LTE4475 NB-IoT Multiple Coverage Levels

SR001602 LTE 18 IoT features for SRAN

Network Engineering Information

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- V1.1
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LTE4475 NB-IoT Multiple Coverage Levels*

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*No differences in implementation in SRAN18 (status for 27-03-2018).
Please track upcoming related release notes to get familiarized with the latest solutions

Introduction

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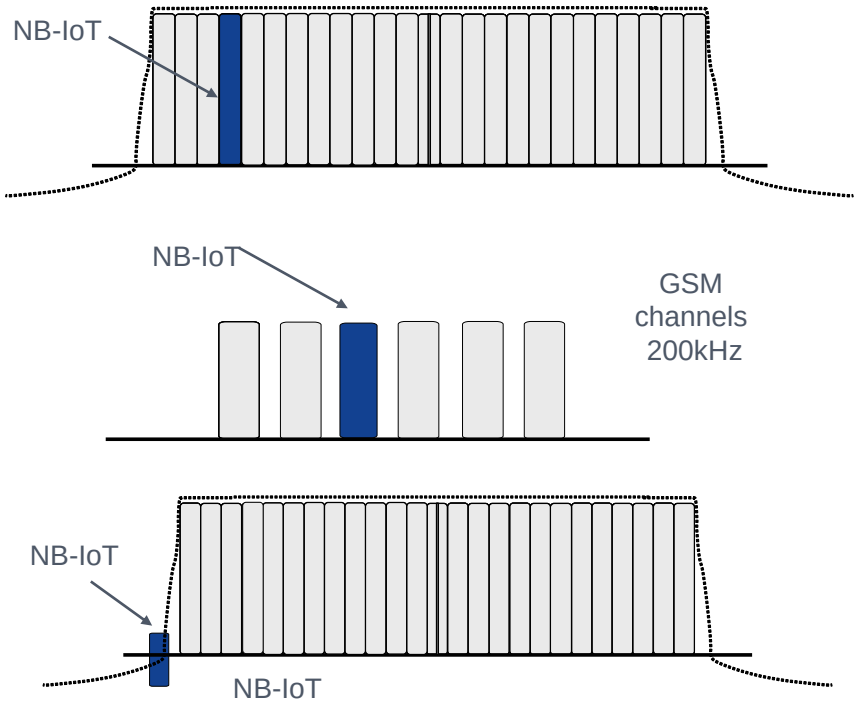
Introduction
NB-IoT 200kHz

NB-IoT technology utilizes 200kHz carrier.

3GPP defines 3 different modes of operation:

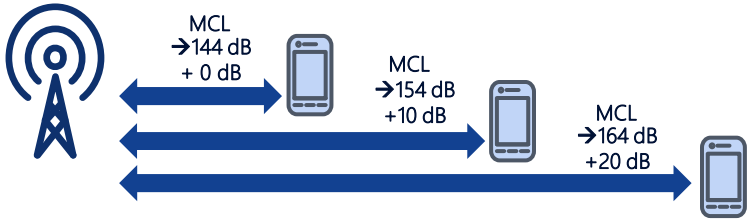
- 'In-band operation' utilizing resource blocks within a normal LTE carrier and shares some HW and SW resources with host LTE cell (LTE3071)
- 'Stand-alone operation' utilizing for example the unused part of spectrum, but sharing of HW resources with other technology (GSM, WCDMA, LTE) or brand new cell without resource sharing (LTE3543)
- 'Guard band operation' utilizing the unused resource blocks within a LTE carrier's guard-band (LTE4499/LTE3570 in FL18SP)



Introduction

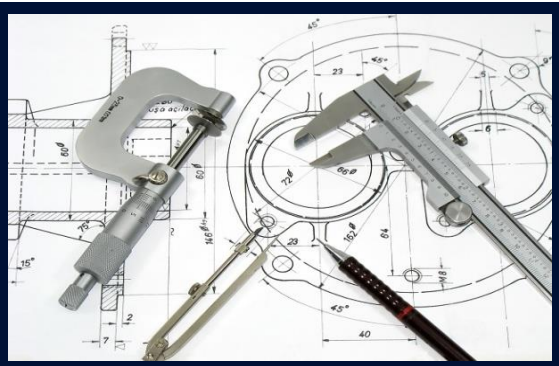
NB-IoT Coverage Enhancements Overview

- Feature LTE4475 extends LTE3668 NB-IoT Coverage Enhancements function by allowing to adjust coverage level according to UE location and UE needs
  - Up to 3 coverage levels can be configured per NB-IoT cell:
    - Coverage level 0 (normal) → +0dB for coverage enhancement
    - Coverage level 1 (robust)→ +10dB for coverage enhancement
    - Coverage level 2 (extreme) → +20dB for coverage enhancement



  - NB-IoT UE detects coverage level by comparing measured RSRP against dedicated thresholds and decides which profile it belongs to (selects appropriate NPRACH preamble)
  - There are dedicated configurable parameters allowing to tune the MCS, number of repetitions for physical channels per each coverage level , the RSRP thresholds and other parameters
- Hint: With previous NB-IoT feature LTE3668 NB-IoT Coverage Enhancements only one coverage level per NB-IoT cell was supported
  - The same repetitions profile was configured for all UE irrespective of their coverage conditions
  - For more details regarding LTE3668 NB-IoT Coverage Enhancements feature please refer to LTE3668 NEI materials

Technical Details



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Dependency Table (LTE)

Sales information

BSW/ASW	ASW

Release information

Release/version	RL release	eNodeB	NetAct
FDD LTE	FDD-LTE18	FL18	NetAct18
TDD LTE	N/A	N/A	N/A
Flexi Zone Micro (FZM/FZP)	FDD-LTE18	FLF18	NetAct18
Flexi Zone Controller (FZC)	N/A	N/A	N/A
Single RAN	SRAN18	SBTS18	NetAct18

Release information – general

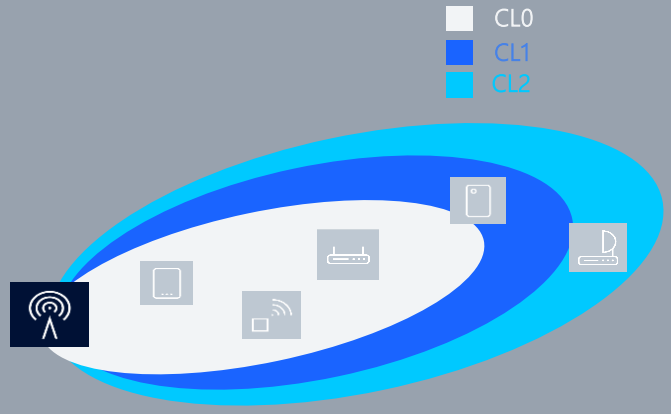
HW & IOT	HW requirements	MME	SAE GW	UE	Specified by 3GPP
	FSMF/AirScale/FZM			Rel. 13 Cat-NB1	3GPP R13 UE capabilities

Technical Details

Before and after LTE4475 NB-IoT Multiple Coverage Levels activation

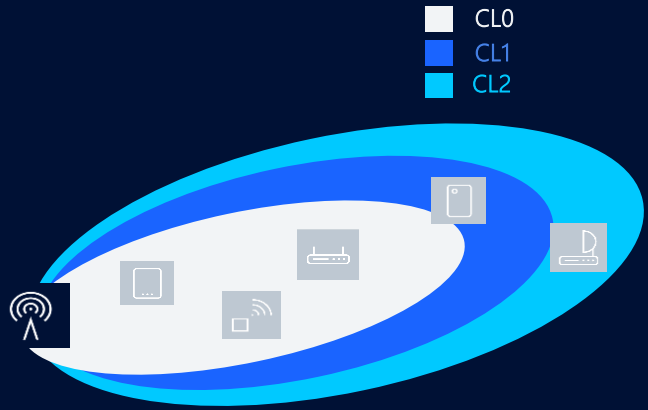
Before

- With LTE3668 the coverage up to +20dB for NB-IoT users was allowed (resulting up to 164dB maximum path loss) under NB-IoT cell
- **Only one coverage level was supported per NB-IoT cell**, therefore all UEs under NB-IoT cell have been using the same numer of configured repetitions regardless of their coverage conditions



After

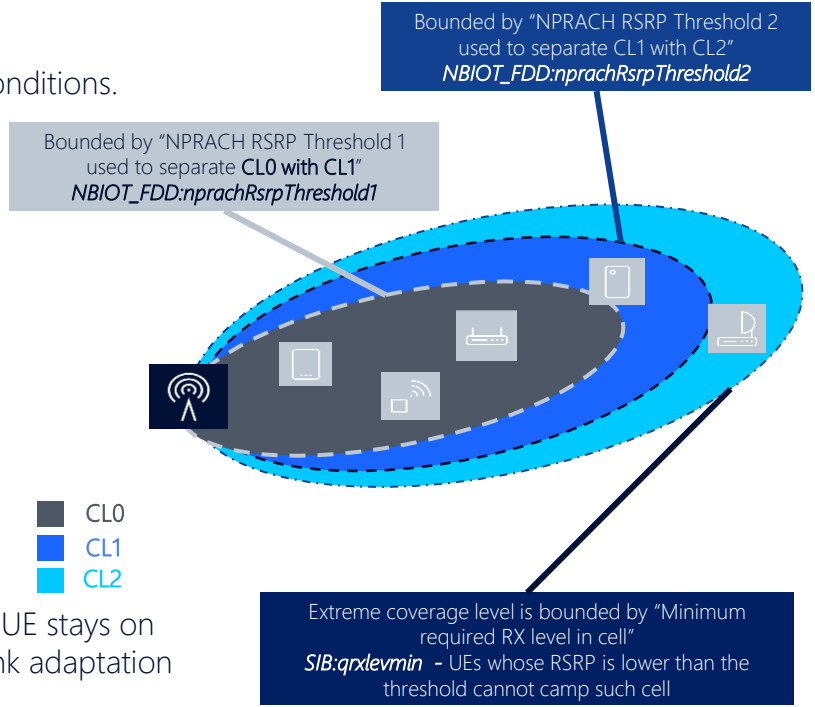
- The main benefit of the LTE4475 in comparison with LTE3668 is **support of coverage level selection** (normal +0dB, robust +10dB or extreme +20dB) per UE basis – **based on UE RF condition (RSRP measurements).**



Technical Details

Coverage level selection

- The coverage level is determined at **RACH procedure** based on UE's RF conditions.
  - **NB-IoT NPRACH preambles are divided into up to 3 ranges in time domain** corresponding to the different coverage level and belonging to the respective profile provided by SIB2-NB.
  - UE detects coverage level by comparing **measured RSRP** against a **given threshold.**
  - Basing on the **RSRP measurements** UE decides to **which profile it belongs to**, and **selects appropriate NPRACH configuration** from the predefined pool for each coverage level.
  - It directly indicates to the eNB **which repetition confiugration profile** has to be used.
- This feature uses appropriate repetition profile and the assumption is that UE stays on the same coverage level during the call, nevertheless LTE4475 supports link adaptation where the repetition can be adjusted based on ACK/NACK feedback during the call without CL changing.



See configuration example for *qrxlevMin* and nprachRsrpThreshold1/2

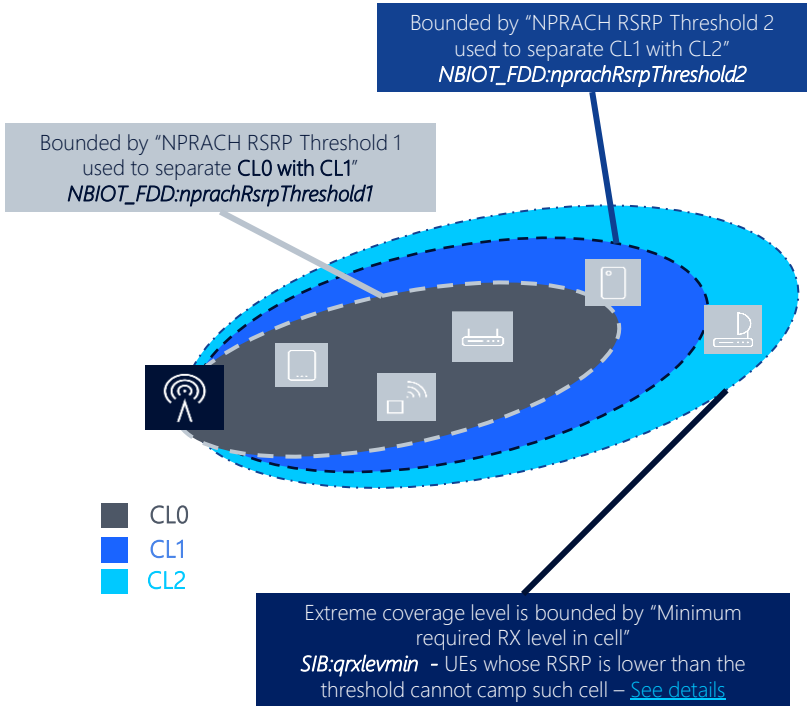
Technical Details

UE coverage level adjustment based on NPRACH thresholds

New **RSRP thresholds are defined to split three NB-IoT coverage levels**

- Coverage Level 0 with Coverage Level 1
- Coverage Level 1 with Coverage Level 2

NBIOT_FDD: numCoverageLevels	NPRACH selection by UE	Parameters used from NBIOT profile
1	N/A	NorCov
2	RSRP >= NBIOT_FDD:nprachRsrpThreshold1	NorCov
	RSRP < NBIOT_FDD:nprachRsrpThreshold1	RobCov
3	RSRP >= NBIOT_FDD:nprachRsrpThreshold1	NorCov
	NBIOT_FDD:nprachRsrpThreshold2 <=RSRP< NBIOT_FDD:nprachRsrpThreshold1	RobCov
	RSRP < NBIOT_FDD:nprachRsrpThreshold2	ExtCov



Technical Details

Coverage Level configuration - example

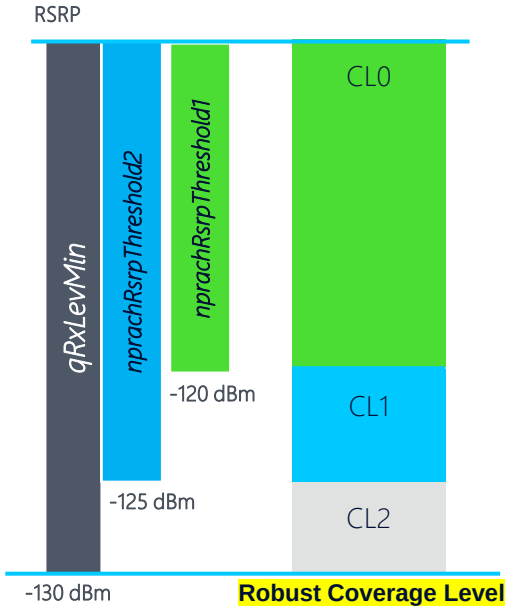
To support multiple coverage levels (up to 3), it is mandatory to define:

- Maximum Coupling Loss for NB-IoT cell that NB-IoT UE can access (*NBIOT_FDD:maxCoverageMCL*)

NBIOT_FDD:maxCoverageMCL	Supported Coverage Level
144 dB	Normal
154 dB	Robust
164 dB	Extreme

- In addition to MCL configuration, the minimum required RX level threshold in the NB-IoT cell ***(SIB:qrxlevmin)*** should be set properly – see details
- If number of coverage levels is higher than 1 (*NBIOT_FDD:numCoverageLevels* >1), dedicated **RSRP thresholds** (*NBIOT_FDD:nprachRsrpThreshold1* and *NBIOT_FDD:nprachRsrpThreshold2*) have to be adjusted accordingly to separate two (or three) coverage levels - according to the attached table
- Example calculation in term of parameters setting – see details

Example parameters setting for
maxCoverageMCL = 154 dB
numCoverageLevels = *3*



Technical Details

qrxlevmin calculation formula for Inband mode of operation – refresher

Consistency check for ***qrxlevmin*** ensures that UEs with RSRP less than ***qrxlevmin*** cannot access this NB-IoT cell:

If ***dlMimoMode*** = 'SingleTX',
pMax - dlCellPwrRed - 10*log10((#PRBs) * 12)* + *dlPwrBoost - qrxlevmin* <= *maxCoverageMCL*
If ***dlMimoMode*** = 'TXDiv' or ***'Duplicated TXDiv'***,
pMax - dlCellPwrRed - dlpcMimoComp + 3 - 10*log10(*#PRB*12) + *dlPwrBoost* – *qrxlevmin* <= *maxCoverageMCL*

For **NB-IoT UEs**, the possible minimum RX level required to access the cell was extended from existing range **-140dBm...-44dBm** towards new range **-156dBm...-44dBm**

In **SIB1-NB** the values from the range **-140dBm...-44dB** are signaled by information element **IE:q-RxLevMin**

To allow extended range of **-156dBm...-142dBm** new additional information element **IE:delta-RxLevMin** was introduced by 3GPP in **SIB1-NB** reflecting the value from the range **-16dB...-2dB**, with **step 2dB**

NB-IoT UEs rel.13 evaluate the minimum RX level required to access the cell based on the information received in **SIB1-NB** defined as a sum of **IE:q-RxLevMin** and **IE:delta-RxLevMin**

As result it is possible to configure in **SIB1-NB** any value from the range **-156dBm...-142dB**

Example: if required minimum RX level is **-156dBm** the **SIB1-NB** will signal this as **IE:q-RxLevMin = -140dBm** and **IE:delta-RxLevMin = -16dB**

pMax - Maximum output power of the cell
dlCellPwrRed - Cell power reduce
dlpcMimoComp - MIMO power compensation
#P – depends on DL Channel BW
dlPwrBoost - Downlink channel power boost for inband NB-IoT
qrxlevmin - Minimum required RX level in cell

Green parameters from host cell
Red parameters from NB-IoT cell

Technical Details

qrxlevmin calculation formula for Standalone and Guardband mode of operation

Standalone deployment:

nbIoTMode = 'standalone'
maxCoverageMCL = '144dB' or '154dB'

- If *dlMimoMode* = 'SingleTX',
pMax - *dlCellPwrRed* - 10log10(12) - *qrxlevmin* <= *maxCoverageMCL*
- If *dlMimoMode* = 'TXDiv' or *'Duplicated TXDiv'*,
pMax - *dlCellPwrRed* + 3 - 10log10(12) - *qrxlevmin* <= *maxCoverageMCL*

where, *pMax*, *dlCellPwrRed*, *dlpcMimoComp* and *qrxlevmin* from NB-IoT cell (*cellTechnology* = NB-IoT-FDD)

Guardband deployment:

nbIoTMode = 'guardband'
maxCoverageMCL = '144dB' or '154dB'

- If *dlMimoMode* = 'SingleTX',
pMax - *dlCellPwrRed* - 10*log10((#PRBs+1) * 12)* + *dlPwrBoost* - *qrxlevmin* <= *maxCoverageMCL*
- If *dlMimoMode* = 'TXDiv' or *'Duplicated TXDiv'*,
pMax - *dlCellPwrRed* - *dlpcMimoComp* + 3 - 10*log10((#PRBs+1) * 12)* + *dlPwrBoost* - *qrxlevmin* <= *maxCoverageMCL*

where, *pMax*, *dlCellPwrRed*, *dlpcMimoComp* and #PRBs from host FDD cell (with *cellTechnology* = FDD)
dlPwrBoost, *dlMimoMode* and *qrxlevmin* from NB-IoT cell (*cellTechnology* = NB-IoT-FDD)

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Technical Details
NPRACH Config Index

Please note: Starting from FL19A, SRAN19A - Manual NPRACH Configuration is allowed even if number of coverage levels is 2 or 3. Means NPRACH configuration is decided from O&M parameters under *nprachProfNBNorCov / nprachProfNBRobCov / nprachProfNBExtCov* structures - LTERLCR-28830

- New parameter NBIOT-FDD:*nprachConfigIndex* indicates if NPRACH configuration pattern will be pre-defined or manually configured.
  - If 'Manual Configuration' is selected (can be configured only if *numCoverageLevels* = 1), the NPRACH configuration refers to parameters under NBIOTPR profile (nprachProfNBNorCov structure).
  - If any ‚Pre-defined' pattern is selected, the NPRACH configuration will be decided from pre-defined pattern – see below.

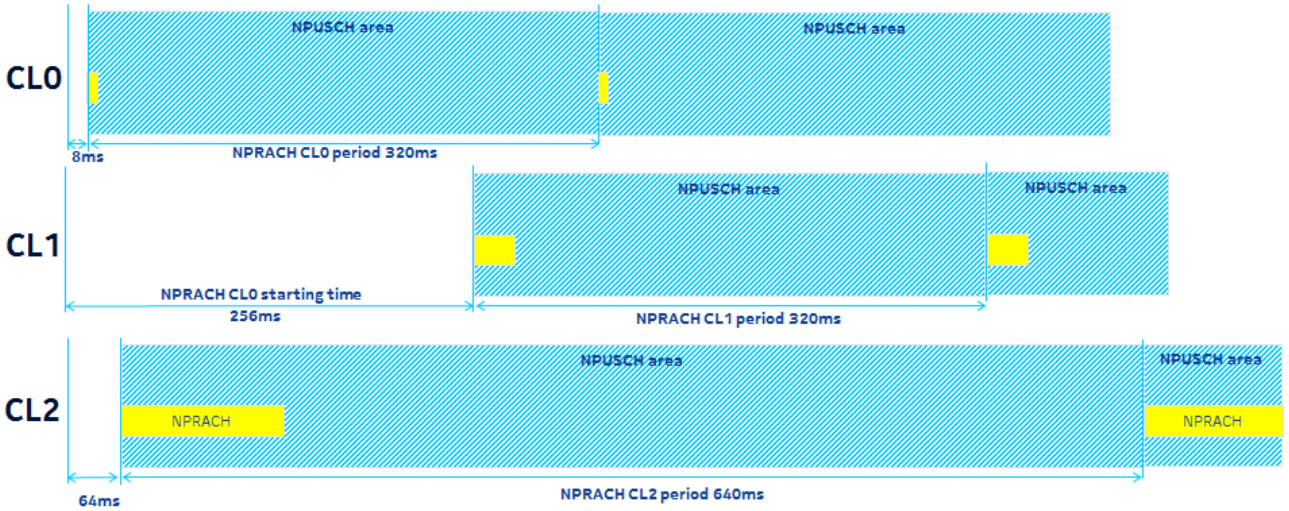
maxCoverageLevelMCL	144 dB			154 dB			154 dB			164 dB			154 dB			164 dB		
numCoverageLevels	1			1			2			2			3			3		
Coverage Levels	CL0	CL1	CL2	CL0	CL1	CL2	CL0	CL1	CL2	CL0	CL1	CL2	CL0	CL1	CL2	CL0	CL1	CL2
nprachconfigindex	Pre-defined 1-1			Pre-defined 1-2			Pre-defined 2-1			Pre-defined 2-2			Pre-defined 3-1			Pre-defined 3-2		
nprachMaxNumPreambleCE	5	-	-	5	-	-	5	5	-	5	5	-	5	5	5	5	5	5
nprachNumRepPreamble	n4	-	-	n16	-	-	n4	n16	-	n4	n64	-	n1	n4	n16	n4	n16	n64
nprachPeriod	160	-	-	320	-	-	320	320	-	640	2560	-	320	320	640	640	1280	2560
nprachStartTime	8	-	-	8	-	-	8ms	64	-	8	64	-	8	256	64	8	512	64
nprachNumSubcarriers	n12	-	-	n12	-	-	n12	n12	-	n12	n12	-	n12	n12	n12	n12	n12	n12
nprachSubcarrierOffset	n12	-	-	n12	-	-	n12	n12	-	n12	n12	-	n12	n12	n12	n12	n12	n12

Technical Details

NPRACH Configuration for Multiple Coverage Enhancements

NPRACH resources are same in frequency domain for all CL, nevertheless are divided in time domain

maxCoverageLevelMCL	154 dB		
numCoverageLevels	3		
Coverage Levels	CL0	CL1	CL2
nprachconfigindex	Pre-defined 3-1		
nprachMaxNumPreambleCE	5	5	5
nprachNumRepPreamble	n1	n4	n16
nprachPeriod	320	320	640
nprachStartTime	8	256	64
nprachNumSubcarriers	n12	n12	n12
nprachSubcarrierOffset	n12	n12	n12



Technical Details

SystemInformationBlockType2-NB

```
SystemInformationBlockType2-NB-r13 ::=    SEQUENCE {
    radioResourceConfigCommon-r13             RadioResourceConfigCommonSIB-NB-r13,
    ue-TimersAndConstants-r13                 UE-TimersAndConstants-NB-r13,
    freqInfo-r13                              SEQUENCE {
        ul-CarrierFreq-r13                        CarrierFreq-NB-r13          OPTIONAL,    -- Need OP
        additionalSpectrumEmission-r13            AdditionalSpectrumEmission
    },
    timeAlignmentTimerCommon-r13          TimeAlignmentTimer,
    multiBandInfoList-r13    SEQUENCE (SIZE (1..maxMultiBands)) OF A
    OPTIONAL,    -- Need OR
    lateNonCriticalExtension              OCTET STRING
    ...,
    [[  cp-Reestablishment-r14                ENUMERATED {true}
    ]]
}
```

← The IE *SystemInformationBlockType2-NB* contains radio resource configuration information that is common for all UEs.

The IE *RadioResourceConfigCommonSIB-NB* → is used to specify common radio resource configurations in the system information, e.g., the random access parameters and the static physical layer parameters.

```
RadioResourceConfigCommonSIB-NB-r13 ::= SEQUENCE {
    rach-ConfigCommon-r13                 RACH-ConfigCommon-NB-r13,
    bcch-Config-r13                       BCCH-Config-NB-r13,
    pcch-Config-r13                       PCCH-Config-NB-r13,
    nprach-Config-r13                     NPRACH-ConfigSIB-NB-r13, RACH-ConfigCommon-NB-r13
    npdsch-ConfigCommon-r13               NPDSCH-ConfigCommon-NB-r13,
    npusch-ConfigCommon-r13               NPUSCH-ConfigCommon-NB-r13,
    dl-Gap-r13                            DL-GapConfig-NB-r13         OPTIONAL,       -- Need OP
    uplinkPowerControlCommon-r13          UplinkPowerControlCommon-NB-r13,
    ...,
    [[  nprach-Config-v1330               NPRACH-ConfigSIB-NB-v1330   OPTIONAL        -- Need OR
    ]],
    [[  nprach-Config-v1450               NPRACH-ConfigSIB-NB-v1450   OPTIONAL        -- Cond
EnhPowerControl
    ]]
}

BCCH-Config-NB-r13 ::=                    SEQUENCE {
    modificationPeriodCoeff-r13               ENUMERATED {n16, n32, n64, n128}
}


PCCH-Config-NB-r13 ::=                    SEQUENCE {
    defaultPagingCycle-r13                    ENUMERATED {rf128, rf256, rf512, rf1024},
    nB-r13                                    ENUMERATED {
                                                  fourT, twoT, oneT, halfT, quarterT, one8thT,
                                                  one16thT, one32ndT, one64thT,
                                                  one128thT, one256thT, one512thT, one1024thT,
                                                  spare3, spare2, spare1},
    npdcch-NumRepetitionPaging-r13            ENUMERATED {
                                                  r1, r2, r4, r8, r16, r32, r64, r128,
                                                  r256, r512, r1024, r2048,
                                                  spare4, spare3, spare2, spare1}
}
```

Technical Details

SystemInformationBlockType2-NB → NPRACH-ConfigSIB-NB-r13

```
NPRACH-ConfigSIB-NB-r13 ::=          SEQUENCE {
    nprach-CP-Length-r13                ENUMERATED {us66dot7, us266dot7},
    rsrp-ThresholdsPrachInfoList-r13    RSRP-ThresholdsNPRACH-InfoList-NB-r13   OPTIONAL,   -- need
OR
    nprach-ParametersList-r13       NPRACH-ParametersList-NB-r13
}

NPRACH-ConfigSIB-NB-v1330 ::=        SEQUENCE {
    nprach-ParametersList-v1330         NPRACH-ParametersList-NB-v1330
}

NPRACH-ConfigSIB-NB-v1450 ::=        SEQUENCE {
    maxNumPreambleAttemptCE-r14         ENUMERATED {n3, n4, n5, n6, n7, n8, n10, spare1}
}

NPRACH-ParametersList-NB-r13 ::=     SEQUENCE (SIZE (1.. maxNPRACH-Resources-NB-r13)) OF NPRACH-
Parameters-NB-r13

NPRACH-ParametersList-NB-v1330 ::=   SEQUENCE (SIZE (1.. maxNPRACH-Resources-NB-r13)) OF NPRACH-
Parameters-NB-v1330

NPRACH-Parameters-NB-r13::=          SEQUENCE {
    nprach-Periodicity-r13                  ENUMERATED {ms40, ms80, ms160, ms240,
                                                        ms320, ms640, ms1280, ms2560},
    nprach-StartTime-r13                    ENUMERATED {ms8, ms16, ms32, ms64,
                                                        ms128, ms256, ms512, ms1024},
    nprach-SubcarrierOffset-r13             ENUMERATED {n0, n12, n24, n36, n2, n18, n34, spare1},
    nprach-NumSubcarriers-r13               ENUMERATED {n12, n24, n36, n48},
    nprach-SubcarrierMSG3-RangeStart-r13    ENUMERATED {zero, oneThird, twoThird, one},
    maxNumPreambleAttemptCE-r13             ENUMERATED {n3, n4, n5, n6, n7, n8, n10, spare1},
    numRepetitionsPerPreambleAttempt-r13    ENUMERATED {n1, n2, n4, n8, n16, n32, n64, n128},
    npdcch-NumRepetitions-RA-r13            ENUMERATED {r1, r2, r4, r8, r16, r32, r64, r128,
                                                        r256, r512, r1024, r2048,
                                                        spare4, spare3, spare2, spare1},
    npdcch-StartSF-CSS-RA-r13               ENUMERATED {v1dot5, v2, v4, v8, v16, v32, v48, v64},
    npdcch-Offset-RA-r13                    ENUMERATED {zero, oneEighth, oneFourth, threeEighth}
}

NPRACH-Parameters-NB-v1330 ::=       SEQUENCE {
    nprach-NumCBRA-StartSubcarriers-r13     ENUMERATED {n8, n10, n11, n12, n20, n22, n23, n24,
                                                        n32, n34, n35, n36, n40, n44, n46, n48}
}

RSRP-ThresholdsNPRACH-InfoList-NB-r13 ::= SEQUENCE (SIZE(1..2)) OF RSRP-Range
```

←The IE *NPRACH-ConfigSIB-NB* is used to specify the NPRACH configuration (related to for the anchor carrier.

NPRACH-ConfigSIB-NB IE contains:

- *rsrp-ThresholdsPrachInfoList* - up to 2 RSRP threshold values can be broadcasted, where first value corresponds to RSRP threshold 1 (nprachRsrpThreshold1) and the second corresponds to RSRP threshold 2 (nprachRsrpThreshold1).
- *maxNPRACH-Resources-NB-r13* indicates maximum number of NPRACH resources for NB-IoT – depending on configured number of coverage levels (up to 3 resources can be broadcasted).

NPRACH and NPUSCH multiplexing

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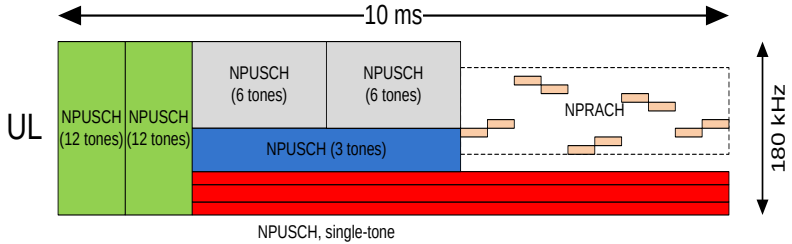
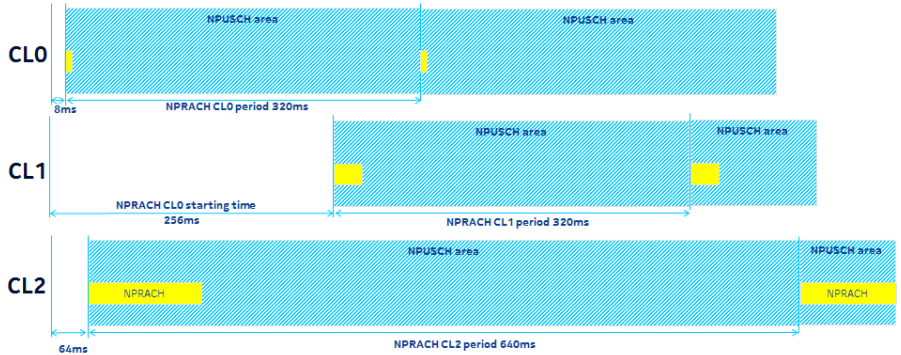
Technical Details

NPRACH and NPUSCH multiplexing support

- If multiple coverage levels feature is activated in the NB-IoT cell, the number of NPRACH subcarriers to be used is limited to 12 (*NBIOTPR:nprachNumSubcarriers = n12*), moreover **NPRACH subcarrier offset** (which indicates the frequency location of the NPRACH resource) is recommended to be set to 12 as well (*NBIOTPR:nprachSubcarrierOffset* = n12)
  - Above settings indicate that **LTE4475 feature allows to use 12 out of 48 available NPRACH subcarriers** starting from 12th (12-23 subcarriers) for all coverage levels
- With LTE4475 the **NB-IoT scheduler supports NPRACH and NPUSCH multiplexing in frequency domain**
- **As 180kHz in frequency domain is available and only 12 subcarriers (12 x 3.75kHz) are used for NPRACH** transmission, the **remaining resources can be still utilized for NPUSCH allocation** (9 x 15kHz).
  - NPRACH resources are the same in frequency domain for all CLs, nevertheless are divided into up to 3 ranges in time domain – see table with pre-defined NPRACH setting
  - Multiplexing of several NPRACH resources in frequency domain is not supported with LTE4475



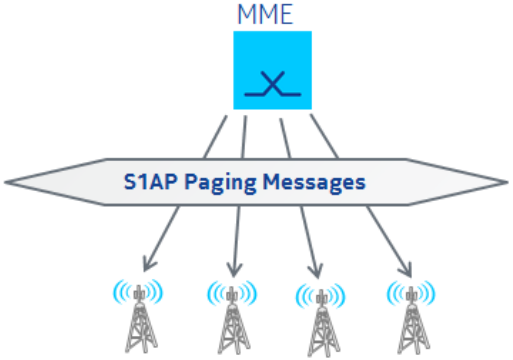


Paging support

Technical Details

Paging Optimization for Multiple Coverage Levels

- NB-IoT Paging function is applicable with dedicated feature - **LTE3669 NB-IoT Paging Support from FL17A** which supports **Mobile Terminated calls for NB-IoT solution**
- In order to page particular UE, MME should know where the UE may be, in which coverage level (CL0, CL1or CL2) within such NB-IoT cell.
- In order to optimize the paging resources feature **LTE4475 Multiple Coverage Levels** allows to adjust appropriate coverage for a given UE based on information about previous status of coverage level of such UE (stored in MME)
  - As **paging record list** within RRC paging-NB message **includes multiple NB-IoT UEs (up to 15 for NB-IoT),** the **maximum coverage level** assigned to NB-IoT UEs in paging record list **will be used during paging procedure**



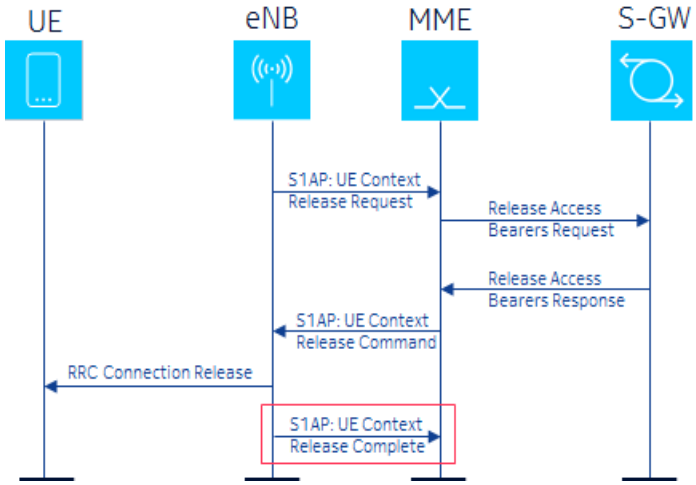
Paging procedure in term of NB-IoT solution was introduced by LTE3669 NB-IoT Paging Support feature – For details please refer to LTE3669 NEI materials

Please note: LTE4475 increases capacity due to adjusted number of repetitions for all UEs (per RRC paging-NB message)

Technical Details

Paging Optimization for Multiple Coverage Levels

- During S1AP UE Context Release the **eNB sends information through the MME about current coverage level** – number of repetition over NPDCCH for paging transmission and cell identifier of the NB-IoT UE
    - **Cell Identifier and Coverage Enhancement Level IEs** are included in **S1AP UE Context Release Complete** to indicate **current coverage level** and **ECGI of particular UE**
- Upon subsequent paging of the same NB-IoT UE, the **MME informs the eNB** about the previous coverage level for Paging which will be used by the eNB to optimize the paging resources (**Assistance Data for CE capable UEs IE in S1AP Paging message**).
- If those **IEs are not received** (as are an optional IEs) – **the eNB will use a configured default Paging repetition** (*NBIOTPR:defaultPagNumRep*).

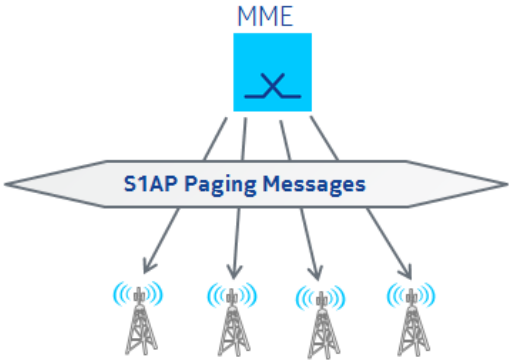


- If the **received Assistance Data for CE Capable UE IE does not match with the eNB configured number of NPDCCH paging repetitions,** the eNB will adjust NPDCCH paging repetition to the configured value.
- If **paging record list includes multiple NB-IoT UEs**, **'the maximum coverage level of NB-IoT UEs in paging record list** will be used.

Technical Details

Paging Optimization for Multiple Coverage Levels

- In case *NBIOTPR:pagAttMaxCovNB* is configured and Paging Attempt Information IE is provided and Paging Attempt Count >= *pagAttMaxCovNB* then the eNB will apply the highest (maximum) configured coverage level (except in the case of duplicated paging records) and its parameters for NPDCCH and NPDSCH as initial paging repetitions for that paging request:
  - if *numCoverageLevels* = 1, coverage level 0 will be used
  - if *numCoverageLevels* = 2, coverage level 1 will be used
  - if *numCoverageLevels* = 3, coverage level 2 will be used.
- In case of repeated paging records for the same NB-IoT UE (same IMSI, S-TMSI) in *pagingRecordList* :
  - The eNB will select the record with the highest coverage level and number of repetitions, then the eNB will proceed with the normal handling (the highest coverage level within paging record list will be used).



Radio Admission Control

Technical Details

Radio Admission Control – thresholds

- *NBIOT_FDD:maxNumRrcNB* – dedicated threshold to limit the maximum number of NB-IoT UEs in the cell which may establish a RRC connection.

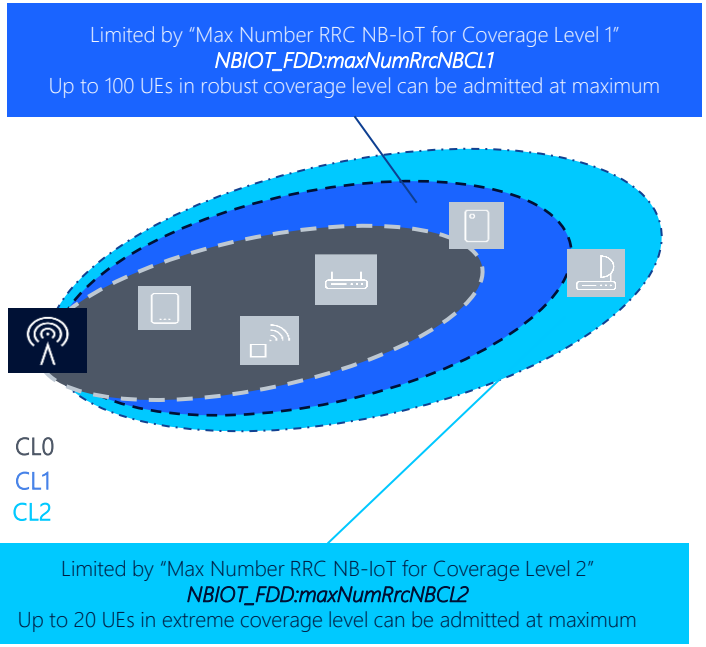
  Range: 0 – 420, Default: 20

- *NBIOT_FDD:maxNumRrcNBCL1* – new threshold for the maximum number of NB-IoT UEs in the coverage level 1 (robust) which may establish RRC connection in NB-IoT cell.

  Range: 0 – 100, Default: 10

- *NBIOT_FDD:maxNumRrcNBCL2* - new threshold for the maximum number of NB-IoT UEs in the coverage level 2 (extreme) which may establish RRC connection in NB-IoT cell.

  Range: 0 – 20, Default: 4



Moreover in addition to RAC checks against *maxNumRrcNBCL1* and *maxNumRrcNBCL2* thresholds, check against *NBIOT_FDD:maxNumRrcNB* threshold which limits max number of RRC Connected NB-IoT users per NB-IoT cell must be done as well.

Technical Details
Radio Admission Control

- Feature LTE4475 defines two NEW separate active NB-IoT users pools for CL1 and CL2. New parameters are defined to limit the amount of admitted NB-IoT UEs in the NB-IoT cell for coverage level 1 and 2 which can establish a RRC Connection
  - *NBIOT_FDD:maxNumRrcNBCL1* for CL1. New NB-IoT UE in coverage level 1 can be admitted to NB-IoT cell if:

    $$\mathbf{1 + numRrcNBCL1} \leq \boldsymbol{maxNumRrcNBCL1}$$

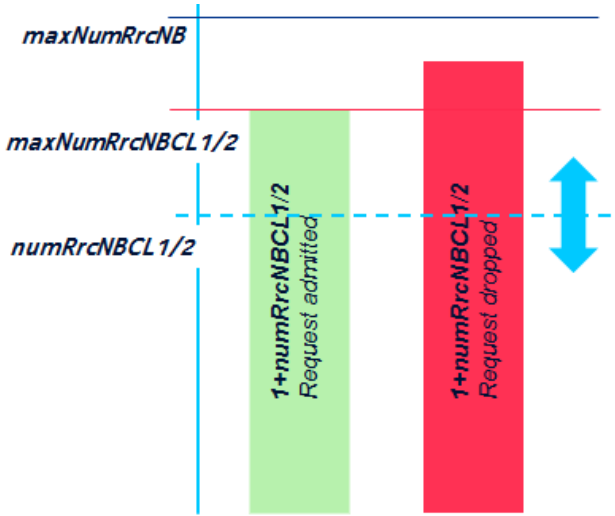
  - *NBIOT_FDD:maxNumRrcNBCL2* for CL2. New NB-IoT UE in coverage level 2 can be admitted to NB-IoT cell if:

    $$\mathbf{1 + numRrcNBCL2} \leq \boldsymbol{maxNumRrcNBCL2}$$

- Moreover, new NB-IoT UE can be admitted in CL0, CL1 or CL2, if additional legacy check is fulfilled as well:

  $$1 + \text{numRrcNB*} \leq \textit{maxNumRrcNB}$$

- Besides checks on above thresholds depending on HW and mode of operation deployment additional checks are performed as well (see details: LTE3509, LTE4415, LTE3543)



Please note: numRrcNBCL1/2 are the RAC counter for consumed RRC connections for NB-IoT UEs in coverage level 1 and 2
*numRrcNB is an RAC internal counter to keep track of admitted NB-IoT UEs

UL/DL Link Adaptation

Technical Details

Link adaptation in UL and DL

- Link Adaptation algorithm cannot relay on the channel quality measure reported by the NB-IoT UE to adapt the transmission aspects as there are no measurements for NB-IoT.
- eNB performs an UL/DL link adaptation functionality acting on each initial TB transmission based on ACK/NACK HARQ feedback from UE.
- As a consequence MCS, number of repetitions and number of subframes (only for NPDSCH) are adapted based on target code rate and data in buffer which are a determinants in such selection.

Uplink:

- The **number of repetitions and MCS of NPUSCH format 1** (data transmission) **will be adjusted** by uplink link adaptation.
- The **number of repetition of uplink NPUSCH format 2** (ACK/NACK feedback) **is fixed to the initial value *NBIOTPR:ackNACKNumRep* per coverage level)**
- The number of **resource units of uplink NPUSCH format 1** (data transmission) is **hardcoded to 4** as previously.

Downlink:

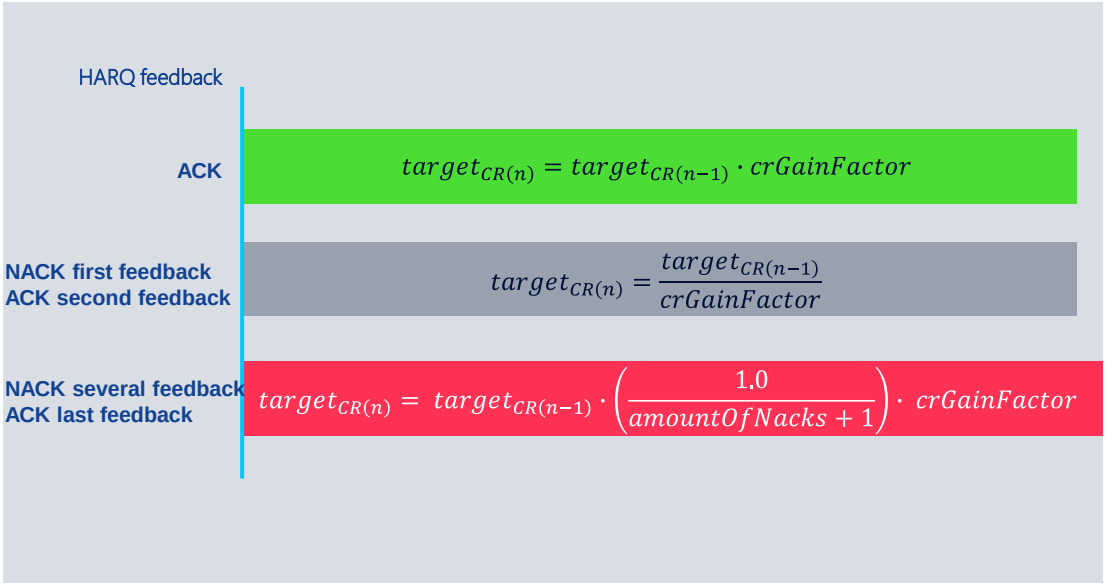
- The **number of repetitions, MCS and number of subframes of NPDSCH** (data transmission) **will be adjusted** by **downlink link adaptation and payload in the buffer**.
- The **number of repetition NPDCCH is fixed** to the initial value(***NBIOTPR:iniNpdcchNumRepRa*** **per coverage level)**

Please note: Link adaptation for LTE4475 NB-IoT Multiple Coverage Levels has been introduced via CRL21799

Technical Details

NB-IoT Uplink and Downlink link adaptation (1/3)

The HARQ feedback (ACK/NACK) for NPUSCH format 1 (UL) and NPDSCH (DL) triggers the update of target code rate.



Where:

- *crGainFactor* is a internal parameter and set to 1.05 by default.
- amountOfNacks is the number of NACK received after the last link adaptation. The amountOfNacks is set to 0 when no NACK is received after the last link adaptation.

target_CR(0) = initial_CR with *iniMcsUl and iniNpuschNumRep*

Technical Details

NB-IoT Uplink link adaptation (2/3)

MCS and repetition adaptation for uplink

eNB decides the MCS and repetition for each new TB transmission based on target Code Rate and data in buffer

- eNB selects the candidates of MCS and repetition combination based on the target code rate – see details
    - The CR for each candidate must be less or equal to the target coding rate calculated on previous slide.

Step 1. For each candidate I_{TBS}, number of repetition is selected.

Step 2. For each candidate I_{TBS}, scheduler will assign 4 subframes for uplink NPUSCH format 1.

Step 3. For values from step 1 and 2 scheduler will select most efficient (to reach the highest throughput) combination of MCS and repetition.

I_{TBS}	TBS for 4RU
0	88
1	144
2	176
3	208
4	256
5	328
6	392
7	472
8	536
9	616
10	680

Please note: SDA analysis for DL/UL code rate with different MCS, repetition and numer of subframes located under the link

Technical Details

NB-IoT Downlink link adaptation (3/3)

MCS and repetition and number of subframes adaptation for downlink

eNB decides the MCS, repetition and number of subframes for each new TB transmission based on target Code Rate and data in buffer

- eNB selects the candidates of MCS and repetition combination based on the target code rate – see details
    - The CR for each candidate MCS must be less or equal to the target coding rate.

Step 1. For each candidate I_{TBS}, number of repetition is selected.

Step 2. For each candidate I_{TBS}, **scheduler** will find number of subframes based on current buffer status.

Step 3. For values from step 1 and 2 **scheduler** will select most efficient **(to reach the highest throughput) combination of MCS, TBS and repetition.**

I_{TBS}	No of subframes							
	1	2	3	4	5	6	8	10
0	16	32	56	88	120	152	208	256
1	24	56	88	144	176	208	256	344
2	32	72	144	176	208	256	328	424
3	40	104	176	208	256	328	440	568
4	56	120	208	256	328	408	552	680
5	72	144	224	328	424	504	680	
6	88	176	256	392	504	600		
7	104	224	328	472	584	680		
8	120	256	392	536	680			
9	136	296	456	616				
10	144	328	504	680				
11	176	376	584					
12	208	440	680					

Please note: SDA analysis for DL/UL code rate with different MCS, repetition and numer of subframes located under the link

Technical Details

LTE4475 NB-IoT Multiple Coverage Levels - summary

Source of change	Change for NB-IoT Multiple Coverage Levels
Link Adaptation in UL/DL	MCS, number of repetitions (in both UL - NPUSCH/DL - NPDSCH) and SF adaptation (only DL - NPDSCH) based on HARQ feedback
RAC modification	RAC per coverage level is supported, Robust and Extreme coverage levels
NPRACH/NPUSCH	eNB supports the multiplexing in frequency for NPRACH and NPUSCH
System information	LTE4475 allows to configure all profiles (like CSS for NPDCCH, RACH, NPRACH, MAC, RLC, and scheduler profile) for all 3 coverage levels specific structures (with LTE3668 only Normal structure was modifiable): • Coverage Level 0 - Normal • Coverage Level 1 - Robust • Coverage Level 2 - Extreme Therefore, SIB2-NB was modified to support 3 coverage levels (for example NPRACH configuration, RACH parameters, the number of repetitions for physical channels, NPDCCH search space to be broadcasted with up to 3 coverage levels).
NPRACH configuration	NPRACH configuration pattern can be pre-defined or manually configured in LTE4475. 6 pre-defined NPRACH configurations are supported by the eNB

Interdependencies

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Interdependencies

prerequisites

LTE3668 NB-IoT Coverage enhancements

More details available on WebNEI: link

LTE3668 is a prerequisite for LTE4475 for coverage enhancements

LTE3071 NB-IoT Inband

More details available on WebNEI: link

LTE3071 is a prerequisite feature for LTE4475 in inband NB-IoT cells on FSMr3

LTE3509 NB-IoT Inband on AirScale without Baseband Pooling

More details available on WebNEI: link

LTE3509 is prerequisite for LTE4475 over AirScale without BB pooling

Interdependencies

prerequisites

LTE4415 NB-IoT Inband with partial Baseband Pooling

More details available on WebNEI: link

LTE4415 is prerequisite for LTE4475 over AirScale with BB pooling

LTE3543 NB-IoT Standalone

More details available on WebNEI: link

LTE3543 is prerequisite for LTE4475 for standalone deployment

LTE3669 NB-IoT Paging support

More details available on WebNEI: link

LTE3669 is prerequisite for LTE4475 for paging support

Interdependencies

extensions

LTE3819 Cat-M and NB-IoT on same frequency carrier

More details available on WebNEI: link

LTE4475 is supported in inband NB-IoT cell with Cat-M enabled on same host LTE cell with 10MHz bandwidth (over FSMF only) if LTE3819 enabled.

LTE4040 Cat-M and NB-IoT on same LTE cell – Phase II

More details available on WebNEI: link

LTE4475 supports multiple coverage levels in NB-IoT inband cell with Cat-M enabled on same host LTE cell (5, 15 or 20MHz BW over AirScale and FSMF).

LTE4499 NB-IoT Guardband
LTE3750 NB-IoT Guardband 15/20MHz

More details available on WebNEI: link

Multiple coverage levels are required for guardband NB-IoT cell (10, 15 or 20MHz host cell BW).

LTE3722: NB-IoT: Additional configurations (4Rx, 4Tx or 1Tx eNB support)

More details available on WebNEI: link

Thanks to the LTE3722 feature, the LTE4475 feature is supported in 4Rx, 4Tx, 1Tx Inband NB-IoT cells or 4Rx, 4Tx standalone NB-IoT cells.

NOKIA

Interdependencies

limitations (LTE4475)

LTE3125 eDRX Idle

More details available on WebNEI: link

LTE4475 does not support paging prioritization between eDRX paging and normal paging, so when number of paging requests within RRC paging message is exceeded, redundant paging requests per RRC paging message will be dropped (as following FIFO paging buffer order) regardless if paging is "normal" or "eDRX".

LTE4414 NB-IoT Intra-frequency idle mode mobility

More details available on WebNEI: link

When ***numCoverageLevels*** is set to 3 and SIB3-NB is configured, some configurations must be adjusted because more DL subframes will be used by SIB3-NB.

Interdependencies

limitations

As following features are prerequisites for **LTE4475 NB-IoT Multiple Coverage Levels**, limitations specified for each of those features are still valid for LTE4475 and there is a list of features which have to be deactivated in the NB-IoT cell.

- LTE3071 NB-IoT Inband limitations
- LTE3509 NB-IoT Inband on AirScale without Baseband Pooling limitations
- LTE3668 NB-IoT Coverage enhancements limitations
- LTE3669 NB-IoT Paging support limitations
- LTE4415 NB-IoT Inband with partial Baseband Pooling limitations
- LTE3543 NB-IoT Standalone limitations

For details regarding feature limitations please refer to appropriate NEI materials.

Benefits and Gains

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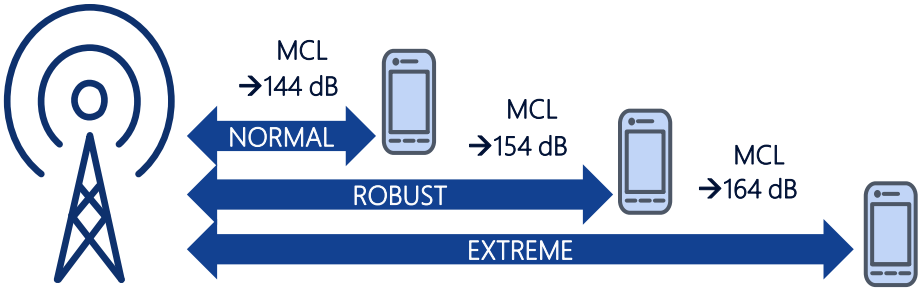
Benefits and Gains

LTE4475 NB-IoT Multiple Coverage Levels

- Most significant **benefit of LTE4475** NB-IoT Multiple Coverage Levels is **support of coverage level selection** (CL0, CL1 and CL2) per UE basis – based on UE location in the NB-IoT cell.
- With LTE4475 **lower data overall duration, higher throughputs and improved capacity are expected** in comparison to LTE3668 feature. LTE4475 allows to adjust number of repetitions according to UE RF condition in the NB-IoT cell – with LTE3668 all UEs under NB-IoT cell use the same numer of configured repetitions regardless of their coverage conditions
  - Paging capacity for NB-IoT UEs in coverage enhancement is still very limited. However, **capacity for paging** of NB-IoT UEs **would be much better due to use of lower repetitions level**



Configuration Management

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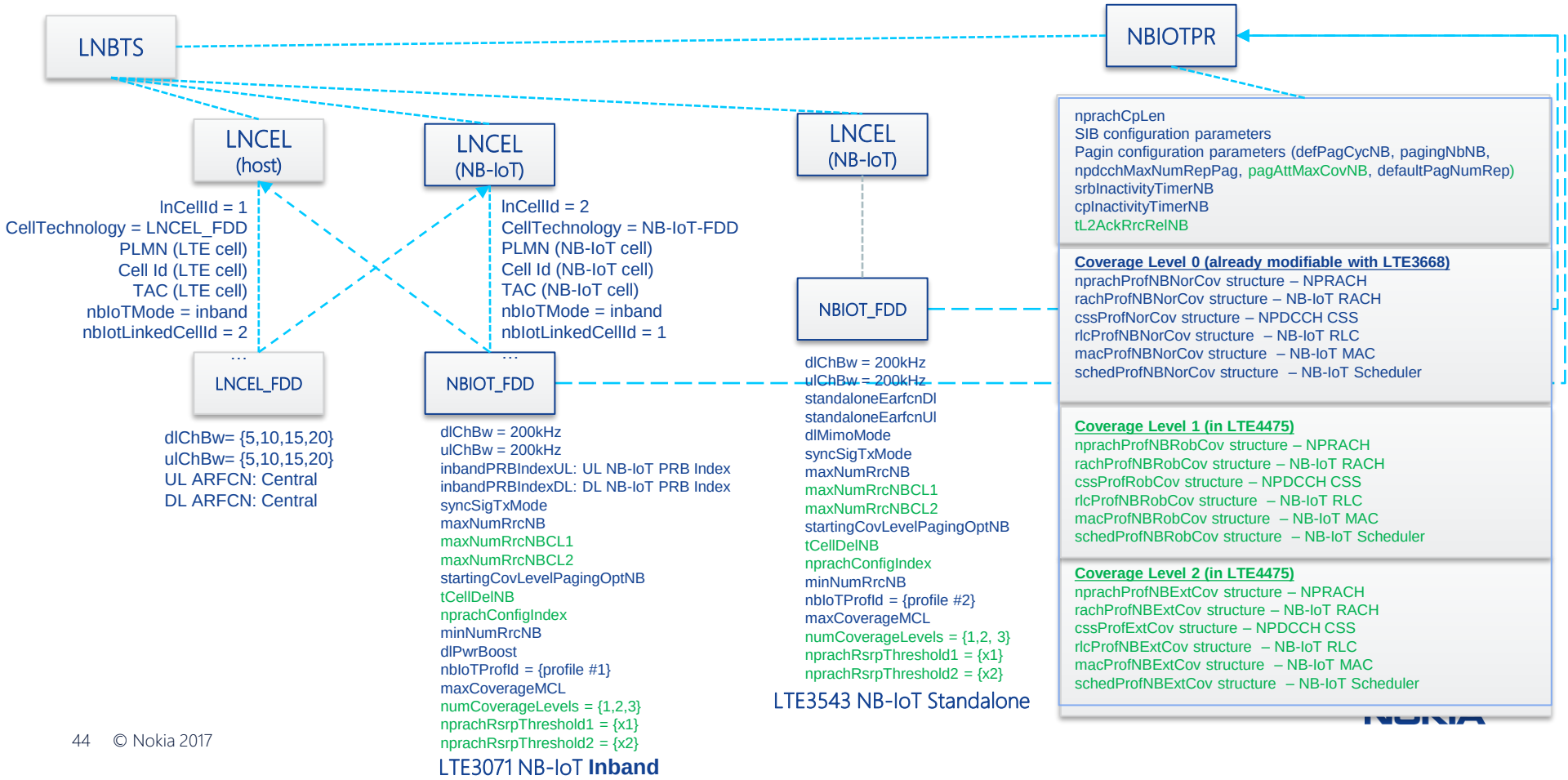
Configuration Management – new and modified parameters



Configuration Management
New parameters

Abbreviation	Full name	PKDB link
NBIOT_FDD:maxNumRrcNBCL1	Max Number RRC NB-IoT for Coverage Level 1	Parameter Knowledge Database
NBIOT_FDD:maxNumRrcNBCL2	Max Number RRC NB-IoT for Coverage Level 2	Parameter Knowledge Database
NBIOT_FDD:tCellDelNB	Guard time to force the release of UE context(s) when NB-IoT cell deletion	Parameter Knowledge Database
NBIOT_FDD:nprachConfigIndex	NPRACH Config Index	Parameter Knowledge Database
NBIOTPR:pagAttMaxCovNB	Maximum Coverage Level used for NB-IoT further paging attempts	Parameter Knowledge Database
NBIOTPR:tL2AckRrcRelNB	Timer missing L2 ack for NB-IoT RRC connection release	Parameter Knowledge Database

Configuration Management
Related parameters

Abbreviation	Full name	PKDB link
NBIOT_FDD:numCoverageLevels	Number of Coverage Levels	Parameter Knowledge Database
NBIOT_FDD:nprachRsrpThreshold1	NPRACH RSRP Threshold-1	Parameter Knowledge Database
NBIOT_FDD:nprachRsrpThreshold2	NPRACH RSRP Threshold-2	Parameter Knowledge Database
NBIOT_FDD:startingCovLevelPagingOptNB	Starting Coverage Level supports Paging Optimization for NB-IoT	Parameter Knowledge Database

Configuration Management

Related parameters

Abbreviated name	Full name	PKDB link
NBIOT_FDD:standaloneEarfcnDL	NB-IoT standalone EARFCN Uplink	Parameter Knowledge Database
NBIOT_FDD:standaloneEarfcnUL	NB-IoT standalone EARFCN Downlink	Parameter Knowledge Database
NBIOT_FDD:inbandPRBIndexDL	NB-IoT inband downlink PRB index	Parameter Knowledge Database
NBIOT_FDD:inbandPRBIndexUL	NB-IoT inband uplink PRB index	Parameter Knowledge Database
NBIOT_FDD:dlMimoMode	NB-IoT Downlink MIMO mode	Parameter Knowledge Database
LNCEL:nbIoTMode	NB-IoT operation mode – Inband/Standalone	Parameter Knowledge Database
LNCEL:p0NomPusch	Nominal power for UE PUSCH TX power calculation	Parameter Knowledge Database

Configuration Management
Related parameters

NPDCCH search space configuration

Abbreviated name	Full name	PKDB
NBIOTPR: cssProfNBNorCov	Common Search Space profile for NB-IoT first level coverage	Parameter Knowledge Database
NBIOTPR: npdcchMaxNumRepRa	Maximum number of repetitions for NPDCCH common search space for RA	Parameter Knowledge Database
NBIOTPR:npdcchOffsetRa	Offset for NPDCCH Common Search Space	Parameter Knowledge Database
NBIOTPR:npdcchStartSfRa	Starting subframes of the NPDCCH Common Search Space for RA	Parameter Knowledge Database

Configuration Management
Related parameters

Timers

Abbreviated name	Full name	PKDB
NBIOTPR: srbInactivityTimerNB	SRB inactivity timer	Parameter Knowledge Database
NBIOTPR: cpInactivityTimerNB	C-Plane inactivity timer	Parameter Knowledge Database
NBIOTPR:tHalfRrcConNB	Timer min lifetime of half-open RRC connection for NB-IoT	Parameter Knowledge Database
NBIOTPR: t300NB	Timer of T300 for NB-IoT	Parameter Knowledge Database
NBIOTPR: t310NB	Timer of T310 for NB-IoT	Parameter Knowledge Database

Configuration Management
Related parameters

NPRACH configuration

Abbreviated name	Full name	PKDB
NBIOTPR: nprachProfNBNorCov	NPRACH profile for NB-IoT first level coverage	Parameter Knowledge Database
NBIOTPR: nprachMaxNumPreambleCE	Max number of preamble attempts of NPRACH	Parameter Knowledge Database
NBIOTPR: nprachNumRepPreamble	Number of repetitions per preamble attempt of NPRACH	Parameter Knowledge Database
NBIOTPR: nprachStartTime	NPRACH start time	Parameter Knowledge Database
NBIOTPR: nprachPeriod	NPRACH periodicity	Parameter Knowledge Database
NBIOTPR:nprachSubcarrierOffset	NPRACH subcarrier offset	Parameter Knowledge Database
NBIOTPR:nprachNumSubcarriers	Number of subcarriers of NPRACH	Parameter Knowledge Database

Configuration Management
Related parameters

RACH configuration

Abbreviated name	Full name	PKDB
NBIOTPR: rachProfNBNorCov	RACH profile for NB-IoT first level coverage	Parameter Knowledge Database
NBIOTPR: raContResoTimNB	Contention resolution timer for NB-IoT	Parameter Knowledge Database
NBIOTPR: raRespWinSizeNB	RA response window size for NB-IoT	Parameter Knowledge Database

Configuration Management

Related parameters

Scheduler configuration

Abbreviated name	Full name	PKDB
NBIOTPR: schedProfNBNorCov	Scheduler profile in NB-IoT normal coverage	Parameter Knowledge Database
NBIOTPR: iniMcsDl	Initial MCS in downlink	Parameter Knowledge Database
NBIOTPR: iniMcsUl	Initial MCS in uplink	Parameter Knowledge Database
NBIOTPR:ackNACKNumRep	Repetition Number of ACK/NACK for NB-IoT	Parameter Knowledge Database
NBIOTPR:ackNACKNumRepMsg4	Repetition Number of Msg4 ACK/NACK for NB-IoT	Parameter Knowledge Database
NBIOTPR:iniNpdcchNumRepRa	Initial repetition number of NPDCCH for RA	Parameter Knowledge Database
NBIOTPR:iniNpdschNumRep	Initial repetition number of NPDSCH	Parameter Knowledge Database
NBIOTPR:iniNpdschNumRep	Initial repetition number of NPUSCH	Parameter Knowledge Database

Configuration Management
Related parameters

Paging configuration

Abbreviated name	Full name	PKDB
NBIOTPR:defPagCycNB	Default paging cycle for NB-IoT cell	Parameter Knowledge Database
NBIOTPR:pagingNbNB	Paging nB for NB-IoT	Parameter Knowledge Database
NBIOTPR:npdcchMaxNumRepPag	Maximum number of repetitions for N-PDCCH common search space for paging	Parameter Knowledge Database
NBIOT_FDD:startingCovLevelPagingOptNB	Starting Coverage Level supports Paging Optimization for NB-IoT	Parameter Knowledge Database

Configuration Management
Related parameters

Consistency Check

Abbreviated name	Full name	PKDBLL
LNCEL:pMax	Maximum Output Power	Parameter Knowledge Database
LNCEL:dlCellPwrRed	Cell power reduce	Parameter Knowledge Database
SIB:qrxlevmin	Minimum required RX level in cell	Parameter Knowledge Database
NBIOT_FDD:maxCoverageMCL	Maximum Coupling Loss (MCL) for NB-IoT cell	Parameter Knowledge Database

Deployment Aspects

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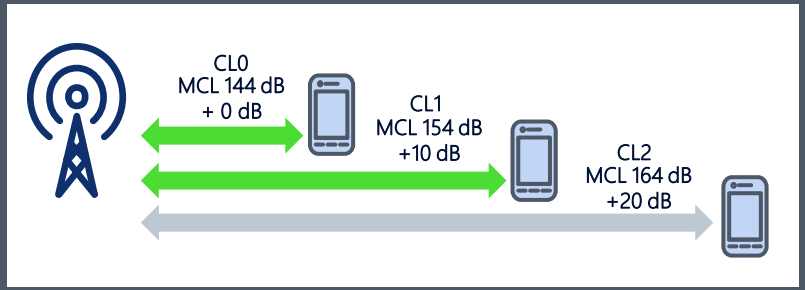
Deployment Aspects

Coverage level adjustment per UE basis

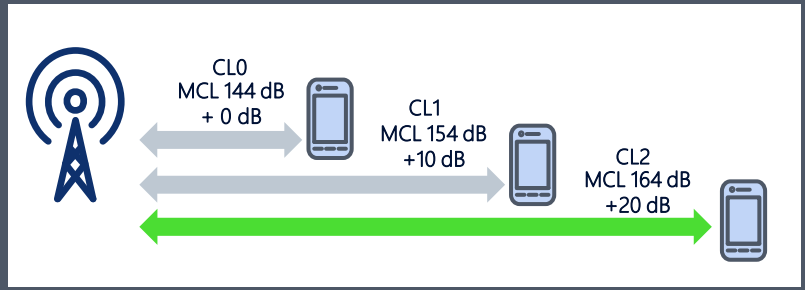
Example:

- If particular UE is camped in area where CL0 (e.g. normal +0 dB) or CL1 (e.g. robust+10 dB) coverage enhancement is sufficient – UE in good radio condition, the eNB will select eligible coverage level and as a result higher data rates can be achieved if only a few repetitions are configured for such UE and no additional (redundant) repetition are used.



Example:

- In areas where CL2 coverage (e.g. extreme +20 dB) enhancement is required, coverage performance can be maintained by more repetitions. We can expect that the data rates for UEs in these areas will be lower due to configuration of high number of repetitions. Nevertheless **CL2 (extreme coverage)** is used **only if needed** - enables to save resources and increases network capacity (in comparison to LTE3668 deployment) .



Deployment Aspects
Feature Activation

Feature activation:

- Please note that activation and deactivation rules for **LTE4475 NB-IoT Multiple Coverage Levels** are reused from LTE3071 NB-IoT In-band, nevertheless **LTE4475** can be enabled on NB-IoT cell by setting feature activation flag *NBIOT_FDD:numCoverageLevels* to the value **'2' or '3'.**

LTE4475
NB-IoT Multiple Coverage Levels

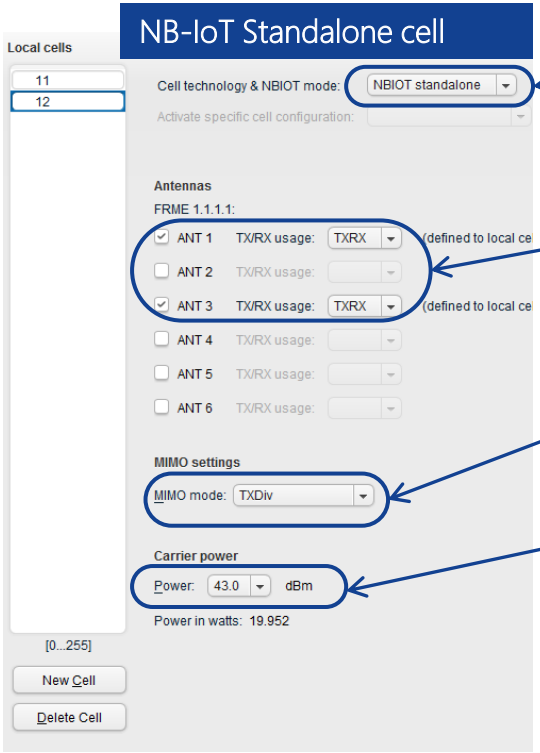
NBIOT_FDD:***numCoverageLevels*** = (2 or 3)

- As features LTE3668 NB-IoT Coverage Enhancements and LTE3669 NB-IoT Paging Support are prerequisites for LTE4475 NB-IoT Multiple Coverage Levels activation, thus are needed beforehand
- **LTE4475 feature activation** requires either **inband or standalone cell creation and feature configuration** – for details please refer to LTE3071 NB-IoT Inband or LTE3543 NB-IoT Standalone NEI materials
- Depending on HW deployment (FSMF, AirScale) following feature are prerequisites accordingly:
  - LTE3071 NB-IoT Inband
  - LTE3509 NB-IoT Inband on AirScale w/o Baseband Pooling (to support Baseband Pooling also LTE4415 has to be activated)

Deployment Aspects

LTE4475 feature activation

STEP 1 – Creation and configuration of Standalone (or Inband) NB-IoT cell



NB-IoT Standalone cell

Choose the appropriate antenna line mapping for the added Standalone cell:
here 2TX2RX configuration

Configure the MIMO mode within the cell view

Select the NB-IoT Standalone Carrier output power

Disclaimer: Please note that in the following slides only most relevant and new parameters in term of NB-IoT Multiple Coverage Levels feature are presented. If not explicitly stated remaining procedures follows rules defined within legacy NB-IoT features.

Please refer to NEI materials:

LTE3071/ LTE3509 NB-IoT inband
LTE3543 NB-IoT Standalone
LTE3668 NB-IoT: Coverage enhancements
LTE3669 NB-IoT: Paging support

Deployment Aspects

LTE4475 feature activation

STEP 2 – NB-IoT Standalone carrier configuration

Downlink (TX) carriers

Local cell	Frequency band	Bandwidth	EARFCN	Frequency (MHz)
11	800MHz (E-UTRA 20)	10 MHz	6300	806.0
12	800MHz (E-UTRA 20)	0.2 MHz	6152	791.2

Allowed EARFCN values

800MHz (E-UTRA 20, FRME): [6150...6349]
The EARFCN value must be at a bandwidth-dependent distance from the lower and upper limits of the allowed range.

In the Downlink (TX) carriers section set the appropriate values for the EARFCN

Uplink (RX) carriers

Local cell	Frequency band	Bandwidth	EARFCN	Frequency (MHz)	Flexible duplexing gap
11	800MHz (E-UTRA 20)	10 MHz	24300	847.0	☐
12	800MHz (E-UTRA 20)	0.2 MHz	24152	832.2	☐

Allowed EARFCN values

800MHz (E-UTRA 20, FRME): [24150...24449]
The EARFCN value must be at a bandwidth-dependent distance from the lower and upper limits of the allowed range.

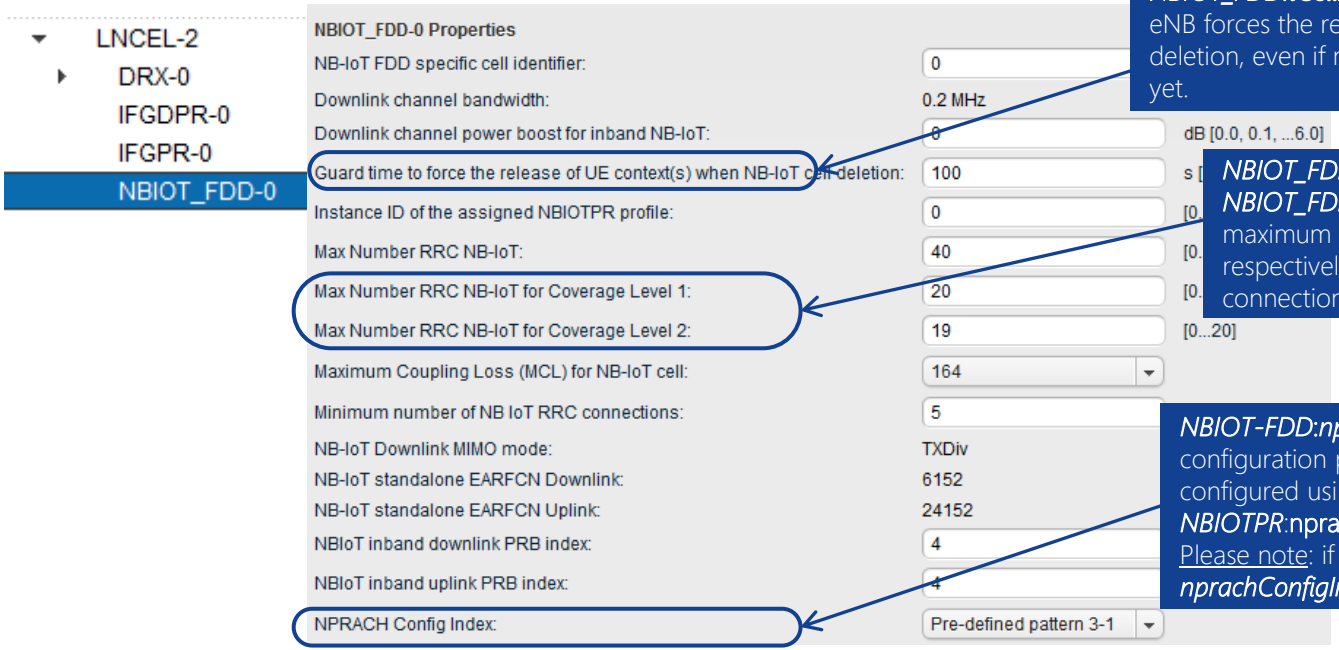
UL EARFCN will be automatically updated

Disclaimer: Please note that in the following slides only most relevant and new parameters in term of NB-IoT Multiple Coverage Levels feature are presented. If not explicitly stated remaining procedures follows rules defined within legacy NB-IoT features.

Deployment Aspects

LTE4475 feature activation

STEP 3 – NB-IoT Standalone carrier configuration – NBIOT_FDD



NBIOT_FDD:tCellDelNB defines the time after which the eNB forces the release of UE context(s) for NB-IoT cell deletion, even if not all RRC Connections were released yet.

NBIOT_FDD:maxNumRrcNBCL1 and *NBIOT_FDD:maxNumRrcNBCL2* are thresholds for the maximum number of NB-IoT users in CL1 and CL2 respectively which are allowed to establish RRC connection in NB-IoT cell

NBIOT-FDD:nprachConfigIndex indicates if NPRACH configuration pattern will be pre-defined or manually configured using parameters under *NBIOTPR*:nprachProfNB(Nor/Rob/Ext)Cov
Please note: if *NBIOT_FDD:numCoverageLevels* > 1, *nprachConfigIndex must be set as a pre-defined*

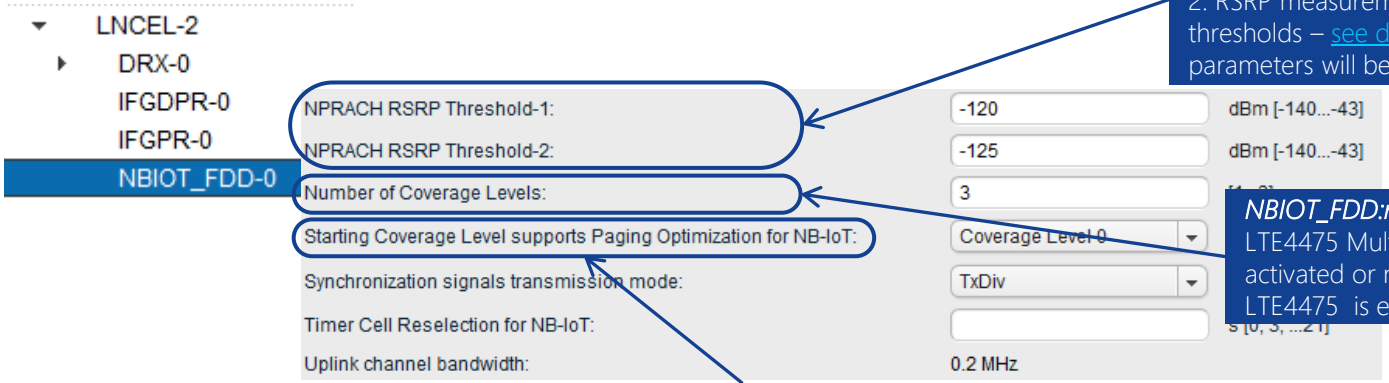
Disclaimer: Please note that in the following slides only most relevant and new parameters in term of NB-IoT Multiple Coverage Levels feature are presented. If not explicitly stated remaining procedures follows rules defined within legacy NB-IoT features.

Deployment Aspects

LTE4475 feature activation

STEP 4 – NB-IoT Standalone carrier configuration – NBIOT_FDD

NBIOT_FDD:nprachRsrpThreshold1 and *2* are RSRP thresholds to separate NB-IoT coverage levels 0, 1 and 2. RSRP measurement is checked against those thresholds – see details to indicate which set of parameters will be used for a particular NB-IoT UE



NBIOT_FDD:numCoverageLevels indicates whether LTE4475 Multiple Coverage Levels feature is activated or not. If set to the value 2 or 3 – LTE4475 is enabled.

NBIOT_FDD: startingCovLevelPagingOptNB supports Paging Optimization configured for NB-IoT cell. Paging optimization will send the paging over specific cell for first paging message from MME, and paging over TAC region for re-paging messages from MME.

- Coverage Level 0 - Paging Optimization support start from coverage level 0 (all levels)
- Coverage Level 1 - Paging Optimization support start from coverage level 1
- Coverage Level 2 - Paging Optimization support in coverage level 2

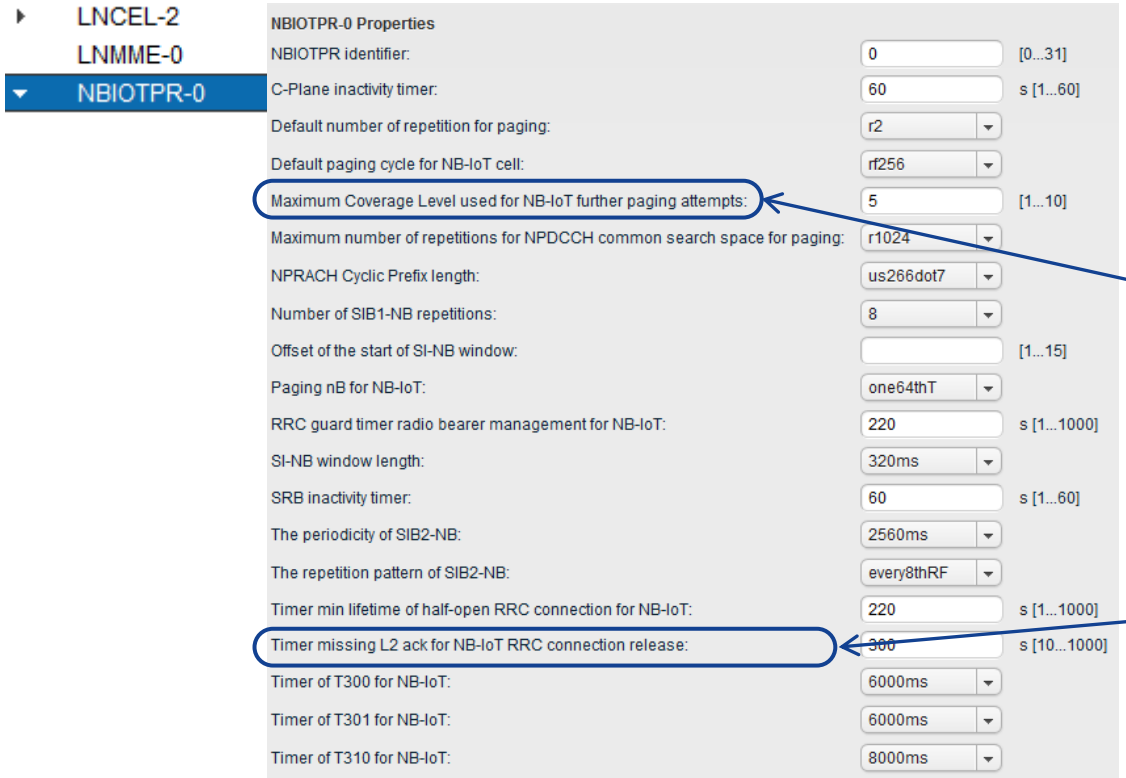
if this parameter is not configured, then this function is considered to be disabled.

Disclaimer: Please note that in the following slides only most relevant and new parameters in term of NB-IoT Multiple Coverage Levels feature are presented. If not explicitly stated remaining procedures follows rules defined within legacy NB-IoT features.

Deployment Aspects
LTE4475 feature activation

Disclaimer: Please note that in the following slides only most relevant and new parameters in term of NB-IoT Multiple Coverage Levels feature are presented. If not explicitly stated remaining procedures follows rules defined within legacy NB-IoT features.

STEP 5 – NB-IoT Standalone carrier configuration – NBIOTPR

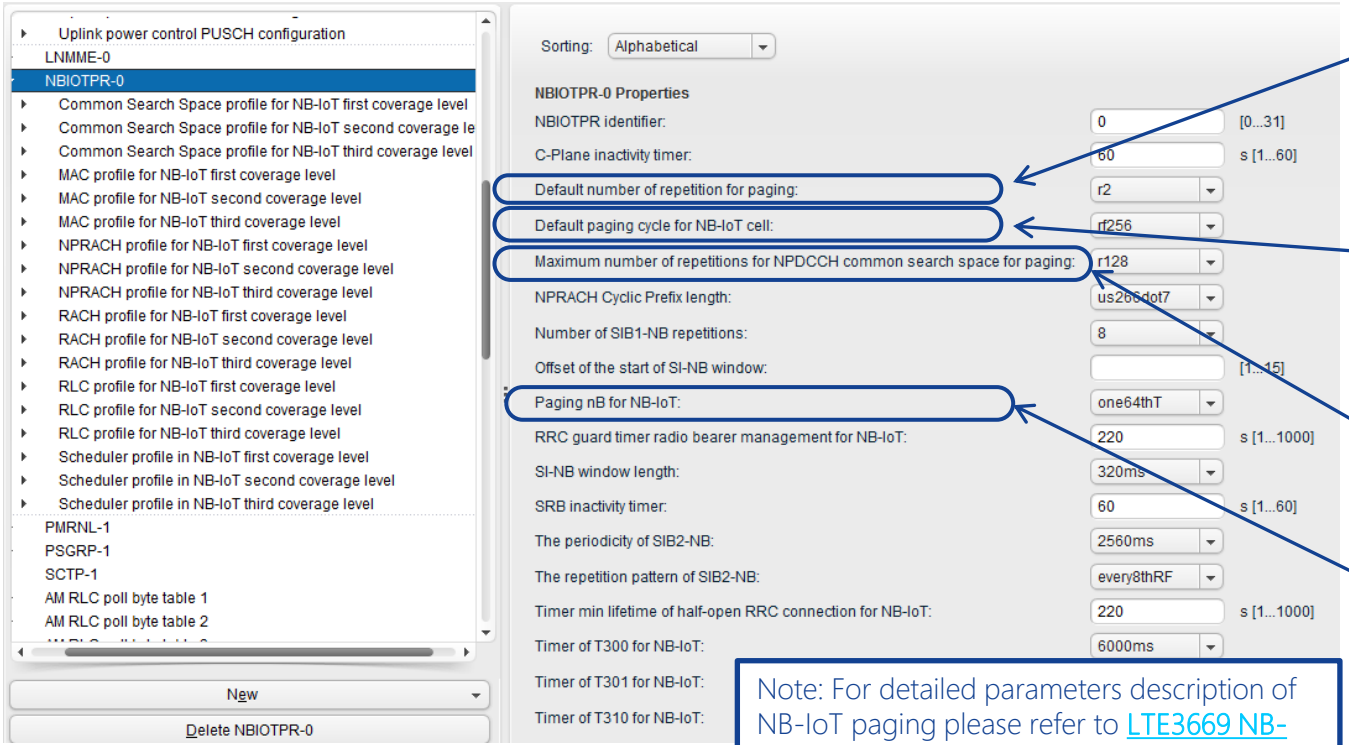


NBIOTPR:pagAttMaxCovNB indicates a threshold in case of Paging Attempt Count greater than this, eNB will apply the highest (maximum) configured coverage level parameters for NPDCCH and NPDSCH

NBIOTPR:tL2AckRrcRelNB defines the maximum time period that the eNB waits for an L2 ack on an RRC CONNECTION RELEASE for NB-IoT

Deployment Aspects
LTE4475 feature activation

Step 6 – NBIOTPR configuration: paging



Default number of repetition for paging used **for paging optimization** for LTE4475 **Multiple Coverage Levels** feature.

Default DRX paging cycle **indicates time between two Paging Occasion** PO of the same CAT1-NB UE or the same group of UEs. For particular CAT1-NB UE paging occasion occurs once per DRX cycle. Please note: Parameter ***defPagCycNB*** which determines DRX Cycle length should not be lower than the ***pagingNbNB*** parameter value.

Maximum number of repetitions for NPDCCH common search space for paging.

NB-IoT nB is used to derive the Paging Frame PF and PO. Parameter ***pagingNbNB*** must be set carefully as it impacts the number of PO in each DRX cycle.

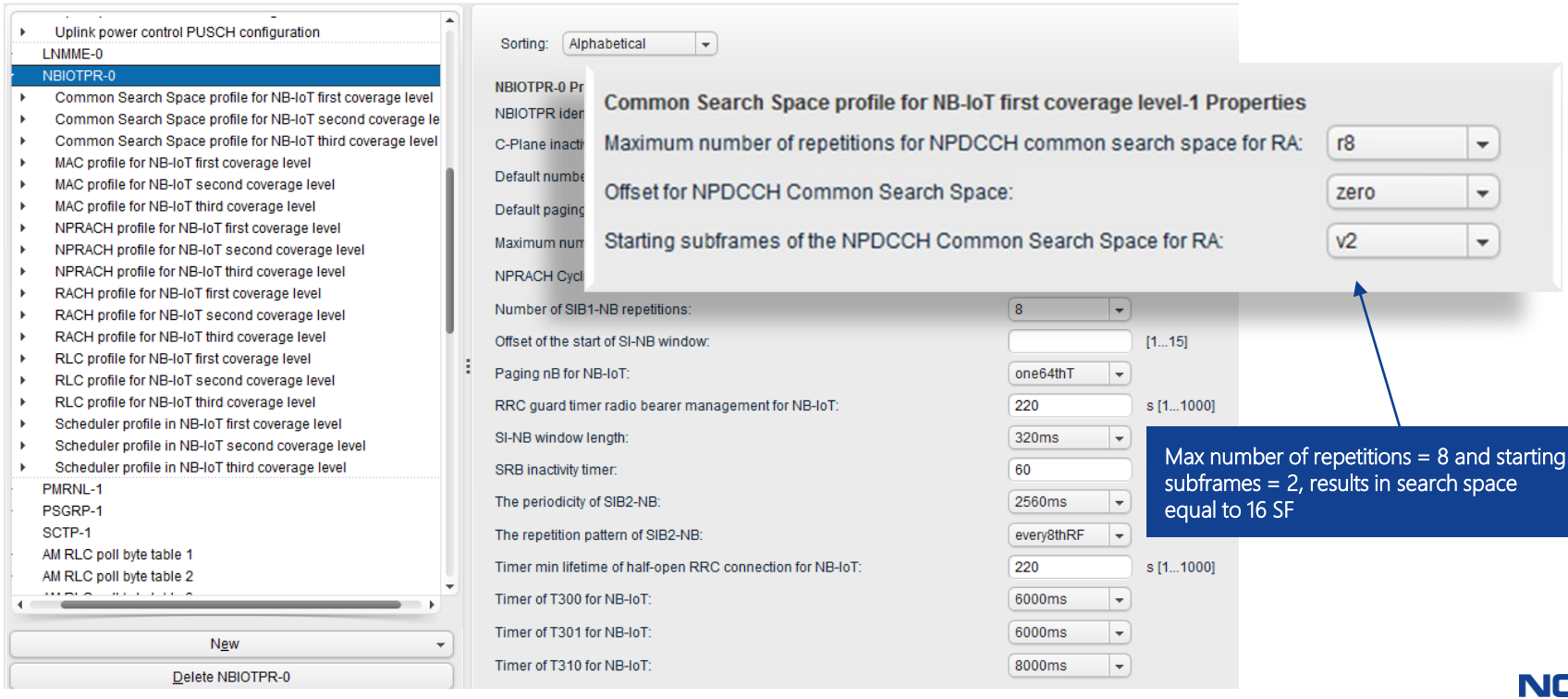
Note: For detailed parameters description of NB-IoT paging please refer to LTE3669 NB-IoT: Paging support NEI slides.

Deployment Aspects
LTE4475 feature activation

Please note: LTE4475 allows to configure all profiles (like CSS for NPDCCH, RACH, NPRACH, MAC, RLC, and scheduler profile) for all 3 coverage levels specific structures (with LTE3668 only CL0 structure was modifiable):

- Coverage Level 0
- Coverage Level 1
- Coverage Level 2

Step 7 – NBIOTPR configuration, Common Search Space for NPDCCH



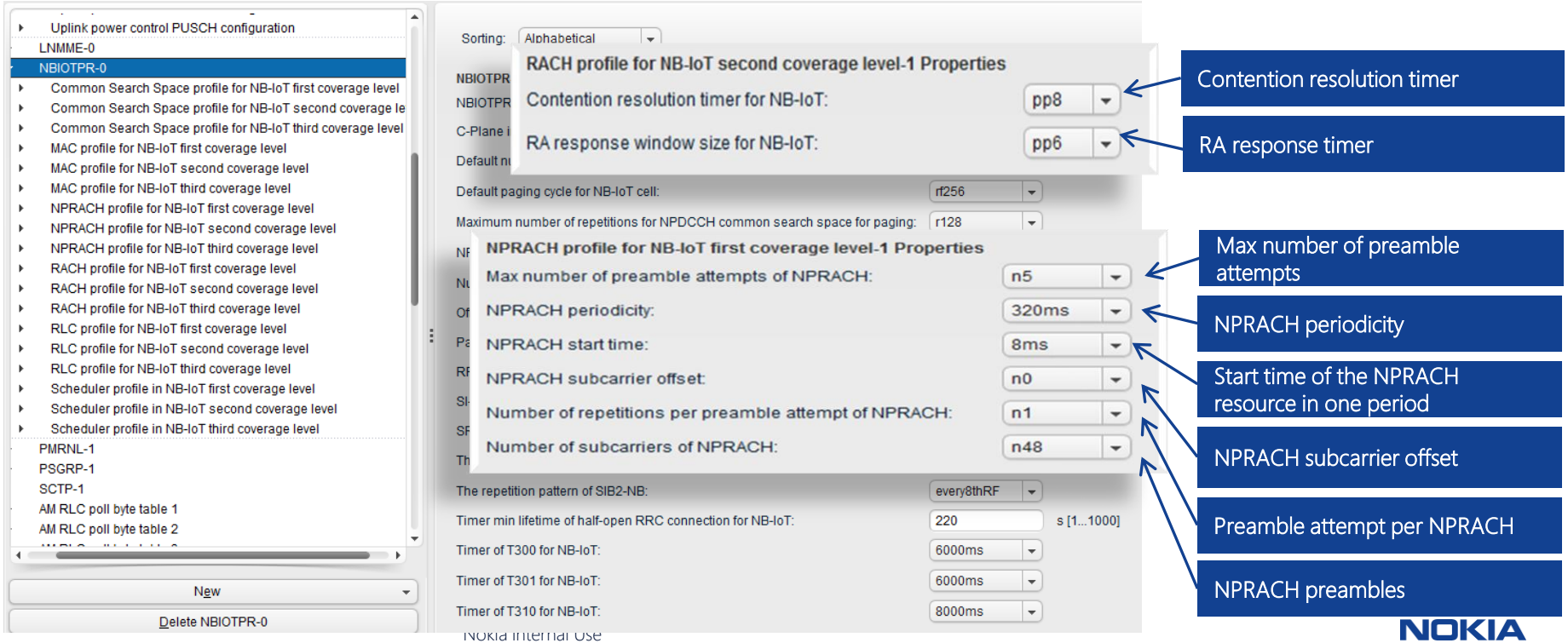
Max number of repetitions = 8 and starting subframes = 2, results in search space equal to 16 SF

Deployment Aspects
LTE4475 feature activation

Please note: LTE4475 allows to configure all profiles (like CSS for NPDCCH, RACH, NPRACH, MAC, RLC, and scheduler profile) for all 3 coverage levels specific structures (with LTE3668 only CL0 structure was modifiable):

- Coverage Level 0
- Coverage Level 1
- Coverage Level 2

Step 8 – NBIOTPR configuration, RACH and NPRACH profiles



Deployment Aspects
LTE4475 feature activation

Please note: LTE4475 allows to configure all profiles (like CSS for NPDCCH, RACH, NPRACH, MAC, RLC, and scheduler profile) for all 3 coverage levels specific structures (with LTE3668 only CL0 structure was modifiable):

- Coverage Level 0
- Coverage Level 1
- Coverage Level 2

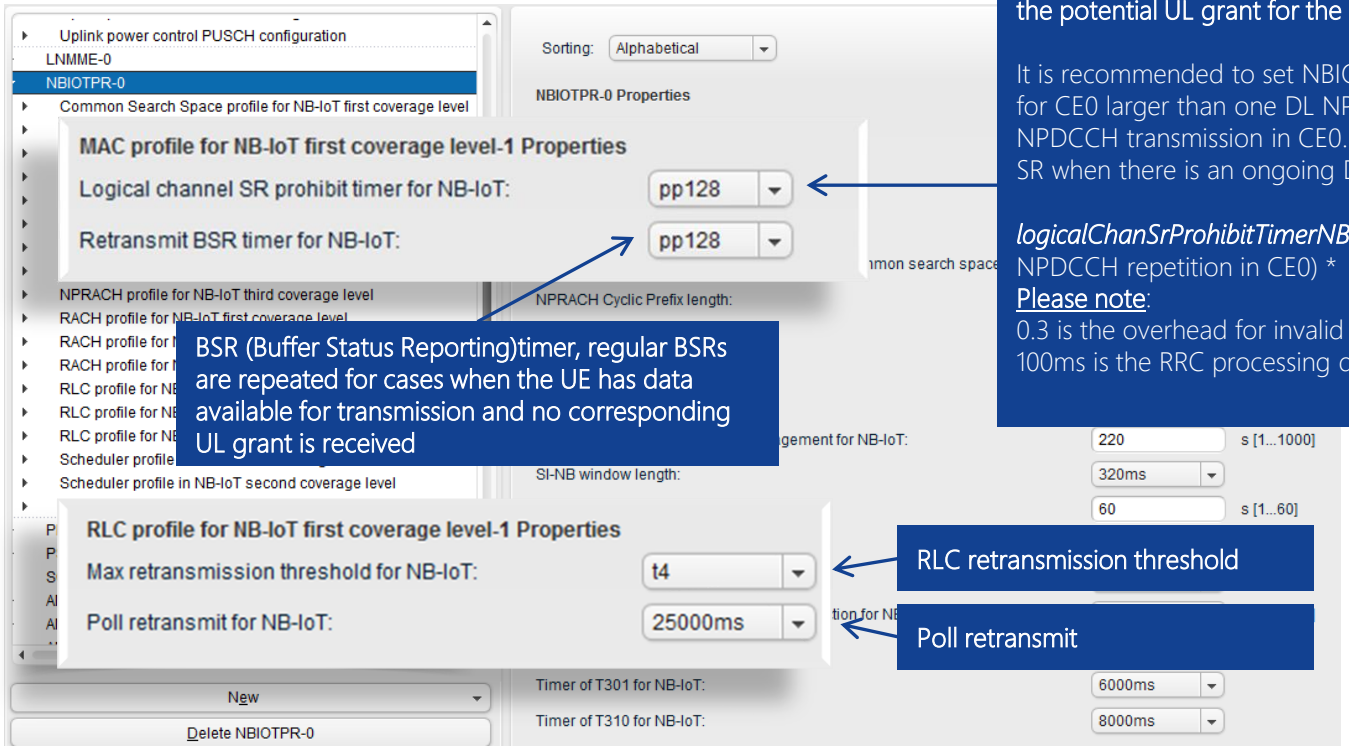
Step 9 – NBIOTPR configuration, MAC and RLC profiles

MAC prohibit timer, to delay the transmission of an SR in NB-IoT, to wait the potential UL grant for the UL transmission.

It is recommended to set NBIOTPR:*logicalChanSrProhibitTimerNB* timer for CE0 larger than one DL NPDCCH transmission in CE2 and one DL NPDCCH transmission in CE0. It tries to avoid UE sending a re-RACH for SR when there is an ongoing DL transmission in CE2:

logicalChanSrProhibitTimerNB> (100ms+(NPDCCH repetition in CE2+ NPDCCH repetition in CE0) * （1+0.3 invalid overhead）)/(CSS for CE0)

Please note:
0.3 is the overhead for invalid subframes in DL;
100ms is the RRC processing delay



BSR (Buffer Status Reporting)timer, regular BSRs are repeated for cases when the UE has data available for transmission and no corresponding UL grant is received

RLC retransmission threshold

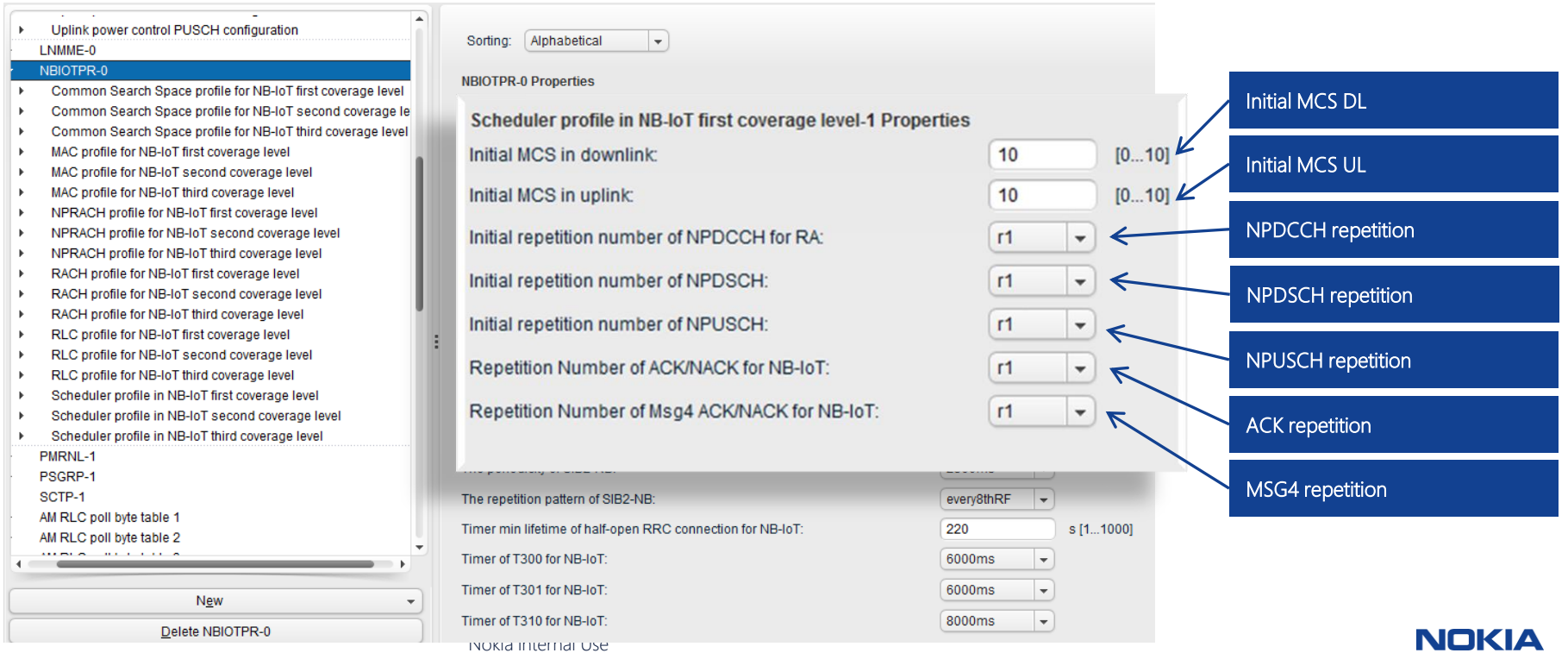
Poll retransmit

Deployment Aspects
LTE4475 feature activation

Please note: LTE4475 allows to configure all profiles (like CSS for NPDCCH, RACH, NPRACH, MAC, RLC, and scheduler profile) for all 3 coverage levels specific structures (with LTE3668 only CL0 structure was modifiable):

- Coverage Level 0
- Coverage Level 1
- Coverage Level 2

Step 10 – NBIOTPR configuration, Scheduler profile



Dimensioning

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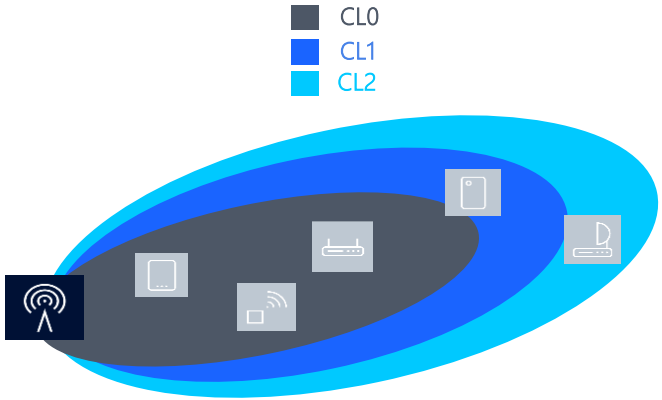
Dimensioning

LTE4475 Multiple Coverage Levels – system performance and capacity

- Feature LTE4475 Multiple Coverage Levels
  improves capacity by optimizing usage of resources (MCS, repetitions, etc.) based on UE radio frequency conditions
- Paging capacity for NB-IoT UEs in coverage enhancement is still limited by *pagingNbNB* limitations. However, capacity for paging of NB-IoT UEs is foreseen to be much better due to use of lower number of repetitions whether possible
- Please refer to NB-IoT Paging Calculator to see how configuration of *pagingNbNb* affects paging capacity

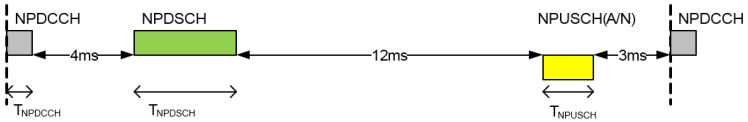


For details please refer to NB-IoT Capacity calculator

Dimensioning

Downlink Transmission Times Comparison

- This example set of figures illustrates the significant impact upon capacity that **LTE4475 NB-IoT Multiple Coverage Levels** feature has relative to **LTE3668 NB-IoT Coverage Enhancements.**
- With LTE3668 if extreme coverage level is configured per NB-IoT cell – all UEs are using high number of repetitions even if no needed for the UE in good radio conditions.
  - **LTE4475 NB-IoT Multiple Coverage Levels** enables to configure up to three coverage levels (normal, robust and extreme) and adjust coverage level per UE basis, it **allows to save resources and increases network capacity and throughputs.**



	inband		standalone	
	CL0 + 0 dB	CL2 +20 dB	CL0 + 0 dB	CL2 +20 dB
NPDCCH duration [ms]	1	1	1	1
NPDCCH Repetitions	1	512	1	128
NPDCCH Transmission Time [ms]	**1**	**512**	**1**	**128**
NPDCCH to NPDSCH Gap [ms]	4	4	4	4
NPDSCH TBS duration [ms]	4	4	4	4
NPDSCH Repetition	1	256	1	32
NPDSCH Transmission Time [ms]	**4**	**1024**	**4**	**128**
NPDSCH to NPUSCH Gap [ms]	12	12	12	12
NPUSCH Format 2 (ACK/NACK) duration [ms]	2	2	2	2
NPUSCH Repetition	1	128	1	128
NPUSCH Transmission Time [ms]	**2**	**256**	**2**	**256**
NPUSCH to NPDCCH Gap [ms]	3	3	3	3
1 TBS Transmission Time [ms]	26	1811	26	531
Max HARQ Retransmission	1	1	1	1
Total Transmission	2	2		2
1 TBS Transmission Time with max HARQ [ms]	52	3622	52	1062
Ovehead of Invalid SF	25%	25%	25%	25%
DL Data Overall Duration [ms]	65	4528	65	1328

DISCLAIMER: The results shown in this presentation are examples only. They demonstrate trends (not absolute values) expected after feature activation. They may differ from results achievable in real networks.

Dimensioning

NB-IoT throughput Calculation for each Coverage Level – Inputs (LTE3668 and LTE4475)

LTE3668 activated – inband deployment, only one coverage level can be configured per NB-IoT cell which is applicable for all UEs under such cell

Structure: schedProfNBNorCov

Parameter	CL2 → *maxCoverageMCL* = 164 dB
ackNACKNumRep	r128
ackNACKNumRepMsg4	r128
iniMcsDl	1
iniMcsUl	1
iniNpdcchNumRepRa	r512
iniNpdschNumRep	r256
iniNpuschNumRep	12

LTE4475 activated – inband deployment, three coverage levels configured. Coverage level is selected and adjusted per UE basis

Parameter	Structure		
	schedProfNBNorCov	schedProfNBRobCov	schedProfNBExtCov
ackNACKNumRep	r1	r4	r128
ackNACKNumRepMsg4	r1	r4	r128
iniMcsDl	9	4	1
iniMcsUl	9	4	1
iniNpdcchNumRepRa	r2	r64	r512
iniNpdschNumRep	r1	r16	r256
iniNpuschNumRep	r1	r4	12

DISCLAIMER: The results shown in this presentation are examples only. They demonstrate trends (not absolute values) expected after feature activation. They may differ from results achievable in real networks.

Dimensioning

NB-IoT throughput Calculation for each Coverage Level – Inputs (LTE3668 and LTE4475)

Assumption:

- 3 UEs per NB-IoT cell
- Inband deployment
  - LTE3668 activated with high number of repetitions (defined for extreme coverage level) under ***schedProfNBNorCov*** – all UEs use configuration set from Normal Coverage Level Profile regardless of their coverage conditions
  - LTE4475 activated with three coverage levels defined under ***schedProfNBNorCov, schedProfNBRobCov*** and ***schedProfNBExtCov*** at the same time - allows to adjust appropriate coverage level per each UE under NB-IoT cell – for simplification let's assume that one UE is configured per each coverage level (1UE per normal, 1UE per robust and 1UE per extreme coverage level)

UL transmission with coverage specific repetitions:

- T_{NPDCCH} = *iniNpdcchNumRepRa * 1 ms*
- T_{NPUSCH_1} = *iniNpuschNumRep * 32 ms*

DL transmission with coverage specific repetitions:

T_{NPDCCH} = *iniNpdcchNumRepRa * 1 ms*
T_{NPDSCH} = *iniNpdschNumRep * 4 ms*
T_{NPUSCH_2} = *ackNACKNumRep * 2 ms*

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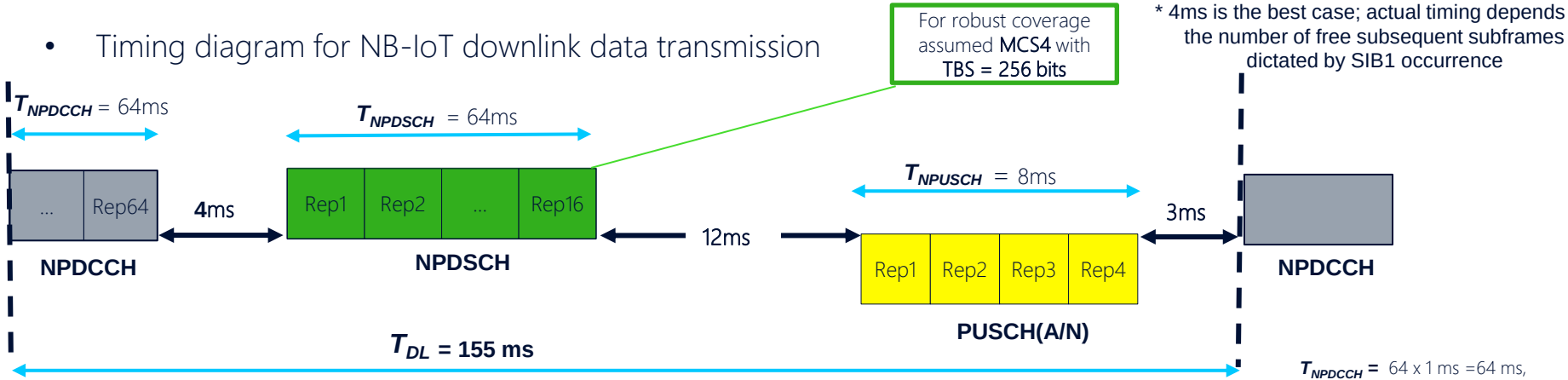
Dimensioning

NB-IoT DL Throughput – Example of Robust Coverage Calculation

0	1	2	3	4	5	6	7	8	9
MIB				SIB1	PSS				SSS

* 4ms is the best case; actual timing depends on the number of free subsequent subframes dictated by SIB1 occurrence

- Timing diagram for NB-IoT downlink data transmission



T_{NPDCCH} = 64 x 1 ms =64 ms,
T_{NPDSCH} = 16 x 4 ms = 64 ms,
T_{NPUSCH} = 4 x 2 ms = 8 ms

- Instantaneous throughput is is given by:

  TBS_{max}/T_{NPDSCH} = **4 kbps** (TBS=256 bits, T_{NPDSCH}= 64ms)

- Sustained throughput :

  $TBS_{max}/(T_{NPDCCH} + 4ms + T_{NPDSCH} + 12ms + T_{NPUSCH} + 3ms)$ kbps = 256 bits/155 ms = **1.65 kbps**

Sustained throughput is approximately **1.65 kbps** without considering NPBCH/NPSS/NSSS overhead, and **0.99 kbps** when 40% DL overhead is taken into account (PBCCH, SIBx, PSS, SSS)

Please note: With LTE3668 all UEs under NB-IoT cell use the same numer of configured repetitions regardless of their coverage conditions what has strong impact on the average cell level throughput calculation

Dimensioning
NB-IoT DL Throughputs

	Coverage Level		
	CL0	CL1	CL2
MCS	9	4	1
TBS [bits]	616	256	144
Instantaneous throughput [kbps]	154	4	0.14
Sustained throughput [kbps]	22.81	1.65	0.08
Sustained throughput including 40% overhead [kbps]	13.69	0.99	0.048

Deployment mode	Average instantaneous throughput per UE [kbps]	Average sustained throughput per UE [kbps]	Sustained throughput including 40% overhead per UE [kbps]
LTE3668	0.14	0.08	0.048
LTE4475	154	22.81	13.69

- With previous solution LTE3668, if operator wants to support a coverage of MCL=164dB (extreme), all NB-IoT UEs would be forced to use the same repetitions to reach 164dB MCL.
- LTE4475 allows NB-IoT UEs within cell to be distributed across available coverage levels. As a result the NB-IoT throughput will increase accordingly in comparison to legacy throughput (LTE3668).
  - Assumed that one UE is configured per each coverage level (1UE per normal, 1UE per robust and 1UE per extreme coverage level)

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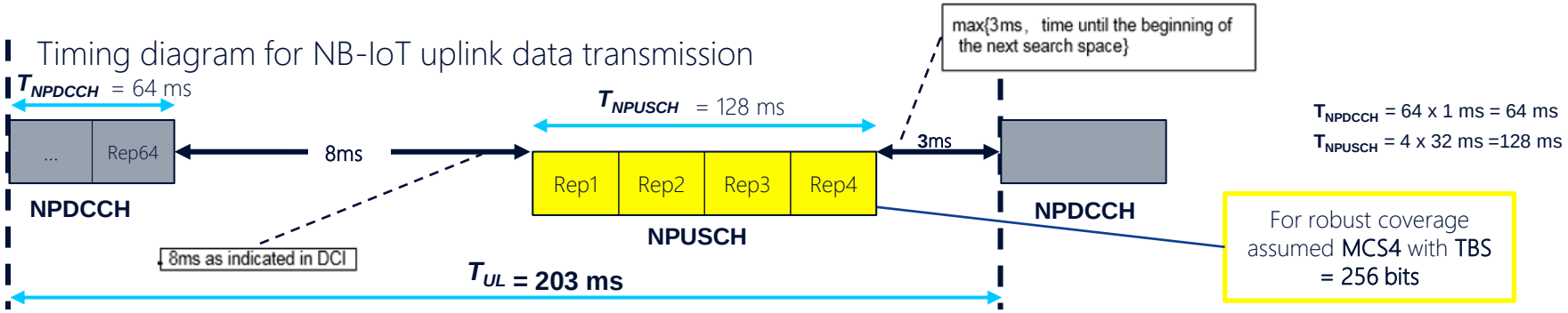
Dimensioning

NB-IoT UL Throughput – Example of Robust Coverage Calculation

- Timing diagram for NB-IoT uplink data transmission



- Instantaneous throughput is given by:

  TBS_{max}/T_{NPUSCH} = **2 kbps** (TBS=256 bits, TTI=128 ms)

- Sustained throughput:

  $TBS_{max}/(T_{NPDCCH} + 8ms + T_{NPUSCH} + 3ms)$ kbps = 256 bits/203 ms = **1.25 kbps**

Approximately **1.25 kbps** without considering NPRACH overhead. NPRACH occasion is every 1280 ms and lasts for 102.4 ms, **8% overhead** reduces sustained peak rate to **1.15 kbps** for robust coverage

Please note: With LTE3668 all UEs under NB-IoT cell use the same numer of configured repetitions regardless of their coverage conditions what has strong impact on the average cell level throughput calculation

Dimensioning

NB-IoT UL Throughputs

	Coverage Level		
	CL0	CL1	CL2
MCS	9	4	1
TBS [bits]	616	256	176
Instantaneous throughput [kbps]	19.3	2	0.043
Sustained throughput [kbps]	13.7	1.25	0.038
Sustained throughput including NPRACH overhead [kbps]	16% overhead →11.5	8% overhead →1.15	32% overhead →0.026

Deployment mode	Average instantaneous throughput per UE [kbps]	Average sustained throughput per UE [kbps]	Average sustained throughput including NPRACH overhead per UE [kbps]
LTE3668	0.043	0.038	0.026
LTE4475	7.11	5.0	4.23

- With previous solution LTE3668, if operator wants to support a coverage of MCL=164dB (extreme), all NB-IoT UEs would be forced to use the same repetitions to reach 164dB MCL.
- LTE4475 allows NB-IoT UEs within cell to be distributed across available coverage levels. As a result the NB-IoT throughput will increase accordingly in comparison to legacy throughput (LTE3668).
  - Assumed that one UE is configured per each coverage level (1UE per normal, 1UE per robust and 1UE per extreme coverage level)

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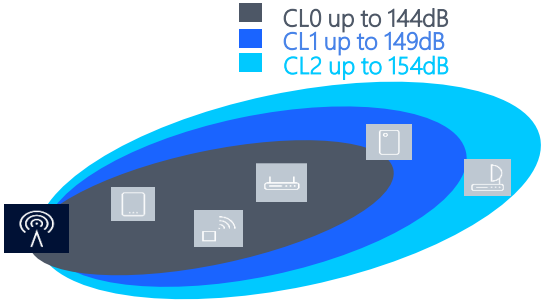
Dimensioning

Coverage level configuration

1. Assumption:

- *numCoverageLevels* = 3
- *maxCoverageMCL* = 154 dB



Coverage Level	MCL [dB]
Normal	CL0<144
Robust	144 < CL1< 149
Extreme	CL2 < 154

2. Inputs for consistency check (ensures that UEs with RSRP less than *qrxlevmin* cannot access this NB-IoT cell) related to *SIB:qrxlevmin* settings:

pMax - *dlCellPwrRed* - *dlpcMimoComp* + 3 - 10*log10(*#PRB*12) + *dlPwrBoost* – *qrxlevmin* <= *maxCoverageMCL*

Green parameters from host cell
Red parameters from NB-IoT cell

- *pMax* = 43dBm
- *dlCellPwrRed* = 1.2dB
- *#PRB*= 50 PRBs in DL for 10MHz host cell
- *dlpcMimoComp* = 0dB
- *dlPwrBoost* = 6 dB
- *maxCoverageMCL* = 154 dB

3. Outputs:

- PSD_0 = (*pMax* – *dlCellPwrRed*) – 10log10(*#PRB* x 12) =
  = 43dBm-1.2dB-10log10 (50*12)= **14.02 dBm**
- PSD_MIMO_NB = PSD_0 + *dlPwrBoost* – *dlpcMimoComp* =
  = 14.02 +6 = **20.02 dBm**
- 20.02 dBm + 3 – *qrxlevMin* <= 154dB
- *qrxlevmin*>= -130.98 dBm

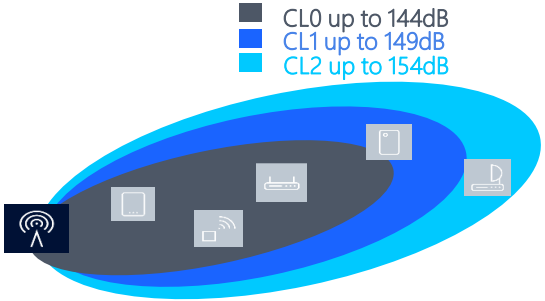
The Minimum required RX level in cell *qrxlevmin* is set to -130dBm, which allows the UEs with 154dB MCL access to this cell (*qrxlevmin* >= -130.98dBm)

Dimensioning

Coverage level configuration

Assumption:

- *numCoverageLevels* = 3
- *maxCoverageMCL* = 154 dB



Coverage Level	MCL [dB]
Normal	CL0<144
Robust	144 < CL1< 149
Extreme	CL2 < 154

4. Inputs for configuration RSRP thresholds:
NBIOT_FDD:nprachRsrpThreshold1 and *NBIOT_FDD:nprachRsrpThreshold2*

- For MCL = 154 dB → *qrxlevmin* = -130 dBm (UE with lower RSRP cannot camp to this cell)
- Coverage levels are split into three parts:
  - CL0 < 144
  - 144 < CL1 < 149
  - CL2 < 154 → RSPR > -130 dBm (calculated for *qrxlevmin*)

5.Outputs:

- *nprachRsrpThreshold2** = -130dBm + (154 – 149)dB = -130dBm +5dB = *nprachRsrpThreshold2* = -125dBm
- *nprachRsrpThreshold1* *= -130dBm + (154 – 144)dB = -130dBm +10dB = *nprachRsrpThreshold1* = -120 dBm

Parameters used for coverage level:	RSRP threshold [dBm]
CL0	RSRP >= -120
CL1	-125 <=RSRP< -120
CL2	RSRP <-130

*Please note: If *numCoverageLevels* is = 3, *nprachRsrpThreshold1* > *nprachRsrpThreshold2*

Dimensioning

NPRACH capacity

- RACH attempts per cell due UE transition from idle to connected depends on the number of devices per cell and BHCA.
- We can assume certain probability for correct NPRACH reception P_{NPRACH} which impacts number of NPRACH messages needed.

$$RACH\ attempts/s = \frac{\#UE \cdot BHCA}{3600 \cdot P_{NPRACH}} = \frac{52547 \cdot 0.47}{3600 \cdot 0.9} = 7.6$$

- The number of NPRACH preambles is limited to 12, and RACH channel can be accessed by number of UEs simultaneously, so when estimating NPRACH capacity expected RACH load and allowed collision probability P_{coll} should be assumed.
- RACH occasion for a given CL is repeated every NPRACH periodicity *nprachPeriod*

$$RACH\ occasions/s = \sum_{i=0}^{2} \left(\frac{-1}{\boldsymbol{nprachPeriod}_i[s]} \right) 12 \cdot \ln\left(1 - \frac{P_{coll}}{100}\right) \rightarrow RACH\ occasions/s = 7{,}817$$

- Offered RACH traffic should not be higher than NPRACH occasions/s

$$NPRACH\ occassions/s > RACH\ attempts/s$$

- For the default traffic model and 90% of NPRACH reception probability the target of the offered RACH traffic of 7.6 RACH/s can be guaranteed with collision probability lower than 8% (12 preambles, NPRACH repetition every 320 ms for CL0 and CL1 and 640 ms for CL2).

Coverage Level	*nprachPeriod*	RACH occasions/s
CL0	320	3,1268
CL1	320	3,1268
CL2	640	1,5634
(CL0 + CL1 + CL2)	-	7,817

Performance Aspects

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NOKIA

Deployment Aspects

Performance verification

- There are no new NB-IoT specific counters and KPIs introduced and related to LTE4475 functionality
  - Starting from FL18A on SBM request new Counters and KPIs for NB-IoT Setup Success Rate per Coverage Level are introduced via LTERLCR-25672
- Existing counters introduced with LTE3071 NB-IoT Inband and LTE3669 NB-IoT Paging Support features can be reused for monitoring of the feature performance

Performance Aspects

NB-IoT cell performance monitoring after NB-IoT Multiple Coverage Levels activation

KPI description	How to measure?
Total Ratio of Successful NB IoT Sessions This KPI provides total ratio of successful NB IoT sessions covering both NB IoT UEs doing data transmissions on SRB1 bis and SRB1.	E-UTRAN Total Ratio of Successful NB IoT Sessions LTE_6174a = 100* (sum([NB_IOT_RRC_CONN_ESTAB_SUCC]) / sum([NB_IOT_RRC_CONN_ESTAB_ATT]))*(sum([NB_IOT_S1_SIGN_CONN_ESTAB_SUCC]) / sum([NB_IOT_S1_SIGN_CONN_ESTAB_ATT]))*(sum([NB_IOT_UE_CTX_REL_UE_INACTIVE] + [NB_IOT_UE_CTX_REL_DETACH] + [NB_IOT_UE_CTX_REL_NORMAL]) / sum([NB_IOT_UE_CTX_REL_ENB_INIT] + [NB_IOT_UE_CTX_REL_MME_INIT]))
Average Session Duration for NB-IoT UEs KPI shows average session duration for NB IoT UEs. Under session a NB IoT UE state between RRC Connection Request (received by eNB) and RRC Connection Release (sent by eNB) for only those NB IoT UEs which have successfully sent RRC Connection Setup Complete message to the eNB is meant.	E-UTRAN Average Session Duration for NB IoT UEs LTE_6177b = sum([NB_IOT_UE_BATT_USAGE_TIME_SUM]) / sum([NB_IOT_RRC_CONN_ESTAB_SUCC])

Performance Aspects

NB-IoT cell performance monitoring after NB-IoT NB-IoT Multiple Coverage Levels activation

KPI description	How to measure?
UL Resource Utilization Ratio for NB IoT UEs The KPI shows the ratio of the used UL resources and available resources given in the number of one ms intervals assigned for NB IoT UEs in the observation period.	E-UTRAN UL Resource Utilization Ratio for NB IoT Ues LTE_6175a = 100*sum([NB_IOT_RESOURCES_USED_UL]) / (48*sum([NB_IOT_TIME_RESERVED_UL]))
DL Resource Utilization Ratio for NB IoT UEs The KPI shows the ratio of the used and available PRBs for NB IoT UEs in DL direction in the observation period.	E-UTRAN DL Resource Utilization Ratio for NB IoT Ues LTE_6176a = 100*sum([NB_IOT_RESOURCES_USED_DL]) / sum([NB_IOT_RESOURCES_AVAIL_DL])

Performance Aspects

NB-IoT cell performance monitoring after NB-IoT Multiple Coverage Levels activation

KPI description	How to measure?
RRC Connection Setup Success Ratio with Cause mt-Access for NB IoT UEs The KPI shows the setup success ratio for the elementary procedure "RRC connection establishment" used to set up a radio connection from NB IoT UE to eNB (involves SRB1 establishment) for mt-Access cause.	E-UTRAN RRC Connection Setup Success Ratio with cause mt-Access for NB IoT UEs LTE_6280a = 100*sum([NB_IOT_RRC_ESTAB_MT_SUCC]) / sum([NB_IOT_RRC_ESTAB_MT_ATT])
Percentage of Completed RRC connection requests with mt-Access cause for NB-IoT Ues The KPI shows ratio of completed RRC connection requests with mt-Access cause for NB-IoT UEs to total number of completed RRC connection requests for NB-IoT UEs.	E-UTRAN Percentage of Completed RRC connection requests with mt-Access cause for NB-IoT UEs LTE_6282a = 100*sum([NB_IOT_RRC_ESTAB_MT_SUCC]) / sum([NB_IOT_RRC_CONN_ESTAB_SUCC])

Performance Aspects

NB-IoT cell performance monitoring after NB-IoT Multiple Coverage Levels activation – FL18A LTERLCR-25672

KPI description	How to measure?
RRC Connection Setup Success Ratio for NB IoT UEs per CE Level 0 The KPI shows the setup success ratio for the elementary procedure "RRC connection establishment" used to set up a radio connection from NB IoT UE to eNB (involves SRB1 establishment) per Coverage enhancement level 0.	E-UTRAN RRC Connection Setup Success Ratio for NB IoT UEs per CE Level 0 LTE_6670a = 100*sum([NB_IOT_RRC_CONN_ESTAB_SUCC] – [NB_IOT_RRC_CONN_EST_CE1_SUCC] – [NB_IOT_RRC_CONN_EST_CE2_SUCC]) / sum([NB_IOT_RRC_CONN_ESTAB_ATT] – [NB_IOT_RRC_CONN_ESTAB_CE1_ATT] – [NB_IOT_RRC_CONN_ESTAB_CE2_ATT])
RRC Connection Setup Success Ratio for NB IoT UEs per CE Level 1 The KPI shows the setup success ratio for the elementary procedure "RRC connection establishment" used to set up a radio connection from NB IoT UE to eNB (involves SRB1 establishment) per Coverage enhancement level 1.	E-UTRAN RRC Connection Setup Success Ratio for NB IoT UEs per CE Level 1 LTE_6671a = 100*sum([NB_IOT_RRC_CONN_EST_CE1_SUCC]) / sum([NB_IOT_RRC_CONN_ESTAB_CE1_ATT])
RRC Connection Setup Success Ratio for NB IoT UEs per CE Level 2 The KPI shows the setup success ratio for the elementary procedure "RRC connection establishment" used to set up a radio connection from NB IoT UE to eNB (involves SRB1 establishment) per Coverage enhancement level 2.	E-UTRAN RRC Connection Setup Success Ratio for NB IoT UEs per CE Level 2 LTE_6672a = 100*sum([NB_IOT_RRC_CONN_EST_CE2_SUCC]) / sum([NB_IOT_RRC_CONN_ESTAB_CE2_ATT])

Performance Aspects

NB-IoT cell performance monitoring after NB-IoT Multiple Coverage Levels activation – FL18A LTERLCR-25672

KPI description	How to measure?
UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per CE Level 0 This KPI shows the UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per coverage enhancement level 0.	E-UTRAN UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per CE Level 0 LTE_6673a = 100*sum([NB_IOT_S1_SIGN_CONN_ESTAB_SUCC] – [NB_IOT_S1_SGN_CON_EST_SUCC_CE1] – [NB_IOT_S1_SGN_CON_EST_SUCC_CE2]) / sum([NB_IOT_S1_SIGN_CONN_ESTAB_ATT] – [NB_IOT_S1_SIGN_CON_EST_ATT_CE1] – [NB_IOT_S1_SIGN_CON_EST_ATT_CE2])
UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per CE Level 1 This KPI shows the UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per coverage enhancement level 1.	E-UTRAN UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per CE Level 1 LTE_6674a = 100*sum([NB_IOT_S1_SGN_CON_EST_SUCC_CE1]) / sum([NB_IOT_S1_SIGN_CON_EST_ATT_CE1])
UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per CE Level 2 This KPI shows the UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per coverage enhancement level 2.	E-UTRAN UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per CE Level 2 LTE_6675a = 100*sum([NB_IOT_S1_SGN_CON_EST_SUCC_CE2]) / sum([NB_IOT_S1_SIGN_CON_EST_ATT_CE2])

Performance Aspects

NB-IoT counters (M8066)

Counter Id	Full name	Abbreviated name
M8066C0	Maximum number of RRC connected NB-IoT UEs	NB_IOT_RRC_CONN_MAX
M8066C1	Sum of RRC Connected NB-IoT UEs	NB_IOT_RRC_CONN_SUM
M8066C2	Attempted RRC Connection Establishment for NB-IoT UEs	NB_IOT_RRC_CONN_ESTAB_ATT
M8066C3	Successful RRC Connection Establishment for NB-IoT UEs	NB_IOT_RRC_CONN_ESTAB_SUCC
M8066C4	Attempted UE-associated logical S1-Connection Establishments for NB-IoT UEs	NB_IOT_S1_SIGN_CONN_ESTAB_ATT
M8066C5	Successful UE-associated logical S1-Connection Establishments for NB-IoT UEs	NB_IOT_S1_SIGN_CONN_ESTAB_SUCC
M8066C6	Denominator for average number of RRC connected NB-IoT UEs	NB_IOT_RRC_CONN_UE_DENOM

Performance Aspects

NB-IoT counters (M8066)

Counter Id	Full name	Abbreviated name
M8066C7	UE movement to ECM idle state due to user inactivity	NB_IOT_UE_CTX_REL_UE_INACTIVE
M8066C8	UE movement to ECM idle state due to insufficient radio resources	NB_IOT_UE_CTX_REL_RRNA
M8066C9	UE movement to ECM idle state due to detach	NB_IOT_UE_CTX_REL_DETACH
M8066C10	UE movement to ECM idle state due to first level call release	NB_IOT_UE_CTX_REL_NORMAL
M8066C11	UE movement to ECM idle state (eNB initiated)	NB_IOT_UE_CTX_REL_ENB_INIT
M8066C12	UE movement to ECM idle state (MME initiated)	NB_IOT_UE_CTX_REL_MME_INIT
M8066C13	Accumulated time duration in RRC_CONNECTED for NB-IoT UEs	NB_IOT_RRC_CONN_TIME_SUM
M8066C14	MAC PDU volume in UL for NB-IoT UEs	NB_IOT_MAC_PDU_VOL_UL
M8066C15	MAC PDU volume in DL for NB-IoT UEs	NB_IOT_MAC_PDU_VOL_DL
M8066C16	Number of used NB-IoT UL resources	NB_IOT_RESOURCES_USED_UL
M8066C17	Total number of one millisecond intervals reserved for NB-IoT UEs in UL	NB_IOT_TIME_RESERVED_UL
M8066C18	Used NB-IoT DL resources	NB_IOT_RESOURCES_USED_DL
M8066C19	Available NB-IoT DL resources	NB_IOT_RESOURCES_AVAIL_DL

Performance Aspects

NB-IoT counters (M8066)

Counter Id	Full name	Abbreviated name
M8066C20	Number of RRC paging requests (records) for NB-IoT UEs.	NB_IOT_RRC_PAGE_REQ
M8066C21	Number of dropped RRC paging records for NB-IoT UEs due to paging record list overflow.	NB_IOT_RRC_PAGE_REQ_DISC_OVL
M8066C22	Number of dropped RRC paging records for NB-IoT UEs due to overlapping paging occasions (POs).	NB_IOT_RRC_PAGE_REQ_DISC_OVLAP
M8066C23	Number of attempted RRC Connection Establishment requests with cause "mt-Access" for NB-IoT UEs.	NB_IOT_RRC_ESTAB_MT_ATT
M8066C24	Number of successful RRC Connection Establishments with cause "mt-Access" for NB-IoT UEs.	NB_IOT_RRC_ESTAB_MT_SUCC

Performance Aspects

NB-IoT counters per CL (M8066) - FL18A LTERLCR-25672

Counter Id	Full name	Abbreviated name
([M8066C3] – [M8066C44] – [M8066C45])	RRC connection setup completions for NB IOT UEs per CE0	NB_IOT_RRC_CONN_ESTAB_SUCC] – [NB_IOT_RRC_CONN_EST_CE1_SUCC] – [NB_IOT_RRC_CONN_EST_CE2_SUCC])
M8066C44	RRC connection setup completions for NB IOT UEs per CE1	NB_IOT_RRC_CONN_EST_CE1_SUCC
M8066C45	RRC connection setup completions for NB IOT UEs per CE2	NB_IOT_RRC_CONN_EST_CE2_SUCC
([M8066C2] – [M8066C33] – [M8066C34])	RRC connection requests for NB IoT UES per CE0	([NB_IOT_RRC_CONN_ESTAB_ATT] – [NB_IOT_RRC_CONN_ESTAB_CE1_ATT] – [NB_IOT_RRC_CONN_ESTAB_CE2_ATT]
M8066C33	RRC connection requests for NB IoT UES per CE1	NB_IOT_RRC_CONN_ESTAB_CE1_ATT
M8066C34	RRC connection requests for NB IoT UES per CE2	NB_IOT_RRC_CONN_ESTAB_CE2_ATT

RRC Connection Setup Success Ratio for NB IoT UEs per CE Level

Performance Aspects

NB-IoT counters per CL (M8066) - FL18A LTERLCR-25672

Counter Id	Full name	Abbreviated name
([M8066C5] – [M8066C48] - [M8066C49])	Number of Succesful NB IoT UE-associated logical S1-Connection Establishments per CE0	NB_IOT_S1_SIGN_CONN_ESTAB_SUCC] – [NB_IOT_S1_SGN_CON_EST_SUCC_CE1] – [NB_IOT_S1_SGN_CON_EST_SUCC_CE2])
M8066C48	Number of Succesful NB IoT UE-associated logical S1-Connection Establishments per CE1	NB_IOT_S1_SGN_CON_EST_SUCC_CE1
M8066C49	Number of Succesful NB IoT UE-associated logical S1-Connection Establishments per CE2	NB_IOT_S1_SIGN_CON_EST_ATT_CE1
([M8066C4] – [M8066C46] – [M8066C47])	Number of Attempted NB IoT UE-associated logical S1-Connection Establishments per CE0	([NB_IOT_S1_SIGN_CONN_ESTAB_ATT] – [NB_IOT_S1_SIGN_CON_EST_ATT_CE1] – [NB_IOT_S1_SIGN_CON_EST_ATT_CE2])
M8066C46	Number of Attempted NB IoT UE-associated logical S1-Connection Establishments per CE1	NB_IOT_S1_SGN_CON_EST_SUCC_CE2
M8066C47	Number of Attempted NB IoT UE-associated logical S1-Connection Establishments per CE2	NB_IOT_S1_SIGN_CON_EST_ATT_CE2

UE-associated logical S1-Connection Establishment Success Ratio for NB IoT UEs per CE Level

Technical Details
Forced RRC Connection Release

New timer *NBIOT_FDD:tCellDelNB* is introduced as a guard time to force release UE context(s).

- Timer starting or restarting triggers cell deletion (or cell locking).
    - Once *tCellDelNB* is started, the eNB will set in SIB1-NB cellBarred-r13 IE to 'barred'.
- If timer expires, all the UE contexts are released and their radio resources are forced to be deleted.
    - The eNB will stop and interrupt ongoing: RRC Connection Release, RLF timer expiration will force deletion of all related radio resources.

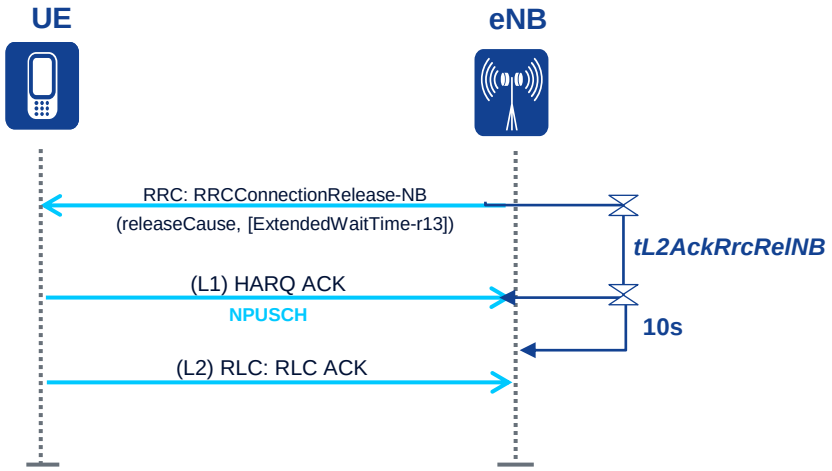
Timer	Start/ Restart	Expiry	Stop
tCellDelNB	Trigger for procedures: - cell delete - cell lock	All UE Contexts 'not properly' released and their radio resources are forced to be deleted. Note: 'forced release' - eNB stops: -scheduling RRC Conn. Releases if not sent yet -waiting for tL2AckRrcRelNB expiry and L1/L2 ACK - waiting for RLF timer expiry	All UE Contexts are 'properly' released before timer expiration.

Technical Details

RRC Connection Release NB-IoT UEs procedure

New *NBIOTPR*:*tL2AckRrcRelNB* was introduced for RRC Connection Release procedure for NB-IoT Users.

- RRC Connection Release procedure starts ***tL2AckRrcRelNB*** timer to guard RRC Connection Release procedure:
  - If ACK HARQ (on L1) is received shall be supervised and if receive, ***tL2AckRrcRelNB*** is to be restarted to fixed 10s. If the timer expires or L2 RLC ACK is received meanwhile, the eNB will send **S1AP: UE CONTEXT RELEASE COMPLETE** and release the RRC connection and all eNB resources assigned to this UE Context.
  - If there is **no HARQ ACK (L1)** sent and if ***tL2AckRrcRelNB*** **expires** or "**maximum number of RLC retransmissions reached**", the eNB will send **S1AP: UE CONTEXT RELEASE COMPLETE** and release the RRC connection and all eNB resources assigned to this UE Context.



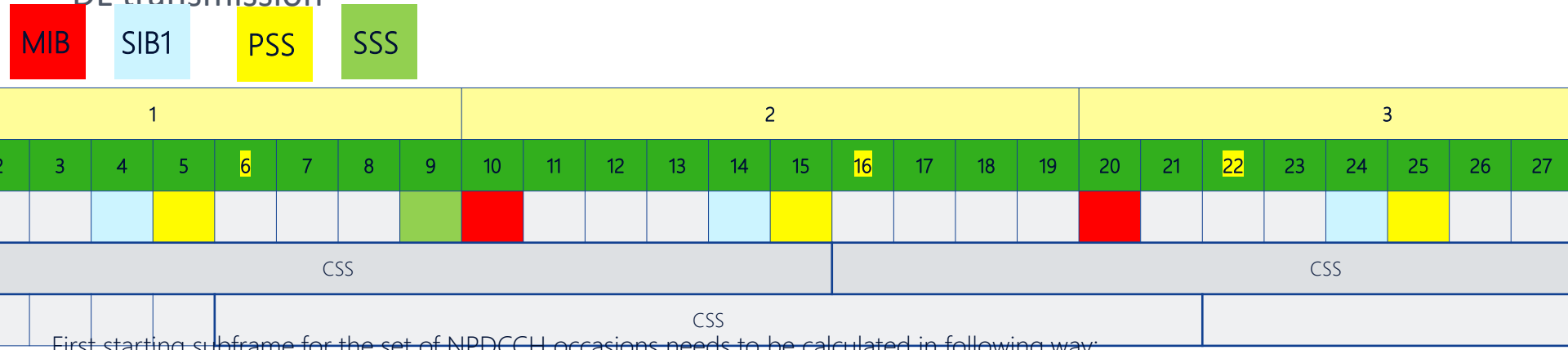
Timer	Start / Restart	Expiry	Stop
tL2AckRrcRelNB	Start: Transmission of RRC Connection Release-NB. Restart: to fixed 10 sec after reception of L1 HARQ ACK.	The eNB sends S1AP: UE CONTEXT RELEASE COMPLETE and all transport, radio and internal resources related to the concerned RRC connection are released (e.g. RAC, TAC, U-Plane).	L2 ACK received or "maximum number of RLC retransmissions reached". Then eNB sends S1AP: UE CONTEXT RELEASE COMPLETE and all transport, radio and internal resources related to the concerned RRC connection are released (e.g. RAC, TAC, U-Plane)

Please note: The RRC Connection Release message for NB-IoT UE is sent only once.

Copyright and confidentiality

Technical Details

DL transmission



First starting subframe for the set of NPDCCH occasions needs to be calculated in following way:

npdcchOffsetRa * (CSS duration).

Assumptions:

(R_max) npdcchMaxNumRepRa = 8

(G_factor) npdcchStartSfRa = 2

a) npdcchOffsetRa = 0

b) npdcchOffsetRa = 3/8

Outputs:

CSS duration = (R_max x G_factor) = *npdcchMaxNumRepRa* x *npdcchStartSfRa*

a) for *npdcchOffsetRa* = 0 SFN 0, 16, 32, 48 …. are NPDCCH starting SFs

b) for *npdcchOffsetRa* = 3/8 SFN 6, 22, 38, 54 …. are NPDCCH starting SFs


NOKIA