TS 38.331: an examination

Milind Kumar V (EE16B025), Kanish B (EE16B106)

Architecture

UE STATES

At any point in time the UE is in one of the following RRC states

- RRC_CONNECTED
- RRC_INACTIVE
- RRC_IDLE

RRC_IDLE

- UE specific DRX may be configured by upper layers
  - DRX refers to discontinuous reception
  - Helps UE save power by allowing network to determine when UE can sleep or listen using an RRC message
- UE controlled mobility based on network configuration
  - In the idle mode, the mobility is UE controlled, the UE makes the decision to in which cell it is camping (or tries to camp)

RRC_IDLE

When in RRC_IDLE state the UE:

- Monitors Short Messages transmitted with P-RNTI (paging Radio Network Temporary Identifier) over DCI (Downlink Control Information).
  - P-RNTI is a common RNTI used by UE for paging
- Monitors a Paging channel for CN paging using 5G-S-TMSI
- Performs neighbouring cell measurements and cell (re-)selection - In 5G NR, for the procedures such as handover to a stronger cells or adding a new Carrier Component (CC) in the case of CA, it is required to measure the serving cell and neighbor cell signal strength or signal quality matrix
- Acquires system information and can send SI request

RRC_INACTIVE

- UE specific DRX may be configured by upper layers or by RRC layer
- UE controlled mobility based on network configuration
- UE stores the UE Inactive AS context
- A RAN-based Notification Area (RNA) is configured by RRC layer
  - The UE will perform a RNA update procedure if it moves to a cell which is not part of the current RNA assigned.

RRC_INACTIVE

When in RRC_INACTIVE state the UE:

- Monitors Short Messages transmitted with P-RNTI over DCI
- Monitors a Paging channel for CN paging using 5G-S-TMSI and RAN paging using fullI-RNTI
- Performs neighbouring cell measurements and cell (re-)selection
- Performs RAN-based notification area updates periodically and when moving outside the configured RAN-based notification area
- Acquires system information and can send SI request (if configured)

RRC_CONNECTED

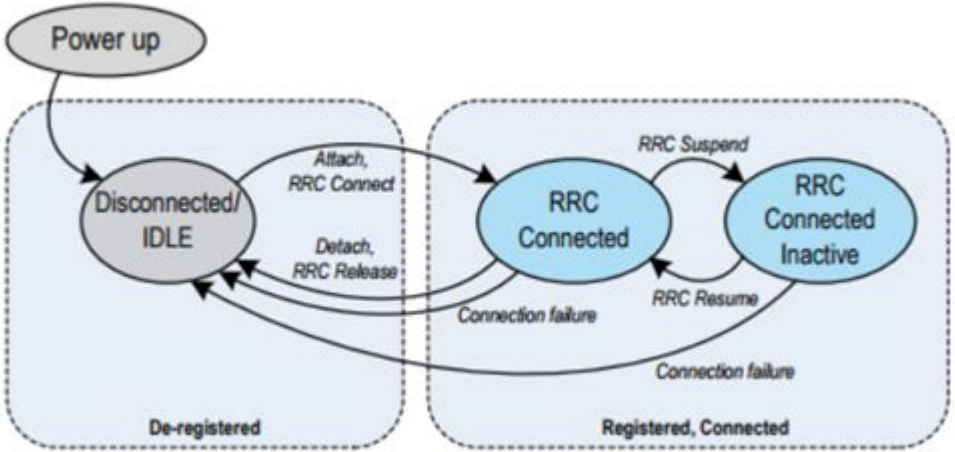
- The UE stores the AS context
- Transfer of unicast data to/from UE
- At lower layers, the UE may be configured with a UE specific DRX
- For UEs supporting CA, use of one or more SCells, aggregated with the SpCell, for increased bandwidth
- For UEs supporting DC, use of one SCG, aggregated with the MCG, for increased bandwidth
- Network controlled mobility within NR and to/from E-UTRA. (refer Procedures section for details)

RRC_CONNECTED

When in RRC_CONNECTED state the UE:

- Monitors Short Messages transmitted with P-RNTI over DCI, if configured
- Monitors control channels associated with the shared data channel to determine if data is scheduled for it
- Provides channel quality and feedback information
- Performs neighbouring cell measurements and measurement reporting
- Acquires system information.

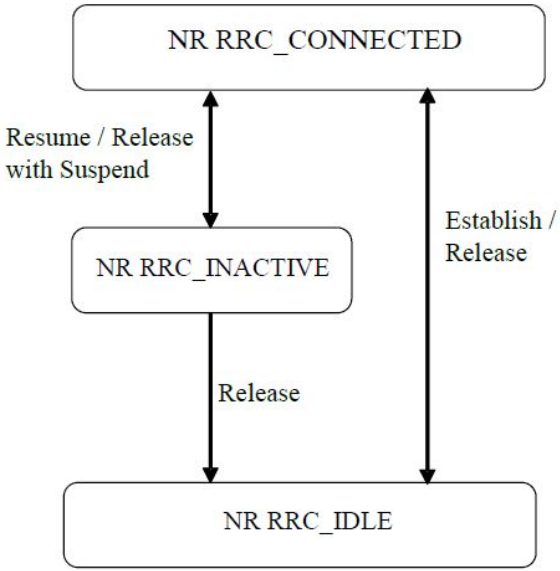
RRC STATE TRANSITIONS



- When UE is powered up it is in RRC_IDLE state
- It can move RRC_CONNECTED with initial attach or with connection establishment
- If there is no activity from UE for a short time, it can suspend its session by moving to RRC_INACTIVE and can resume its session moving to RRC_CONNECTED state

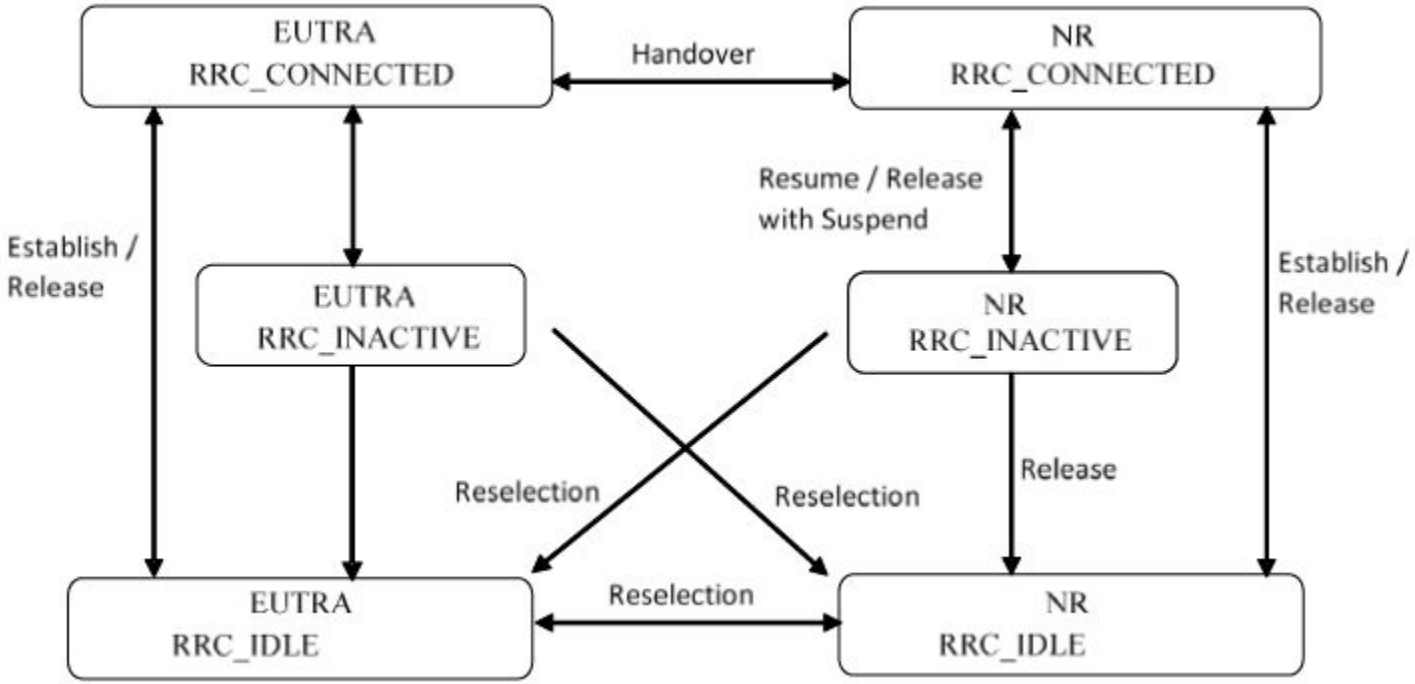
RRC STATE TRANSITIONS

- **RRC_CONNECTED**: UE can move to RRC_IDLE with Connection Release and can move to RRC_INACTIVE with Connection Release with Suspend
- **RRC_INACTIVE**: UE can move to RRC_CONNECTED with Connection Resume and can move to RRC_IDLE with Connection Release
- **RRC_IDLE**: UE can move only to RRC_CONNECTED with Connection Establish



UE state machine and state transitions in NR

NR and E-UTRA RRC STATE TRANSITIONS



UE state machine and state transitions between NR/5GC, E-UTRA/EPC andEUTRA/5GC

NR and E-UTRA RRC STATE TRANSITIONS

- In CONNECTED state Handover can be performed between NR to E-UTRA and E-UTRA to NR.
- In IDLE state NR can Reselect to E-UTRA and E-UTRA can Reselect to NR.
- In INACTIVE state NR can Reselect E-UTRA RRC_IDLE and E-UTRA can Reselect to NR RRC_IDLE.

SIGNALLING RADIO BEARERS

Signalling Radio Bearers (SRBs) are defined as RBs that are used only for the transmission of RRC and NAS messages

The 4 SRBs defined in NR are as follows,

- SRB0 is for RRC messages using CCCH logical channel
- SRB1 is for RRC messages (which may include a piggybacked NAS message) as well as for NAS messages prior to the establishment of SRB2 using DCCH logical channel

SIGNALLING RADIO BEARERS

- SRB2 is for NAS messages, using DCCH logical channel and has a lower priority than SRB1 and may be configured by the network after AS security activation
- SRB3 is for specific RRC messages when UE is in (NG)EN-DC or NR-DC, using DCCH logical channel

Services

SERVICES PROVIDED TO UPPER LAYERS

- Broadcast of common control information
- Notification of UEs in RRC_IDLE
- Notification of UEs about ETWS and/or CMAS
  - ETWS (Earthquake and Tsunami Warning System) is a warning system in which the primary message is expected to be delivered to subscribers within 4s of generation (see Bibliography)
  - CMAS (Commercial Mobile Alert System) also offers warning messages.
- Transfer of dedicated signalling

SERVICES EXPECTED FROM LOWER LAYERS

- Integrity protection
- Ciphering
- Loss-less in-sequence delivery of information

Functions

BROADCAST OF SYSTEM INFORMATION

- NAS common information
- Information for UEs in RRC states
- ETWS, CMAS notification

RRC CONNECTION CONTROL

- Paging
- Establishment/modification/suspension/resumption/release of RRC connection, SRBs and RBs
- Access barring
- Initial AS security activation and AS ciphering
- RRC connection mobility
- Radio configuration
- DC and CA cell management
- QoS control
- Recovery from radio link failure

MEASUREMENT CONFIGURATION AND REPORTING

- Establishment/modification/release of measurement configuration
- Setup and release of measurement gaps
- Measurement reporting

Other functions

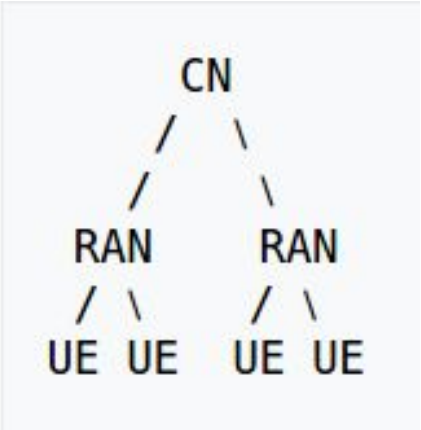
Other functions include

- generic protocol error handling
- transfer of dedicated NAS information
- transfer of UE radio access capability information
- Inter-RAT mobility

Procedures

RAN

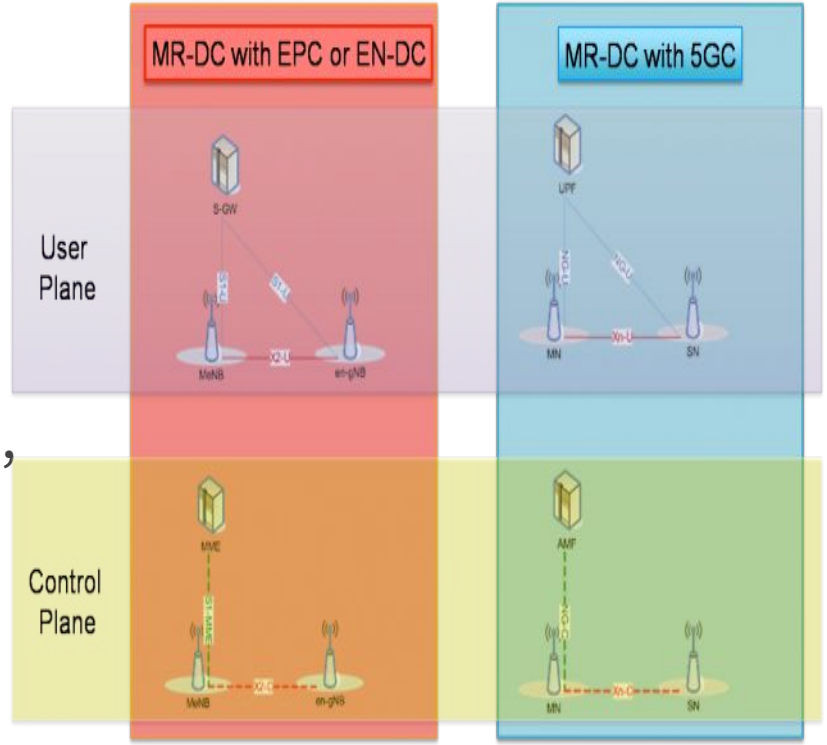
- Stands for Radio Access Network.
- Exists between the UE and Core Network.
- Handles radio-related functionality including radio-resource handling, retransmission protocols, coding, and various multi-antenna schemes.
- Examples include GRAN, GERAN, UTRAN and E-UTRAN.
- E-UTRA is the air interface (consisting of physical and data link layers) for LTE.



Source: Wikipedia

MR-DC

- Stands for Multi-RAT Dual Connectivity.
- It is possible to connect NR RAN to the LTE core network.
- This helps increase data rates, reliability, improve load-balancing and reuse LTE infrastructure.



Source: [4G 5G World]

MR-DC

The UE is considered to be in MR-DC if it is in one of the following situations

- EN-DC
- NGEN-DC
- NE-DC
- NR-DC

MR-DC

	MasterNode	SecondaryNode	RAN	CoreNW
EN-DC	eNB	gNB or engNB	EUTRAN	EPC (corresponds to LTE)
NE-DC	gNB	eNB or ngeNB	NG-RAN	5GC
NGEN-DC	eNB or ngeNB	gNB	NG-RAN	5GC
NR-DC	gNB	gNB	NG-RAN	5GC

- **gNB** (generalized NodeB): logical 5G radio node, handles radio communications with 5G UE, uses 5G air interface, may connect to EPC or 5GC
- **eNB** (E-UTRAN NodeB): 4G LTE equivalent of gNB
- **ngeNB** (next generation eNB): communicates with 5G UE, uses 4G LTE air interface, connects to the 5G core network.
- **engNB**: used in EUTRA dual connectivity, acts as secondary node

UE requirements for MR-DC

- UE state in EN-DC and NGEN-DC depends on the IE nr-SecondaryCellGroupConfig. Core network needs to be selected appropriately.
- UE is in NE-DC if mrdc-SecondaryCellGroup is set to eutra-SCG.
- UE is in NE-DC if mrdc-SecondaryCellGroup is set to nr-SCG.

UE requirements for MR-DC

- mrdc-SecondaryCellGroup is an information element in the RRCReconfiguration message.

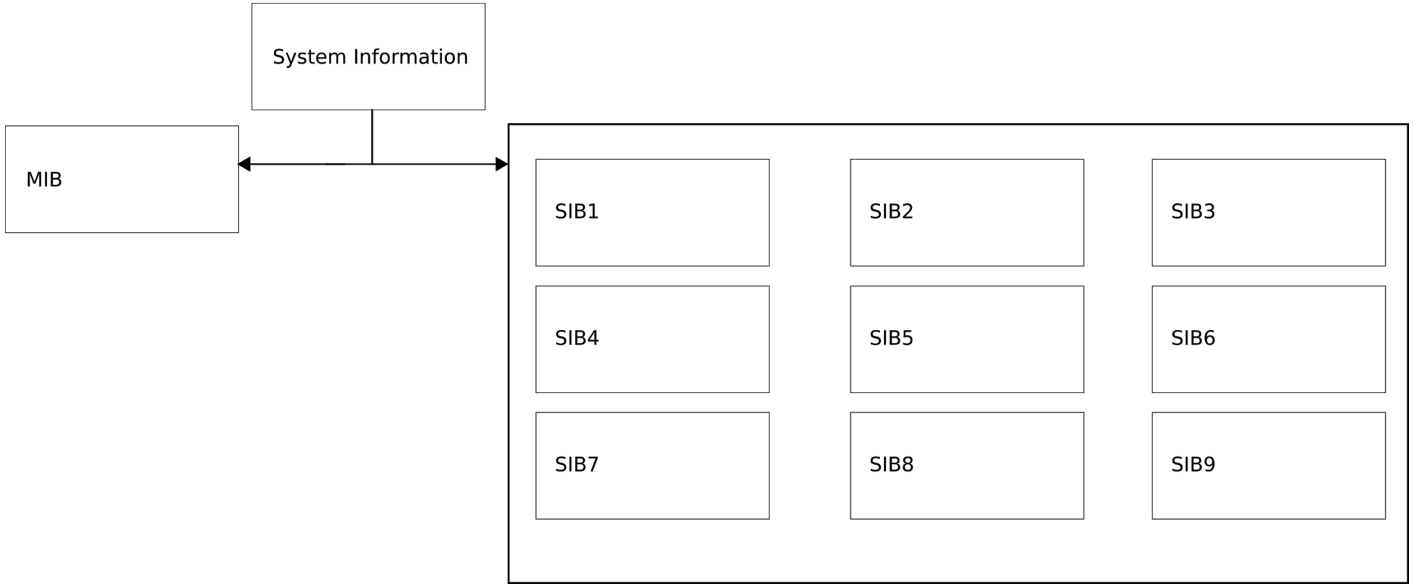
```
RRCReconfiguration-v1560-IEs ::=            SEQUENCE {
    mrdc-SecondaryCellGroupConfig               SetupRelease { MRDC-SecondaryCellGroupConfig }      OPTIONAL,   -- Need M
    radioBearerConfig2                          OCTET STRING (CONTAINING RadioBearerConfig)         OPTIONAL,   -- Need M
    sk-Counter                                  SK-Counter                                          OPTIONAL,   -- Need N
    nonCriticalExtension                        SEQUENCE {}                                         OPTIONAL
}

MRDC-SecondaryCellGroupConfig ::=       SEQUENCE {
    mrdc-ReleaseAndAdd                  ENUMERATED {true}                                           OPTIONAL,   -- Need N
    mrdc-SecondaryCellGroup             CHOICE {
        nr-SCG                              OCTET STRING  (CONTAINING RRCReconfiguration),
        eutra-SCG                           OCTET STRING
    }
}
```

mrdc-SecondaryCellGroup
Includes an RRC message for SCG configuration in NR-DC or NE-DC.
For NR-DC (nr-SCG), *mrdc-SecondaryCellGroup* contains the *RRCReconfiguration* message as generated (entirely) by SN gNB. In this version of the specification, the RRC message can only include fields *secondaryCellGroup* and *measConfig*.
For NE-DC (eutra-SCG), *mrdc-SecondaryCellGroup* includes the E-UTRA *RRCConnectionReconfiguration* message as specified in TS 36.331 [10]. In this version of the specification, the E-UTRA RRC message can only include the field *scg-Configuration*.

System Information Acquisition

System Information

System refers to all the common information that a device needs in order to properly operate within the network.



MIB

- MIB stands for the Master Information Block.
- Transmitted on BCH with a periodicity of 80ms.
- Expected to remain same for this duration and for all the SS blocks in the SS burst set.
- Contains a small amount of information required by UE to obtain the remaining system information.

MIB

```
-- ASN1START
-- TAG-MIB-START

MIB ::=                             SEQUENCE {
    systemFrameNumber                   BIT STRING (SIZE (6)),
    subCarrierSpacingCommon             ENUMERATED {scs15or60, scs30or120},
    ssb-SubcarrierOffset                INTEGER (0..15),
    dmrs-TypeA-Position                 ENUMERATED {pos2, pos3},
    pdcch-ConfigSIB1                    PDCCH-ConfigSIB1,
    cellBarred                          ENUMERATED {barred, notBarred},
    intraFreqReselection                ENUMERATED {allowed, notAllowed},
    spare                               BIT STRING (SIZE (1))
}

-- TAG-MIB-STOP
-- ASN1STOP
```

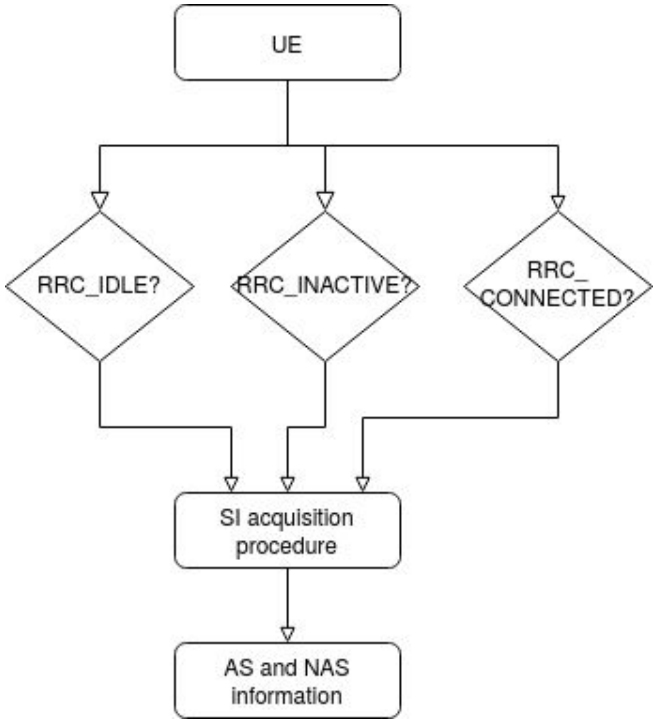
SIB

Stands for System Information Block.Transmitted on the DL-SCH.SIB1 is cell specific. Other SIBs can be cell specific or area specific.

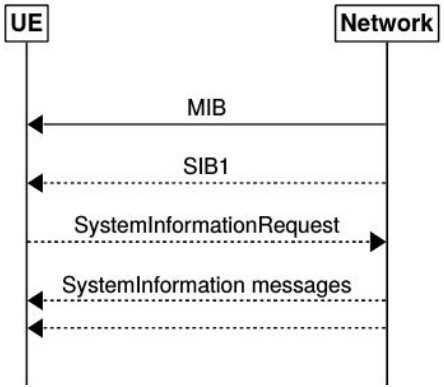
***SIB1* message**

```
-- ASN1START
-- TAG-SIB1-START

SIB1 ::=        SEQUENCE {
    cellSelectionInfo                   SEQUENCE {
        q-RxLevMin                          Q-RxLevMin,
        q-RxLevMinOffset                    INTEGER (1..8)                                  OPTIONAL,   -- Need S
        q-RxLevMinSUL                       Q-RxLevMin                                      OPTIONAL,   -- Need R
        q-QualMin                           Q-QualMin                                       OPTIONAL,   -- Need S
        q-QualMinOffset                     INTEGER (1..8)                                  OPTIONAL    -- Need S
    }                                                                                       OPTIONAL,   -- Cond Standalone
    cellAccessRelatedInfo               CellAccessRelatedInfo,
    connEstFailureControl               ConnEstFailureControl                           OPTIONAL,   -- Need R
    si-SchedulingInfo                   SI-SchedulingInfo                               OPTIONAL,   -- Need R
    servingCellConfigCommon             ServingCellConfigCommonSIB                      OPTIONAL,   -- Need R
    ims-EmergencySupport                ENUMERATED {true}                               OPTIONAL,   -- Need R
    eCallOverIMS-Support                ENUMERATED {true}                               OPTIONAL,   -- Cond Absent
    ue-TimersAndConstants               UE-TimersAndConstants                           OPTIONAL,   -- Need R

    uac-BarringInfo                     SEQUENCE {
        uac-BarringForCommon                UAC-BarringPerCatList                       OPTIONAL,   -- Need S
        uac-BarringPerPLMN-List             UAC-BarringPerPLMN-List                     OPTIONAL,   -- Need S
        uac-BarringInfoSetList              UAC-BarringInfoSetList,
        uac-AccessCategory1-SelectionAssistanceInfo CHOICE {
            plmnCommon                          UAC-AccessCategory1-SelectionAssistanceInfo,
            individualPLMNList                  SEQUENCE (SIZE (2..maxPLMN)) OF UAC-AccessCategory1-SelectionAssistanceInfo
        }                                                                               OPTIONAL    -- Need S
    }                                                                                   OPTIONAL,   -- Need R

    useFullResumeID                     ENUMERATED {true}                               OPTIONAL,   -- Need R

    lateNonCriticalExtension            OCTET STRING                                    OPTIONAL,
    nonCriticalExtension                SEQUENCE{}                                      OPTIONAL
}

UAC-AccessCategory1-SelectionAssistanceInfo ::=    ENUMERATED {a, b, c}

-- TAG-SIB1-STOP
-- ASN1STOP
```

UE's acquisition of System Information

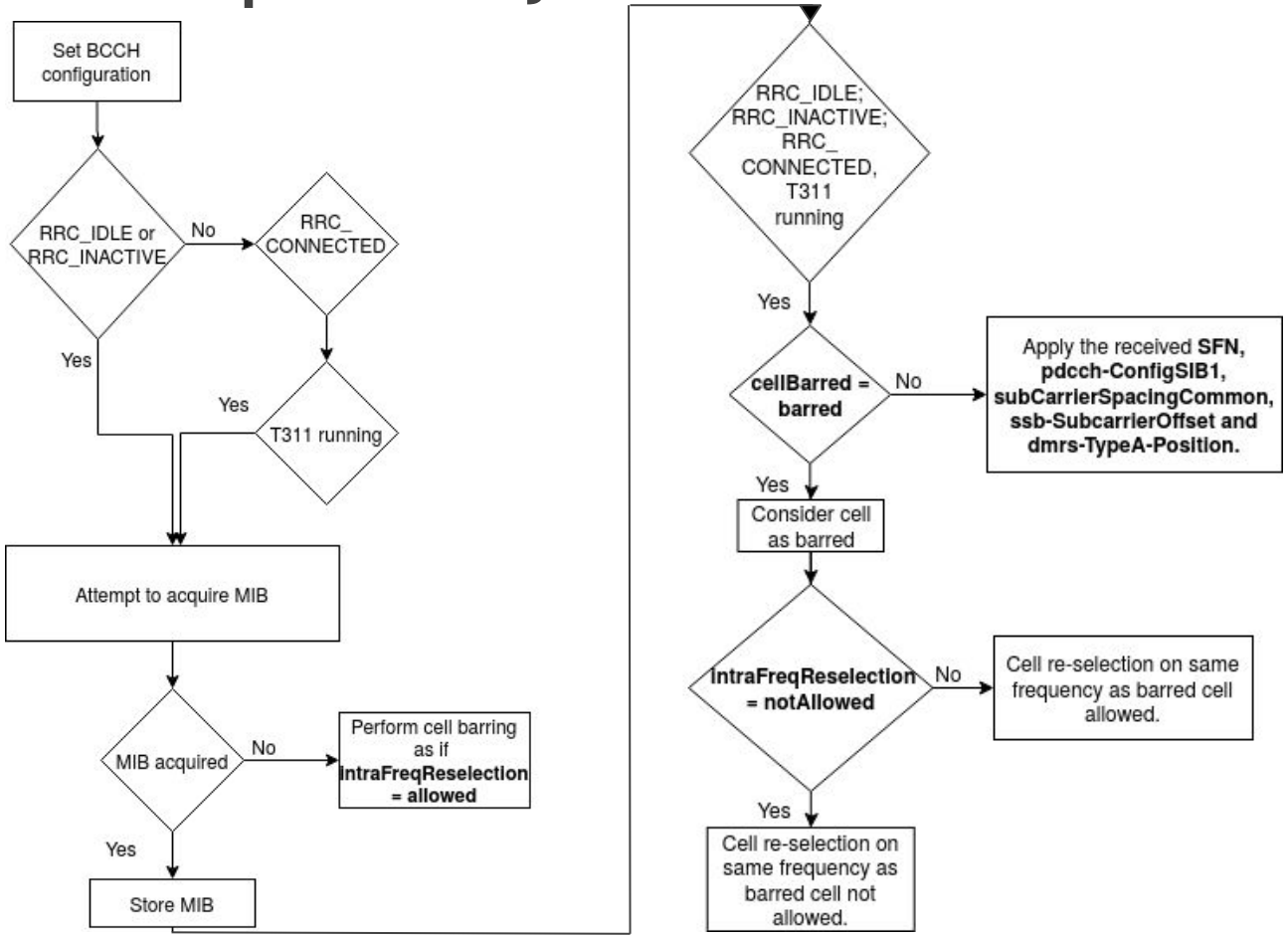


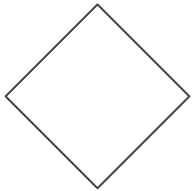
- NAS (Non-access stratum)
  - Maintains communication as UE moves.
  - Protocol for messages between UE and core nodes
- AS (Access stratum)
  - Handles data transport over the wireless connection and manages radio resources.



MIB acquisition by UE

38.331
38.304

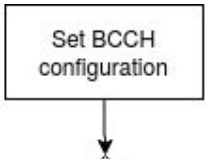




: Check condition

: Execute action

MIB acquisition by UE



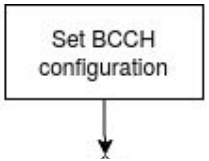
BCCH (Broadcast Control Channel) configuration

Name	Value	Semantics description	Ver
SDAP configuration	Not used		
PDCP configuration	Not used		
RLC configuration	TM		
Logical channel configuration	Not used		

38.331
37.324

MIB acquisition by UE

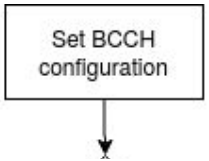
BCCH (Broadcast Control Channel) configuration



- SDAP (Service Data Adaptation Protocol)
  - Transfers User Plane data
  - Maps QoS flow and data radio bearer for UL and DL.
- PDCP (Packet Data Convergence Protocol)
  - Part of the protocol stack above the RLC layer.
  - Services RRC and user plane upper layers.
  - Handles transfer of user and control plane data, ciphering, header compression, etc.

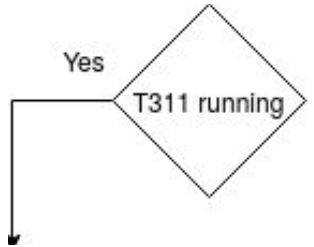
MIB acquisition by UE

BCCH (Broadcast Control Channel) configuration



- RLC (Radio Link Control)
  - Layer 2 Radio Link Protocol between MAC and PDCP layers.
  - Refer 38.322 for more details.
- Logical channel
  - MAC provides services to the RLC via logical channels.
  - These are either control or traffic channels.

MIB acquisition by UE



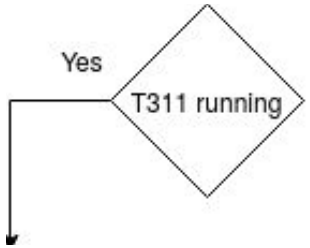
T311: a UE timer. Can be specified by the IES below.

The IE UE-TimersAndConstants contains timers and constants used by the UE in RRC_CONNECTED, RRC_INACTIVE and RRC_IDLE.

***UE-TimersAndConstants* information element**

```
-- ASN1START
-- TAG-UE-TIMERSANDCONSTANTS-START

UE-TimersAndConstants ::=           SEQUENCE {
    t300                                ENUMERATED {ms100, ms200, ms300, ms400, ms600, ms1000, ms1500, ms2000},
    t301                                ENUMERATED {ms100, ms200, ms300, ms400, ms600, ms1000, ms1500, ms2000},
    t310                                ENUMERATED {ms0, ms50, ms100, ms200, ms500, ms1000, ms2000},
    n310                                ENUMERATED {n1, n2, n3, n4, n6, n8, n10, n20},
    t311                                ENUMERATED {ms1000, ms3000, ms5000, ms10000, ms15000, ms20000, ms30000},
    n311                                ENUMERATED {n1, n2, n3, n4, n5, n6, n8, n10},
    t319                                ENUMERATED {ms100, ms200, ms300, ms400, ms600, ms1000, ms1500, ms2000},
    ...
}

-- TAG-UE-TIMERSANDCONSTANTS-STOP
-- ASN1STOP
```

MIB acquisition by UE



***RLF-TimersAndConstants* information element**

```
-- ASN1START
-- TAG-RLF-TIMERSANDCONSTANTS-START

RLF-TimersAndConstants ::=          SEQUENCE {
    t310                                ENUMERATED {ms0, ms50, ms100, ms200, ms500, ms1000, ms2000, ms4000, ms6000},
    n310                                ENUMERATED {n1, n2, n3, n4, n6, n8, n10, n20},
    n311                                ENUMERATED {n1, n2, n3, n4, n5, n6, n8, n10},
    ...,
    [[
    t311                                ENUMERATED {ms1000, ms3000, ms5000, ms10000, ms15000, ms20000, ms30000}
    ]]
}

-- TAG-RLF-TIMERSANDCONSTANTS-STOP
-- ASN1STOP
```

T311 details

Timer	Start	Stop	At expiry
T311	Upon initiating the RRC connection re-establishment procedure	Upon selection of a suitable NR cell or a cell using another RAT.	Enter RRC_IDLE

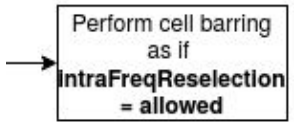
38.331
38.304

MIB acquisition by UE

---

intraFreqReselection: a field in the MIB

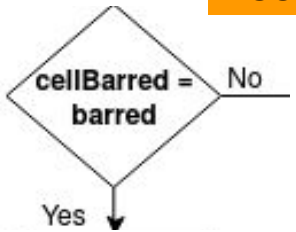
intraFreqReselection
Controls cell selection/reselection to intra-frequency cells when the highest ranked cell is barred, or treated as barred by the UE, as specified in TS 38.304 [20].



- If set to “allowed”, the UE may select another cell on the same frequency if re-selection criteria are fulfilled. The barred cell is excluded as a candidate for cell selection/reselection for 300 seconds.
- If set to “not allowed”, the UE can not select another cell on the same frequency. The UE excludes the barred cell and the cells on the same frequency as a candidate for cell selection/reselection for 300 seconds.

38.331
38.304

MIB acquisition by UE

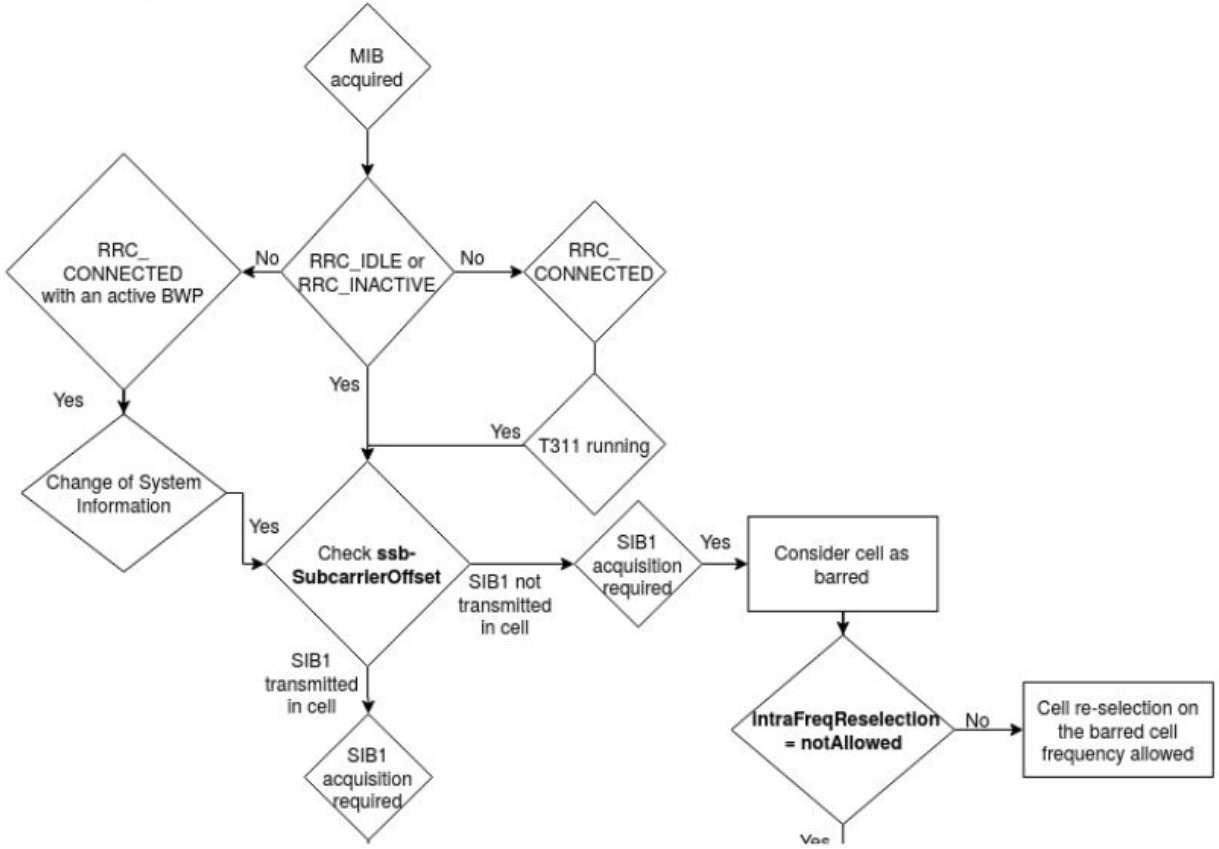


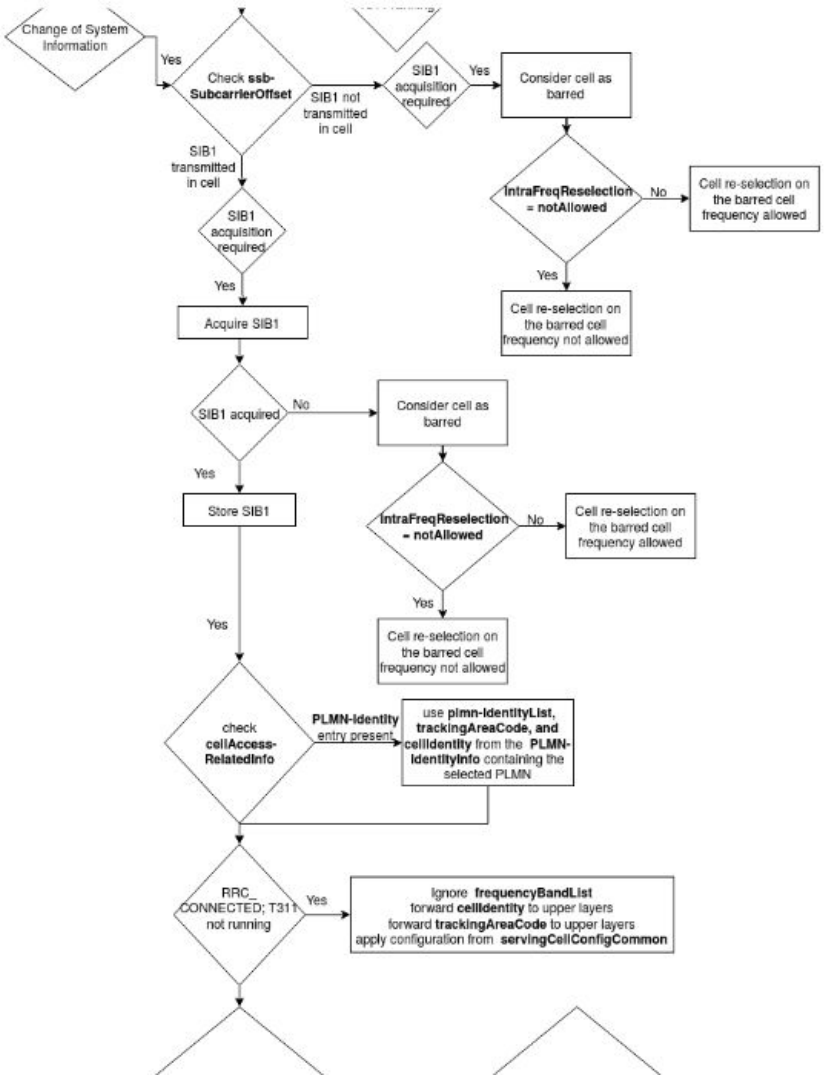
cellBarred: an IE in MIB

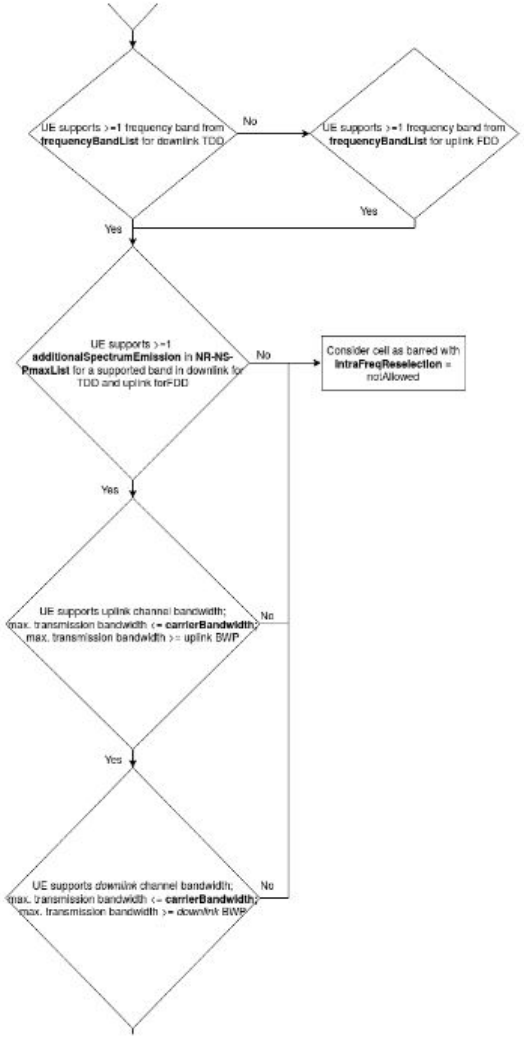
cellBarred
Value *barred* means that the cell is barred, as defined in TS 38.304 [20].

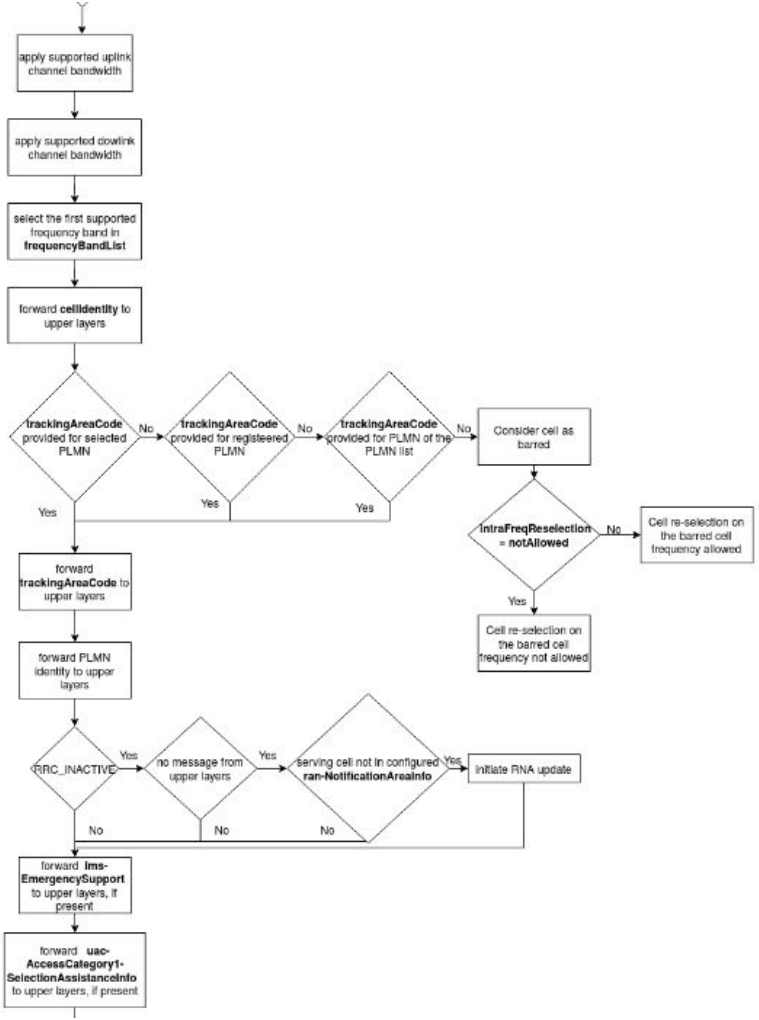
- A Barred cell is one that a UE is not allowed to camp on.
- It can not even be used for emergency calls.

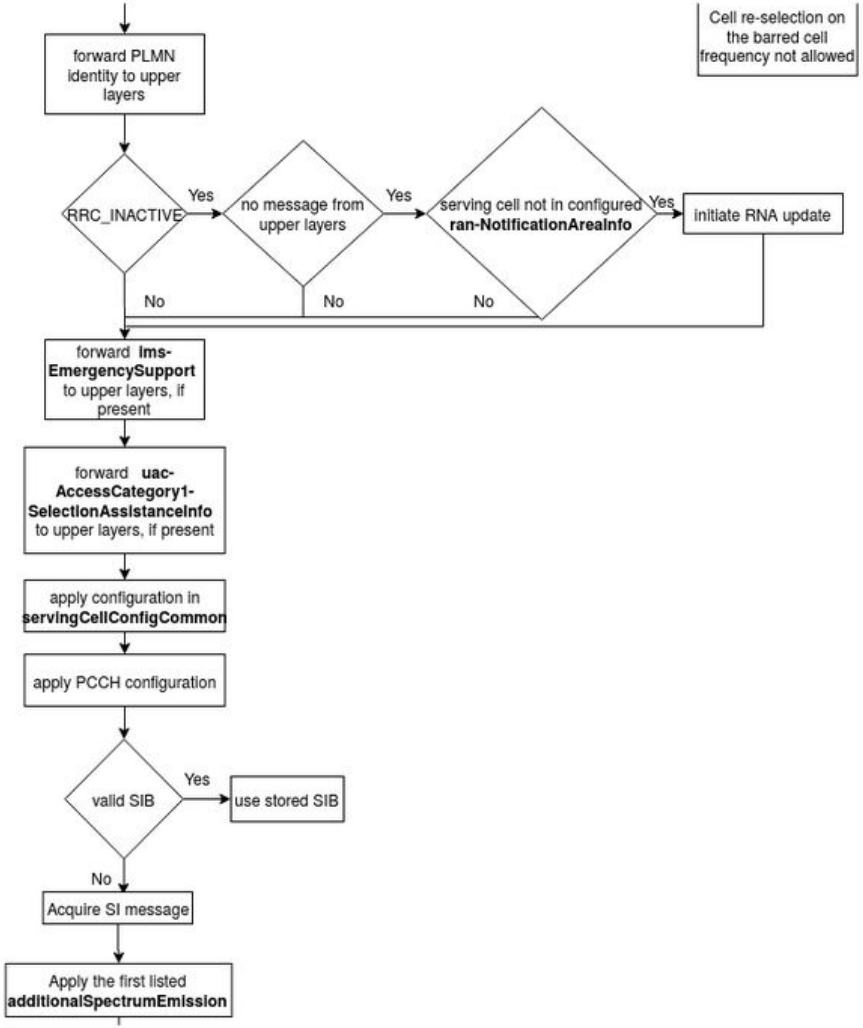
Acquisition of SIB1

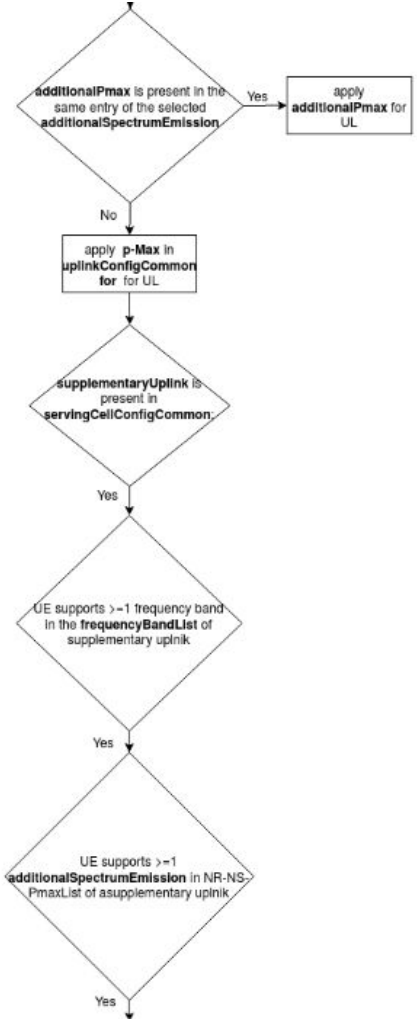


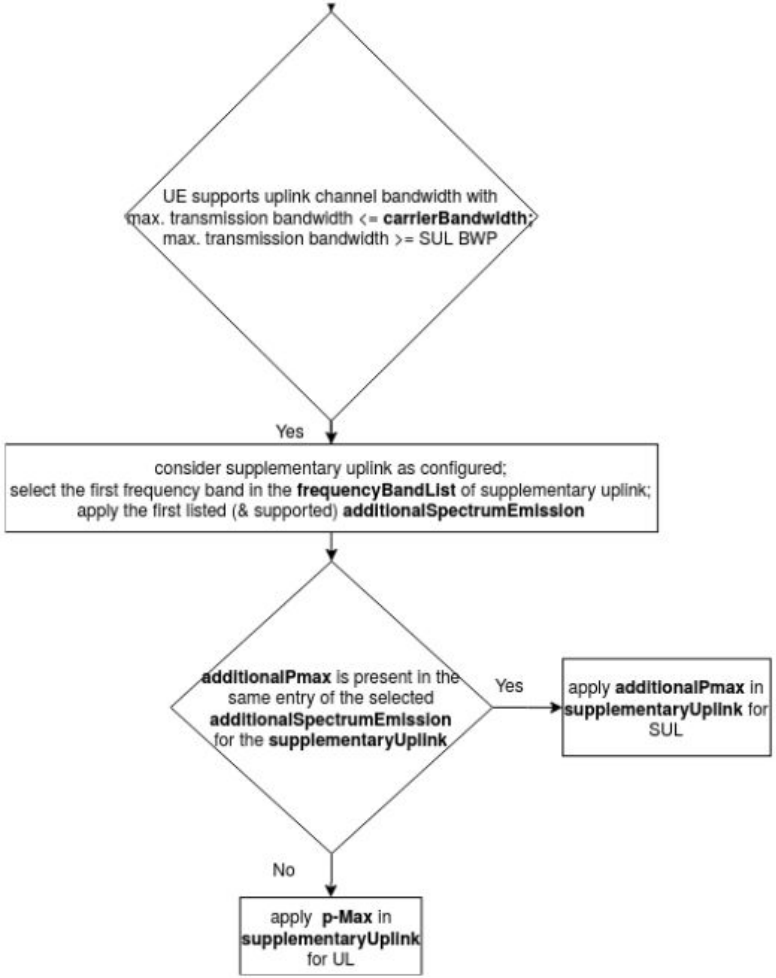

Change of System Information
Yes
Check ssb-SubcarrierOffset
SIB1 not transmitted in cell
SIB1 acquisition required
Yes
Consider cell as barred
SIB1 transmitted in cell
intraFreqReselection = notAllowed
No
Cell re-selection on the barred cell frequency allowed
SIB1 acquisition required
Yes
Yes
Cell re-selection on the barred cell frequency not allowed
Acquire SIB1
SIB1 acquired
No
Consider cell as barred
Yes
Store SIB1
intraFreqReselection = notAllowed
No
Cell re-selection on the barred cell frequency allowed
Yes
Yes
Cell re-selection on the barred cell frequency not allowed
check cellAccess-RelatedInfo
PLMN-Identity entry present
use plmn-IdentityList, trackingAreaCode, and cellIdentity from the PLMN-IdentityInfo containing the selected PLMN
RRC_ CONNECTED; T311 not running
Yes
Ignore frequencyBandList
forward cellIdentity to upper layers
forward trackingAreaCode to upper layers
apply configuration from servingCellConfigCommon


UE supports >=1 frequency band from **frequencyBandList** for downlink TDD
No
UE supports >=1 frequency band from **frequencyBandList** for uplink FDD
Yes
Yes
UE supports >=1 **additionalSpectrumEmission** in **NR-NS-PmaxList** for a supported band in downlink for TDD and uplink forFDD
No
Consider cell as barred with **IntraFreqReselection** = notAllowed
Yes
UE supports uplink channel bandwidth; max. transmission bandwidth <= **carrierBandwidth**; max. transmission bandwidth >= uplink BWP
No
Yes
UE supports downlink channel bandwidth; max. transmission bandwidth <= **carrierBandwidth**; max. transmission bandwidth >= downlink BWP
No


apply supported uplink channel bandwidth
apply supported dowlink channel bandwidth
select the first supported frequency band in **frequencyBandList**
forward **cellIdentity** to upper layers
trackingAreaCode provided for selected PLMN
No
trackingAreaCode provided for registeered PLMN
No
trackingAreaCode provided for PLMN of the PLMN list
No
Consider cell as barred
Yes
Yes
Yes
intraFreqReselection = notAllowed
No
Cell re-selection on the barred cell frequency allowed
Yes
Cell re-selection on the barred cell frequency not allowed
forward **trackingAreaCode** to upper layers
forward PLMN identity to upper layers
RRC_INACTIVE
Yes
no message from upper layers
Yes
serving cell not in configured **ran-NotificationAreaInfo**
Yes
Initiate RNA update
No
No
No
forward **ims-EmergencySupport** to upper layers, if present
forward **uac-AccessCategory1-SelectionAssistanceInfo** to upper layers, if present


Cell re-selection on the barred cell frequency not allowed
forward PLMN identity to upper layers
RRC_INACTIVE
Yes
no message from upper layers
Yes
serving cell not in configured ran-NotificationAreaInfo
Yes
initiate RNA update
No
No
No
forward ims-EmergencySupport to upper layers, if present
forward uac-AccessCategory1-SelectionAssistanceInfo to upper layers, if present
apply configuration in servingCellConfigCommon
apply PCCH configuration
valid SIB
Yes
use stored SIB
No
Acquire SI message
Apply the first listed additionalSpectrumEmission

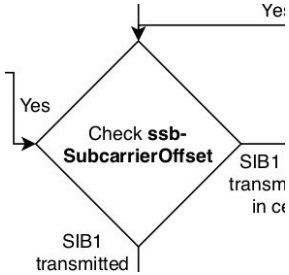

additionalPmax is present in the same entry of the selected **additionalSpectrumEmission**
Yes
apply **additionalPmax** for UL
No
apply **p-Max** in **uplinkConfigCommon for** for UL
supplementaryUplink is present in **servingCellConfigCommon**
Yes
UE supports >=1 frequency band in the **frequencyBandList** of supplementary uplnik
Yes
UE supports >=1 **additionalSpectrumEmission** in NR-NS-PmaxList of asupplementary uplnik
Yes


UE supports uplink channel bandwidth with max. transmission bandwidth <= **carrierBandwidth**; max. transmission bandwidth >= SUL BWP
Yes
consider supplementary uplink as configured; select the first frequency band in the **frequencyBandList** of supplementary uplink; apply the first listed (& supported) **additionalSpectrumEmission**
additionalPmax is present in the same entry of the selected **additionalSpectrumEmission** for the **supplementaryUplink**
Yes
apply **additionalPmax** in **supplementaryUplink** for SUL
No
apply **p-Max** in **supplementaryUplink** for UL

38.331

38.213

SIB1 acquisition



ssb-SubcarrierOffset: an IE in the MIB.

```
-- ASN1START
-- TAG-MIB-START

MIB ::=                             SEQUENCE {
    systemFrameNumber                   BIT STRING (SIZE (6)),
    subCarrierSpacingCommon             ENUMERATED {scs15or60, scs30or120},
    ssb-SubcarrierOffset                INTEGER (0..15),
```

ssb-SubcarrierOffset

Corresponds to k_{SSB} (see TS 38.213 [13]), which is the frequency domain offset between SSB and the overall resource block grid in number of subcarriers. (See TS 38.211 [16], clause 7.4.3.1).

The value range of this field may be extended by an additional most significant bit encoded within PBCH as specified in TS 38.213 [13].

This field may indicate that this cell does not provide *SIB1* and that there is hence no CORESET#0 configured in *MIB* (see TS 38.213 [13], clause 13). 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* (see TS 38.213 [13], clause 13).

Presence of CORESET for Type0-PDCCH CSS set

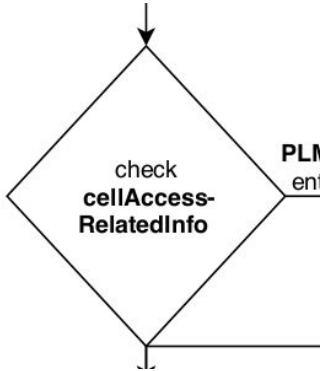
- Present if k_SSB <= 23 for FR1
- Present if k_SSB <= 11 for FR2

38.331
38.304

SIB1 acquisition

---

cellAccessRelatedInfo: an IE in SIB1



***SIB1* message**

```
-- ASN1START
-- TAG-SIB1-START

SIB1 ::=        SEQUENCE {
    cellSelectionInfo                   SEQUENCE {
        q-RxLevMin                          Q-RxLevMin,
        q-RxLevMinOffset                    INTEGER (1..8)                  OPTIONAL,   -- Need S
        q-RxLevMinSUL                       Q-RxLevMin                      OPTIONAL,   -- Need R
        q-QualMin                           Q-QualMin                       OPTIONAL,   -- Need S
        q-QualMinOffset                     INTEGER (1..8)                  OPTIONAL    -- Need S
    }                                                                       OPTIONAL,   -- Cond Standalone
    cellAccessRelatedInfo               CellAccessRelatedInfo,
```

***CellAccessRelatedInfo* information element**

```
-- ASN1START
-- TAG-CELLACCESSRELATEDINFO-START

CellAccessRelatedInfo   ::=         SEQUENCE {
    plmn-IdentityList                   PLMN-IdentityInfoList,
    cellReservedForOtherUse             ENUMERATED {true}  OPTIONAL,            -- Need R
    ...
}

-- TAG-CELLACCESSRELATEDINFO-STOP
-- ASN1STOP
```

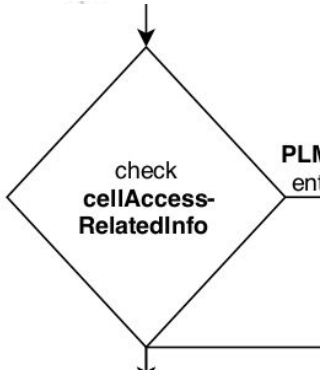
38.331

38.304

SIB1 acquisition

---

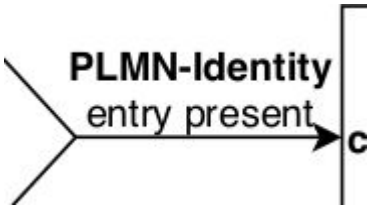
cellAccessRelatedInfo: an IE in SIB1



***CellAccessRelatedInfo* field descriptions**
cellReservedForOtherUse Indicates whether the cell is reserved, as defined in 38.304 [20]. The field is applicable to all PLMNs.
plmn-IdentityList The *plmn-IdentityList* is used to configure a set of *PLMN-IdentityInfoList* elements. Each of those elements contains a list of one or more PLMN Identities and additional information associated with those PLMNs. The total number of PLMNs in the *PLMN-IdentityInfoList* does not exceed 12. The PLMN index is defined as *b1+b2+…+b(n-1)+i* for the PLMN included at the *n*-th entry of *PLMN-IdentityInfoList* and the *i*-th entry of its corresponding *PLMN-IdentityInfo*, where *b(j)* is the number of *PLMN-Identity* entries in each *PLMN-IdentityInfo*, respectively.

- Reserved cell: Camping is not allowed on this cell. Only certain UEs can camp on this cell (determined by the System Information). Exceptions are
  - UE has an ongoing emergency call.
  - UE camped on a cell belonging to a registration area that is forbidden for regional provision of service

SIB1 acquisition



PLMN (Public Land Mobile Network): a combination of wireless communication services offered by a specific operator in a specific country.

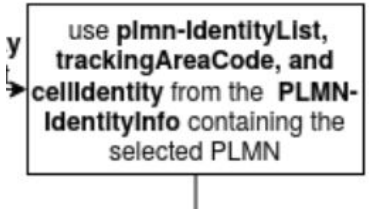
***PLMN-Identity* information element**

```
-- ASN1START
-- TAG-PLMN-IDENTITY-START

PLMN-Identity ::=                   SEQUENCE {
    mcc                                 MCC                 OPTIONAL,               -- Cond MCC
    mnc                                 MNC
}

MCC ::=                             SEQUENCE (SIZE (3)) OF MCC-MNC-Digit

MNC ::=                             SEQUENCE (SIZE (2..3)) OF MCC-MNC-Digit

MCC-MNC-Digit ::=                   INTEGER (0..9)


-- TAG-PLMN-IDENTITY-STOP
-- ASN1STOP
```

***PLMN-Identity* field descriptions**
mcc The first element contains the first MCC digit, the second element the second MCC digit and so on. If the field is absent, it takes the same value as the *mcc* of the immediately preceding IE PLMN-Identity. See TS 23.003 [21].
mnc The first element contains the first MNC digit, the second element the second MNC digit and so on. See TS 23.003 [21].

Conditional Presence	Explanation
MCC	This field is mandatory present when PLMN-Identity is not used in a list or if it is the first entry of PLMN-Identity in a list. Otherwise it is optionally present, Need S.

SIB1 acquisition



trackingAreaCode: IE in PLMN-IdentityInfoList, used to identify a tracking area within the scope of a PLMN

PLMN-IdentityInfoList **information element**

```
-- ASN1START
-- TAG-PLMN-IDENTITYINFOLIST-START

PLMN-IdentityInfoList ::=               SEQUENCE (SIZE (1..maxPLMN)) OF PLMN-IdentityInfo

PLMN-IdentityInfo ::=                   SEQUENCE {
    plmn-IdentityList                       SEQUENCE (SIZE (1..maxPLMN)) OF PLMN-Identity,
    trackingAreaCode                        TrackingAreaCode                                    OPTIONAL,       -- Need R
    ranac                                   RAN-AreaCode                                        OPTIONAL,       -- Need R
    cellIdentity                            CellIdentity,
```

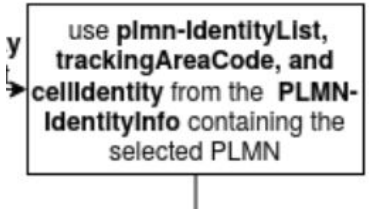
TrackingAreaCode **information element**

```
-- ASN1START
-- TAG-TRACKINGAREACODE-START

TrackingAreaCode ::= BIT STRING (SIZE (24))

-- TAG-TRACKINGAREACODE-STOP
-- ASN1STOP
```

SIB1 acquisition

---

cellIdentity: used to identify a cell in within a PLMN.



PLMN-IdentityInfoList **information element**

```
-- ASN1START
-- TAG-PLMN-IDENTITYINFOLIST-START

PLMN-IdentityInfoList ::=               SEQUENCE (SIZE (1..maxPLMN)) OF PLMN-IdentityInfo

PLMN-IdentityInfo ::=                   SEQUENCE {
    plmn-IdentityList                       SEQUENCE (SIZE (1..maxPLMN)) OF PLMN-Identity,
    trackingAreaCode                        TrackingAreaCode                                    OPTIONAL,       -- Need R
    ranac                                   RAN-AreaCode                                        OPTIONAL,       -- Need R
    cellIdentity                            CellIdentity,
```

CellIdentity **information element**

```
-- ASN1START
-- TAG-CELLIDENTITY-START

CellIdentity ::=                        BIT STRING (SIZE (36))

-- TAG-CELLIDENTITY-STOP
-- ASN1STOP
```

38.331
38.101-1
38.101-2

SIB1 acquisition

Additional IEs

- **additionalSpectrumEmission**: used to indicate emission requirements to be fulfilled by the UE (see TS 38.101-1 and TS 38.101-2)
- **NR-NS-PmaxList:** used to configure a list of additionalSpectrumEmission for a given frequency band
- **ims-EmergencySupport:** part of SIB1, presence indicates that the cell supports IMS emergency bearer services for UEs in limited service mode
- **p-Max:** used to limit the UE's uplink transmission power on a carrier frequency

SIB1 acquisition

Additional IEs

- **carrierBandwidth**: width of the carrier in number of PRBs (can be specified separately for UL and DL)
- **uac-AccessCategory1-SelectionAssistanceInfo:** part of SIB1, used to determine whether Access Category 1 applies to the UE
- **servingCellConfigCommon:** part of SIB1, gives configuration of the serving cell
- **uplinkConfigCommon:** provides common uplink parameters of a cell

Other SIBs

- SIB2, SIB4, SIB6, SIB7, SIB8 require action from the UE on being received.
- SIB3, SIB5, SIB9 do not require anything of the UE unless specified elsewhere.
- This system information acquired by the procedures detailed above is used for UE uplink transmission and PRACH.

Bibliography

- 5G-NR
  - Dahlman, Erik, Stefan Parkvall, and Johan Skold. *5G NR: The next generation wireless access technology*. Academic Press, 2018.
  - TS 38.331
  - TS 38.304
  - TS 38.101-1, TS 38.101-2
- MR-DC
  - https://www.mpirical.com/glossary/mr-dc-multi-rat-dual-connectivity
  - http://5gstuff.blogspot.com/2018/02/dc-mr-dc-en-dc-and-so-on.html
  - https://www.sharetechnote.com/html/5G/5G_LTE_Interworking.html
  - https://www.youtube.com/watch?v=julMJFRx04g
  - http://4g5gworld.com/blog/mr-dc-5g
  - https://www.awardsolutions.com/portal/shareables/what-is-5G/5G-Training-Online/getting-your-gs-and-ns-right-hooman-razani

Bibliography

- RAT and RAN
  - https://en.wikipedia.org/wiki/Radio_access_network
  - https://en.wikipedia.org/wiki/Radio_access_technology
- Layers of the stack
  - https://en.wikipedia.org/wiki/Non-access_stratum
  - https://en.wikipedia.org/wiki/Access_stratum
  - http://www.advancecomputing.co.in/2019/01/20/460/
  - https://en.wikipedia.org/wiki/PDCP
  - https://en.wikipedia.org/wiki/Radio_Link_Control
  - http://www.techplayon.com/5g-nr-logical-channels-and-transport-channels-channel-mapping/

Bibliography

– – –

- PLMN
  - https://en.wikipedia.org/wiki/Public_land_mobile_network
- RRC states
  - https://www.sharetechnote.com/html/Handbook_LTE_DRX.html
  - https://www.sharetechnote.com/html/5G/5G_DCI.html
  - http://www.techplayon.com/5g-nr-radio-network-temporary-identifier-rnti/
  - http://telecompedia.net/public-warning-system-etws/