., PO), is determined by:

$$i_s = \lfloor UE_{ID}/N \rfloor \bmod N_s$$

T is determined by the shortest of the UE specific DRX value, if configured by RRC or upper layers, and a default DRX value broadcast in system information. If UE specific DRX is not configured by RRC or by upper layers, the default value is applied.

$〚UE〛\_ID$: Refers to UE Identity Index value sent by AMF in the NGAP:PAGING message and it is calculated as 5G-S-TMSI mod 1024.

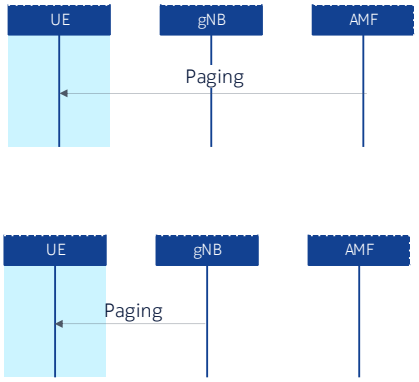
If the UE has no 5G-S-TMSI, for instance when the UE has not yet registered onto the network, the UE shall use as default identity $〚UE〛\_ID$=0 in the PF and i_s formulas above.

5G-S-TMSI is a 48-bit long bit string as defined in TS 23.501. 5G-S-TMSI shall in the formulae above be interpreted as a binary number where the left most bit represents the most significant bit.

RRC Connection Control
Paging Message

The Paging message is used for the notification of one or more UEs

Paging	Paging message
• Signalling radio bearer: N/A • RLC-SAP: TM • Logical channel: PCCH	PagingRecordList: • SEQUENCE (SIZE(1..maxNrofPageRec)) OF PagingRecord PagingRecord: • ue-Identity • PagingUE-Identity: • NG-5G-S-TMSI • Or full I-RNTI accessType: It indicates whether Paging is originated due to the PDU sessions from the non-3GPP access



The IE NG-5G-TMSI contains a 5G S-Temporary Mobile Subscription Identifier (5G-S-TMSI), a temporary UE identity provided by the 5GC which uniquely identifies the UE within the tracking area.

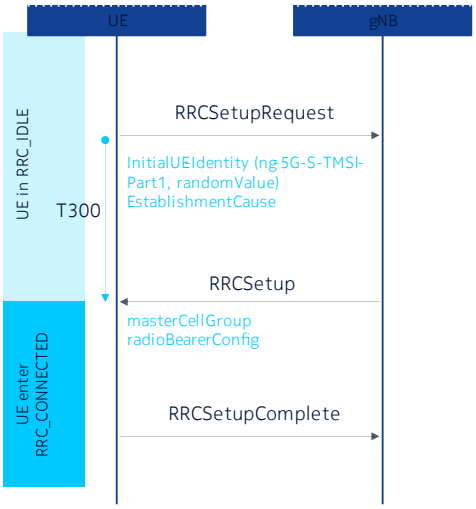
RRC Connection Control
Quiz 3

1. What is the objective of Paging procedure? (Select all that apply)
   a. It is used to transmit paging information to a UE in RRC_IDLE or RRC_INACTIVE
   b. It is used also to notify UEs of system information change
   c. It is used for ETWS/CMAS indications
   d. It is used to transmit paging information to an UE in RRC_CONNECTED state
2. How many paging occasion (PO) per DRX cycle does the UE monitor?
   a. one paging occasion
   b. two paging occasions
   c. three paging occasions
   d. four paging occasions

RRC Connection Control
RRC Connection Establishment

RRC connection establishment procedure is used to establish an RRC connection

RRCSetupRequest	RRCSetupRequest-IEs field descriptions
• Signalling radio bearer: SRB0 • RLC-SAP: TM • Logical channel: CCCH	establishmentCause: Provides the establishment cause for the RRC request in accordance with the information received from upper layers.
	ue-Identity: UE identity included to facilitate contention resolution by lower layers.
RRCSetup	**RRCSetup-IEs field descriptions**
• Signalling radio bearer: SRB0 • RLC-SAP: TM • Logical channel: CCCH	masterCellGroup The network configures only the RLC bearer for the SRB1, maeCellGroupConfig, physicalCellGroupConfig and spCellConfig.
	radioBearerConfig Only SRB1 can be configured in RRC setup.



RRC connection establishment procedure is used to establish an RRC connection. This procedure involves SRB1 establishment. It is also used to transfer the initial NAS dedicated information/ message from the UE to the network.

The network applies the procedure as follows:

- When establishing an RRC connection;
- When UE is resuming or re-establishing an RRC connection, and the network is not able to retrieve or verify the UE context. In this case, UE receives RRCSetup and responds with RRCSetupComplete.

The UE initiates the procedure when upper layers request establishment of an RRC connection while the UE is in RRC_IDLE.

The network completes RRC connection establishment prior to completing the establishment of the NG connection, i.e., prior to receiving the UE context information from the 5GC. Consequently, AS security is not activated during the initial phase of the RRC connection. During this initial phase of the RRC connection, the network may configure the UE to perform measurement reporting, but the UE only sends the corresponding measurement reports after successful security activation. However, the UE only accepts a re-configuration with sync message when security has been activated.

T300: Start Upon transmission of RRCSetupRequest.

Stop: Upon reception of RRCSetup or RRCReject message, cell re-selection and upon abortion of connection establishment by upper layers.

establishmentCause:

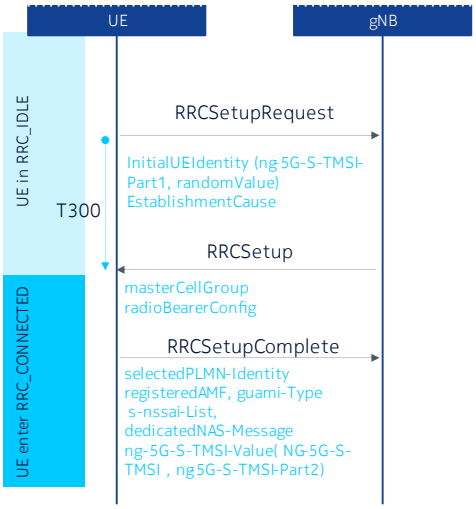
Provides the establishment cause (emergency, highPriorityAccess, mt-Access, mo-Signaling, mo-Data, mo-VoiceCall, mo-VideoCall, mo-SMS, mps-PriorityAccess, mcs-PriorityAccess) for the RRC request in accordance with the information received from upper layers.

InitialUE-Identity field descriptions:

- ng-5G-S-TMSI-Part1 The rightmost 39 bits of 5G-S-TMSI
- randomValue: Integer value in the range 0 to 2^{39} - 1.

RRC Connection Control
RRC Connection Establishment

RRCSetupComplete	RRCSetupComplete-IEs field descriptions
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	guami-Type This field is used to indicate whether the guami included is native (derived from native 5G-GUTI) or mapped (from EPS, derived from EPS GUTI).
	ng-5G-S-TMSI-Part2 The leftmost 9 bits of 5G-S-TMSI
	registeredAMF This field is used to transfer the AMF where the UE is registered, as provided by upper layers.
	selectedPLMN-Identity Index of the PLMN selected by the UE from the plmn-IdentityList fields included in SIB1



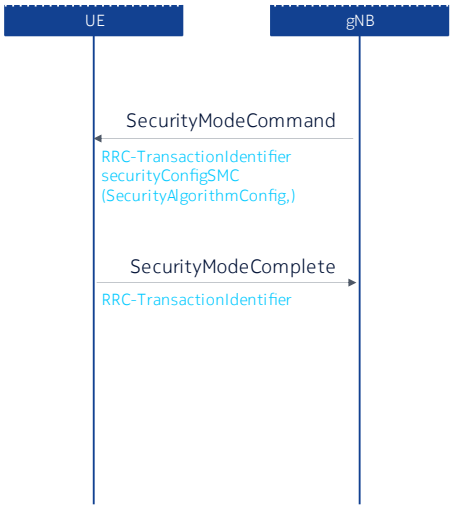
The RRCSetupComplete message is used to confirm the successful completion of an RRC connection establishment.

RRC Connection Control
Initial Security Activation

This procedure is used to activate AS security upon RRC connection establishment

SecurityModeCommand	SecurityModeCommand-IEs
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	RRC-TransactionIdentifier securityConfigSMC (SecurityAlgorithmConfig,)

SecurityModeComplete	SecurityModeComplete-IEs
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	RRC-TransactionIdentifier



This procedure is used to activate AS security upon RRC connection establishment

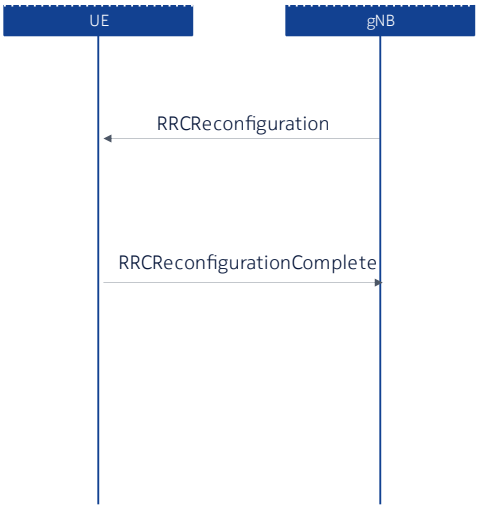
The network initiates the security mode command procedure to a UE in RRC_CONNECTED (when only SRB1, is established, i.e., prior to establishment of SRB2 and/ or DRBs).

Upon receiving the UE context from the 5GC, the RAN activates AS security (both ciphering and integrity protection) using the initial security activation procedure. The RRC messages to activate security (command and successful response) are integrity protected, while ciphering is started only after completion of the procedure. That is, the response to the message used to activate security is not ciphered, while the subsequent messages (e.g., used to establish SRB2 and DRBs) are both integrity protected and ciphered. After having initiated the initial security activation procedure, the network initiates the establishment of SRB2 and DRBs, i.e., the network may do this prior to receiving the confirmation of the initial security activation from the UE. In any case, the network will apply both ciphering and integrity protection for the RRC reconfiguration messages used to establish SRB2 and DRBs. The network should release the RRC connection if the initial security activation and/ or the radio bearer establishment fails.

RRC Connection Control
RRC Reconfiguration

RRC reconfiguration procedure is used to modify an RRC connection:
- to establish/modify/release RBs, to perform reconfiguration with sync, to setup/modify/release measurements, to add/modify/release SCells and cell groups. As part of the procedure, NAS dedicated information may be transferred from the Network to the UE.

RRCReconfiguration	RRCReconfiguration-IEs field
• Signalling radio bearer: SRB1 or SRB3 • RLC-SAP: AM • Logical channel: DCCH	radioBearerConfig dedicatedNAS-MessageList dedicatedSIB1-Delivery dedicatedSystemInformationDelivery fullConfig keySetChangeIndicator masterCellGroup nas-Container nextHopChainingCount otherConfig secondaryCellGroup



RRC reconfiguration procedure is used to modify an RRC connection, e.g., to establish/modify/release RBs, to perform reconfiguration with sync, to setup/modify/release measurements, to add/modify/release SCells and cell groups. As part of the procedure, NAS dedicated information may be transferred from the Network to the UE.

The Network may initiate the RRC reconfiguration procedure to a UE in RRC_CONNECTED. The Network applies the procedure as follows:

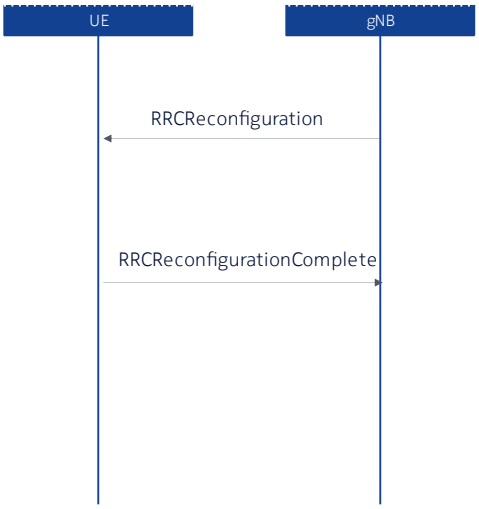
- the establishment of RBs (other than SRB1, that is established during RRC connection establishment) is performed only when AS security has been activated;
- the addition of Secondary Cell Group and SCells is performed only when AS security has been activated;
- the reconfigurationWithSync is included in secondaryCellGroup only when at least one DRB is setup in SCG.

RRCReconfiguration-IEs field descriptions:

- dedicatedNAS-MessageList: This field is used to transfer UE specific NAS layer information between the network and the UE. The RRC layer is transparent for each PDU in the list.
- dedicatedSIB1-Delivery: This field is used to transfer SIB1 to the UE.
- dedicatedSystemInformationDelivery: This field is used to transfer SIB6, SIB7, SIB8 to the UE.
- fullConfig: Indicates that the full configuration option is applicable for the RRCReconfiguration message.
- keySetChangeIndicator: True is used in an intra-cell handover when a KgNB key is derived from a KAMF key taken into use through the latest successful NAS SMC procedure, or N2 handover procedure with KAMF change, for KgNB re-keying. False is used in an intra-NR handover when the new KgNB key is obtained from the current KgNB key or from the NH.
- masterCellGroup: Configuration of master cell group.
- nas-Container: This field is used to transfer UE specific NAS layer information between the network and the UE. The RRC layer is transparent for this field, although it affects activation of AS- security after inter-system handover to NR. The content is defined in TS 24.501.
- nextHopChainingCount: Parameter NCC (See TS 33.501)
- otherConfig: Contains configuration related to other configurations.
- radioBearerConfig: Configuration of Radio Bearers (DRBs, SRBs) including SDAP/PDCP. In EN-DC this field may only be present if the RRCReconfiguration is transmitted over SRB3.
- secondaryCellGroup: Configuration of secondary cell group (EN-DC).

RRC Connection Control
RRC Reconfiguration

RRCReconfigurationComplete	RRCReconfiguration-IEs field
• Signalling radio bearer: SRB1 or SRB3 • RLC-SAP: AM • Logical channel: DCCH	uplinkTxDirectCurrentList: • The Tx Direct Current locations for the configured serving cells and BWPs if requested by the NW (related to reportUplinkTxDirectCurrent which enables reporting of uplink Direct Current location information).



The RRCReconfigurationComplete message is used to confirm the successful completion of an RRC connection reconfiguration.

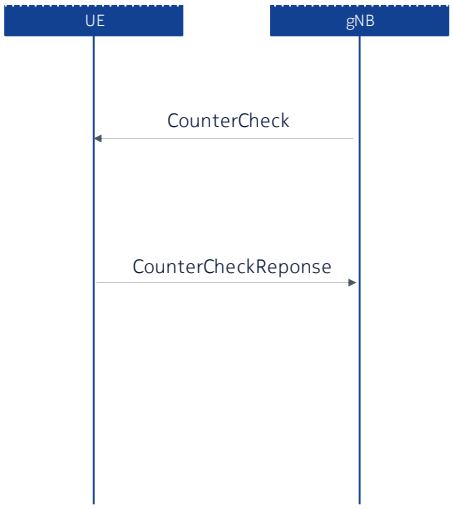
reportUplinkTxDirectCurrent:

Enables reporting of uplink Direct Current location information upon BWP configuration and reconfiguration. This field is only present when the BWP configuration is modified, or any serving cell is added or removed.

RRC Connection Control
Counter Check

This procedure is used by the network to request the UE to verify the amount of data sent/ received on each DRB

CounterCheck	CounterCheck-IEs
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	drb-CountMSB-InfoList DRB-CountMSB-Info: • countMSB-Downlink • countMSB-Uplink
CounterCheckResponse	**CounterCheckResponse-IEs**
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	drb-CountInfoList count-Downlink count-Uplink



This procedure is used by the network to request the UE to verify the amount of data sent/ received on each DRB. More specifically, the UE is requested to check if, for each DRB, the most significant bits of the COUNT match with the values indicated by the network.

It enables the network to detect packet insertion by an intruder (a 'man in the middle').

The CounterCheck message is used by the network to indicate the current COUNT MSB values associated to each DRB and to request the UE to compare these to its COUNT MSB values and to report the comparison results to the network.

drb-CountMSB-InfoList

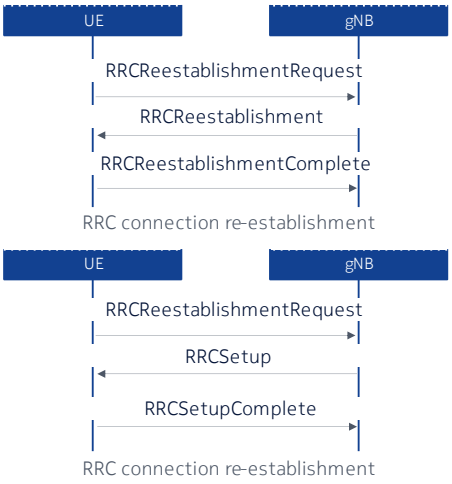
Indicates the MSBs of the COUNT values of the DRBs.

RRC Connection Control
RRC Connection Re-establishment

A UE in RRC_CONNECTED may initiate the reestablishment procedure to continue the RRC connection when a failure condition occurs (e.g., radio li failure, reconfiguration failure, integrity check failure…).

The connection re-establishment succeeds if the network is able to find and verify a valid UE context or, if the UE context cannot be retrieved, and the network responds with an RRCSetup

RRCReestablishmentRequest	RRCReestablishmentRequest-IEs
• Signalling radio bearer: SRB0 • RLC-SAP: TM • Logical channel: CCCH	ue-Identity (c-RNTI) physCellId reestablishmentCause (reconfigurationFailure, handoverFailure, otherFailure)



A UE in RRC_CONNECTED may initiate the re-establishment procedure to continue the RRC connection when a failure condition occurs (e.g., radio link failure, reconfiguration failure, integrity check failure…).

The purpose of this procedure is to re-establish the RRC connection. A UE in RRC_CONNECTED, for which security has been activated, may initiate the procedure in order to continue the RRC connection. The connection re-establishment succeeds if the network is able to find and verify a valid UE context or, if the UE context cannot be retrieved, and the network responds with an RRCSetup. If AS security has not been activated, the UE does not initiate the procedure but instead moves to RRC_IDLE directly.

The network applies the procedure as follows:

- When AS security has been activated and the network retrieves or verifies the UE context:
  - to re-activate AS security without changing algorithms;
  - to re-establish and resume the SRB1;
- When UE is re-establishing an RRC connection, and the network is not able to retrieve or verify the UE context:
  - to discard the stored AS Context and release all RB;
  - fallback to establish a new RRC connection.

The RRCReestablishmentRequest message is used to request the reestablishment of an RRC connection.

physCellId: The Physical Cell Identity of the PCell the UE was connected to prior to the failure.

reestablishmentCause: Indicates the cause of failure that triggered the re-establishment procedure.

gNB is not expected to reject a RRCReestablishmentRequest due to unknown cause value being used by the UE.

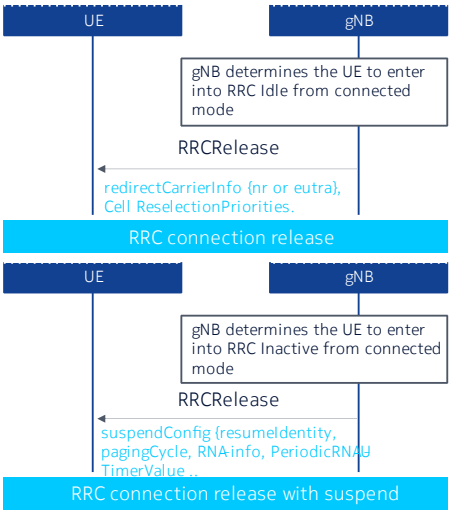
ue-Identity: UE identity included to retrieve UE context and to facilitate contention resolution by lower layers.

RRC Connection Control
RRC Connection Release

This procedure is used to:

- to release the RRC connection, which includes the release of the established radio bearers as well as all radio resources; or
- to suspend the RRC connection, which includes the suspension of the established radio bearers

RRCRelease message	RRCRelease fields
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	cnType deprioritisationReq deprioritisationTimer suspendConfig T380 ran-PagingCycle redirectedCarrierInfo



The release of the RRC connection normally is initiated by the network. The procedure may be used to re-direct the UE to an NR frequency or an EUTRA carrier frequency.

The network initiates the RRC connection release procedure to transit a UE in RRC_CONNECTED to RRC_IDLE; or to transit a UE in RRC_CONNECTED to RRC_INACTIVE; or to transit a UE in RRC_INACTIVE back to RRC_INACTIVE when the UE tries to resume; or to transit a UE in RRC_INACTIVE to RRC_IDLE when the UE tries to resume. The procedure can also be used to release and redirect a UE to another frequency.

RRCRelease field descriptions:

- cnType: Indicate that the UE is redirected to EPC or 5GC.
- deprioritisationReq: Indicates whether the current frequency or RAT is to be de-prioritized.
- deprioritisationTimer: Indicates the period for which either the current carrier frequency or NR is deprioritised. Value minN corresponds to N minutes.
- suspendConfig: Indicates configuration for the RRC_INACTIVE state.
- T380: Refers to the timer that triggers the periodic RNAU procedure in UE. Value min5 corresponds to 5 minutes, value min10 corresponds to 10 minutes and so on.
- ran-PagingCycle: Refers to the UE specific cycle for RAN-initiated paging. Value rf32 corresponds to 32 radio frames, rf64 corresponds to 64 radio frames and so on.
- redirectedCarrierInfo: Indicates a carrier frequency (downlink for FDD) and is used to redirect the UE to an NR or an inter-RAT carrier frequency, by means of cell selection at transition to RRC_IDLE or RRC_INACTIVE.

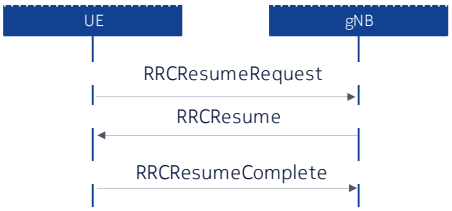
RRC Connection Control
RRC Connection Resume

The purpose of this procedure is to resume a suspended RRC connection, including resuming SRB(s) and DRB(s) or perform an RNA update

- The UE initiates the procedure when upper layers or AS (when responding to RAN paging or upon triggering RNA updates while the UE is in RRC_INACTIVE) requests the resume of a suspended RRC connection

RRCResumeRequest message	RRCResumeRequest field
• Signalling radio bearer: SRB0 • RLC-SAP: TM • Logical channel: CCCH	resumeCause resumeIdentity resumeMAC-I

RRCResume message	RRCResume-IEs field
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	radioBearerConfig masterCellGroup measConfig



RRCResumeComplete	RRCResumeComplete-IEs
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	dedicatedNAS-Message selectedPLMN-Identity uplinkTxDirectCurrentList

The RRCResumeRequest is the 48bit message used to request the resumption of a suspended RRC connection or perform an RNA update.

Note that The RRCResumeRequest1 is the 64 bit message used to request the resumption of a suspended RRC connection or perform an RNA update.

The RRCResume message is used to resume the suspended RRC connection.

The RRCResumeComplete message is used to confirm the successful completion of an RRC connection resumption.

RRCResumeRequest field descriptions:

- resumeCause: Provides the resume cause for the RRC connection resume request as provided by the upper layers or RRC.
- resumeIdentity: UE identity to facilitate UE context retrieval at gNB.
- resumeMAC-I: Authentication token to facilitate UE authentication at gNB.

RRCResume-IEs field descriptions:

- masterCellGroup: Configuration of the master cell group (NR Standalone):
- radioBearerConfig: Configuration of Radio Bearers (DRBs, SRBs) including SDAP/PDCP.

RRCResumeComplete-IEs field descriptions:

- selectedPLMN-Identity: Index of the PLMN selected by the UE from the plmn-IdentityList fields included in SIB1.
- uplinkTxDirectCurrentList: The Tx Direct Current locations for the configured serving cells and BWPs if requested by the NW (see reportUplinkTxDirectCurrent).

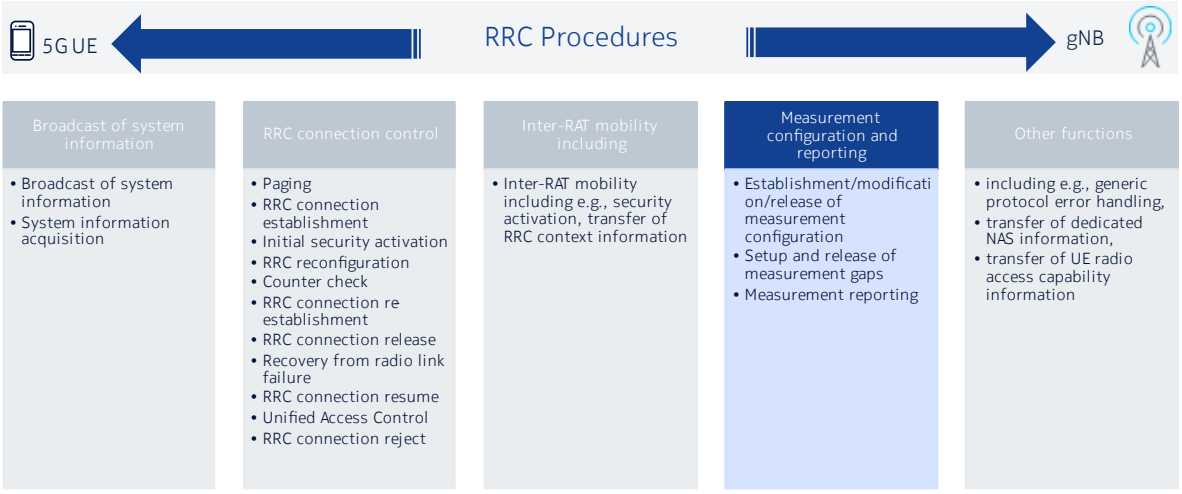
RRC Connection Control
Quiz 4

1. Which SRB is configured in RRC setup?
   a. SRB0
   b. SRB1
   c. SRB2
   d. SRB3
2. What is the RRC message sent to the UE to suspend the RRC connection?
   a. RRCSuspend
   b. RRCResume
   c. RRCRelease
   d. RRCResumeRequest

Measurement Configuration and Reporting

Measurement Configuration and Reporting

Measurement Configuration and Reporting – RRC Procedures



Measurement configuration and reporting:

- Establishment/modification/release of measurement configuration (e.g., intra-frequency, inter-frequency and inter- RAT measurements);
- Setup and release of measurement gaps;
- Measurement reporting.

Measurement Configuration and Reporting

Measurement Configuration and Reporting - MeasConfig

MeasConfig field descriptions
MeasGapSharingConfig: The IE MeasGapSharingConfig specifies the measurement gap sharing scheme
measObjectToAddModList: List of measurement objects to add and/or modify.
measIdToAddModList: List of measurement identities to add and/or modify.
measObjectToRemoveList: List of measurement objects to remove.
measIdToRemoveList: List of measurement identities to remove.
s-MeasureConfig: Threshold for NR SpCell RSRP measurement controlling when the UE is required to perform measurements on non-serving cells. Choice of ssb-RSRP corresponds to cell RSRP based on SS/PBCH block and choice of csi-RSRP corresponds to cell RSRP of CSI-RS.
measGapConfig: Used to setup and release measurement gaps in NR.
reportConfigToAddModList: List of measurement reporting configurations to add and/or modify
reportConfigToRemoveList: List of measurement reporting configurations to remove.

The measurement configuration includes:

- Measurement objects: A list of objects on which the UE shall perform the measurements
- Reporting configurations: A list of reporting configurations (Reporting criterion, RS type, Reporting format) where there can be one or multiple reporting configurations per measurement object.
- Measurement identities
- Quantity configurations
- Measurement gaps

The gNB may configure an RRC_CONNECTED UE to perform measurements and report them in accordance with the measurement configuration. The measurement configuration is provided by means of dedicated signaling i.e., using the RRCReconfiguration.

The network may configure the UE to perform the following types of measurements:

- NR measurements;
- Inter-RAT measurements of E-UTRA frequencies.

The network may configure the UE to report the following measurement information based on SS/PBCH block(s):

- Measurement results per SS/PBCH block;
- Measurement results per cell based on SS/PBCH block(s);
- SS/PBCH block(s) indexes.

The network may configure the UE to report the following measurement information based on CSI-RS resources:

- Measurement results per CSI-RS resource;
- Measurement results per cell based on CSI-RS resource(s);
- CSI-RS resource measurement identifiers.

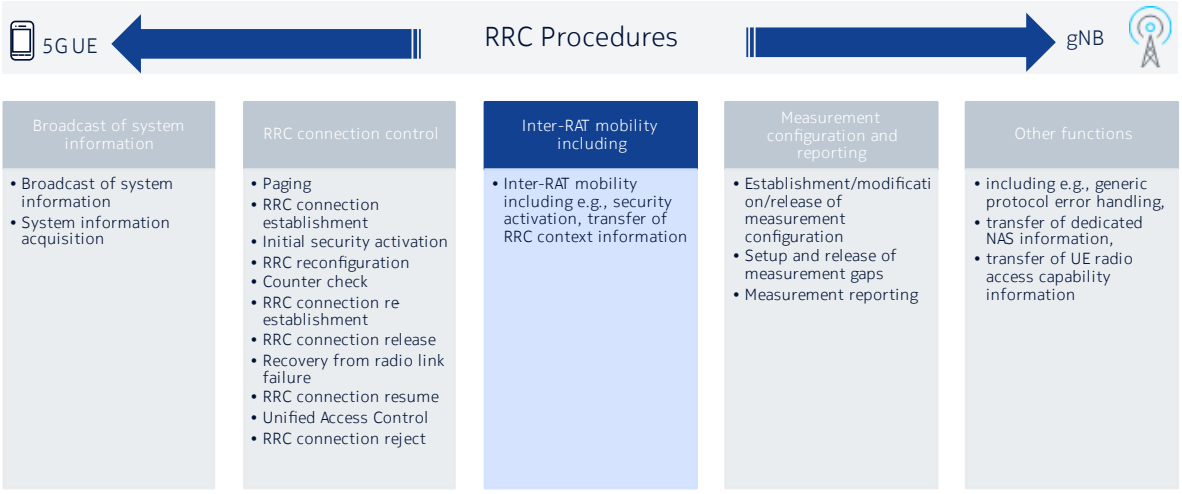
The IE MeasConfig specifies measurements to be performed by the UE, and covers intra-frequency, inter-frequency and inter-RAT mobility as well as configuration of measurement gaps.

Measurement reporting procedure is used to transfer measurement results from the UE to the network. The UE shall initiate this procedure only after successful security activation.

Inter-RAT Mobility

Inter-RAT Mobility

Inter-RAT Mobility – RRC Procedures

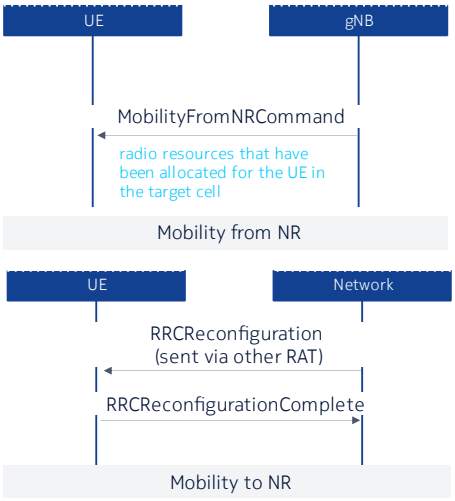


Inter-RAT mobility including e.g., security activation, transfer of RRC context information.

Inter-RAT Mobility
Mobility to/from NR

Mobility from NR procedure is used to move a UE in RRC_CONNECTED to E-UTRA (connected to EPC or 5GC).

MobilityFromNRCommand	MobilityFromNRCommand-IEs
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	targetRAT -Type targetRAT -MessageContainer nas-SecurityParamFromNR



Mobility from NR:

The purpose of this procedure is to move a UE in RRC_CONNECTED to a cell using other RAT, e.g., E-UTRA. The mobility from NR procedure covers the following type of mobility:

- handover, i.e., the MobilityFromNRCommand message includes radio resources that have been allocated for the UE in the target cell.

The network initiates the mobility from NR procedure to a UE in RRC_CONNECTED, possibly in response to a MeasurementReport message, by sending a MobilityFromNRCommand message.

Mobility to NR:

- The purpose of this procedure is to, under the control of the network, transfer a connection between the UE and another Radio Access Network (e.g., E-UTRAN) to NR.
- The handover to NR procedure applies when SRBs, possibly in combination with DRBs, are established in another RAT. Handover from E-UTRA to NR applies only after integrity has been activated in E-UTRA.

The RAN using another RAT initiates the handover to NR procedure, in accordance with the specifications applicable for the other RAT, by sending the RRCReconfiguration message via the radio access technology from which the inter-RAT handover is performed.

The network applies the procedure as follows:

- to activate ciphering, possibly using NULL algorithm, if not yet activated in the other RAT;
- to re-establish SRBs and one or more DRBs;

Note that NR supports network controlled inter-RAT mobility between NR and E-UTRA which can be connected to either EPC or 5GC.

MobilityFromNRCommand-IEs field descriptions:

- nas-SecurityParamFromNR: used to deliver the key synchronization and Key freshness for the NR to LTE/EPC handovers and contains the 4 LSB of the downlink NAS COUNT.
- targetRAT-MessageContainer: contains a message specified in another standard, as indicated by the targetRAT-Type, and carries information about the target cell identifier(s) and radio parameters relevant for the target radio access technology (A complete message is included, as specified in the other standard).
- targetRAT-Type: Indicates the target RAT type.

Other Functions

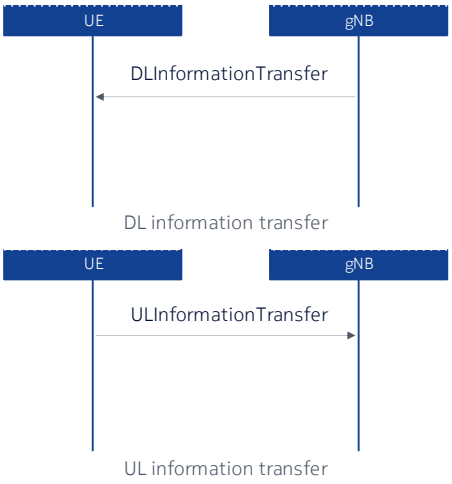
Other Functions
Other Functions – RRC Procedures

Broadcast of system information	RRC connection control	Inter-RAT mobility including	Measurement configuration and reporting	Other functions
• Broadcast of system information • System information acquisition	• Paging • RRC connection establishment • Initial security activation • RRC reconfiguration • Counter check • RRC connection re establishment • RRC connection release • Recovery from radio link failure • RRC connection resume • Unified Access Control • RRC connection reject	• Inter-RAT mobility including e.g., security activation, transfer of RRC context information	• Establishment/modification/release of measurement configuration • Setup and release of measurement gaps • Measurement reporting	• including e.g., generic protocol error handling, • transfer of dedicated NAS information, • transfer of UE radio access capability information

Other Functions
DL/UL Information Transfer

DL/UL Information Transfer procedure is to transfer NAS dedicated information from NG-RAN to a UE in RRC_CONNECTED / from the UE to the network.

DL/UL Information Transfer	DL/UL Information Transfer -IEs
• Signalling radio bearer: SRB2 or SRB1 (only if SRB2 not established yet) • RLC-SAP: AM • Logical channel: DCCH	DedicatedNAS-Message



The network initiates the DL information transfer procedure whenever there is a need to transfer NAS dedicated information. The network initiates the DL information transfer procedure by sending the *DLInformationTransfer* message.

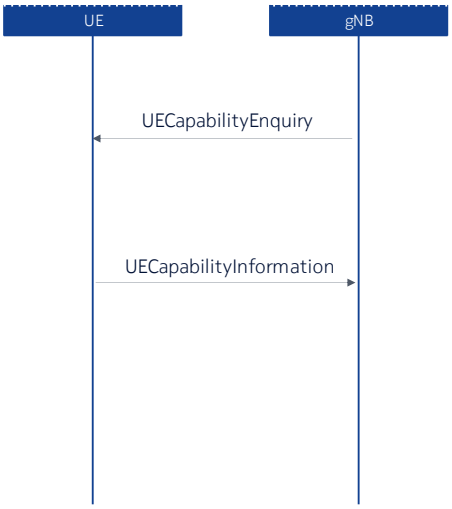
A UE in RRC_CONNECTED initiates the UL information transfer procedure whenever there is a need to transfer NAS dedicated information. The UE initiates the UL information transfer procedure by sending the ULInformationTransfer message.

Other Functions
UE Capability Transfer

The network initiates the procedure to a UE in RRC_CONNECTED when it needs (additional) UE radio access capability information.

UECapabilityEnquiry	UECapabilityEnquiry -IEs
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	UE-CapabilityRAT-RequestList

UECapabilityInformation	UECapabilityInformation-IEs
• Signalling radio bearer: SRB1 • RLC-SAP: AM • Logical channel: DCCH	UE-CapabilityRAT-ContainerList



How does the UE compile and transfer its UE capability information upon receiving a UECapabilityEnquiry from the network?

The *UECapabilityEnquiry* message is used to request UE radio access capabilities for NR as well as for other RATs.

The *UECapabilityInformation* message is used to transfer UE radio access capabilities requested by the network.

Exercise

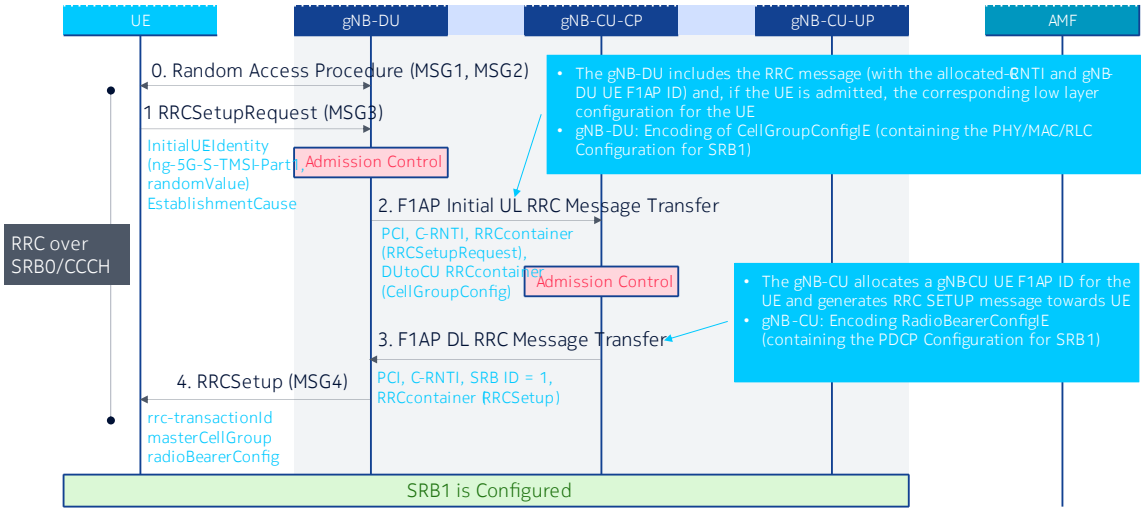
Which RLC -SAP/SRB type and logical channel used for transmission of RRC Signaling Messages given in these tables?

RRC Signaling Messages	RLC Mode	SRB type	Logical channel
MSI (MIB)	TM	?	?
RMSI (SIB1)	TM	?	?
SystemInformation	TM	?	?

RRC Signaling Messages	RLC Mode	SRB type	Logical channel	Direction
RRCSetupRequest	TM	?	?	UE to Network
RRCSetup	TM	?	?	Network to UE
RRCSetupComplete	AM	?	?	UE to Network
RRCReestablishmentRequest	TM	?	?	UE to Network
RRCReestablishment	AM	?	?	Network to UE
RRCReestablishmentComplete	AM	?	?	UE to Network
RRCReconfiguration	AM	?	?	Network to UE
RRCReconfigurationComplete	AM	?	?	UE to Network
RRCResumeRequest	TM	?	?	UE to Network
RRCResumeRequest1	TM	?	?	UE to Network
RRCResume	AM	?	?	Network to UE
RRCRelease	AM	?	?	Network to UE
RRCReject	TM	?	?	Network to UE

NR RRC Connection Setup

NR RRC Connection Setup
NR RRC Connection Setup Flow



1. The UE sends **RRCSetupREQUEST** message to the gNB-DU.

```
InitialUE-Identity ::=              CHOICE {
        ng-5g-s-tmsi                NG-5G-S-TMSI,
        -- FFS Whether ffsValue equals to 40 (as in LTE) or longer.
        randomValue                 BIT STRING (SIZE (ffsValue))
}
```

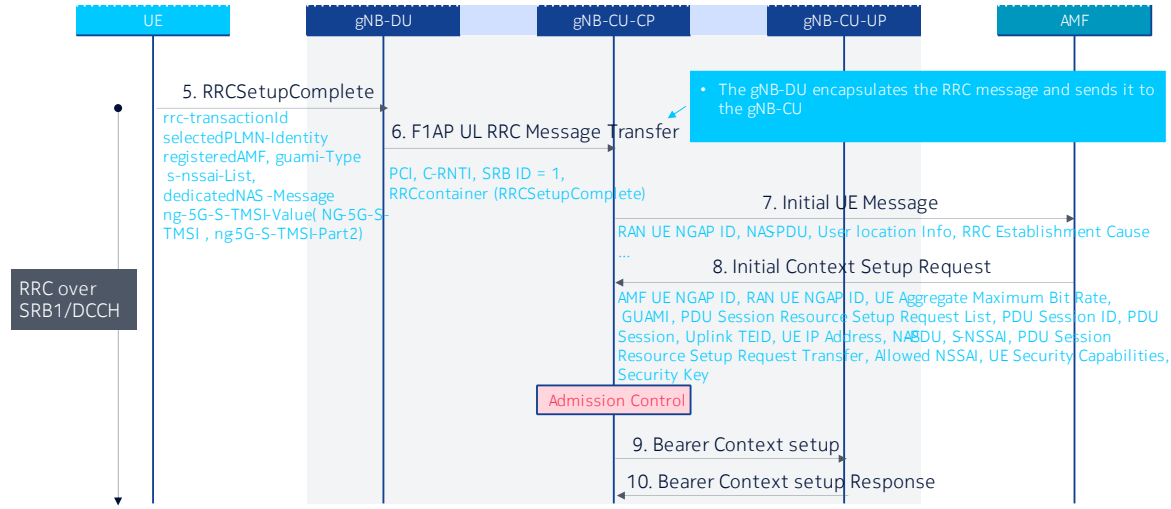
2. The gNB-DU includes the RRC message and, if the UE is admitted, the corresponding low layer configuration for the UE in the F1AP INITIAL UL RRC MESSAGE TRANSFER message and transfers to the gNB-CU.
   The INITIAL UL RRC MESSAGE TRANSFER message includes the C-RNTI allocated by the gNB-DU.
3. The gNB-CU allocates a gNB-CU UE F1AP ID for the UE and generates RRC CONNECTION SETUP message towards UE.
   The RRC message is encapsulated in -the F1AP DL RRC MESSAGE TRANSFER message.

4. The gNB-DU sends the RRC SETUP message to the UE.

```
RRCSetup-IEs ::=            SEQUENCE {
        radioBearerConfig               RadioBearerConfig,
        masterCellGroup                 OCTET STRING (CONTAINING CellGroupConfig),
.....
}
RadioBearerConfig ::=               SEQUENCE {
        srb-ToAddModList                SRB-ToAddModList
                                OPTIONAL, -- Need N
        srb3-ToRelease                  ENUMERATED{true}
                                OPTIONAL, -- Need N
        drb-ToAddModList                DRB-ToAddModList
                                OPTIONAL, -- Need N
        drb-ToReleaseList               DRB-ToReleaseList
                                OPTIONAL, -- Need N
        securityConfig                  SecurityConfig
                                OPTIONAL, -- Cond M
        ...
}
SRB-ToAddModList ::=        SEQUENCE (SIZE (1..2)) OF SRB-ToAddMod
SRB-ToAddMod ::=            SEQUENCE {
        srb-Identity                            SRB-Identity,
        -- may only be set if the cell groups of all linked logical channels are reset or released
        reestablishPDCP                 ENUMERATED{true}                OPTIONAL,       -- Need N
        discardOnPDCP                   ENUMERATED{true}        OPTIONAL,       -- Need N
        pdcp-Config                             PDCP-Config                     OPTIONAL,
        -- Cond PDCP
        ...
}
```

NR RRC Connection Setup

NR RRC Connection Setup Flow

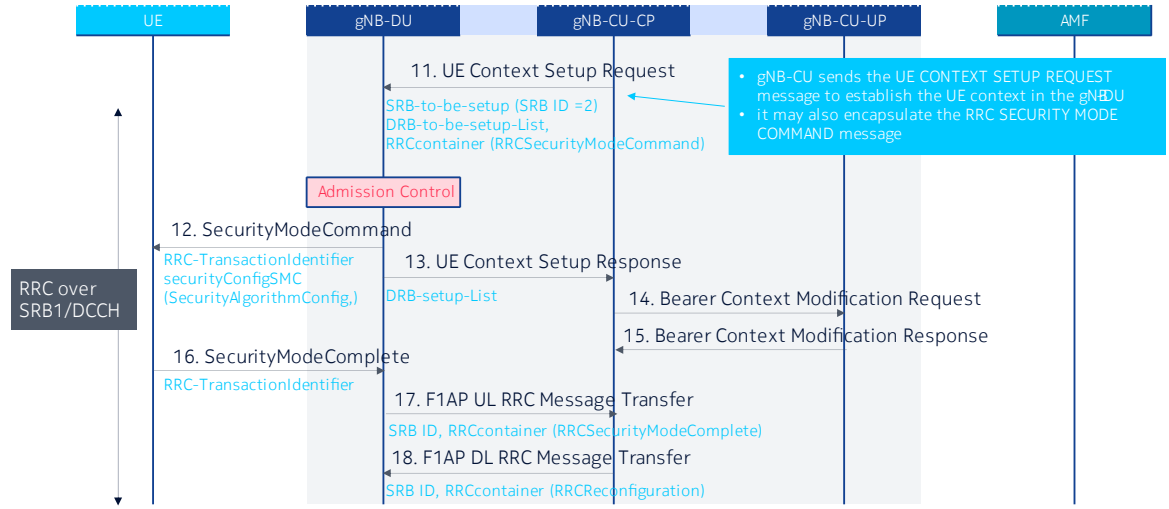


5. The UE sends the RRC SETUP COMPLETE message to the gNB-DU.
6. The gNB-DU encapsulates the RRC message in the F1AP UL RRC MESSAGE TRANSFER message and sends it to the gNB-CU.
7. The gNB-CU sends the INITIAL UE MESSAGE message to the AMF.
8. The AMF sends the INITIAL UE CONTEXT SETUP REQUEST message to the gNB-CU.

9 & 10. setup of the bearer context in the gNB-CU-UP

NR RRC Connection Setup

NR RRC Connection Setup Flow



11. The gNB-CU sends the UE CONTEXT SETUP REQUEST message to establish the UE context in the gNB-DU.

    In this message, it may also encapsulate the RRC SECURITY MODE COMMAND message.

12. The gNB-DU sends the **RRC SECURITY MODE COMMAND** message to the UE.

```
SecurityAlgorithmConfig ::=          SEQUENCE {
        cipheringAlgorithm                      CipheringAlgorithm,
        integrityProtAlgorithm          IntegrityProtAlgorithm
        OPTIONAL,       -- Need R
        ...
}
```

cipheringAlgorithm

Indicates the ciphering algorithm to be used for SRBs and DRBs, as specified in TS 33.501

integrityProtAlgorithm

For EN-DC, this IE indicates the integrity protection algorithm to be used for SRBs, as specified in TS 33.501.

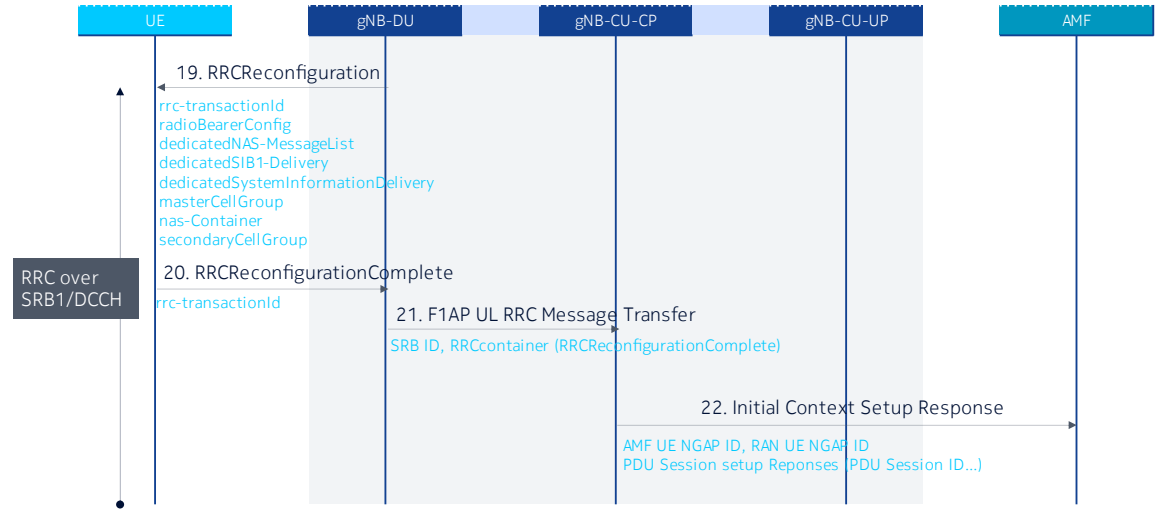
13. The gNB-DU sends the UE CONTEXT SETUP RESPONSE message to the gNB-CU.

14 & 15. update of the bearer context in the gNB-CU-UP

16. The UE responds with the **RRC SECURITY MODE COMPLETE** message
17. The gNB-DU encapsulates the RRC message in the F1AP UL RRC MESSAGE TRANSFER message and sends it to the gNB-CU.
18. The gNB-CU generates the **RRC RECONFIGURATION** message and encapsulates it in the F1AP DL RRC MESSAGE TRANSFER message

NR RRC Connection Setup

NR RRC Connection Setup Flow



19. The gNB-DU sends **RRC RECONFIGURATION** message to the UE.
20. The UE sends **RRC RECONFIGURATION COMPLETE** message to the gNB-DU.
21. The gNB-DU encapsulates the RRC message in the F1AP UL RRC MESSAGE TRANSFER message and send it to the gNB-CU.
22. The gNB-CU sends the INITIAL UE CONTEXT SETUP RESPONSE message to the AMF.

NR RRC Connection Setup
Quiz 5

1. Which of the following is a correct statement?
   a. The network completes RRC connection establishment after completing the establishment of the NG connection
   b. The network completes RRC connection establishment prior to completing the establishment of the NG connection
2. When the network initiates the security mode command procedure?
   a. When only SRB0, is established, i.e., prior to establishment of SRB1 and/ or DRBs
   b. When only SRB1, is established, i.e., prior to establishment of SRB2 and/ or DRBs
   c. When only SRB2, is established, i.e., prior to establishment of SRB3 and/ or DRBs

Wrap-up

In this module we have covered the following items

- Describe NR RRC Protocol
- Explain RRC Functions and Procedures
- Describe RRC Connection Control
- Describe Measurement Configuration and Reporting
- Explain Inter-RAT Mobility
- Describe NR RRC Connection Setup