BIG DATA &
NETWORK ENGINEERING

LTE3071 NB-IoT

Updated with RP001597 “Support of LTE in-band NB-IoT with RF sharing in SRAN "

Part 1&2

Please, always check the latest version of NEI slides.

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Part 1

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LTE3071 NB-IoT

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Introduction

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Introduction

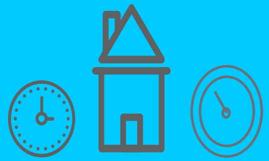
IoT use cases

Internet of Things

Massive IoT connectivity

LTE3071
NB-IoT

- Simple cheap devices
- Low energy consumption
- Massive number of devices
- Full coverage, low datarate
- Example: Smart meters



Critical IoT connectivity

- „Always available“
- Very low latency
- Flexibility
- Example: Connected cars

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Introduction

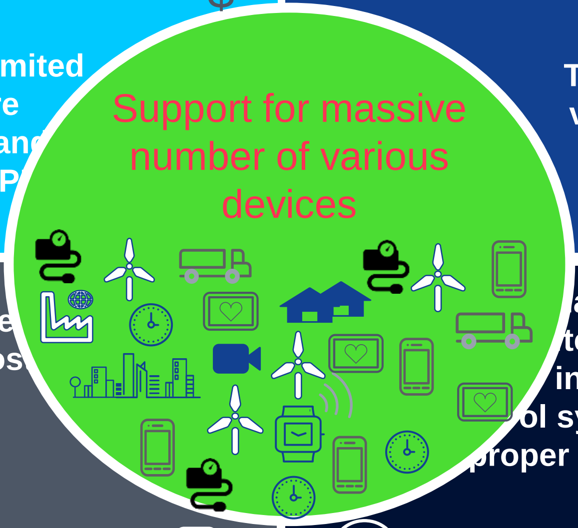
Massive IoT connectivity (key enablers)

Low deployment cost

IoT support introduction should be limited to simple, centrally-triggered software upgrade, without any new hardware and site visits needs. As a result both CAP… and OPEX can be minimized.

Long battery life

The battery replacement interval is a very important cost factor. Many IoT devices must thus operate for a very long time.



To make simple, low data rates device… popular and commonly used, total cos… ownership must be really low.

Current target – device cost < 5USD.

Low device cost

…any devices will be located indoors, …ten in basements (like smart meters) in underground parking lots (parking …ol system). Enhanced coverage needed …proper handling of such devices is a must.

Enhanced coverage

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Introduction
Radio technology space

- Coverage: 164 dB
- Module cost: $2-4
- Battery life: +10 years
- Scalability: +50k/cell*
- Bit rate per UE : <56kbit/s
- Network upgrade: SW
- Spectrum: GSM /LTE (200kHz or shared)

RAN Rel. 13 **NB-IoT 200kHz**

- Coverage: 156 dB
- Module cost: $3-5
- Battery life: +10 years
- Scalability: +50k/cell*
- Bit rate per UE : <1Mbit/s
- Network upgrade: SW
- Spectrum: LTE (1.4 MHz or shared)

RAN Rel. 13 **LTE-M 1.4MHz**

Massive IoT connectivity

- Simple cheap devices
- Low energy consumption
- Massive number of devices
- Improved coverage, low datarate

Internet of Things

- Coverage: 164 dB
- Module cost: $3-5
- Battery life: +10 years
- Scalability: +50k/cell*
- Bit rate per MS : <70kbit/s
- Network upgrade: SW
- Spectrum: GSM (200kHz or shared)

GERAN Rel. 13 **EC-GSM**

*Note: Assumptions according to the Traffic Model defined by 3GPP (3GPP TS 45.820). Different assumptions will lead to different numbers.

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Introduction

Internet of Things example use cases classification

→ Medium size messages
→ Frequent in time
→ Applicable where LTE system is already in place
→ Network resources utilization: up to 6PRBs
→ Coverage: up to 156 dB (Pathloss)

LTE-M

→ Small messages
→ Not frequent in time
→ Applicable where LTE system is already in place
→ Network resources utilization: 1PRB
→ Coverage: up to 164 dB (Pathloss)

NB-IoT

→ Small messages
→ Not frequent in time
→ Applicable where GSM system is already in place and no LTE
→ Network resources utilization: 1TSL for signalling and data traffic multiplexed with legacy users
→ Coverage: up to 164 dB (Pathloss)

EC-GSM

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Introduction
3GPP IoT traffic model (45.820 Annex E)

Report type	Packet size	Inter-arrival time
Mobile Autonomous Reporting (MAR) exception reports → E.g. smoke detectors, power failure notifications from smart meters, tamper notifications etc.	**UL:** 20 bytes	**Months to years** (reaction time up to 10 second latency)
Mobile Autonomous Reporting (MAR) periodic reports → E.g. smart utility (gas/water/electric) metering reports, smart agriculture etc.	**UL**: 20 - 200 bytes Pareto distributed **DL:** Ack	40%: Once per day 40%: Once every 2 hours 15%: Once per hour 5%: Once per 30 min => **Mean = 0.47 times per hour**
Network originated reports → E.g. trigger the device to send an uplink report as a result of the network command e.g. request for a smart meter reading	**DL:** 20 bytes **UL:** 20 – 200 bytes Pareto distributed	40%: Once per day 40%: Once every 2 hours 15%: Once per hour 5%: Once per 30 min => **Mean = 0.47 times per hour**
Software update/reconfiguration model → Software updates or patches of Cellular IoT devices. Rare, but large payload sizes expected for complete software updates	**DL:** 200 - 2000 bytes Pareto distributed	**180 days**

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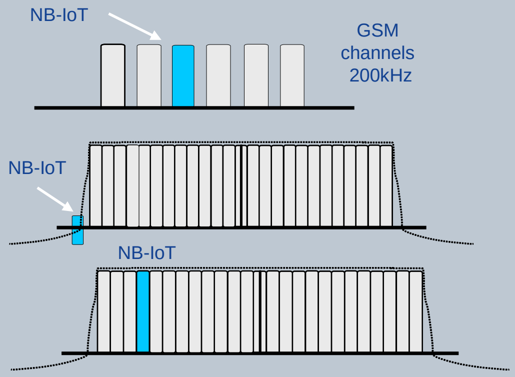
Introduction

NB-IoT 200kHz

Brief description

- Narrowband LTE (NB-IoT) is designed for support of low throughput, low complexity and low energy consumption Machine Type Communications. Inband operation with legacy LTE system is possible.
- NB-IoT specified by Rel-13 3GPP TR 45.820



NB-IoT 200kHz	
Range	<35km
Battery life	>10 years
Frequency bands	LTE bands
Bandwidth	200kHz or shared
Modulation	DL: OFDMA with 15 kHz subcarrier spacing UL: Single tone transmissions – 3.75 and 15 kHz, Multi-tone SC-FDMA with 15 kHz subcarrier spacing
Max throughput	< 56 kbps UL, < 26kbps DL
Link budget	164 dB
Capacity	+50k IoT devices per sector

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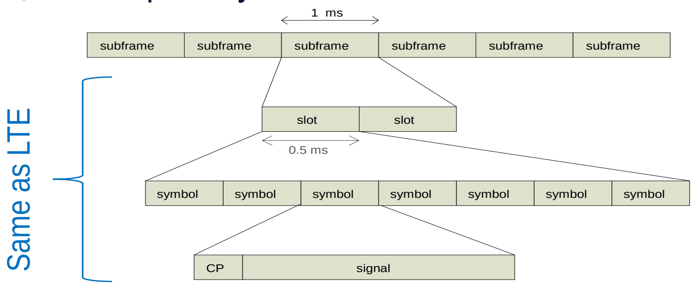
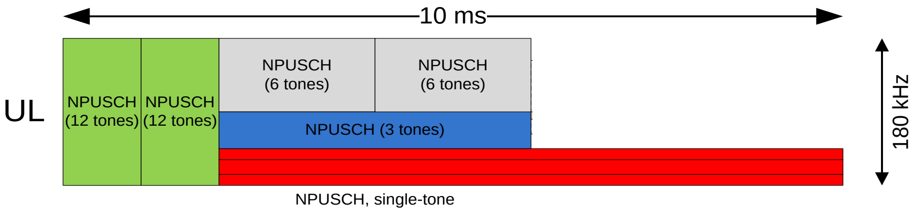
Introduction
NB-IoT 200kHz

- Single NB-IoT carrier occupies one LTE PRB in the frequency domain (180 kHz)
- NB-IoT downlink:
  - The same as for LTE - based on OFDMA with 15 kHz subcarrier spacing. Also slot, subframe, and frame durations are identical to those in LTE as well as Number of OFDM symbols per slot
  - Only Normal CP is supported for NB-IoT.
- Maintaining LTE structure for NB-IoT ensure orthogonality between the NB-IoT PRB and legacy LTE PRBs, valid especially for in-band scenarios





- NB-IoT uplink: 3GPP defines multi-tone and single-tone transmissions
- Multi-tone transmission is based on legacy LTE SC-FDMA with the same 15 kHz subcarrier spacing, 0.5 ms slot, and 1 ms subframe.
- Two options for single-tone transmission exists: 15 kHz and 3.75 kHz.
- The 15 kHz option is identical to LTE and thus achieves the best coexistence performance with LTE in the uplink
- **Only 15 KHz UL single tone option selected for NPUSCH with LTE3071.**

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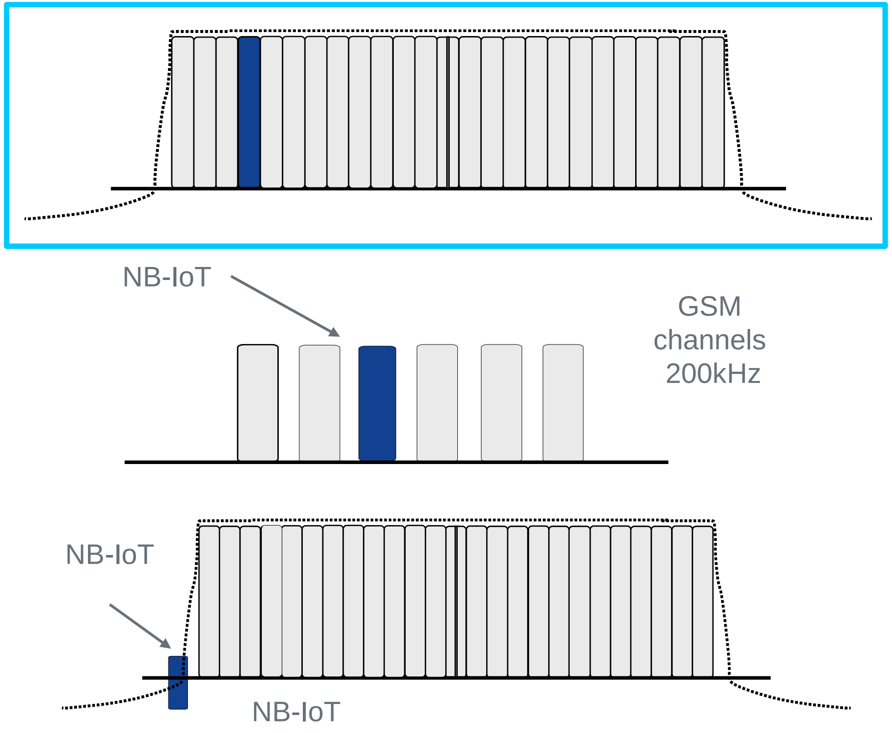
Introduction

NB-IoT 200kHz - Modes of operation

3GPP defines 3 different modes of operation for NB-IoT:

- **'In-band operation' utilizing resource blocks within a normal LTE carrier and shares some HW and SW resources with host LTE cell (FL17SP)**
- 'Stand-alone operation' utilizing for example the spectrum currently being used by GERAN systems as a replacement of one or more GSM carriers, brand new cell without resource sharing with other legacy LTE cells (FL17A)
- 'Guard band operation' utilizing the unused resource blocks within a LTE carrier's guard-band (FL17A+)



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Introduction

Low cost devices

NB-IoT device is characterized by lower: complexity, power consumption and the price

	Release 8	Release 8	Release 12	Release 13	Release 13
	Category 4	Category 1	Category 0	Cat-M1	Cat-NB1
Downlink peak rate	150 Mbps	10 Mbps	1 Mbps	**1 Mbps**	**<26 kbps**
Uplink peak rate	50 Mbps	5 Mbps	1 Mbps	**1 Mbps**	**<56 kbps**
Number of antennas	2	2	1	**1**	**1**
Duplex mode	Full duplex	Full duplex	Half duplex	**Full/Half duplex**	**Half duplex**
UE receive bandwidth	20 MHz	20 MHz	20 MHz	**1.4 MHz**	**200 kHz**
UE transmit power	23 dBm	23 dBm	23 dBm	**20 dBm**	**23 dBm**
Modem complexity	**100%**	**80%**	**40%**	**20%**	**15%**

NB-IoT UE complexity reduction may be achieved due to half duplex, single antenna usage and smaller bandwidth. At the same time it implies smaller data rates, leading to smaller energy consumption as well as the lower device price.

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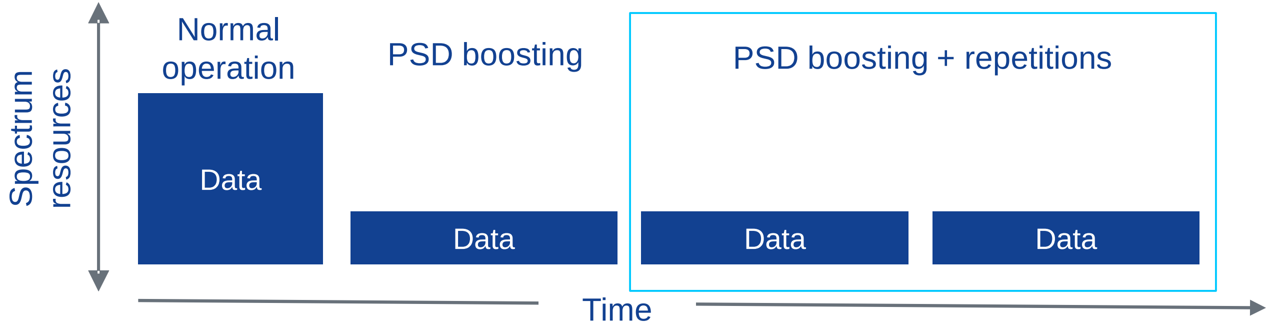
Introduction

Coverage improvements

- IoT optimized technologies have target of 15-20 dB coverage improvement comparing to legacy solutions
- One of the techniques is Power Spectral Density (PSD) boosting where less resources are used in the frequency domain to concentrate transmitted power
- Repetition is also well known technique, wanted signal is constructed from many transmissions
- Note that coverage techniques compromise capacity and increase delays as more time is needed for signal acquisition



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Introduction
Before & after

Before

- M2M/IoT traffic was served by legacy networks ineffectively
- A lot of small messages would create control plane blocking
- Problems with coverage for devices in critical locations
- Modem cost blocks massive deployment

After

- NB-IoT technology was developed to serve massive number of IoT devices
- Optimized for improved coverage
- Simplified modem helps to reduce implementation costs
- Easy deployment by software upgrade of the legacy network

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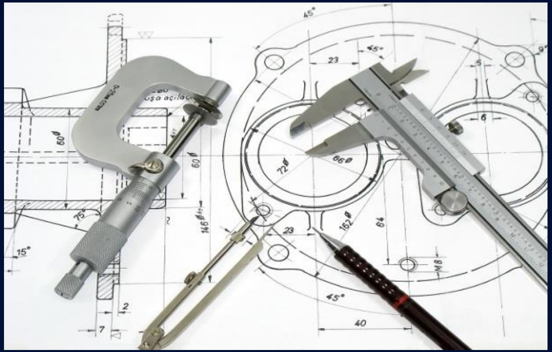
Technical Details



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Technical Details
Dependency Table (LTE)

Sales information

BSW/ASW	ASW

Release information

Release/version	RL release	eNodeB	NetAct
FDD LTE	FDD-LTE 17A	FL17A	NetAct 17.8
TDD LTE	-	-	-
Flexi Zone Micro (FZM/FZP)	FDD-LTE 17A	FLF17A	NetAct 17.8
Flexi Zone Controller (FZC)	-	-	-
Single RAN	SRAN17A	SBTS17A	NetAct 17.8

Release information – general

HW & IOT	HW requirements	MME	SAE GW	UE	Specified by 3GPP
	FSMF, FZM, (AirScale support comes with LTE3509)			Rel. 13 Cat-NB1	Rel-13 TR 45.820

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Technical Details
FL17A NB-IoT Overview

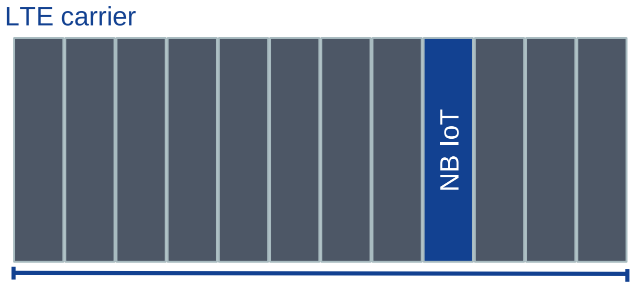
Basic 3GPP Rel. 13 **in-band NB-IoT** functionality is introduced with **LTE 3071** feature.

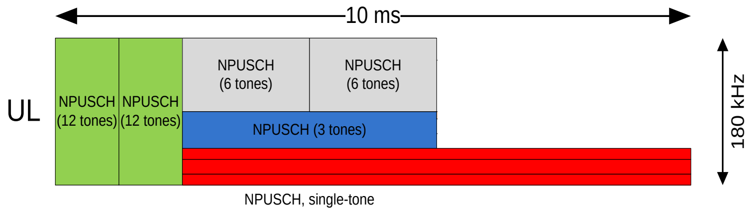
- New cell concept and deployment options:
  - FDD mode, **half duplex operations, 200 kHz** UE RF bandwidth for both downlink and uplink
  - DL: OFDMA with 15 kHz subcarrier spacing, TM2
  - UL: **single tone transmissions –15 kHz**, **2 RX MRC* receiver**
- The data transmission over **SRB1bis** (data over NAS)
- **First level coverage** (without coverage enhancement) with MCL pathloss target up to **144dB** is supported
- **FSMF and FZM deployments**

Airscale support comes separately with **LTE3509**

Higher coverage levels are supported with **LTE3668** NB-IoT Coverage Enhancements

Paging support for NB-IoT will be activated with **LTE3669**





MRC* Maximum Ratio Combining

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Technical Details
NB-IoT support for SRAN17A

- **NB-IoT is introduced into SRAN with RP001597 feature**
- The RP001597 feature basically consists of porting the below LTE features to SBTS:
  - **LTE3071 NB-IoT Inband**
  - LTE3509 NB-IoT: Inband on Airscale without Baseband Pooling
  - LTE3668 NB-IoT: Coverage enhancements
  - LTE3819 IoT: Cat-M and NB-IoT on same frequency carrier
  - LTE3669 NB-IoT: Paging support
- RP001597 allows for:
  - in-band NB-IoT cells on both FSMr3 and FSMr4 HW releases
  - up to 20dB coverage enhancement so that to reach 164dB for the Maximum coupling loss (MCL) of the NB-IoT cell
  - simultaneous activation of Cat-M and in-band NB-IoT in a hosting LTE cell 2Tx2Rx 10MHz on FSMr3
  - paging of NB-IoT UE for mobile terminated connections in normal or extreme coverage

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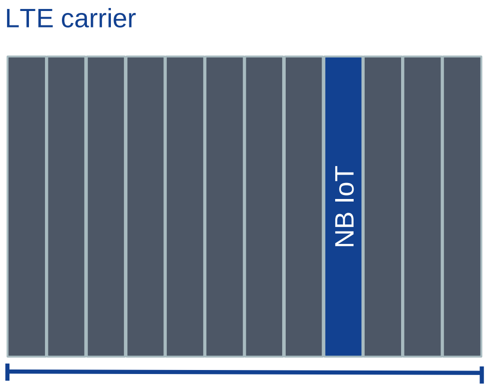
LTE 3071 NB-IoT – Inband operation

- **One NB-IoT carrier** can be configured for each legacy 5/10/15/20 MHz FDD LTE cell in a 2x2 configuration.
- Allocation of DL NB-IoT carrier is **predefined by 3GPP**. The location of downlink and uplink can be configured separately.
- Selected UL PRB should not overlap with PUCCH or PRACH area (also with UL PUCCH area expansions).
- eNB power is shared between NB-IoT and LTE, power ramping
  for NB-IoT is possible.
- Dedicated RRC connected limit for NB-IoT UEs. This static limit reduces number of legacy RRC connected UEs to keep the total eNB limit unchanged.
- There is **no paging support** with LTE3071, hence only mobile originated calls can be handled.



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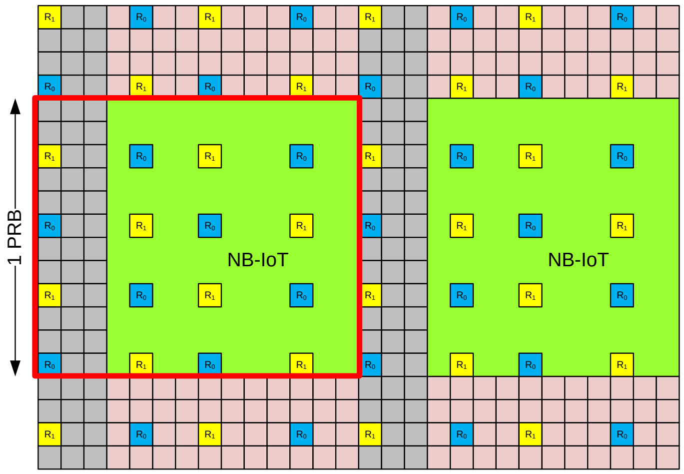
LTE 3071 NB-IoT – Inband operation

- Since the same OFDM modulation with 15 kHz subcarrier spacing is used in DL there is no interference between
  NB-IoT and legacy LTE, providing that NB-IoT signals are not mapped to the resource elements occupied by the legacy LTE.
- A **protection** of legacy cell resource elements is supported for the **fixed first 3 OFDM symbols** (wideband PDCCH area) and for **CRS area**. NB-IoT is punctured out to accommodate legacy LTE control channels and CRS.
- With LTE3071 only **one NB-IoT PRB per hosting LTE cell** is supported. Hosting **legacy cell PCI** is used for NB-IoT.
- Dedicated power settings can be applied for NB-IoT resource elements, the maximum DL power offset is 6 dB over normal LTE PRBs.



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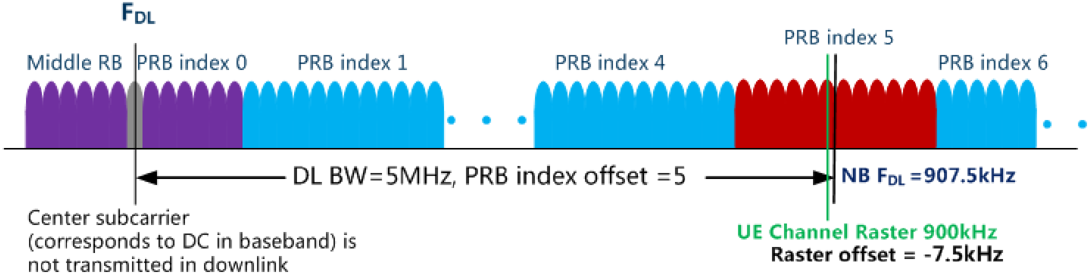
Technical Details

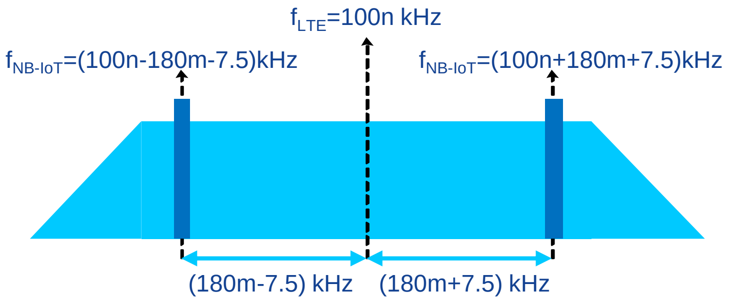
Channel Raster

- According to 3GPP LTE carriers are allocated with 100 kHz channel raster, and channel center refers to the unused DC subcarrier in LTE. NB-IoT carrier center refers to the PRB center.
- There is frequency offset between center of legacy LTE + multiple of 100kHz and center of NB-LTE carrier, depending whether even or odd number of PRBs are in use

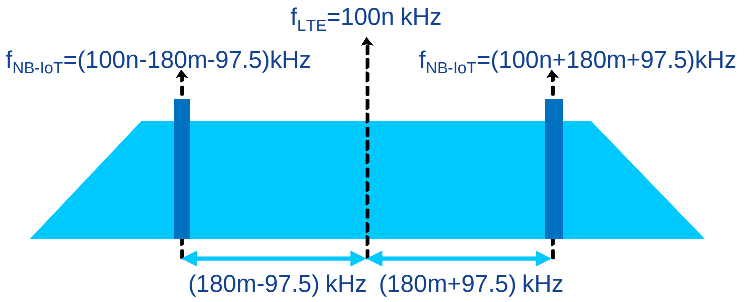


10/20MHz - {**2.5kHz**, 17.5kHz, 22.5kHz, 37.5kHz, 42.5kHz}.

5/15MHz - {**7.5kHz**, 12.5kHz, 27.5kHz, 32.5kHz, 47.5kHz}.



5/15 MHz LTE, m=4,5,6…



10/20 MHz LTE, m=3,4,5…

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PRB selection for in-band operation

- NB-IoT UE follows 3GPP raster rules; it means that is tuned not to the PRB center, but 100kHz multiplicity
- NB-IoT carrier is used for UE initial synchronization, that is why frequency error have to be minimized, and PRB indexes with the lowest offset selected (+/-7.5 or 2.5 kHz). They are referred as an anchor carriers ***(NBIOT_FDD: inbandPRBIndexDL)*** . Middle 6 PRBs of the LTE carrier are restricted due to occupation by synchronization and broadcast channels

PRB index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
PRB offset	12	11	10	9	8	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	10	11	12
PRB frequency	5832.5	6012.5	6192.5	6372.5	6552.5	6732.5	6912.5	7092.5	7272.5	7452.5	7632.5	7812.5		8187.5	8367.5	8547.5	8727.5	8907.5	9087.5	9267.5	9447.5	9627.5	9807.5	9987.5	10168

if (odd bandwidth and offset <0) FDL_delta = - 180*m - 7.5kHz

if (odd bandwidth and offset >0) FDL_delta = + 180*m + 7.5kHz

LTE system bandwidth	5 MHz	10 MHz	15 MHz	20 MHz
DL PRB indices	2, 7, 17, 22	4, 9, 14, 19, 30, 35 40, 45	2, 7, 12, 17, 22, 27, 32, 42, 47, 52, 57, 62, 67, 72	4, 9, 14, 19, 24, 29, 34, 39, 44, 55, 60, 65, 70, 75, 80, 85, 90, 95

- NB-IoT UL PRB can be configured from **any uplink PRB *(NBIOT_FDD: inbandPRBIndexUL)*** not used for PRACH/PUCCH and possible PRACH/PUCCH if dynamic PUCCH enabled in host LTE cell.
  - PRB from the outer region outside area in host LTE cell by PUCCH blanking.
  - PRB from the inner region of PUSCH. The adjacent PRB near PUCCH is preferred to avoid uplink resource fragment if dynamic PUCCH is not enabled.

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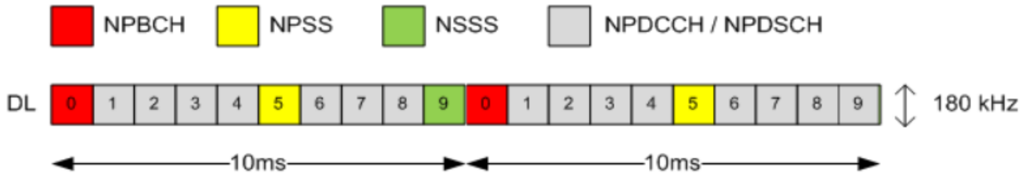
Technical Details
NB-IoT – Downlink

- DL uses OFDMA with 15 kHz subcarrier spacing, 12 subcarriers available in 1 NB-IoT carrier, 10ms frame, 100 kHz channel raster



- Narrow 200 kHz UE bandwidth does not allow for legacy channels utilization, new DL channels:
  - Narrowband Primary and Secondary Synchonization signals **NPSS/NSSS** - time/frequency synchronization, cell ID and timing for NPBCH detection.
  - Narrowband Common Reference Signals **NRS** for 2 antenna ports transmission schemes
  - Narrowband Physical Broadcast Channel **NPBCH** conveys Narrowband Master Information Block **MIB-NB**.
  - Narrowband Physical Dowlink Control Channel **NPDCCH** carries scheduling information for both DL and UL data channels, HARQ ack and random access response scheduling information.
  - Narrowband Physical Dowlink Shared Channel **NPDSCH** carries data from the higher layers, system information and the random access response messages.

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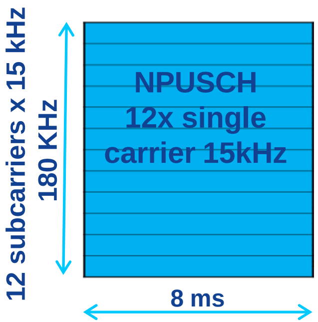
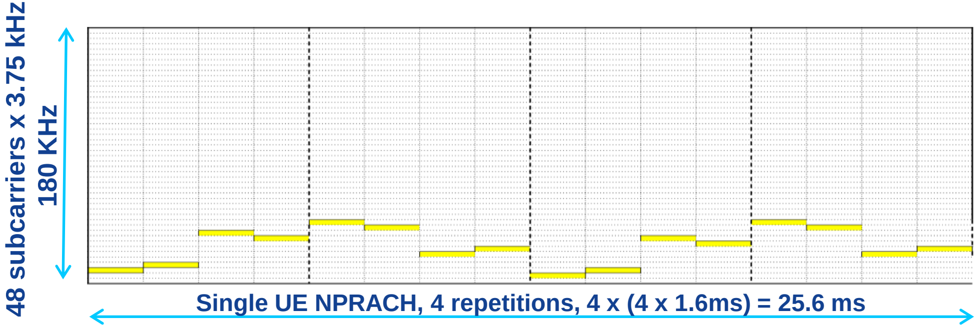
Technical Details

NB-IoT – Uplink Physical Channels

- Narrowband Physical Random Access Channel **NPRACH** carries preamble for Random Access procedure. NPRACH operates on 3.75 kHz subcarrier spacing and predefined hopping schemes with repetitions.
- Narrowband Physical Uplink Shared Channel **NPUSCH**. Among several NPUSCH transmissions options defined by 3GPP (single-, multi-tone, 15 or 3.75 kHz subcarrier spacing) 15 kHz single-tone will be supported for FL17SP LTE3071, 12 subcarriers available.
- The use of a dedicated PUCCH, as used in LTE for carrying uplink control information, is not necessary as its function can be integrated to NPRACH and NPUSCH. ACK/NACK is carried by the NPUSCH, no CQI and SR support.





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Technical Details

NPSS/NSSS

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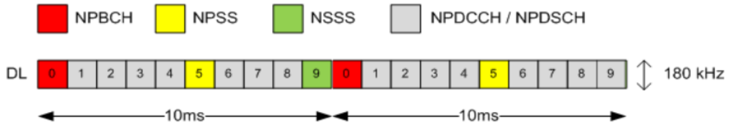
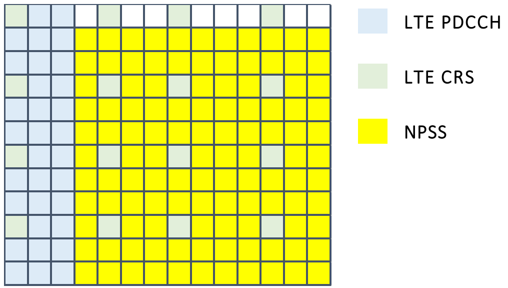
Technical Details
NPSS

- Two synchronization channels are available: primary **NPSS** and secondary **NSSS.**
- NPSS is used for a first frame and subframe synchronization, with NPSS UE determines the frame boundary.
- NPSS carries Zadoff-Chu sequence mapped to the lowest 11 subcarriers within the NB-IoT PRB. The sequence is fixed and therefore carries no information about cell id.
- NPSS is transmitted every 10 ms in subframe #5 and occupies the last 11 OFDM symbols of the subframe.
- NPDSCH/NPDCCH are not mapped to subframes containing NPSS, no NRS on subframes containing NPSS
- NPSS is punctured by LTE CRS





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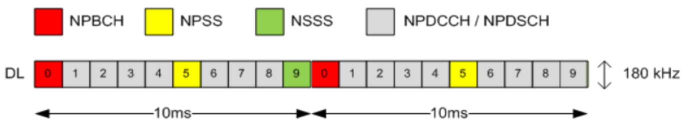
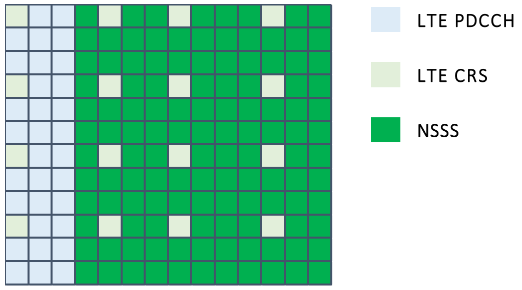
Technical Details
NSSS

- **NSSS** (Narrowband Secondary Synchronisation Signal) indicates PCID and 80 ms boundary (for NPBCH detection).
  In LTE3071 the PCID is same as legacy host LTE cell.
- The NSSS sequence is generated from a length-131 frequency domain Zadoff-Chu sequence, binary scrambled and cyclically shifted depending on the radio frame number.
- The root of the ZC sequence and binary scrambling sequence are determined by narrowband physical cell identity NPCID. Like in LTE, 504 PCI values are defined.
- 80 ms boundary is indicated by one of 4 time-domain cyclic shifts
- NSSS is transmitted in subframe #9, every even number radio frame, uses 12 subcarriers and occupies the last 11 OFDM symbols of the subframe.
- NPDSCH/NPDCCH are not mapped to subframes containing NSSS, no NRS on subframes containing NSSS, punctured by LTE CRS.





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NRS

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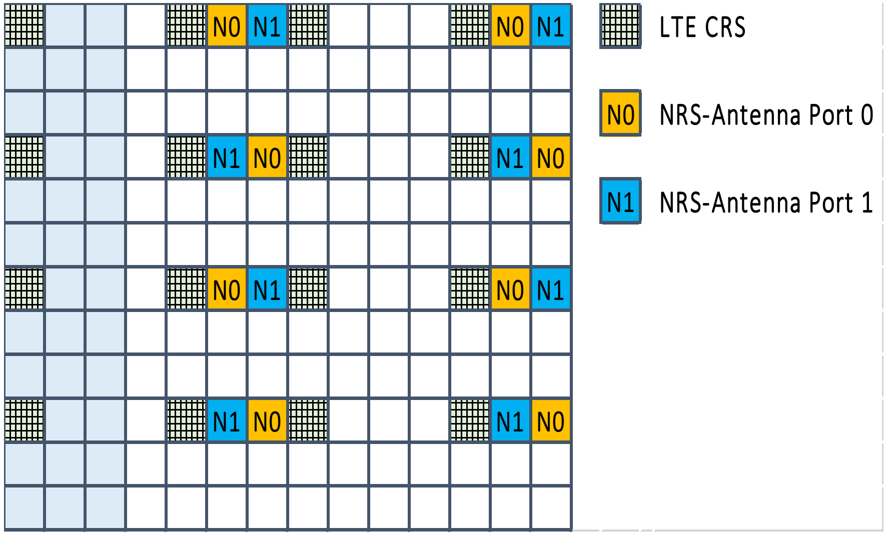
NRS

- The downlink cell specific physical reference signal NB-IoT (**NRS**) is used to channel estimation and measurement purposes.
- NB-IoT uses the same PCI as host cell, it is indicated in MIB.
- Since only 2 antenna ports are supported in LTE3071 for NB-IoT, also **host cell configuration is fixed to 2 antenna ports only.**
- NRS is defined for 2 antenna ports transmission schemes. NRS uses a cell-specific frequency shift derived as NB-IoT Cell ID mod 6.
- There are no NRS in subframes containing NPSS/NSSS
- NRS can be boosted by up to 6 dB, power offset is indicated in SIB.



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Technical Details

NPBCH

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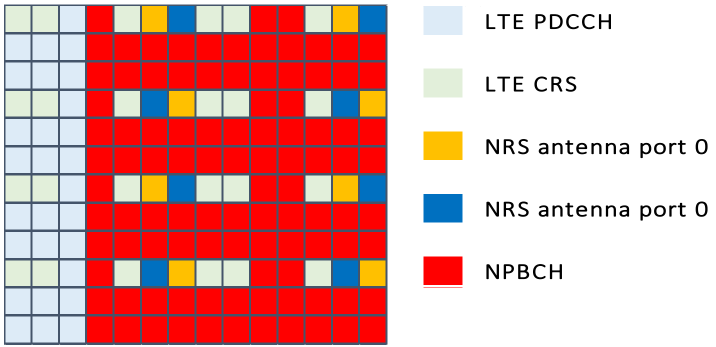
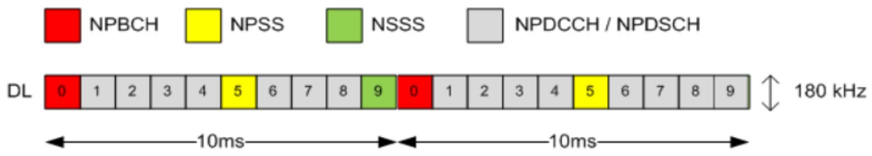
Technical Details

NPBCH

- **NPBCH** (Narrowband Physical Broadcast Channel) is used to carry the Narrowband Master Information Block (**MIB-NB**)
- NPBCH is transmitted every 10 ms in subframe #0
- NPDSCH/NPDCCH are not mapped to subframes containing NPBCH
- The modulation is QPSK, thus in each subframe #0 200 bits are available
- The NPBCH demodulation is based on NB-IoT reference signal (NRS).



NPBCH uses all except the first 3 OFDM symbols for LTE control channel and reserved LTE CRS resource elements (4 antenna ports).



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System Information

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Technical Details

Narrowband System Information SI-NB

- There are new narrowband dedicated versions of System Information Broadcast: **MIB-NB, SIB1-NB, SIB2-NB.** All other system information blocks (without NB suffix) are not applicable to NB-IoT.
- UE shall neither initiate the RRC connection establishment procedure until a valid version of the MIB-NB, SIB1-NB and SIB2-NB are gathered.

MIB-NB defines the most essential information of the cell required to receive further system information; contains all information required to acquire SIB1-NB. Fixed schedule with a periodicity of 640 ms.

SIB1-NB cell access/selection, contains all information required to acquire other SI-NB messages. Fixed schedule with a periodicity of 2560 ms.

SIB2-NB radio resource configuration information; SIB2-NB periodicity is indicated within SIB1-NB message.

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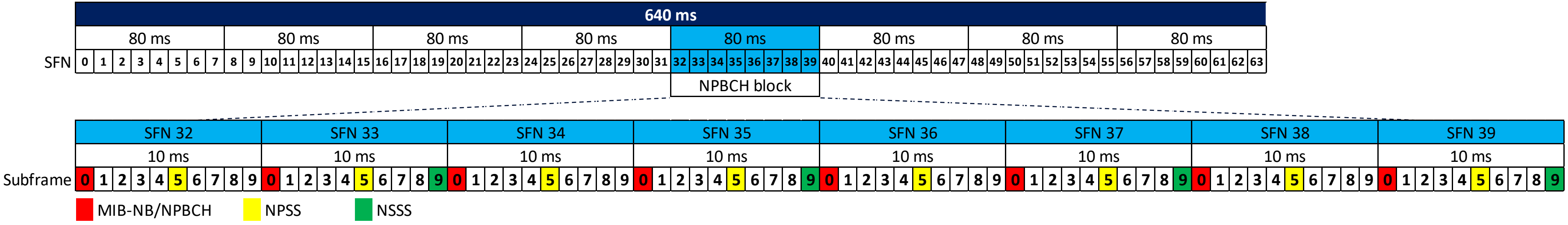
Technical Details

MIB-NB scheduling

- The MIB-NB uses a fixed schedule with a periodicity of 640 ms and repetitions made within 640 ms.
- After physical layer baseband processing, the resulting MIB-NB is split into 8 blocks
- Each block is transmitted on the first subframe (SF0) and repeated in SF0 of the next 7 consecutive radio frames, respectively. It means that each block spans 80 ms. All 8 repetitions are identical in terms of coded and scrambled bits.
- This process is continued until the whole MIB-NB is transmitted. A MIB remains unchanged over the 640 ms transmission time interval (TTI).



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Technical Details

MIB-NB content

Field			Size (bits)
SFN			4
HyperSFN			2
NB-SIB1 scheduling info			4
System info value tag			5
Access barring info			1
Operation mode			2
Based on operation mode			5
(1) in-band with same PCI	**CRS and PRB info**	5	
(2) in-band with different PCI	Num of LTE CRS ports	1	
	Raster offset	2	
	Spare	2	
(3) guard-band	Raster offset	2	
	Spare	3	
(4) stand-alone	Spare	5	
Spare			11
CRC			16
Total Size			50

SFN Most significant bits (MSBs), the remaining LSBs are implicitly derived from the MIB-NB start (64 frames starting from 000000, the last radio frame: 111111)
Two LSBs of the hyper frame number. Remaining bits present in SIB1-NB.
SIB1-NB scheduling and size,
Value tag, changed to announce changes in SI-NB other than MIB-NB.
In LTE3071, access barring is not supported and the field always set to 'FALSE'
Inband for LTE3071

Indicates an in-band deployment and that the NB-IoT and LTE cell share the same physical cell id and have the same number of NRS and CRS ports. In LTE3071, if the host cell is using 2TX and if operation mode is inband (i.e. actNBIoT = 'INBAND',), eNB will broadcast this field.

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Technical Details

SIB1-NB scheduling

- SIB1-NB contains the scheduling information for the SI-NB message common setting: window, radio frame offset, and SI-NB message specific setting: periodicity, repetition pattern and TBS.
- TBS for SIB1-NB and the repetitions made within the 2560 ms are indicated by ***schedulingInfoSIB1-NB-r13*** field in the MIB-NB.
- The starting frame for the first transmission of the SIB1-NB is derived from the cell PCID and the number of repetitions within the 2560 ms period

Value of *schedulingInfoSIB1-NB-r13*	Number of NPDSCH repetitions	SIB1-NB TBS
0	4	208
1	8	208
2	16	208
3	4	328
4	8	328
5	16	328
6	4	440
7	8	440
8	16	440
9	4	680
10	8	680
11	16	680
12~15	Reserved	Reserved

$R_{NB\text{-}SIB1}$	PCID	Starting radio frame number for NB-SIB1 repetitions
4	PCID mod 4 = 0	SFN mod 256 = 0
	PCID mod 4 = 1	SFN mod 256 = 16
	PCID mod 4 = 2	SFN mod 256 = 32
	PCID mod 4 = 3	SFN mod 256 = 48
8	PCID mod 2 = 0	SFN mod 256 = 0
	PCID mod 2 = 1	SFN mod 256 = 16
16	PCID mod 2 = 0	SFN mod 256 = 0
	PCID mod 2 = 1	SFN mod 256 = 1

NBIOTPR: numSib1RepNB

The eNB determines the TBS for SIB1-NB by choosing the smallest one from {208, 328, 440, 680} which is equal to or larger than the SIB1-NB message size

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Technical Details

SIB1-NB scheduling

RNB-SIB1		SFN\SF#4	0	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160	168	176	184	192	200	208	216	224	232	240	248	256
4	PCI mod 4=0	4	r0								r1								r2								r3								

4 repetitions

RNB-SIB1		SFN\SF#4	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
4	PCI mod 4 = 0	4	r0,t0		r0,t1		r0,t2		r0,t3		r0,t4		r0,t5		r0,t6		r0,t7

8 frames sequence, repetition #0

0	1	2	3	4	5	6	7	8	9

- SIB1-NB transmission occurs in **subframe #4**, every second frame, 8 subframes sequence. SIB1-NB TB is composed of 8 NB-IoT downlink subframes.
- Within 256 radio frames period SIB1-NB sequence is repeated 4, 8 or 16 times, depending on the ***schedulingInfoSIB1-NB-r13***. Repetitions are equally distributed within 256 frames period.

$R_{NB\text{-}SIB1}$	PCID	Starting radio frame number for NB-SIB1 repetitions
4	PCID mod 4 = 0	SFN mod 256 = 0
	PCID mod 4 = 1	SFN mod 256 = 16
	PCID mod 4 = 2	SFN mod 256 = 32
	PCID mod 4 = 3	SFN mod 256 = 48
8	PCID mod 2 = 0	SFN mod 256 = 0
	PCID mod 2 = 1	SFN mod 256 = 16
16	PCID mod 2 = 0	SFN mod 256 = 0
	PCID mod 2 = 1	SFN mod 256 = 1

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Technical Details

Main SIB1-NB fields for SIB2-NB message scheduling

Field	comments
eutraControlRegionSize-r13	Indicates the control region size of the E-UTRA cell for the in-band operation mode, in number of OFDM symbols. In LTE3071, fixed value of 3 symbols.
nrs-CRS-PowerOffset-r13	NRS power boost
si-Periodicity-r13	Periodicity of the SI-message in radio frames NBIOT_FDD->**sib2PeriodicityNB.**
si-RepetitionPattern-r13	NBIOT_FDD->**sib2RepPatternNB.**
si-TB-r13	TBS size, calculated value based on SIB message size
si-WindowLength-r13	Common SI scheduling window for all SIs. Unit in milliseconds NBIOT_FDD->**siWindowLenNB**
si-RadioFrameOffset-r13	Offset in number of radio frames to calculate the first radio frame for SI message transmission in the SI window. If the field is absent, no offset is applied. NBIOT_FDD->**siRadioFrameOffNB**

- SIB2-NB messages are transmitted periodically within time domain windows (SI-window, ***NBIOTPR: siWindowLenNB***).
- SIB2-NB TBS is determined by eNB by selecting the smallest value from the SI TBS pool {b56, b120, b208, b256, b328, b440, b552, b680}, big enough to carry SIB content.
- Depending on the TBS configuration SIB2-NB is transmitted over 2 or 8 consecutive NB-IoT downlink subframes within SI-window (56/120 bits 2, remaining 8 subframes)

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Technical Details

SIB2-NB scheduling example

SFN	subframe 0	1	2	3	4	5	6	7	8	9	siRadioFrameOffNB=2
0					SIB1	NPSS				NSSS	offset
1						NPSS					offset
2		SIB2,r0,t0	SIB2,r0,t1	SIB2,r0,t2	SIB1	NPSS	SIB2,r0,t3	SIB2,r0,t4	SIB2,r0,t5	NSSS	
3		SIB2,r0,t6	SIB2,r0,t7			NPSS					
4	MIB				SIB1	NPSS	sib2RepPatternNB=every4th			NSSS	
5						NPSS					
6		SIB2,r1,t0	SIB2,r1,t1	SIB2,r0,t2	SIB1	NPSS	SIB2,r1,t3	SIB2,r1,t4	SIB2,r1,t5	NSSS	
7		SIB2,r1,t6	SIB2,r1,t7			NPSS					
8					SIB1	NPSS				NSSS	
9						NPSS					
10		SIB2,r2,t0	SIB2,r2,t1	SIB2,r2,t2	SIB1	NPSS	SIB2,r2,t3	SIB2,r2,t4	SIB2,r2,t5	NSSS	
11	MIB	SIB2,r2,t6	SIB2,r0,t7			NPSS					
12					SIB1	NPSS				NSSS	
13						NPSS					
14		SIB2,r3,t0	SIB2,r3,t1	SIB2,r3,t2	SIB1	NPSS	SIB2,r3,t3	SIB2,r3,t4	SIB2,r3,t5	NSSS	
15		SIB2,r3,t6	SIB2,r3,t7			NPSS					
16					SIB1	NPSS				NSSS	
17						NPSS					
…	MIB					… …					…
256					SIB1	NPSS				NSSS	offset
257						NPSS					offset
258		SIB2,r0,t0	SIB2,r0,t1	SIB2,r0,t2	SIB1	NPSS	SIB2,r0,t3	SIB2,r0,t4	SIB2,r0,t5	NSSS	
259	MIB	SIB2,r0,t6	SIB2,r0,t7			NPSS					
260					SIB1	NPSS				NSSS	
261						NPSS					
262		SIB2,r1,t0	SIB2,r1,t1	SIB2,r0,t2	SIB1	NPSS	SIB2,r1,t3	SIB2,r1,t4	SIB2,r1,t5	NSSS	
263		SIB2,r1,t6	SIB2,r1,t7			NPSS					
264					SIB1	NPSS				NSSS	
265						NPSS					
266		SIB2,r2,t0	SIB2,r2,t1	SIB2,r2,t2	SIB1	NPSS	SIB2,r2,t3	SIB2,r2,t4	SIB2,r2,t5	NSSS	
267	MIB	SIB2,r2,t6	SIB2,r0,t7			NPSS					
268					SIB1	NPSS				NSSS	
269						NPSS					
270		SIB2,r3,t0	SIB2,r3,t1	SIB2,r3,t2	SIB1	NPSS	SIB2,r3,t3	SIB2,r3,t4	SIB2,r3,t5	NSSS	
271		SIB2,r3,t6	SIB2,r3,t7			NPSS					
272					SIB1	NPSS				NSSS	
273						NPSS					

8 consecutive valid subframes

SI window *siWindowLenNB=160ms*

SI-periodicity **sib2PeriodicityNB=256**

MIB NPSS NSSS SIB1 SIB2

- SIB2-NB is broadcasted in the valid sub-frames, except for NPSS/ NSSS/ NPBCH/ SIB1-NB.
- Single SIB2-NB is transmitted over 2 or 8 consecutive valid subframes. Offset in radio frames for the start of the SI window ***siRadioFrameOffNB***
- SIB2-NB is repeated every ***sib2RepPatternNB*** frame (example: every 4^{th} frame)
- Repetitions are within SI-window, ***siWindowLenNB***
- Whole SIB2-NB sequence is transmitted every ***sib2PeriodicityNB*** period

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Let’s have a short coffee break!

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NPDCCH

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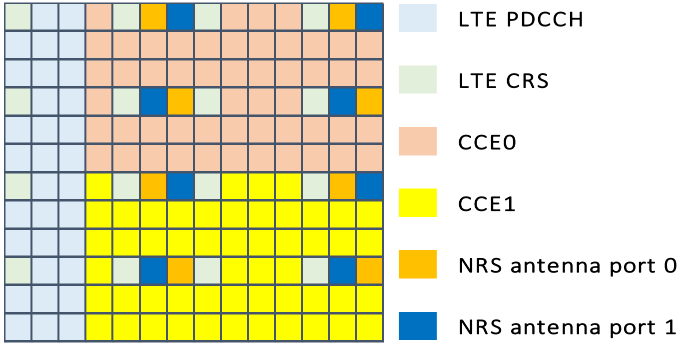
Technical Details

NPDCCH

- **NPDCCH** Narrowband Physical Downlink Control Channel
  - Scheduling information for both DL and UL data channels (DCI)
  - UL data channel HARQ acknowledgement
  - Random access response (RAR) scheduling information.
- 3 OFDM symbols are reserved for legacy LTE control region, as well as legacy CRS for 2 LTE antenna ports and NB-IoT NRS for 2 antenna ports
- 2 **Control Channel Elements CCEs** are defined - upper 6 subcarriers are allocated to one CCE and lower 6 subcarriers are allocated to the other CCE.
- QPSK and TM2 is supported.



For LTE3071 2 CCEs are aggregated to carry single DCI in one subframe (NPDCCH format 1 and aggregation level 2)

It allows utilization of a lower coding rate and improved coverage.

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Technical Details

DCI Formats

- DCI (Downlink Control Information) is used to signal UL and DL scheduling grants to the UE

DCI N0 for UL grant
Relevant fields: Flag for Format N0/N1 differentiation, NPUSCH resources, MCS, NDI, UL HARQ.

DCI N1 for DL grant
Relevant fields: Flag for Format N0/N1 differentiation, NPDSCH resources, MCS, NDI.

- During Random Access procedure UE has been assigned with different radio network temporary identifier (RNTI), one for random access (RA-RNTI), and a UE specific identifier (C-RNTI). Identifiers are implicitly indicated in the NPDCCH's CRC.
- DCI CRC scrambled with C-RNTI → the first bit in the message indicates whether DCI format N0 or N1 is contained. DCI CRC is scrambled with the RA-RNTI → DCI format N1.

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Technical Details
DCI Formats

- DCI format N0 is used for the scheduling of NPUSCH.

N0 (NPUSCH scheduling)	
Field	Size (bits)
Flag for N0/N1 differentiation	1
Subcarrier indication	6
Resource assignment	3
Scheduling delay	2
MCS	4
RV	1
Repetition number	3
NDI	1
DCI subframe repetition number	2
CRC	16
Total	39

The relevant field for DCI format N0 is:

- Flag for format N0/N1 differentiation
- Subcarrier indication
- Resource block assignment
- Modulation and coding scheme and redundancy version
- New data indicator
- Cyclic shift for DM RS and OCC index
- The rest is ignored.

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Technical Details
DCI Formats

- DCI format N1 is used for the scheduling of NPDSCH.

N1 (NPDSCH scheduling)	
Field	Size (bits)
Flag for N0/N1 differentiation	1
NPDCCH order indicator	1
Scheduling delay	3
Resource assignment	3
MCS	4
Repetition number	4
NDI	1
HARQ-ACK resource	**4**
DCI subframe repetition number	2
CRC	16
Total	39

The relevant field for DCI format N1 is:
- Flag for format N0/N1 differentiation
- Resource block assignment
- HARQ assignment
- Modulation and coding scheme
- New data indicator
- The rests are ignored.

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Technical Details

NPDCCH Search Space

- All the possible DL locations for NPDCCH are called 'Search Spaces'.
- CSS Common search space is defined for RARs, MSG3 retransmission and MSG4, USS UE specific search space is all valid PDCCH opportunities.
- **Initial** DCI repetition is hardoced to 2 with the maximum number of repetitions Rmax ***NBIOTPR: npdcchMaxNumRepRa.***
- NPDCCH opportunities are available in all subframes which are not occupied by static allocations (NPBCH, NPSS/NSSS, SIB1-NB/SIB2-NB).
- Example for Common USS and CSS search space:

G=2, Rmax=4, T=8

FN	0										1									
SFN	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
Excluded	MIB				SIB1	PSS				SSS	MIB					PSS				
Search space																				
NPDCCH occasion		1	2	1			2		1			2	1	2			1	2	1	2

FN	2										3									
SFN	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
Excluded	MIB				SIB1	PSS				SSS	MIB					PSS				
Search space																				
NPDCCH occasion		1	2				1	2	1			2	1	2	1		2	1	2	

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NPDSCH

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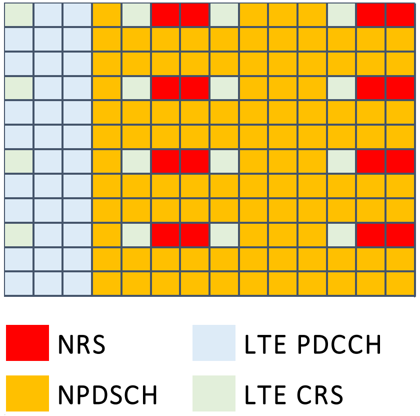
Technical Details
NPDSCH

- Narrowband Physical Downlink Shared Channel **NPDSCH** carries data from the higher layers, system information and the RAR messages
- 3 OFDM symbols are reserved for legacy LTE control region, as well as legacy CRS for 2 LTE antenna ports and NB-IoT NRS for 2 antenna ports, thus 104 REs are available per subframe. **12 subcarriers allocation is always used.**
- NPDSCH codeword occupies the entire PRB and is **mapped to the 4 subsequent valid subframes**. Time extension for NPDSCH will be supported.
- **No repetition** is provided for LTE3071 (only normal coverage supported), apart from NPDSCH carrying SIB content.
- The modulation is QPSK (MCS0-10), only TM2 is supported. No Link adaptation, user selected MCS.



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Technical Details
NPDSCH

- A maximum transport block size (TBS) of 680 bit is supported with 4 subframes (tail biting convolutional code, QPSK)
- Single process HARQ with adaptive and asynchronous re-transmission
- All the subframes that contain NPSS/NSSS/NPBCH/SIB1-NB are not available for NPDSCH transmission (**valid DL subframe**).
- NPDSCH is allocated in 4 consecutive NB-IoT DL subframe(s) not excluded for NPSS/NSSS or used for SI messages transmission.

MCS/TBS size definition

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

FN	0										1										2									
SFN	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
	MIB				SIB1	PSS				SSS	MIB				SIB1	PSS					MIB				SIB1	PSS				SSS
Valid SF																														

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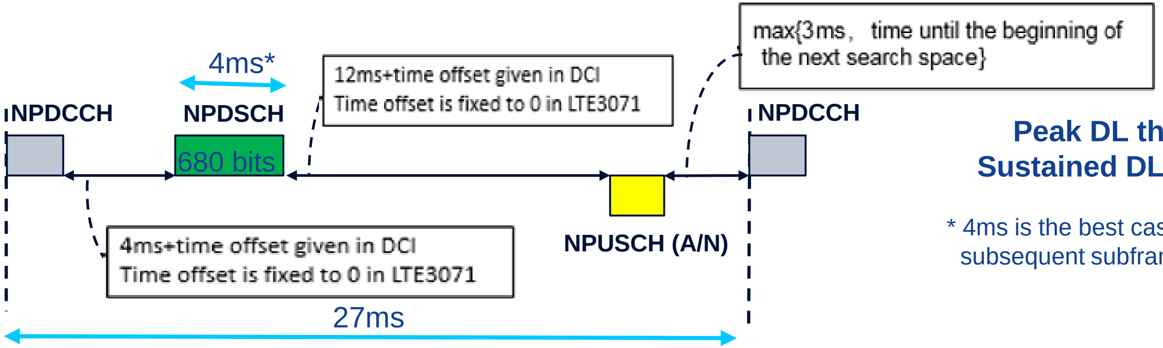
Technical Details

NPDSCH Scheduling



Peak DL throughput: 680bits/4ms=170kbps
Sustained DL throughput: 680bits/27ms=26kbps

* 4ms is the best case; actual timing depends on the number of free subsequent subframes dictated by SIB1 occurrence, see slide 50

- NPDSCH transmission starts in the valid DL subframe at least 4 ms after the end of associated DCI format N1 conveyed via NPDCCH. The reason of such gap is reduced computing capability of low cost IoT devices, they need time for NPDCCH decoding.
- After NPDSCH transmission completed, the UE needs to send back HARQ acknowledgement using NPUSCH Format 2. The allocation of NPUSCH resources for HARQ are indicated in DCI.
- Again, due to the limited computing resources of IoT device, time offset between the end of NPDSCH and the associated HARQ ACK is needed. At least 12 ms, since NPDSCH transport block is up to 680 bits, while DCI is only 23 bits.
- Next scheduling request conveyed by NPDCCH is expected not earlier than 3ms, in the next search space.

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NPRACH

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Technical Details
NPRACH

- Narrowband Physical Random Access Channel **NPRACH** transmits preamble for RACH procedure. NPRACH is used to signal to the cell that the UE is camping on it and wants to get access.
- The preamble is based on symbol groups on a single subcarrier. Each symbol group has a cyclic prefix (CP) followed by 5 symbols

- Preamble formats 1 is used, with CP length of 266.7 µs it gives up to 35 km maximum cell range. The five symbols have a duration of 1.333 ms, giving a total length of 1.6 ms.

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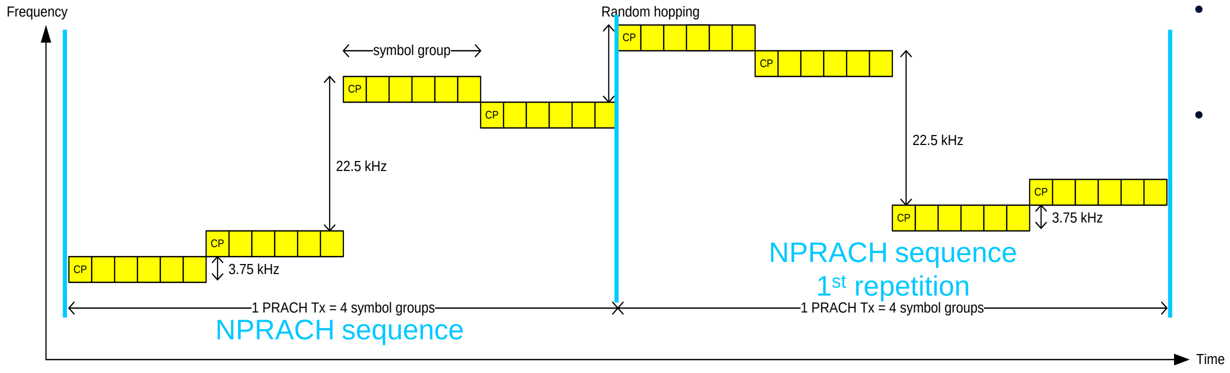
Technical Details
NPRACH

- NPRACH is based on 3.75 kHz single-tone with frequency hopping. One NPRACH preamble consists of 4 symbol groups, transmitted without gaps.
- UE selects the subcarrier for the transmission of the first preamble symbol group. The next 3 symbol groups are determined by an algorithm which depends only on the location of the first one.
  - First level single-subcarrier hopping is used between 1st/2nd and between 3rd/4th symbol groups (3.75 kHz)
  - Second level 6-subcarrier hopping is used between 2nd/3rd symbol groups (22.5 kHz, 6-subcarriers)



- Pseudo-random hopping is used between repetitions of groups of 4 symbol group
- Each sequence is repeated (default 4 times)

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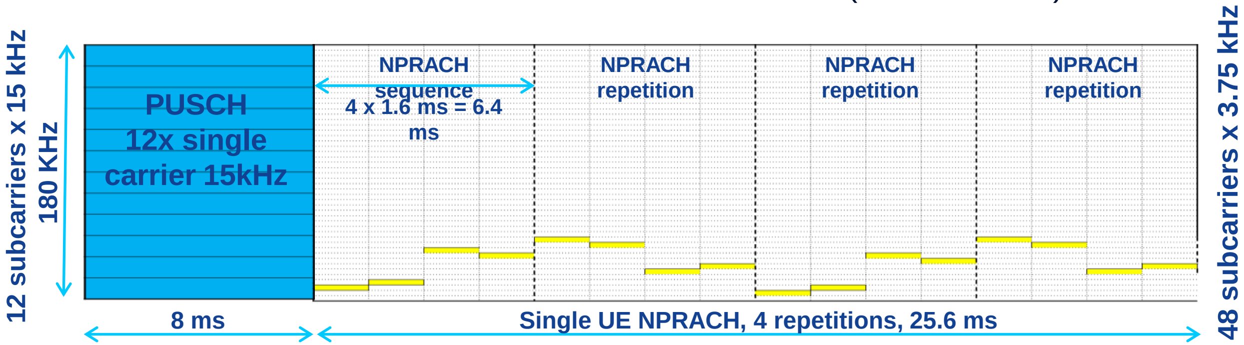
Technical Details

NPRACH configuration

- **Time domain:**
- NPRACH starts from frame defined by ***NBIOTPR: nprachStartTime,*** repeated every ***NBIOTPR: nprachPeriod*** (default 160 ms) and within each period there are repetitions set by ***NBIOTPR: nprachNumRepPreamble*** (default 4 repetitions).
- **Frequency domain:**
- The full NPRACH bandwidth is 180kHz with 48 subcarriers (3.75kHz each)



The Random Access Preamble ID corresponds to the start subcarrier index of NPRACH

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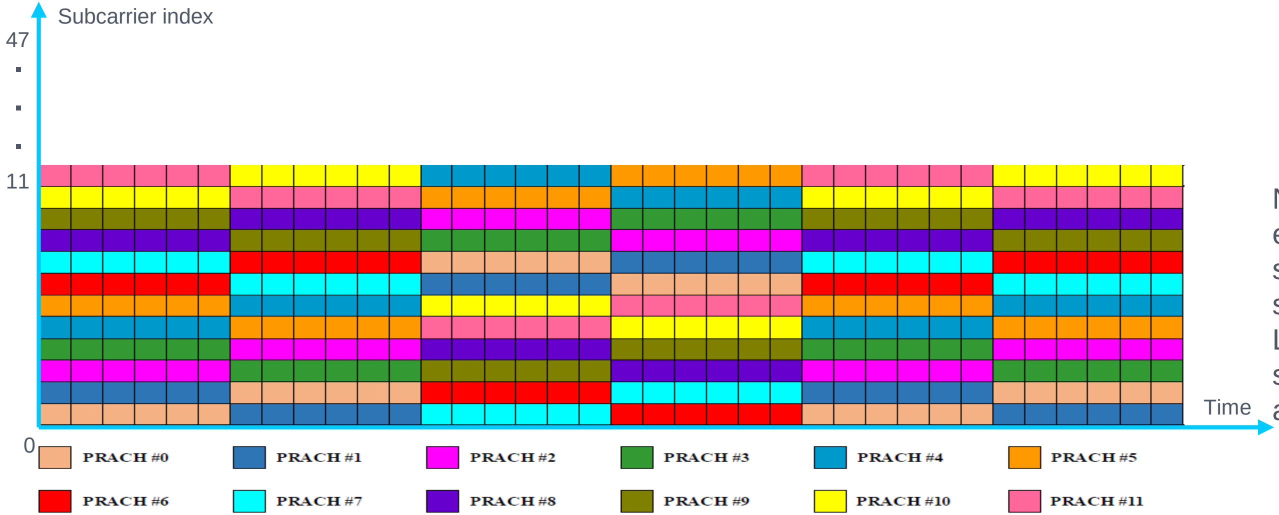
Technical Details
NPRACH multiplexing

- NB-IoT UEs can are multiplexed in the subcarrier frequency domain when accessing NPRACH resources
- The hopping pattern is semi-statically configured (3.75/22.5/3.75KHz, pseudo-random offset in the subcarriers domain for the next sequence of 4 NPRACH), then if collision for the first NPRACH occurrence is avoided, overlapping on the subsequent NPRACHes does not appear.



NPRACH multiplexing example for 12 subcarriers (Note: for the sake of simplicity; for LTE3071 all the 48 subcarriers are available)

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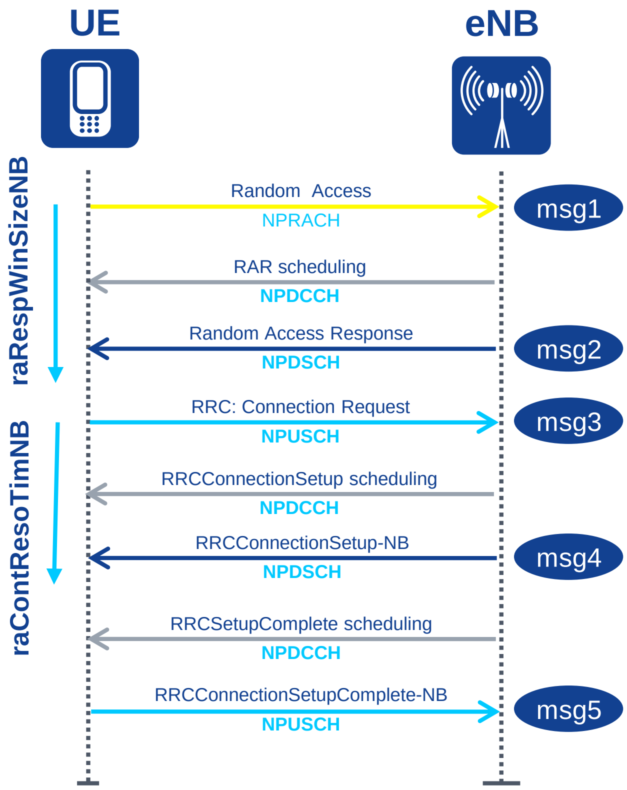
Technical Details

Random Access

- Random Access procedure of NB-IoT is similar to legacy LTE, contention-based random access procedure.

1. UE transmits a Random Access Preamble via NPRACH format 1. In case preamble transmission is not successful, UE repeats it according to the ***NBIOTPR: nprachMaxNumPreambleCE settings*** (default 5).
2. The eNB calculates the RA-RNTI based on the first radio frame number which the preamble was received. RA-RNTI=1+ SFN_id/4, where SFN_id is the index of the first radio frame of the specified NPRACH.
3. The eNB sends DCI Format N1 for Random Access Response RAR scheduling over NPDCCH. Related DCI is recognized by UE since it is scrambled with the RA-RNTI.
4. Then RAR (msg2) is sent over NPDSCH, containing timing advance command and allocation of uplink resources for scheduled transmission. RAR is expected inside the RAR response window ***NBIOTPR: raRespWinSizeNB.***



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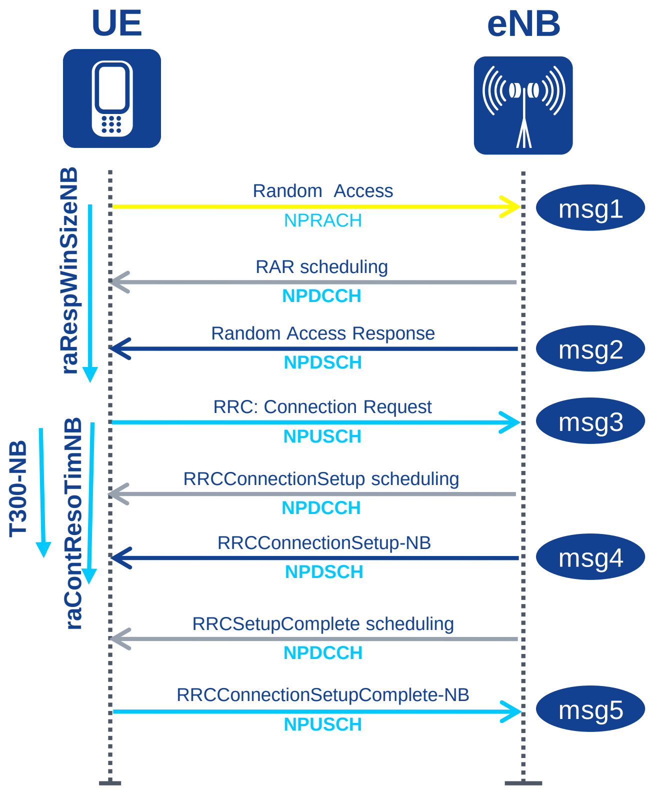
Technical Details

Random Access

5. The UE sends RRCConnectionRequest-NB (msg3) over NPUSCH
6. The eNB sends DCI Format N1 for RRCConnectionSetup-NB (msg4) scheduling over NPDCCH.
7. The eNB sends RRCConnectionSetup-NB (msg4) over NPDSCH, inside the contention resolution timer ***NBIOTPR: raContResoTimNB*** to indicate the successful completion of the RACH procedure.
8. In case msg4 is not received within timer period, RACH access procedure is repeated, providing that ***nprachMaxNumPreambleCE settings*** is not reached
9. The eNB sends scheduling of RRCConnectionSetupComplete-NB (msg5) in DCI Format N0
10. The UE sends RRCConnectionSetupComplete-NB (msg5) over NPUSCH, and moves into RRC_Connected mode.



Timer T300-NB supervises the RRC connection establishment procedure for NB-IoT.
Timer guard the period between RRCConnectionRequest and reception of RRCConnectionSetup or RRCConnectionReject message for NB-IoT.

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NPUSCH

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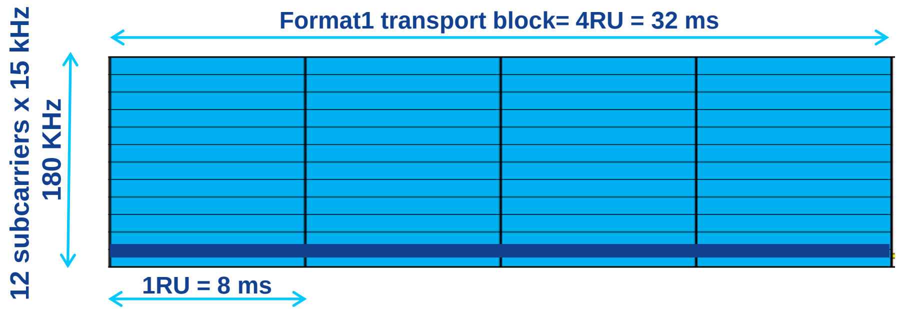
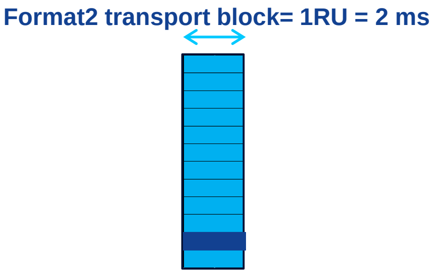
Technical Details

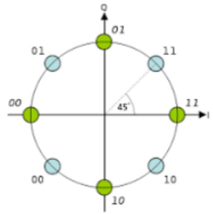
NPUSCH

- The eNB supports 15kHz single-tone NPUSCH in LTE3071, 12 tones. Single-tone operation together with close to 0 dB PAPR modulations helps to ensure coverage extension by PSD boosting.
  - NPUSCH **format 1** is for UL-SCH data (Resource unit **RU=8ms**)
  - NPUSCH **format 2** is for UL control information (**ACK/NACK, RU=2ms**).
- For format 1, Turbo coding with 2 redundancy versions (RV0 and RV2) are used. To reduce peak-to-average power ratio (PAPR), single-tone transmission uses π/2-BPSK and π/4-QPSK with phase continuity between symbols. For format 2, only π/2-BPSK is supported
- 1 HARQ process with adaptive asynchronous HARQ is used for re-transmissions.
- One transport block can be scheduled over more than 1 resource units in time in 3GPP, For LTE3071, **fixed 4 RU is supported for format1** (4*8ms=**32 ms**) and **1RU for format2** (**2 ms**).

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







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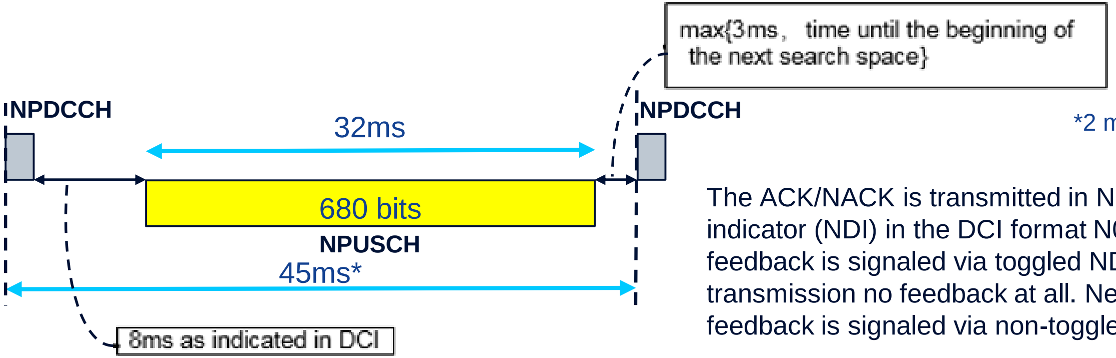
Technical Details

NPUSCH scheduling

- A grant for NPUSCH transmission is indicated in the NPDCCH via DCI format N0.
  - Start time of the NPUSCH, the number of repetitions (hardcoded to 1), the number of RUs used for one transport block (hardcoded to 4 for format 1) and subcarrier position
  - MCS index and the transport block size
- For normal coverage supported with LTE3071 no NPUSCH repetition is foreseen
- The time offset between the end of NPDCCH and the beginning of the associated NPUSCH is at least 8 ms. After completing the NPUSCH transmission, the UE monitors NPDCCH to learn whether NPUSCH is received correctly by the base station, or a retransmission is needed.



Peak DL throughput: 680bits/32ms=21kbps
Sustained DL throughput: 680bits/45ms=15.1kbps

*2 ms (2xNPDCCH) + 8 ms + 32 ms (NPUSCH) + 3 ms = 45 ms

The ACK/NACK is transmitted in NPDCCH by the new data indicator (NDI) in the DCI format N0. Positive UL HARQ feedback is signaled via toggled NDI, or for the last UL data transmission no feedback at all. Negative UL HARQ feedback is signaled via non-toggled NDI.

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Power Control

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Technical Details

Power Control

- Static power allocation for DL is used by eNodeB.
- The NB-IoT downlink power boost parameter (***dlPwrBoost***) is employed in inband NB-IoT PRB.
- In UL direction open loop power control is supported.
- Initial power level derived from RACH preamble process is used for the whole duration of the RRC connection

- **Power headroom**
  - NB-PHR is computed based on a 15kHz single-tone transmit power for NPUSCH data
  - 4 reportable values of PHR. There is no PHR modification after msg3.

Reported value	Measured quantity value (dB)
POWER_HEADROOM_0	[-23] ≤ PH < [5]
POWER_HEADROOM_1	[5] ≤ PH < [8]
POWER_HEADROOM_2	[8] ≤ PH < [11]
POWER_HEADROOM_3	PH ≥ [11]

PRACH:

- W/o repetition: preambleInitialReceivedTargetPower + powerRampingStep
- W/ repetition: Pmax

PUSCH:

- Open loop power control

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RRM and Scheduler

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Technical Details

NB-IoT RRM recap

Uplink

- Frequency domain:15KHz single tone for NPUSCH, 12 subcarriers, 3.75 kHz single tone for NPRACH, 48 subcarriers
- NPUSCH format 1 with data : 4 RUs (32 subframes)
- NPUSCH format 2 ACK/NACK : 1 RU (2 subframes)
- The NPUSCH transmission takes place in subframes not reserved for NPRACH in uplink.
- NPRACH and NPUSCH multiplexing in same TTI are not supported
- Open loop power control
- No link adaptation, statically configured UL MCS, QPSK MCS0-10

Downlink

- Frequency domain: 12 subcarriers, 15KHz tone
- Fixed 4 subframes TTI length
- The NPDSCH and NPDCCH transmission take place in subframes not reserved for NPBCH, NPSS/NSSS, NB-SIBs. In case of conflict with common channels in downlink, the transmission will be skipped.
- NPDCCH aggregation level fixed to 2 CCEs, DCI spans over 1 NPDCCH subframe.
- NPDCCH UE-specific search space and Common search space (CSS) for RAR/Msg3 retransmission/Msg4
- Static configurable power level
- No link adaptation, statically configured DL MCS, QPSK MCS0-10

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Technical Details

NB-IoT RRM

Uplink

The eNB supports up to 11 UEs (in 15kHz single tone) in the cell transmitting simultaneously in UL. One tone is reserved for uplink ACK/NACK.

Downlink

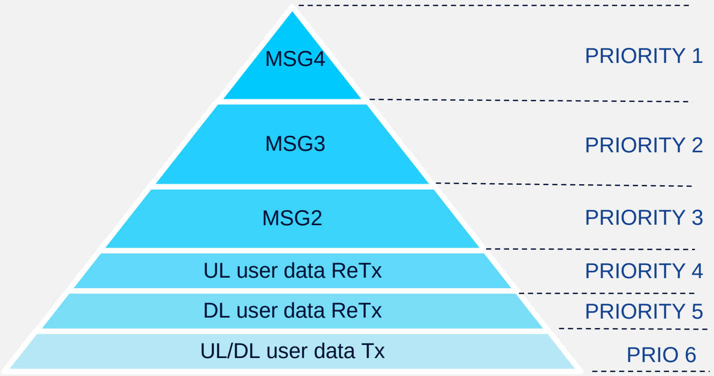
- One UE scheduled per TTI in DL direction

Scheduler

- Half duplex scheduling
- No channel awareness
- No QoS or guaranteed bit rates
- Mobility for NB-IoT happens via UE idle mode cell selection.
- One adaptive, asynchronous HARQ process

Hierarchy of transmissions to/from NB-IoT UEs

- Prioritized lists
- First In First Out within the list



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Technical Details
Link Adaptation

- There is no link adaptation for NB-IoT LTE3071, just configurable initial MCS per cell, separately for UL and DL ***(NBIOTPR: iniMcsDl, NBIOTPR: iniMcsUl)***.
- The downlink and uplink MCS range is 0-10 for NB-IoT in LTE3071 (3GPP downlink:11, 12 will be used for standalone/guardband NB-IoT; uplink: 11, 12 for multi-tone QPSK).
- Fixed pi/2 BPSK modulation for message 2 on NPDSCH

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

MCS Index I_{MCS}	Modulation Order	TBS Index I_{TBS}
0	1	0
1	1	2
2	2	1
3	2	3
4	2	4
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	2	10

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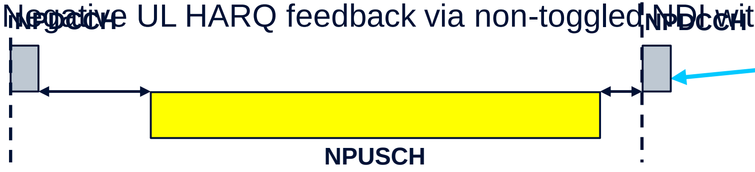
Technical Details
HARQ recap

- Single HARQ process in both downlink and uplink, to enable low-complexity UE implementation. UL ACK/NACK is transmitted in NPDCCH by the new data indicator (NDI) in the DCI format N0.
- Positive UL HARQ feedback is signaled via toggled NDI of DCI format N0, negative feedback via non-toggled NDI. ACK for the last UL data transmission - no feedback at all.
- Positive UL HARQ feedback for msg3 is signaled via non-transmission of DCI format N0. Negative UL HARQ feedback via non-toggled NDI within DCI format N0.



N0 (PUSCH scheduling)	
Field	Size (bits)
Flag for N0/N1 differentiation	1
Subcarrier indication	6
Resource assignment	3
Scheduling delay	2
MCS	4
RV	1
Repetition number	3
NDI	1
DCI subframe repetition number	2
CRC	16
Total	39

- The DL HARQ is carried by the NPUSCH format 2. The size of resource unit for A/N transmission is 2 ms for 15 kHz, there is no repetition for ACK/NACK configured.

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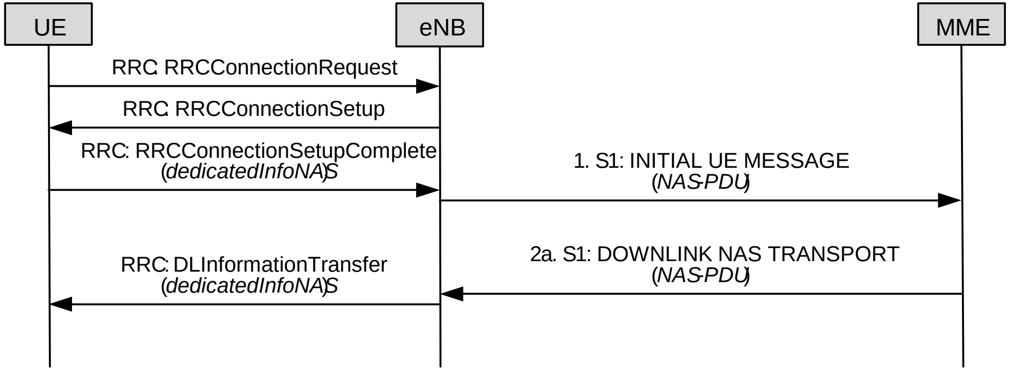
Technical Details

Bearer Management

- For LTE30171 eNB supports only data transmission via control plane (Control Plane CIoT EPS optimizations, CP2 solution). User plane data is encapsulated in the Control Plane messages and using Signaling Radio Bearer (SRB1bis). Data radio bearer (DRB) is not used
- An uplink Non-Access Stratum (NAS) signaling message or uplink NAS message carrying data can be transmitted in an uplink RRC container message (i.e. MSG5 RRC Connection Setup Complete message).
- AS security is not utilized, PDCP layer is bypassed
- RRC connection reconfiguration and RRC connection re-establishment are not supported. When maximum number of RLC retransmissions is reached , RRC connection is released.



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Technical Details
RRC connected

- NB-IoT users are defined in a separate pool on top of normal LTE active users pool
  NBIOT_FDD: maxNumRrcNB.
- The maximum number of NB-IoT users in the NB-IoT cells is up to 280*
- The total number of users per (host LTE + inband NB-IoT) cells is up to 840 users independently of the BW defined, so with a maximum of 2520 users per HW board.

Max # active users per NB-IoT Inband cell	(up to) 3 cells				(up to) 6 cells	
	20MHz	15MHz	10MHz	5MHz	10MHz	5MHz
	280	280	280	280	280	280

- As a consequence, the maximum number of Active users in LTE WB hosting cells might be reduced compared to legacy values depending on the NB-IoT capacity statically defined.
- For instance:
  - in 10MHz cells, legacy WB capacity of 600 users will be reduced if NB-IoT exceed 240 users
  - in 20MHz cells, legacy WB capacity of 840 users will be reduced when Nb-IoT users is defined
- The actual limit for the number of RRC connected users comes from the radio interface and RRC threshold for NB-IoT by admission control reduces number of overload messages exchanged by lower layers.

*Modified from 420 to 280 by LTERLCR-20060

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Technical Details
NB-IoT inactivity timers

- LTE3071 introduces two inactivity timers to monitor activity of NB-IoT connections
- SRB inactivity timer base on UL/DL SRB buffer data : ***srbInactivityTimerNB.***
  - The timer starts when both SRB UL buffer & SRB DL buffer are empty. Upon timer expiry UESTATE will be informed by an inactivity indication (‘SRB inactive’). Timer is stopped when new data arrives to the buffer.
- C-Plane inactivity timer based on S1 interface NAS PDU messages: ***cpInactivityTimerNB***
  - The timer determines when the S1 connection shall be released. The timer monitors activity on S1AP interface for UE-associated S1 logical connection traffic. It's started with UE-associated S1 logical connection establishment and restarted on reception or sending S1AP message that contains NAS PDU IE.
  - When the ***cpInactivityTimerNB*** expires, C-Plane has to check the status of the SRB activity. If the SRB activity status is set to “SRB active”, no further action has to be done. If the status is set to “SRB inactive”, the eNB sends S1AP: UE CONTEXT RELEASE REQUEST to MME with Cause value set to “User Inactivity” and RRC Connection Release – NB.

Timer	Start	Restart	At expiry
cpInactivity TimerNB	Reception of : S1AP: DOWNLINK NAS TRANSPORT or S1AP: CONNECTION ESTABLISHMENT INDICATION	Reception of: S1AP: DOWNLINK NAS TRANSPORT or S1AP: UPLINK NAS TRANSPORT	If the SRB status is set to “SRB inactive” (srbInactivityTimerNB expires), the eNB sends S1AP: UE CONTEXT RELEASE REQUEST to MME with Cause value set to “User Inactivity”.

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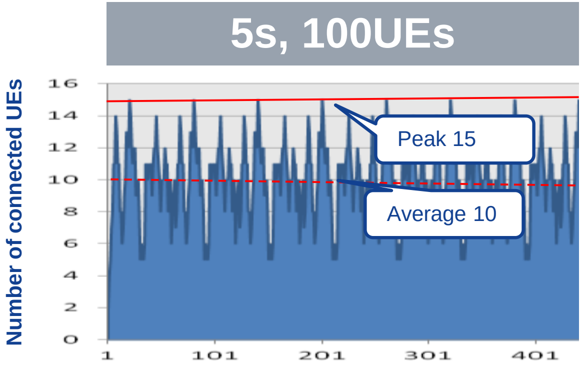
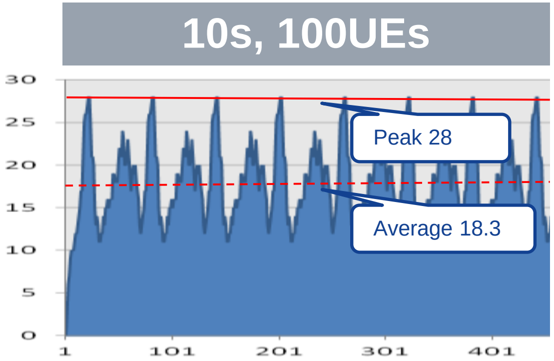
Technical Details

NB-IoT inactivity timers

- Inactivity timers settings are a compromise between few simultaneous RRC connections/high RRC signaling load (short inactivity timer) and many simultaneous RRC connections/low RRC signaling load (long inactivity timer)
- Settings of inactivity timers depends on the traffic profile.
  - When typical traffic profile considers just single message (e.g. single Smart meter reading) lower values are recommended to keep RRC connected time short and reduce total number of RRC connected UE
  - Higher values are recommended when several subsequent messages are exchanged. It saves signaling resources since release and establishment of radio bearer is avoided.





Example: Connected UEs vs inactivity timer

Assumptions: Connected state time: 1s transmission + inactivity. 60s Mean inter-arrival time

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NPDCCH monitoring details

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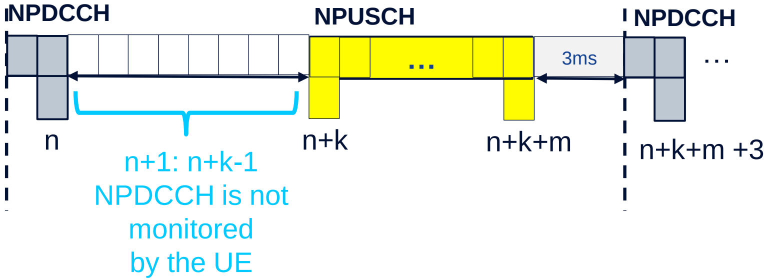
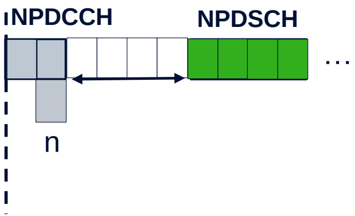
Technical Details

Narrowband physical downlink control channel related procedures

NPUSCH format1 transmission



NPDSCH (RAR) transmission



- If a NB-IoT UE detects **NPDCCH with DCI Format N0** ending in subframe *n* or receives a NPDSCH carrying a random access response grant ending in subframe *n*, and if the corresponding NPUSCH format 1 transmission starts from *n+k*, **the UE is not required to monitor NPDCCH in any subframe starting from subframe *n+1* to subframe *n+k-1 (indicated by white)***.

- Moreover, if a NB-IoT UE has a NPUSCH (f1 or f2) transmission ending in subframe (*n+k+m*) , the UE is not required to monitor NPDCCH in any subframe starting from subframe (*n+k+m*)*+1* to subframe (*n+ k+m*) *+ 3* – as next scheduling request conveyed by NPDCCH is expected not earlier than 3ms after NPUSCH.

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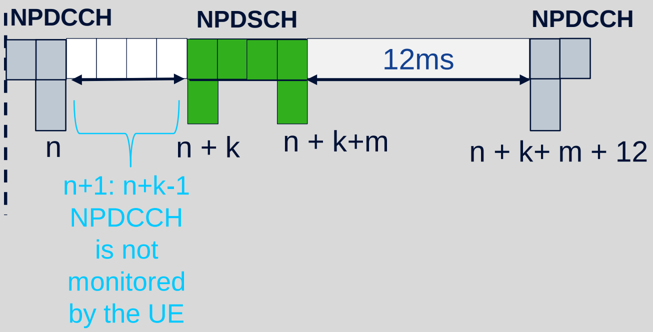
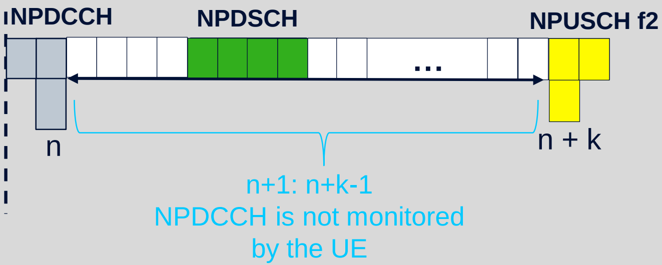
Technical Details

Narrowband physical downlink control channel related procedures

NPDSCH user data or paging transmission



- If a NB-IoT UE detects NPDCCH with DCI Format N1 or N2 ending in subframe *n*, and if the corresponding NPDSCH transmission starts from *n+k*, the UE is not required to monitor NPDCCH in any subframe starting from subframe *n+1* to subframe *n+k-1*.
- If a NB-IoT UE receives a NPDSCH transmission ending in subframe (*n+k+m),* and if the UE is not required to transmit a corresponding NPUSCH format 2, the UE is not required to monitor NPDCCH in any subframe starting from subframe (*n+k+m)+1* to subframe *(n+k+m)+12*.



- If a NB-IoT UE detects NPDCCH with DCI Format N1 ending in subframe *n*, and if the corresponding NPUSCH format 2 transmission starts from subframe *n+k*, the UE is not required to monitor NPDCCH in any subframe starting from subframe *n+1* to subframe *n+k-1*.

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Interdependencies

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Interdependencies

limitations NB-IoT cell

NB-IoT stands for a quite new system with own channels and RRM. Narrow band 200kHz receiver and transmitter with no support for other technologies. That is why most of the legacy LTE features are not supported in the NB-IoT cell.

- **Legacy LTE channels can not be read by NB-IoT receiver**
- **NB-IoT uses its own RRM procedures and operates on the single PRB resources**
    - All legacy LTE related RRM features and resources optimization features are not relevant for NB-IoT cell, e.g. legacy mobility, Inter-system HO, CA, ETWS, CMAS, OTDOA, MBMS, GBR and QCIs, CRAN, all voice related, VoLTE and emergency calls,
- **NB-IoT system was designed to support TM2 Tx and 2Rx with MRC receiver**
    - Any other Tx or Rx schemes are not supported by NB-IoT cell. 4Tx transmission schemes can not be used in the host cell since it is not compatible with NRS design.
    - IRC is not supported by NB-IoT cell, however can be activated in the host LTE cell
- **DRX with LTE3071 operates in idle mode only.**
    - Connected DRX and DRX extensions are not relevant for NB-IoT cell.

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Interdependencies

limitations
host LTE cell

The following features cannot be enabled in the hosting LTE cell together with inband NB-IoT:

LTE3128 LTE-M

NB-IoT and Cat-M can't be enabled in the same cell due to scheduler implementation. NB-IoT and Cat-M can be enabled in different cells in one eNB. Note that support will be allowed with LTE3819 and LTE4040 features.

LTE187 Single TX path mode

LTE1063 Uplink SU MIMO for 4 RX paths

LTE1402 Uplink CoMP

LTE1691 Uplink intra-eNB CoMP 4Rx

NB-IoT LTE3071 is designed assuming support for 2TX and 2RX schemes. As some elements (e.g. LTE CRS) overlaps with inband NB-IoT channels, other transmission schemes are not supported for the host LTE cell. Extension to 4Tx, 4Rx and 1Tx will come with LTE3722.

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Interdependencies

limitations
host LTE cell

The following features cannot be enabled in the hosting LTE cell together with inband NB-IoT:

LTE2180 – FDD-TDD downlink carrier aggregation 2CC

LTE2270 – LTE TDD+FDD inter eNB CA basic BTS

LTE2316 – FDD-TDD downlink carrier aggregation 3CC

LTE2735 – FDD-TDD downlink carrier aggregation with AirScale System Module configurations

LTE2337 - FDD-TDD downlink carrier aggregation 3CC - 2 FDD & 1 TDD;

LTE2623 – FDD-TDD downlink carrier aggregation 4CC

LTE2504 LTE U-plane SW deployment on 4 DSPs

Inter eNB CA TDD+FDD is not supported in the host LTE cell due to conflicting requirements on DSP deployment in eNB FDD. There is no specific feature flag for FDD+TDD CA because 'actInterEnbDLCAggr' is commonly used also for FDD+FDD CA.

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Interdependencies

limitations
host LTE cell

The following features cannot be enabled in the hosting LTE cell together with inband NB-IoT:

LTE1709 Liquid Cell

TM9 CSI-RS may interference to NB-IoT

LTE1542 - FDD Supercell

Super Cell requires specific DSP deployment (not supported in FL17).

LTE2091 - Extended SuperCell

LTE2445 - Combined Supercell

Combined Supercell requires specific DSP deployment (not supported in FL17).

LTE1117 eMBMS

eMBMS may has the interference to/from NB-IoT.

LTE1113 / LTE1496 eICIC

NB-IoT has interference on eICIC ABS subframes

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Interdependencies

limitations
host LTE cell

The following features cannot be enabled in the hosting LTE cell together with inband NB-IoT:

LTE1891 MicroDTX

MicroDTX may muste the subframes impacting NB-IoT

LTE495 OTDOA

OTDOA may has the interference to/from NB-IoT.

AirScale HW

Only FSMr3 will be supported for NB-IoT and wideband host LTE cell.

LTE819 DL inter-cell interference generation

Dummy load generation on both host LTE cell and NB-IoT cell are not supported.

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Interdependencies

limitations
host LTE cell

Following features can be enabled in the hosting wideband LTE cell together with inband NB-IoT, but some consideration on the interaction should be addressed.

LTE1103/LTE1203 Load Based Power Saving

The host and NB-IoT cells will be shutdown together. It's suggested not to add host cell or NB-IoT cell into Power Saving List.

LTE2664 Load based PUCCH

Load based PUCCH will dynamically change the number of PUCCH resources. The uplink NB-IoT position in this feature should be selected considering the maximum PUCCH and PRACH may extend.

LTE46 Channel-aware Scheduler (UL)

LTE46 is not supported in an NB-IoT cell. When LTE46 is activated, SRS may interfere with NB-IoT PRB, there is consistency check to avoid NB-IoT activation in PUSCH area with LTE46. If PUCCH blanking is enabled, an NB-IoT PRB can be in blanked area, so that SRS
in host cell will not cause interference to NB-IoT.

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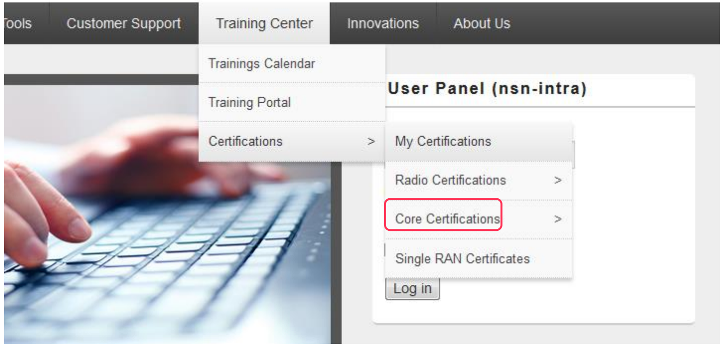

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NB-IoT extensions outlook

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Technical Details
FL17A NB-IoT extensions

- **LTE3668 NB-IoT: Coverage enhancements (+20dB)**
  - This feature extends the coverage for NB-IoT (Inband) mainly by repetitions. Up to 3 coverage levels can be configured (normal + robust + extreme). The eNB will select coverage level per UE based on the level of NPRACH UE sent.
- **LTE3509 NB-IoT: Support on Airscale without Baseband Pooling**
  - Support for 2Tx/2Rx inband NB-IoT
- **LTE3543 NB-IoT Standalone**
  - Standalone NB-IoT over FSMr3 and AirScale.
- **LTE3669 Paging support**
  - Improved NB-IoT implementation by introducing Paging for NB-IoT MT (Mobile Terminated) calls. It applies to either Inband or Standalone mode.
- **LTE3125 e-DRX Idle**

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Technical Details

NB-IoT features outlook

- **LTE3722: support 4T4R and 1Tx**
  - Support for 2Tx/4Rx inband/standalone NB-IoT, support 4TX for host LTE cell, but only 2TX for NB-IoT inband cell, dual TM1 operation

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Part 2

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LTE3071 NB-IoT

Updated with RP001597 “Support of LTE in-band NB-IoT with RF sharing in SRAN "

Part 2

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LTE3071 NB-IoT
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Technical Details

FL17A NB-IoT Overview

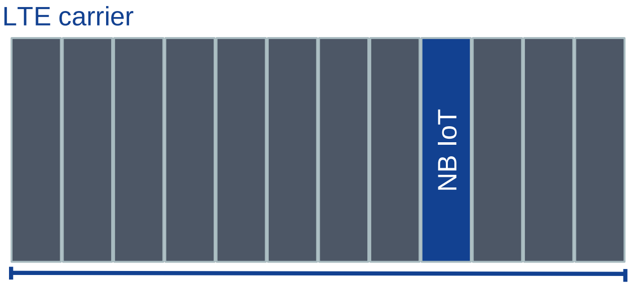
Basic 3GPP Rel. 13 **in-band NB-IoT** functionality is introduced with **LTE 3071** feature.

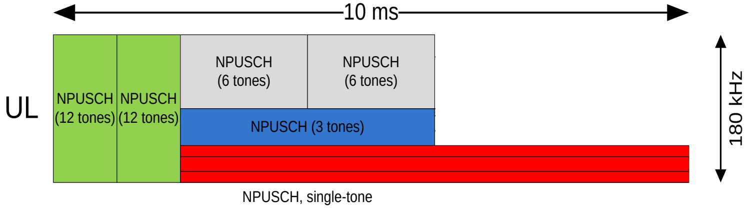
- New cell concept and deployment options:
  - FDD mode, **half duplex operations, 200 kHz** UE RF bandwidth for both downlink and uplink
  - DL: OFDMA with 15 kHz subcarrier spacing, TM2
  - UL: **single tone transmissions –15 kHz**, **2 RX MRC* receiver**
- The data transmission over **SRB1bis** (data over NAS)
- **First level coverage** (without coverage enhancement) with MCL pathloss target up to **144dB** is supported
- **FSMF and FZM deployments**

Airscale support comes separately with **LTE3509**

Higher coverage levels are supported with **LTE3668** NB-IoT Coverage Enhancements

Paging support for NB-IoT will be activated with **LTE3669**





MRC* Maximum Ratio Combining

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Technical Details
NB-IoT support for SRAN17A

- **NB-IoT is introduced into SRAN with RP001597 feature**
- The RP001597 feature basically consists of porting the below LTE features to SBTS:
  - **LTE3071 NB-IoT Inband**
  - LTE3509 NB-IoT: Inband on Airscale without Baseband Pooling
  - LTE3668 NB-IoT: Coverage enhancements
  - LTE3819 IoT: Cat-M and NB-IoT on same frequency carrier
  - LTE3669 NB-IoT: Paging support
- RP001597 allows for:
  - in-band NB-IoT cells on both FSMr3 and FSMr4 HW releases
  - up to 20dB coverage enhancement so that to reach 164dB for the Maximum coupling loss (MCL) of the NB-IoT cell
  - simultaneous activation of Cat-M and in-band NB-IoT in a hosting LTE cell 2Tx2Rx 10MHz on FSMr3
  - paging of NB-IoT UE for mobile terminated connections in normal or extreme coverage

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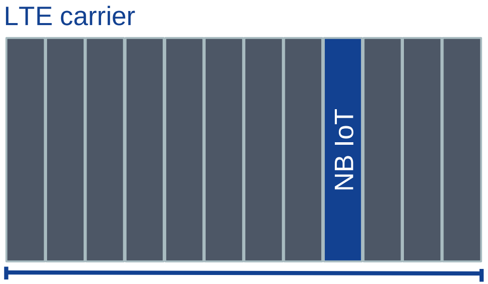
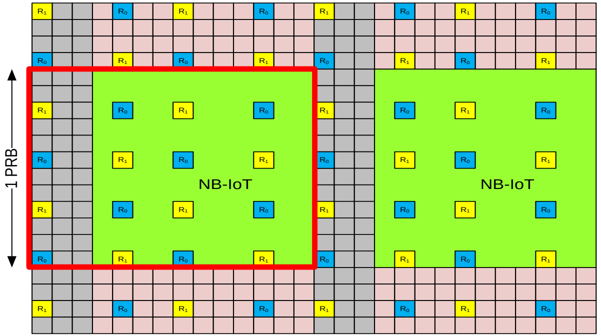
LTE3071 NB-IoT Part 1 refresher

LTE 3071 NB-IoT – Inband operation

- **One NB-IoT carrier** can be configured for each legacy 5/10/15/20 MHz FDD LTE cell in a 2x2 configuration.
- Allocation of DL NB-IoT carrier is **predefined by 3GPP**. The location of downlink and uplink can be configured separately.
- There is **no paging support** with LTE3071, hence only mobile originated calls can be handled.
- The same OFDM modulation with 15 kHz subcarrier spacing is used in DL there is no interference between NB-IoT and legacy LTE.
- A protection of legacy cell resource elements is supported for the fixed first 3 OFDM symbols (wideband PDCCH area) and for CRS area.





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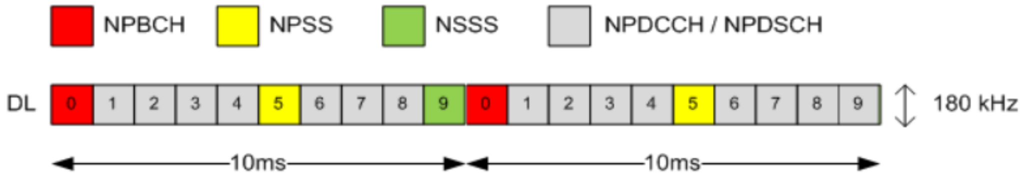
LTE3071 NB-IoT Part 1 refresher

NB-IoT – Downlink

- DL uses OFDMA with 15 kHz subcarrier spacing, 12 subcarriers available in 1 NB-IoT carrier, 10ms frame.



- **Narrow 200 kHz UE bandwidth does not allow for legacy channels utilization, new DL channels are introduced:**
  - Narrowband Primary and Secondary Synchonization signals **NPSS/NSSS** - time/frequency synchronization, cell ID and timing for NPBCH detection,
  - Narrowband Common Reference Signals **NRS** for 2 antenna ports transmission schemes,
  - Narrowband Physical Broadcast Channel **NPBCH** conveys Narrowband Master Information Block **MIB-NB**,
  - Narrowband Physical Downlink Control Channel **NPDCCH** carries scheduling information for both DL and UL data channels, HARQ Ack and random access response scheduling information,
  - Narrowband Physical Downlink Shared Channel **NPDSCH** carries data from the higher layers, system information and the random access response messages..

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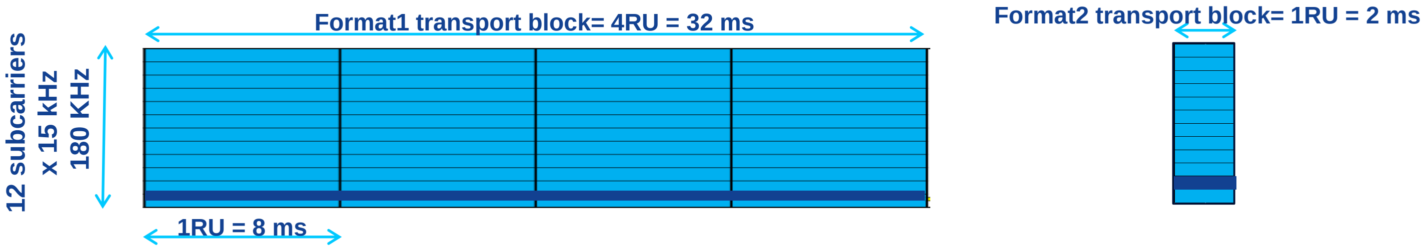
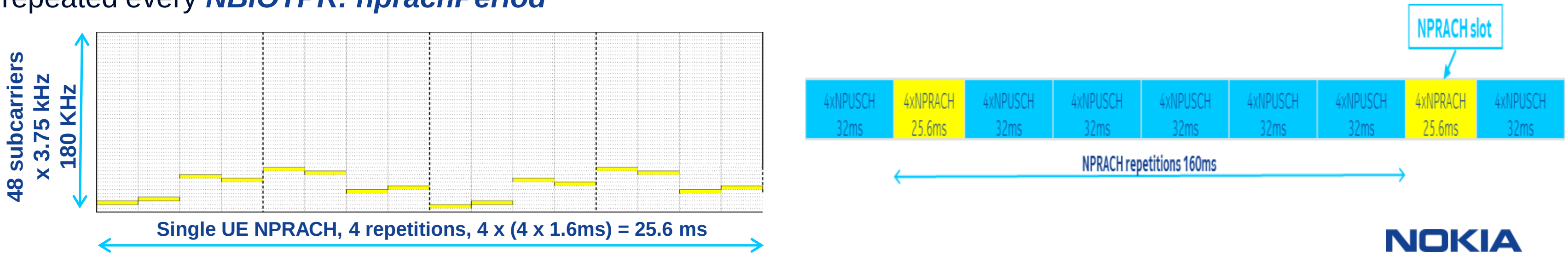
LTE3071 NB-IoT Part 1 refresher
NB-IoT – Uplink Physical Channels

- Narrowband Physical Uplink Shared Channel **NPUSCH**. Among several NPUSCH transmissions options defined by 3GPP (single-, multi-tone, 15 or 3.75 kHz subcarrier spacing) 15 kHz single-tone will be supported for FL17SP LTE3071, 12 subcarriers available.



- Narrowband Physical Random Access Channel **NPRACH** carries preamble for Random Access procedure. NPRACH operates on 3.75 kHz subcarrier spacing and predefined hopping schemes with repetitions. NPRACH window repeated every ***NBIOTPR: nprachPeriod***



Benefits and Gains

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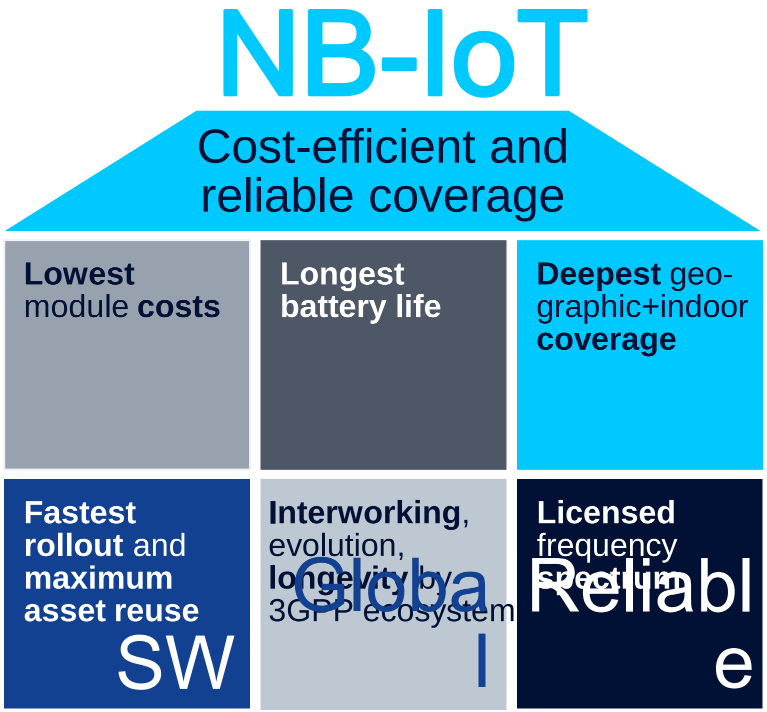
Benefits and Gains

NB-IoT technology

- **NB-IoT is a cost-optimized technology developed to serve massive number of IoT devices**
- NB-IoT provides with **extended coverage**, e.g for reaching sensors, tracking and metering devices at remote locations or within building basements
- Easy and fast deployment on Nokia LTE networks via **software upgrade**
- Allows for **massive deployment** by NB-IoT UE **simplification by 85%** with user equipment Cat-NB1
- Optimized for **low-data volume** metering, control, tracking and sensor devices
- Standardized for **global use** in 3GPP Rel.13
- Allowing for **“install and leave alone”** device operation with >10years device battery life
- IoT businesses and underlying connections protected against (malicious) interference by use of **licensed spectrum**



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Benefits and Gains

LTE3071

Benefits	Drawbacks
• LTE 3071 provides with framework for NB-IoT UE operation • The main benefit is that with the feature legacy network can be seamlessly migrated by means of SW upgrade and allows for serving of NB-IoT devices.	• Allocation of NB-IoT carrier consumes PRB resources; in DL direction not only single PRB, but the whole RBG allocation group • The first release of NB-IoT is incompatible with some generic legacy features, what may bring degradation of the host cell operation. • Improved coverage will not be supported by LTE3071; it will come with further extension features

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Benefits and Gains

NB-IoT benefits over the unlicensed technologies (e.g. LoRa, SigFox)

- No additional site, backhaul, BTS HW nor implementation capex / opex
- Increased coverage and penetration e.g. to inside building basements => avoid redesigning and expanding the macro network
- Avoid building of separate back-office systems for unlicensed technology
- Avoid integration cost of mobile based use-cases and stationary unlicensed use cases

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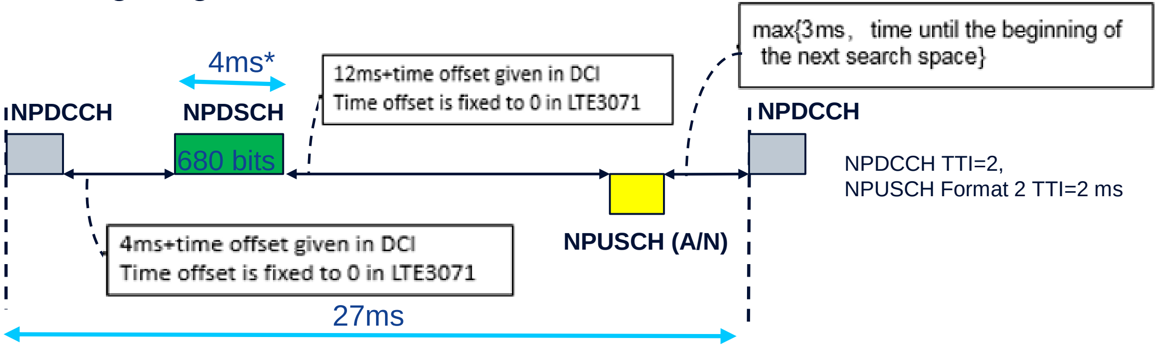
Benefits and Gains

NB-IoT DL Data Rates

- Timing diagram for NB-IoT downlink data transmission



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

- Instantaneous peak rate (in-band) is is given by:

TBS_{max}/T_{NPDSCH} = **170 kbps** (TBS=680 bytes, TTI=4ms)

- Sustained throughput:

$TBS_{max}/(T_{NPDCCH} + 4ms + T_{NPDSCH} + 12ms + T_{NPUSCH} + 3ms)$ kbps

Sustained peak rate is approximately **26.2 kbps** without considering NPBCH/NPSS/NSSS overhead, and **15.7 kbps** when 40% DL overhead is taken into account (PBCCH, SIBx, PSS, SSS)

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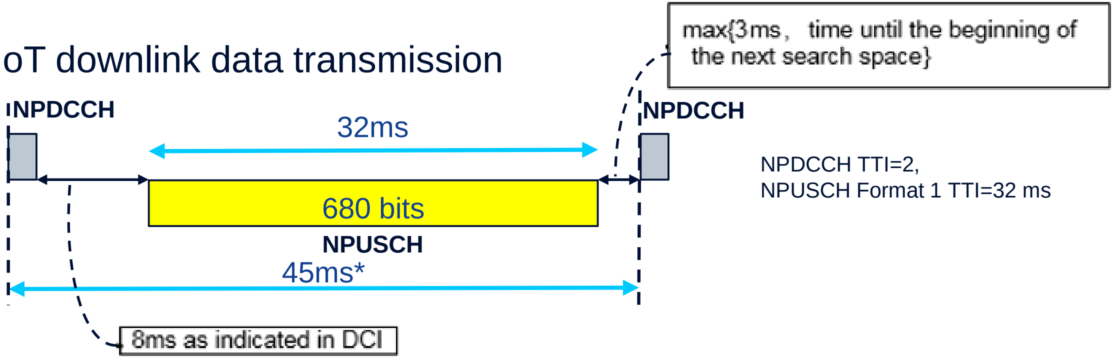
Benefits and Gains

NB-IoT UL Data Rates

- Timing diagram for NB-IoT downlink data transmission



NPDCCH TTI=2,
NPUSCH Format 1 TTI=32 ms

- Instantaneous throughput is given by:

TBS_{max}/T_{NPDSCH} = **21.2 kbps** (TBS=680 bytes, TTI=32ms)

- Sustained throughput:

$TBS_{max}/(T_{NPDCCH} + 8ms + T_{NPUSCH} + 3ms)$ kbps

Approximately **15.4 kbps** without considering NPRACH overhead

NPRACH occasion is every 160 ms and lasts for 25.6 ms, 16% overhead reduces sustained peak rate to **12.9 kbps**

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Benefits and Gains
Simulations

- Product specific system level simulator is under development, hence T&I results are shown for reference
  - **NOTE: The results of simulations demonstrate trends (not absolute values) expected after feature activation. The presented simulations should be analyzed with respect to the assumptions taken. Analysis is based on 3GPP features using single user link analysis. Product may have different constraints from the assumptions used in this analysis.**

- Simulation assumptions:
  - Single user link-level analysis
  - 2Tx-2Rx at eNB, 1Tx-1Rx at UE, 23 dBm UE power class, half-duplex
  - Antenna gain: 16 dBi at eNB, 0 dBi at UE
  - 6 dB PSD boosting for NB-IoT, NB-IoT uses 12 or 1 tones in the uplink (15 kHz)
  - TU 1 Hz channel for NB-IoT,
  - Invalid subframes and subframes used for common channels/signals (e.g. PBCH, PSS/SSS, SIs) are not considered in this analysis

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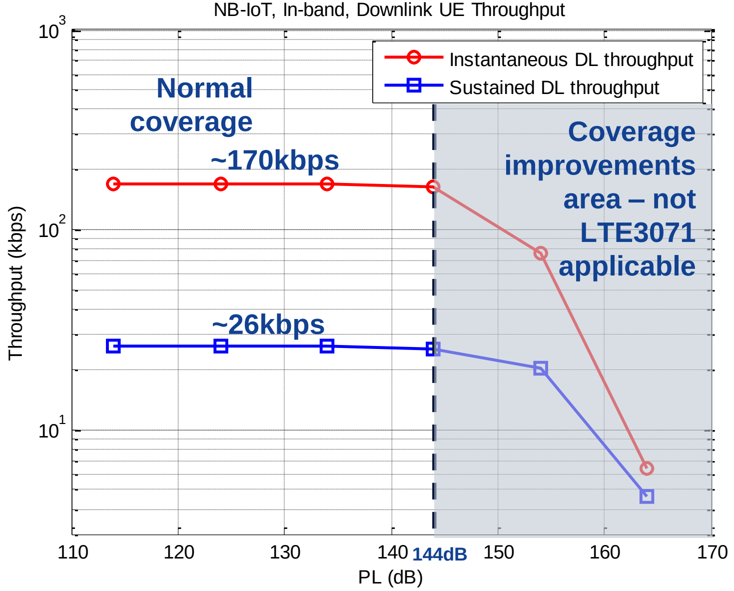
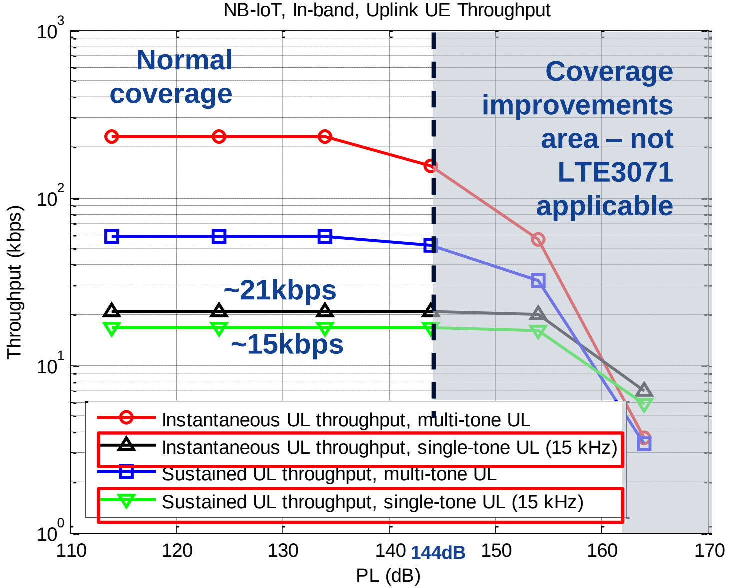
Benefits and Gains

Simulations NB-IoT Data Rates

- Instantaneous and sustained data rates are aligned with theoretical calculations (overheads are not considered)

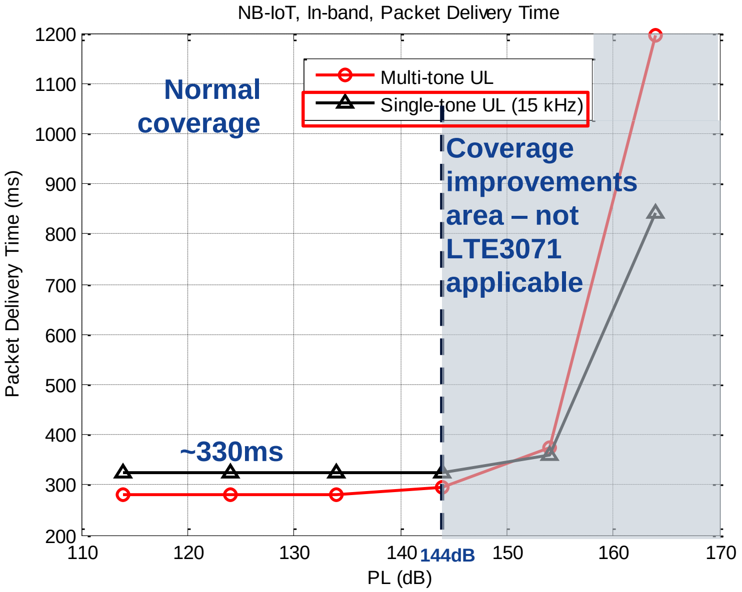




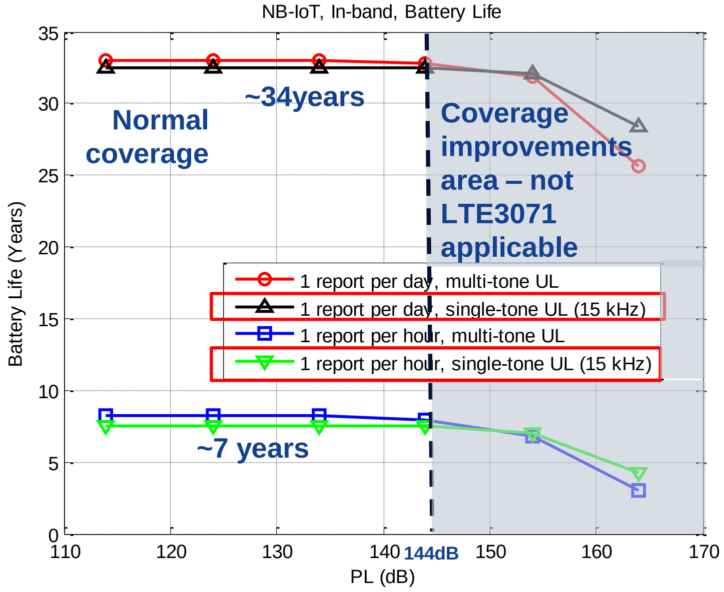
Benefits and Gains

Simulations: latency and battery life

- Packet delivery time (just TBS delivery)
  - 200 bytes packet size



- Battery life (without battery self-discharging)



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Configuration Management

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Configuration Management

Definition of terms and rules for parameter classification*

The **'Basic Parameters'** category contains primary parameters which should be considered during cell deployment and must be adjusted to a particular scenario:

- Network Element (NE) identifiers
- Planning parameters, e.g. neighbour definitions, frequency, scrambling codes, PCI, RA preambles
- Parameters that are the outcome from dimensioning, i.e. basic parameters defining amount of resources
- Basic parameters activating basic functionalities, e.g. power control, admission control, handovers
- Parameters defining operators' strategy, e.g. traffic steering, thresholds for power control, handovers, cell reselections, basic parameters defining feature behaviour

The **'Advanced Parameters'** category contains the parameters for network optimisation and fine tuning:

- Decent network performance should be achieved without tuning these parameters
- Universal defaults ensuring decent network performance need to be defined for all parameters of this category. If this is not possible for a given parameter it must be put to the 'Basic Parameters' category
- Parameters requiring detailed system knowledge and broad experience unless rules for the 'Basic Parameters' category are violated
- All parameters (even without defaults, e.g. optional structures) related to advanced and very complex features

The **'Obsolete parameters'** category is intended for parameters that are candidates to be removed from the product in a future release:

- Parameters always used with default value
- Parameters that are not used by operators
- Parameters that are not relevant anymore

* **- purpose:** Categories of parameters have been defined to simplify network parametrization. Parameterization effort shall be focused mainly on Basic ones. Categorization is reflected in a 'view' definition in NetAct CM Editor.

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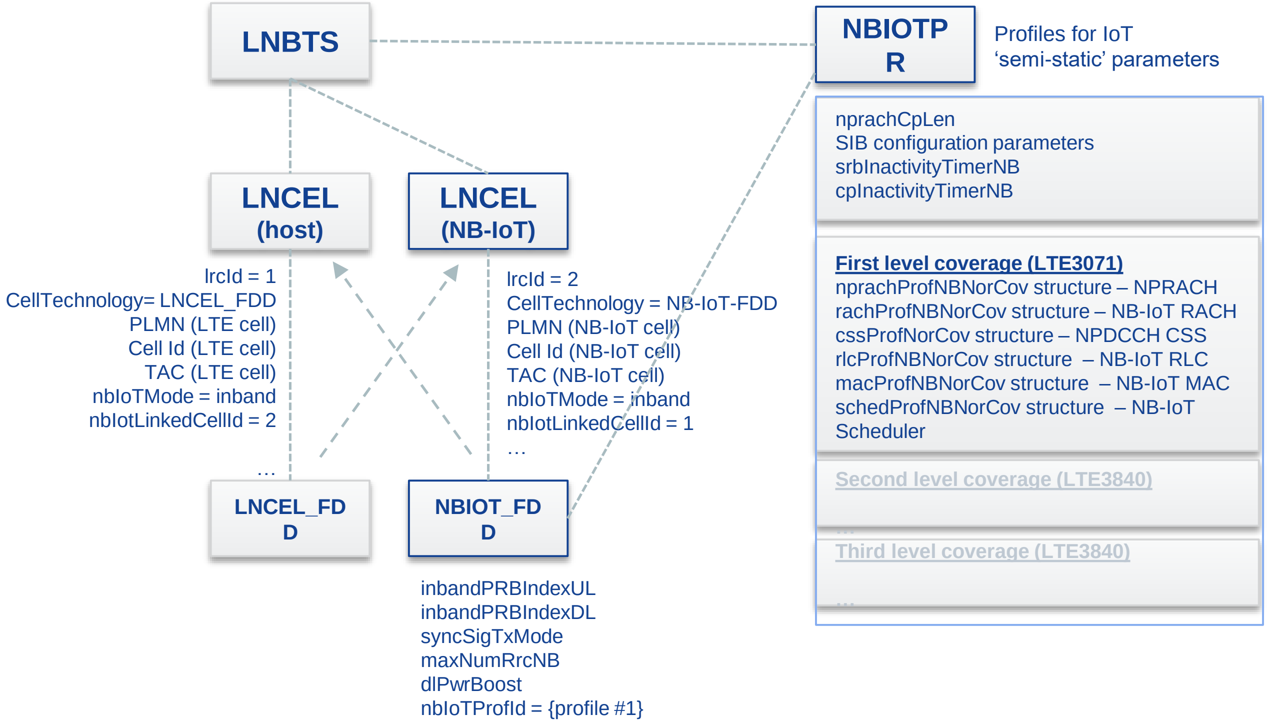
Configuration Management



- New NBIOT_FDD MOC grouping NB-IoT relevant parameters
- NBIOTPR Profiles for IoT 'semi-static' parameters
  - With LTE3071 parameters for first level coverage only
  - Second and third coverage levels with LTE3840
- NB-IoT cell reconfiguration is not supported in current release so all the NB-IoT related parameters update/creation requires cell lock to take effects.
- **Direct Lock/ unlock/ reset/shutdown of inband NB-IoT cell is not supported, host cell have to be locked**

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Configuration Management
New parameters

Abbreviated name	Full name	PKDB link
LNCEL: nbIotLinkedCellId	NBIoT inband linked cell ID between NB-IoT host cell and concrete cell	Parameter Knowledge Database
LNCEL: nbIoTMode	NB-IoT operation mode	Parameter Knowledge Database
NBIOT_FDD: inbandPRBIndexDL	NBIoT inband downlink PRB index	Parameter Knowledge Database
NBIOT_FDD: inbandPRBIndexUL	NBIoT inband uplink PRB index	Parameter Knowledge Database
NBIOT_FDD: nbIoTProfId	Instance ID of the assigned NBIOTPR profile	Parameter Knowledge Database
NBIOT_FDD: dlPwrBoost	Downlink channel power boost for inband NB-IoT	Parameter Knowledge Database

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Configuration Management
New parameters

Abbreviated name	Full name	PKDB link
NBIOT_FDD: maxNumRrcNB	Max Number RRC	Parameter Knowledge Database
NBIOT_FDD: syncSigTxMode	Synchronization signals transmission mode: Enumeration	Parameter Knowledge Database
LNMME: mmeRatSupport	MME RAT support	Parameter Knowledge Database
LNCEL: tExtendedWait	Timer ExtendedWaitTime-r10	Parameter Knowledge Database

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Configuration Management

New parameters

SIB configuration

Abbreviated name	Full name	PKDB link
NBIOTPR: numSib1RepNB	Number of SIB1-NB repetitions	Parameter Knowledge Database
NBIOTPR: sib2PeriodicityNB	The periodicity of SIB2-NB	Parameter Knowledge Database
NBIOTPR: sib2RepPatternNB	The repetition pattern of SIB2-NB	Parameter Knowledge Database
NBIOTPR: siRadioFrameOffNB	Offset of the start of SI-NB window	Parameter Knowledge Database
NBIOTPR: siWindowLenNB	SI-NB window length	Parameter Knowledge Database

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Configuration Management

New parameters

NPDCCH search space configuration

Abbreviated name	Full name	PKDB link
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

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Configuration Management

New parameters

MAC configuration

Abbreviated name	Full name	PKDB link
NBIOTPR: macProfNBNorCov	MAC profile for NB-IoT first level coverage	Parameter Knowledge Database
NBIOTPR: logicalChanSrProhibitTimerNB	Logical channel SR prohibit timer for NB-IoT	Parameter Knowledge Database
NBIOTPR: tReTxBsrTimeNB	Retransmit BSR timer for NB-IoT	Parameter Knowledge Database

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Configuration Management

New parameters

NPRACH configuration

Abbreviated name	Full name	PKDB link
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

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Configuration Management

New parameters

RACH configuration

Abbreviated name	Full name	PKDB link
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

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Configuration Management

New parameters

RLC configuration

Abbreviated name	Full name	PKDB link
NBIOTPR: rlcProfNBNorCov	RLC profile for NB-IoT first level coverage	Parameter Knowledge Database
NBIOTPR: maxRetxThreNB	Max retransmission threshold for NB-IoT	Parameter Knowledge Database
NBIOTPR: tPollRetrNB	Poll retransmit for NB-IoT	Parameter Knowledge Database

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Configuration Management

New parameters

Scheduler configuration

Abbreviated name	Full name	PKDB link
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

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Configuration Management

New parameters

Timers

Abbreviated name	Full name	PKDB link
NBIOTPR: srbInactivityTimerNB	SRB inactivity timer	Parameter Knowledge Database
NBIOTPR: cpInactivityTimerNB	C-Plane inactivity timer	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

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Configuration Management
Related parameters

Abbreviated name	Full name	PKDB link
MBSFNCEL: mbsfnCellId	MBSFN Cell identifier	Parameter Knowledge Database
LNBTS: actCRAN	Activate Centralized RAN: Boolean	Parameter Knowledge Database
ULCOMP: ulCoMpCellList	Uplink CoMP Cell List: Number	Parameter Knowledge Database
LNCEL: actEicic	Activate enhanced inter-cell interference coordination:	Parameter Knowledge Database
LNCEL: actMicroDtx	Activate eNode B power saving - Micro DTX: Boolean	Parameter Knowledge Database

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Configuration Management
Related parameters

Abbreviated name	Full name	PKDB link
LNCEL: actOtdoa	PRS activation: Boolean	Parameter Knowledge Database
LNCEL: csgType	Closed Subscriber Group type: Enumeration	Parameter Knowledge Database
LNCEL_FDD: actCatM	Activate LTE-M feature: Boolean	Parameter Knowledge Database
LNCEL_FDD: actCombSuperCell	Activate combined supercell configuration:	Parameter Knowledge Database
LNCEL_FDD: actLiquidCell	Activate liquid cell configuration:	Parameter Knowledge Database
LNCEL_FDD: actSuperCell	Activate supercell configuration:	Parameter Knowledge Database

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Deployment Aspects

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Deployment Aspects
Frequency layer selection for NB-IoT

- Selection of frequency band for NB-IoT depends on the operator resources and spectrum policy
- NB-IoT in-band solution requires LTE network in operation
- Generally it is expected that lower bands (<1 GHz) provides with higher cell range, the lower frequency bands have smaller building penetration loss
- However one has to be aware that 3GPP Release 13 [36.521] specifies IoT usage on the selected bands only. Further enhancements are expected with Release 14.

eUTRA Band number	Band	Total spectrum	Uplink [MHz]	Downlink [MHz]	3GPP Rel.
1	2100	2x60 MHz	1920 - 1980	2110 -2170	Rel. 13
2	1900	2x60 MHz	1850 - 1910	1930 - 1990	Rel. 13
3	1800	2x75 MHz	1710 - 1785	1805 - 1880	Rel. 13
5	850	2x25 MHz	824 - 849	869 - 894	Rel. 13
8	900	2x35 MHz	880 - 915	925 - 960	Rel. 13
10	1700	2x60 MHz	1710 - 1770	2110 - 2170	Rel. 14
12	700	2x18 MHz	699.4 - 714.8	729.4 - 744.8	Rel. 13
13	700	2x10 MHz	777 - 787	746 - 756	Rel. 13
17	700	2x10 MHz	704.0 - 714.8	734.0 - 744.8	Rel. 13
18	800	2x15 MHz	815 - 830	860 - 875	Rel. 13
19	800	2x15 MHz	830 - 845	875 - 890	Rel. 13
20	800	2x30 MHz	832 - 862	791 -821	Rel. 13
25	1900	2x65 MHz	1850 - 1915	1930 - 1995	Rel. 14
26	850	2x35 MHz	814 - 849	859 - 894	Rel. 13
28	700	2x25 MHz	703 - 738	758 - 794	Rel. 13
31	450	2 x 5 MHz	452.5 - 457.5	462.5 - 467.5	Rel. 14
66	2100	2x70 MHz	1710 - 1780	2110 - 2200	Rel. 13
70	1700	2x15 MHz	1695 – 1710	1995 – 2020	Rel. 14

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Deployment Aspects

Impact on legacy LTE performance

- The main impact on the legacy LTE cell is due to LTE3071 incompatibility with some features activated in the host cell.

Legacy LTE feature not compatible with NB-IoT in same cell	Compatibility issue	Solution
LTE3128 NB-IoT	NB-IoT and Cat-M can't be enabled in the same cell due to scheduler implementation. NB-IoT and Cat-M can be enabled in different cells in one eNB	FL17A LTE3819 LTE-M/NB-IoT on same LTE 10MHz cell in, FL18 LTE4040 for other Bandwidths
LTE187 Single TX path mode **LTE568 DL Adaptive Closed Loop MIMO (4x2)** **LTE1987 DL adaptive CL SU MIMO (4x4)** **LTE2582 DL 4x4 MIMO with Carrier Aggregation** **LTE1063 Uplink SU MIMO for 4 RX paths**	Structure of NB-IoT channels selected for in-band LTE3071 feature assumes 2-port CRS structure. Hence host legacy cell have to operate with 2TX transmission schemes only. 1Tx and 4Tx modes are not compatible with LTE3071, and it should be considered during NB-IoT host cell selection.	LTE3722 NB-IoT: Additional configurations (4Rx, 4Tx or 1Tx eNB support) (FL18 candidate)
LTE1402 Uplink CoMP **LTE1691 Uplink intra-eNB CoMP 4Rx** **LTE2605 4RX diversity 20MHz optimized configurations**	Exceptions also for specific RX modes using DSP allocations conflicting with NB-IoT (e.g. LTE2605). Additionally host cell should not be included in the CoMP set.	Host cell: LTE3571 NB-IoT: Enhancements and Improved Feature interactions - Phase I (FL18 candidate) UL COMP for NB-IoT: LTE3730 NB-IoT: Enhancements and Improved Feature interactions - Phase II (FL18 SP candidate)

Note: Subject to change; some limits will be solved by separate features or during forthcoming NB-IoT features development phase

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Deployment Aspects
Impact on legacy LTE performance

Legacy LTE feature not compatible with NB-IoT in same cell	Compatibility issue	Solution
LTE2180 FDD-TDD downlink carrier aggregation 2CC	Inter eNB CA TDD+FDD is not supported in the host LTE cell due to conflicting requirements on DSP deployment in eNB FDD. There is no specific feature flag for FDD+TDD CA because 'actInterEnbDLCAggr' is commonly used also for FDD+FDD CA	LTE3571 NB-IoT: Enhancements and Improved Feature interactions - Phase I (FL18 candidate)
LTE2270 LTE TDD+FDD inter eNB CA basic BTS		
LTE2316 FDD-TDD downlink carrier aggregation 3CC		
LTE2735 FDD-TDD downlink carrier aggregation with AirScale System Module configurations		
LTE2337 FDD-TDD downlink carrier aggregation 3CC - 2 FDD & 1 TDD		
LTE2623 FDD-TDD downlink carrier aggregation 4CC		

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Deployment Aspects
Impact on legacy LTE performance

Legacy LTE feature not compatible with NB-IoT in same cell	Compatibility issue	Solution
LTE1709 Liquid Cell	TM9 CSI-RS may interference to NB-IoT	LTE3730 NB-IoT: Enhancements and Improved Feature interactions - Phase II (FL18 SP candidate)
LTE1542 FDD Supercell **LTE2091 Extended SuperCell** **LTE2445 Combined Supercell**	Combined Supercell requires specific DSP deployment (currently not supported).	LTE3673:IoT Coexistence with High-Speed UEs & Supercell (FL17A-SP or FL18). Supercell for NB-IoT users: LTE3730 NB-IoT: Enhancements and Improved Feature interactions - Phase II (FL18 SP candidate)
LTE1117 LTE eMBMS	eMBMS may have interference to/from NB-IoT.	LTE3730 NB-IoT: Enhancements and Improved Feature interactions - Phase II (FL18 SP candidate)
LTE1113 eICIC **LTE1496 eICIC**	NB-IoT has interference on eICIC ABS subframes.	LTE3571 NB-IoT: Enhancements and Improved Feature interactions - Phase I (FL18 candidate) LTE3730 NB-IoT: Enhancements and Improved Feature interactions - Phase II (FL18 SP candidate)
LTE1891 MicroDTX	MicroDTX may mute the subframes impacting NB-IoT	
LTE495 OTDOA	PRS subframes will interfere with Nb-IoT.	LTE3571 NB-IoT: Enhancements and Improved Feature interactions - Phase I (FL18 candidate)
LTE819 DL inter-cell interference generation	Dummy load generation on both host LTE cell and NB-IoT cell are not supported	
LTE1900, LTE2470, LTE2291, LTE2564 centralized RAN	CRAN will not be supported in the host cell.	Under study for FL18A

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Deployment Aspects
Selection of PRBs for NB-IoT cell

- **NB-IoT DL PRB** can be configured from predefined PRB indexes, allowing for the lowest frequency error ***NBIOT_FDD: inbandPRBIndexDL***

LTE system bandwidth	5 MHz	10 MHz	15 MHz	20 MHz
DL PRB indices	2, 7, 17, 22	4, 9, 14, 19, 30, 35 40, 45	2, 7, 12, 17, 22, 27, 32, 42, 47, 52, 57, 62, 67, 72	4, 9, 14, 19, 24, 29, 34, 39, 44, 55, 60, 65, 70, 75, 80, 85, 90, 95

- **NB-IoT UL PRB** can be configured from **any uplink PRB** not used for PRACH/PUCCH and possible PRACH/PUCCH if dynamic PUCCH enabled in host LTE cell ***NBIOT_FDD: inbandPRBIndexUL***
- Selection of UL PRB should also avoid fragmentation of PUSCH resources. Since Rel. 8/9 UE are able to allocate only contiguous PRBs in UL, improperly selected PRB may lead to the degradation of UL throughput performance.

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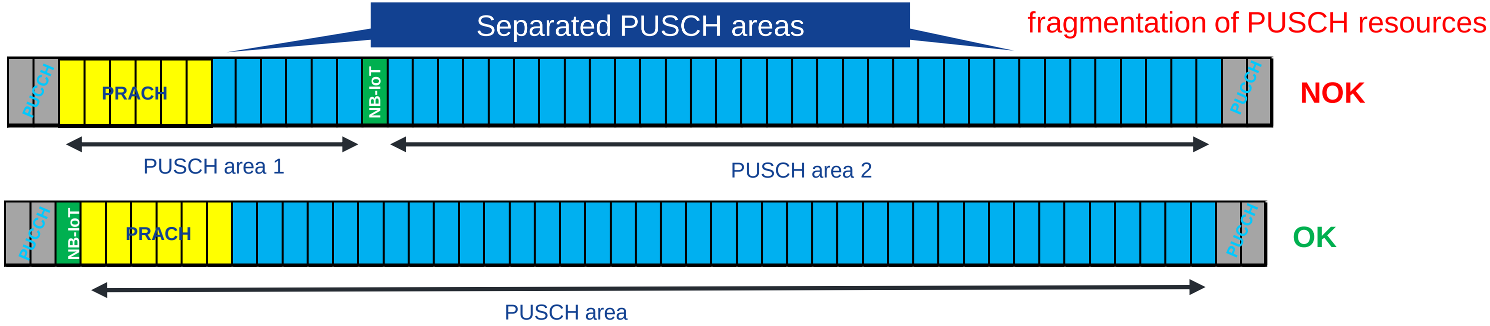
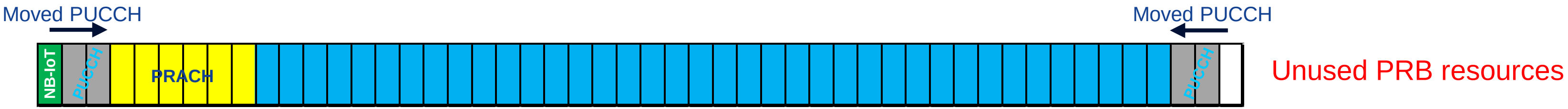
Deployment Aspects
Selection of UL PRB for NB-IoT cell

- The approach of PRB selection depends on whether LTE1130 Dynamic PUCCH allocation is activated
- **If LTE1130 Dynamic PUCCH allocation is not in use** the adjacent PRB near PUCCH is preferred.
- Non-overlapped PRACH area have be selected by PRACH offset ***(prachFreqOffset)***



- Another option is PRB from the outer region outside area in host LTE cell by LTE768 PUCCH blanking . Disadvantage of such solution is unused PRB; the feature blanks PUCCH on both sides of the spectrum.



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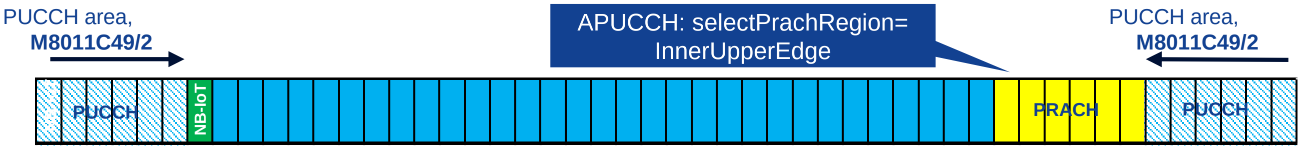
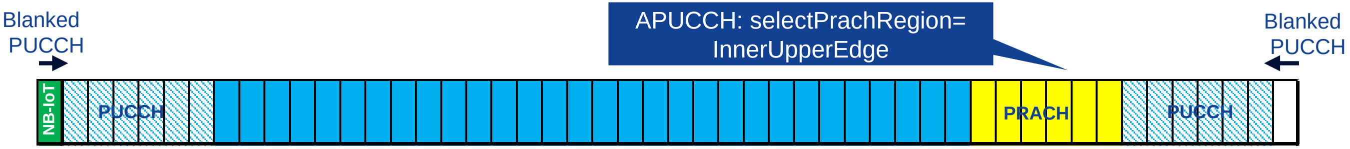
Deployment Aspects
Selection of UL PRB for NB-IoT cell

- **If LTE1130 Dynamic PUCCH allocation is in use.** The features estimates PUCCH resources, based on parameters set by operator and activated features. Since number of PRBs for PUCCH is not explicitly defined, it have to be tracked from the counters **(PRB used PUCCH (M8011C49)).**
- NB-IoT carrier have to be adjacent to PUCCH. PRACH allocation should be opposite to the NB-IoT carrier **(APUCCH: selectPrachRegion)**



Note: In current design, when LTE1130 is activated (actAutoPucchAlloc=true), MaxPucchResourceSize is set to 12, what means that lowest NB-IoT PRB is 7th from each edge.

- There is also option to locate NB-IoT carrier in the outer, blanked PUCCH areas. It causes UL capacity degradation since one of the outer areas is unused.



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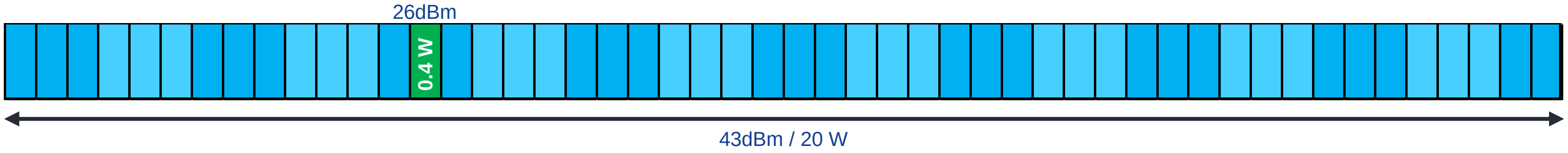
Deployment Aspects
NB-IoT power boosting

- DL power of NB-IoT carrier is derived from the eNB DL power equally distributed among all the PRBs. Example for 10 MHz and 43dBm eNB DL power:

$$\boldsymbol{Power_{DL\ NB\text{-}IoT} = Power_{Host\ LTE} - 10 \cdot \log (N_{PRB\ Host}) = 43 - 10 \cdot \log (50) = 26\ dBm\ (0.4\ W)}$$

LTE BW [MHz]	5 MHz	10 MHz	15 MHz	20 MHz
DL power per PRB [W]	0.8	0.4	0.27	0.2



- DL power can be insufficient for reaching deep indoor mobiles, that is why power boost up to 6dB is foreseen for the NB-IoT carrier

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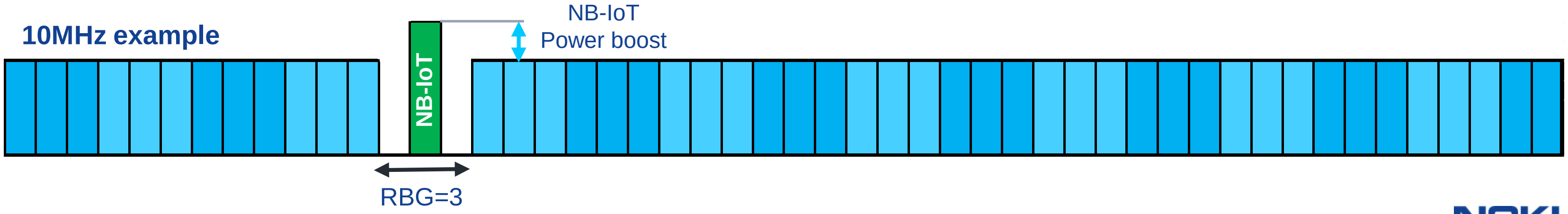
Deployment Aspects
NB-IoT power boosting

- Scheduler allocates resources in the RBG (Resource Block Group), with size depending on the LTE BW. The whole RBG with NB-IoT carrier is excluded from the legacy traffic allocation. It means that power of the non-used PRBs in the RBG can be used for NB-IoT carrier boosting.

LTE BW [MHz]	5 MHz	10 MHz	15 MHz	20 MHz
RBG Size [PRB]	2	3	4	4

- For 15/20MHz, the NB-IoT PRB power boost can be achieved from 3 neighbor PRBs in same RBG, while for 5/10MHz, it can be taken from 1/2 neighbor PRBs in same RBG.
- When it is not sufficient, wideband power reduction is applied

10MHz example



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Deployment Aspects
NB-IoT power boosting

- Power reduction of other PRBs in wide band host cell is needed when sum of unused RBG PRBs in [W] exceeds NB-IoT carrier power boost. Mostly in concerns 5MHz LTE BW.
- Power reduction is applied by the system automatically.

LTE BW [MHz]	5 MHz	10 MHz	15 MHz	20 MHz	
DL power per PRB [W]	0.8	0.4	0.27	0.2	
Unused PRB power [W]	0.8	0.8	0.8	0.6	$(RBG\text{-}1) \cdot DL\_Power_{PRB}$
Max DL power per PRB (w/boost) [W]	1.6	1.2	1.06	0.8	$RBG \cdot DL\_Power_{PRB}$
NB-IoT carrier power @3dB boost [W]	1.60	0.80	0.53	0.40	$2 \cdot DL\_Power_{PRB}$
NB-IoT carrier power @6dB boost [W]	**3.18**	**1.59**	1.06	0.80	$3.97 \cdot DL\_Power_{PRB}$
Host LTE cell power reduction per PRB @6dB [W]	**0.07**	**0.01**	0	0	$(DL\_Power_{NB\text{-}IoT} – Max\_DL\_Power_{NB\text{-}IoT})/(N_{PRB}–RB$
Host LTE cell power reduction per PRB @6dB [dB]	**0.4**	**0.1**	0	0	

Microsoft Excel Worksheet

[NB-IoT power boost calculator](#)
(NPO Chris Johnson)

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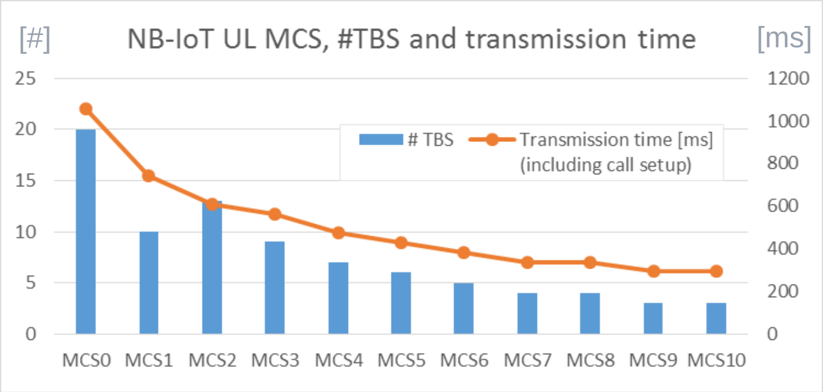
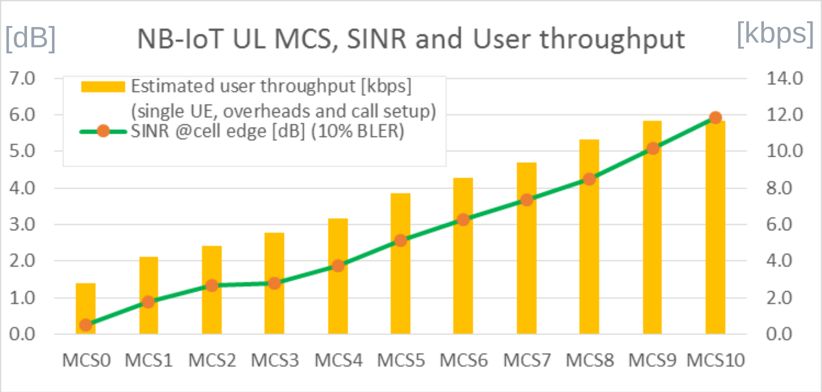
Deployment Aspects
Selection of initial MCS for NB-IoT cell

- NB-IoT cell does not support link adaptation procedure. Hence selected UL ***(NBIOTPR: iniMcsUl)*** and DL MCS ***(NBIOTPR: iniMcsDl)*** is used during the whole IoT call duration. Please also note that only first level coverage with pathloss target up to 144dB is supported with the feature.
- Selection of UL MCS has the higher importance as only uplink originated messages are supported. The lowest MCS are the most robust, however its low TBS size cause message fragmentation and increases message transfer. Examples: 200 bytes message size, EPA model





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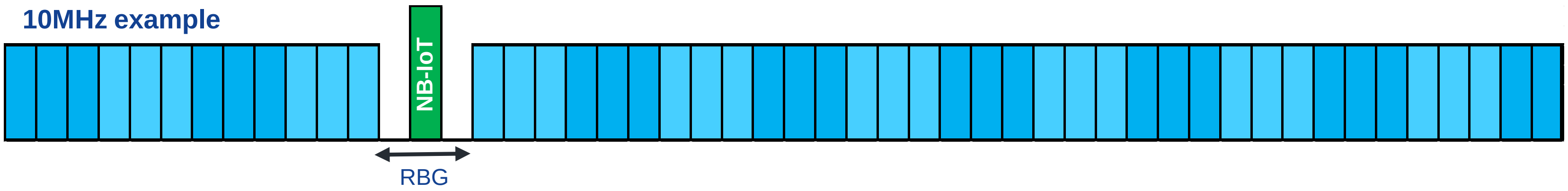
Deployment Aspects
Host LTE cell capacity loss

- DL Scheduler allocation is organized in RBG groups. Unused PRBs from the group containing NB-IoT carrier can not be used for legacy traffic, what causes degradation of the throughput.



LTE BW [MHz]	5 MHz	10 MHz	15 MHz	20 MHz
RBG Size [PRB]	2	3	4	4
DL Capacity loss	8%	6%	5%	4%

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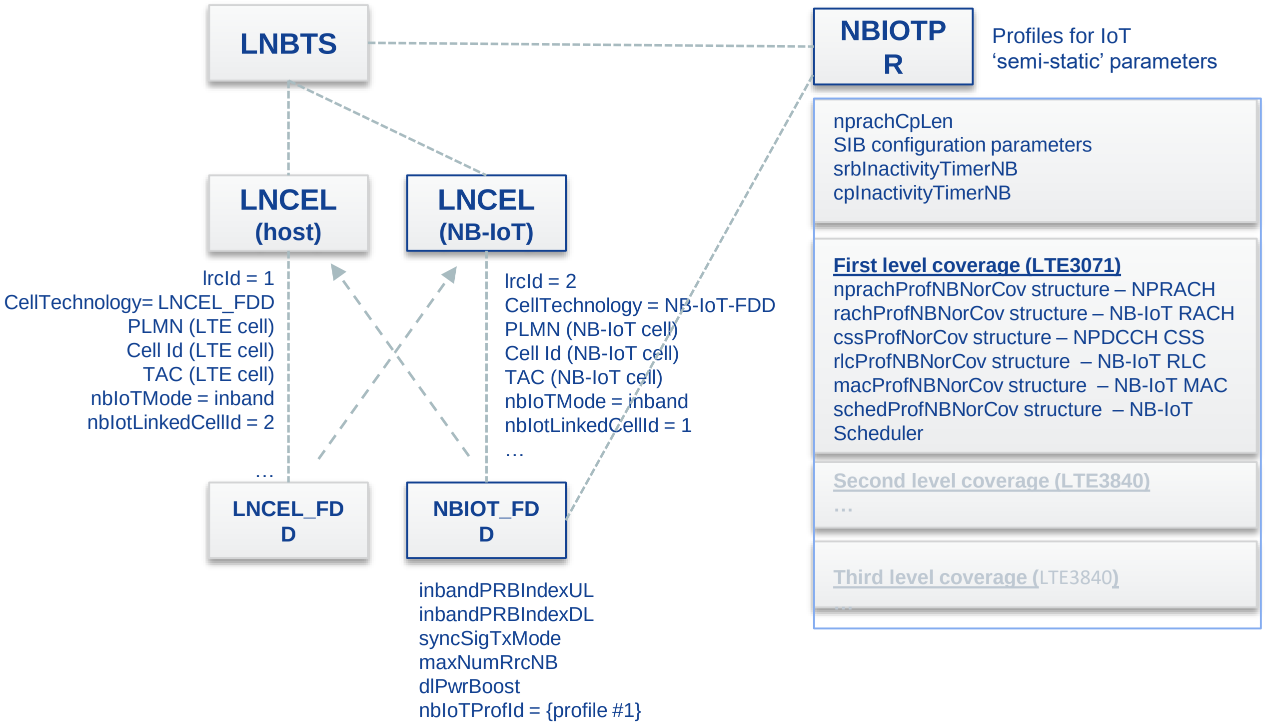
Deployment Aspects
Object Model



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Deployment Aspects
LTE3071 limitation

- Features which are exclusive with LTE3071 have to be deactivated in the **host cell**, even though these consistency checks are not explicitly specified.
- ***MBSFNCEL: mbsfnCellId, actMBMS***
- eMBMS will be disabled in wideband host LTE cell by not configuring MBSFNCEL managed object for that LNCEL instance. BTS level deactivation (actMBMS) is not needed.
- ***LNBTS: actCRAN=false*** ,CRAN will not be supported in eNB if there is NB-IoT cell in this BTS
- ***ULCOMP: ulCoMpCellList, actUlCoMp***
- NB-IoT cell and WB-host cell are excluded from Uplink CoMP Cell List that other cells belong to. BTS level ULCoMP deactivation (actULCoMP) is not needed.
- ***LNCEL: actEicic=false,*** NB-IoT has interference on eICIC ABS subframes
- ***LNCEL: actMicroDtx=false,*** MicroDTX may muste the subframes impacting NB-IoT
- ***LNCEL: actOtdoa=false,*** OTDOA PRS may has the interference to/from NB-IoT.

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Deployment Aspects
LTE3071 limitation

- Features which are exclusive with LTE3071 have to be deactivated in the **host cell**, even though these consistency checks are not explicitly specified.
- ***LNCEL: csgType=openAccess,*** The wideband host LTE cell can't be set to CSG cell.
- ***LNCEL_FDD: actCatM=false,*** Simplify the implementation and verification. NB-IoT and Cat-M can be enabled in different cells in one eNB.
- ***LNCEL_FDD: actCombSuperCell=false*** Combined Supercell requires specific DSP deployment.
- ***LNCEL_FDD: actLiquidCell=false, LNCEL_FDD: actSuperCell=false,*** Super Cell and Liquid cell requires specific DSP deployment (not supported in FL17). Liquid cell: TM9 CSI-RS may interference to NB-IoT

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Deployment Aspects
Feature activation

Note: at the time of materials preparation final Site Manager version was not available. Details may differ in the product version.

- **STEP 1** – Host cell

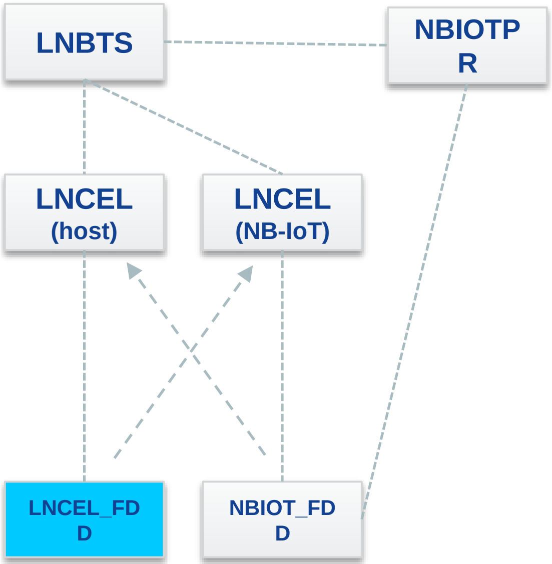
actNBIoT value is set to “inband

NB-IoT operation mode:	inband	
NBIoT inband linked cell ID between NB-IoT host cell and concrete cell:	0	[0...255]

inbandLinkedCellId shall be set to the associated NB-IoT concrete cell’s lcrID

Local cell	Frequency band	Bandwidth	EARFCN	Frequency (MHz)
1	800MHz (E-UTRA 20)	10 MHz	6200	796.0
2	NA	0.2 MHz	NA	NA

ulChBw, dlChBw shall be set to either 5, 10, 15 or 20 MHz



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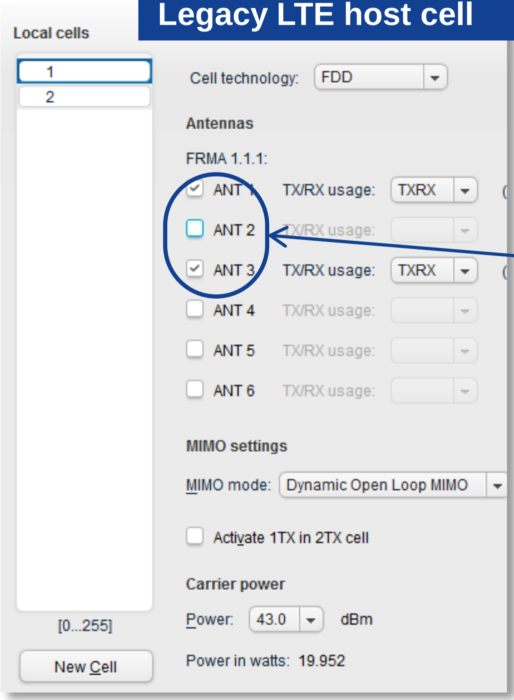
Deployment Aspects
Feature activation

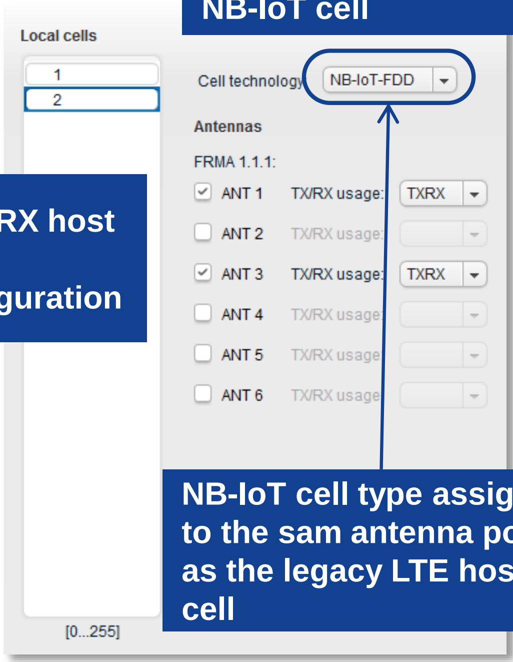
- **STEP 2** – Creation of NB-IoT cell

Legacy LTE host cell

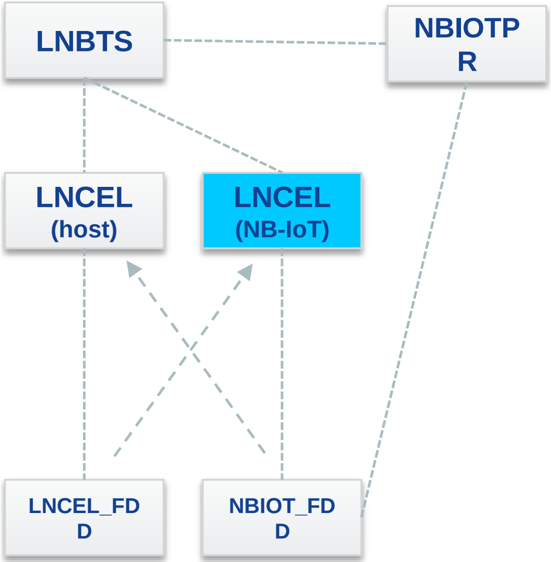


2TX2RX host cell configuration

NB-IoT cell



NB-IoT cell type assigned to the sam antenna ports as the legacy LTE host cell



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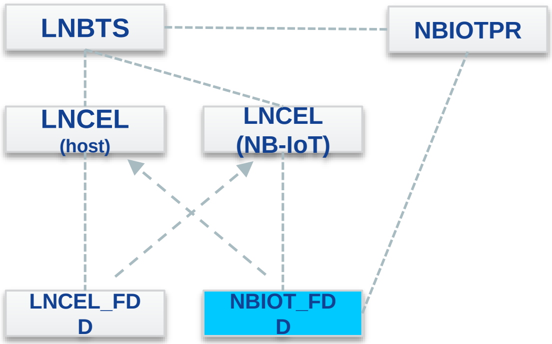
Deployment Aspects
Feature activation

- **STEP 3** – configuration of NBIOT_FDD-0 object



NBIOT_FDD-0 object

Sorting: Alphabetical

NBIOT_FDD-0 Properties

NB-IoT FDD specific cell identifier:	0	[0...0]
Downlink channel bandwidth:	0.2 MHz	
Downlink channel power boost for inband NB-IoT:	6.0	dB [0.0, 0.1, ...6.0]
Instance ID of the assigned NBIOTPR profile:	0	[0...31]
Max Number RRC:	20	[0...420]
NBIoT inband downlink PRB index:	4	[0...99]
NBIoT inband uplink PRB index:	4	[0...99]
Number of Coverage Levels:	1	[1...3]
Synchronization signals transmission mode:	TxDiv	
Uplink channel bandwidth:	0.2 MHz	

Path: MRBTS-1\LNBTS-1\LNCEL-2\NBIOT_FDD-0

Single NB-IoT carrier possible with LTE3071

DL power boost

Single NBIOTPR profile

Legacy and NB-IoT RRC connected users < 840

PRB predefined for DL

Remember PUSCH and PRACH restrictions

Only first level coverage level

Number of ports for NPSS/NSSS

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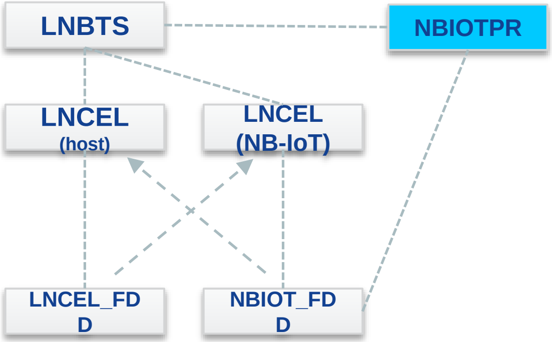
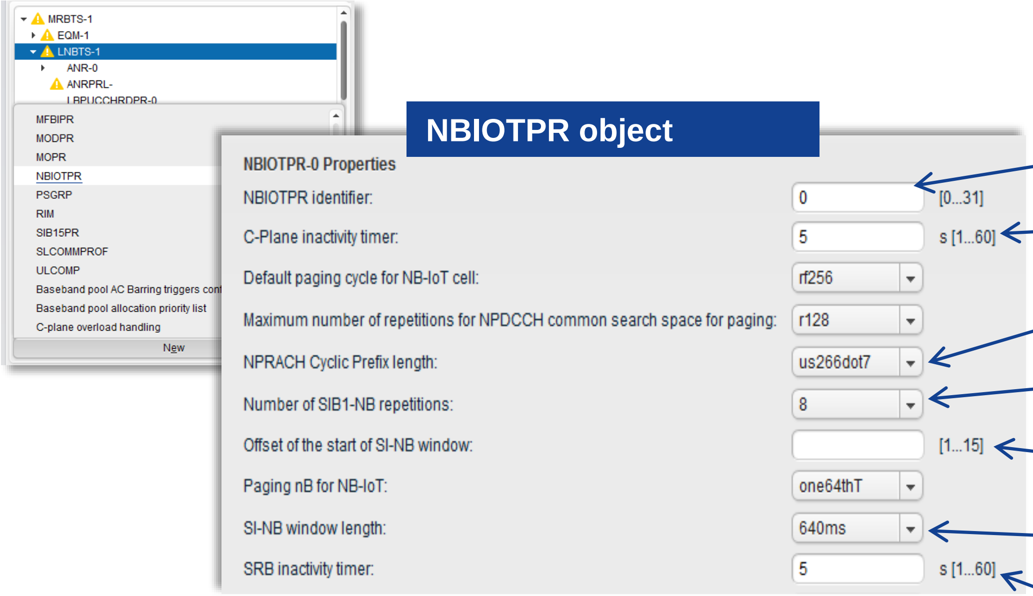
Deployment Aspects
Feature activation



- **STEP 4** – add NBIOTPR profile on the LNBTS level



Single NBIOTPR object for first level coverage

C-plane inactivity

Only normal cyclic prefix supported with LTE3071

SIB1-NB repetitions

SIB2-NB offset

SIB2-NB window

SRB inactivity

Note: All the paging related parameters are not applicable to LTE3071

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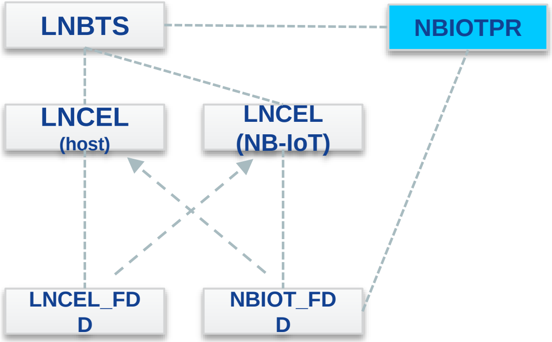
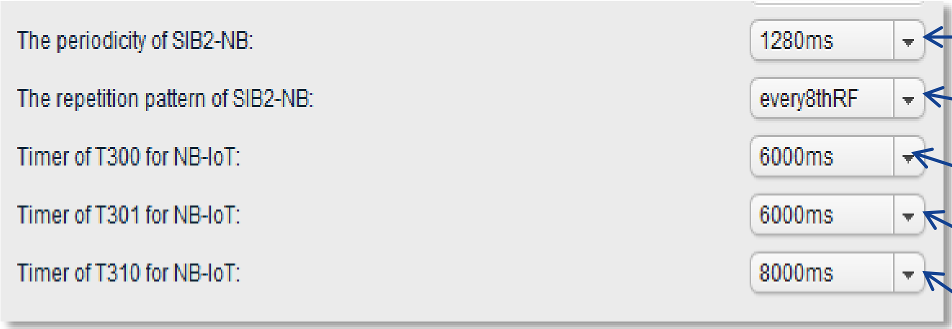
Deployment Aspects
Feature activation



- **STEP 5** – remaining NBIOTPR profile parameters



SIB2-NB periodicity

SIB2-NB repetition pattern

t300NB supervises the RRC connection establishment procedure

t301NB supervises the RRC reestablishment procedure; NOT SUPPORTED with LTE3071

Timer t310NB supervises the recovery from physical layer problems

t300NB guards the period between **RRCConnectionRequest** and reception of **RRCConnectionSetup** or **RRCConnectionReject**.

t310NB starts upon detecting physical layer problems i.e. upon receiving n310 consecutive out-of sync indications from lower layers and stops upon receiving n311 consecutive in-sync indications from lower layers

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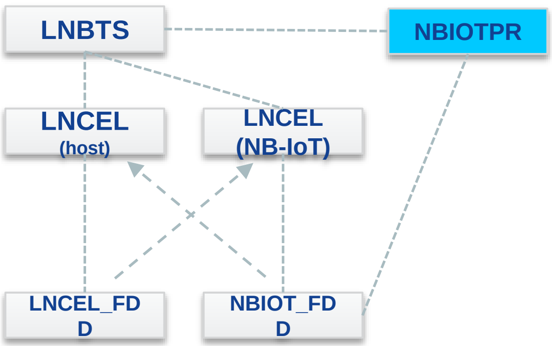
Deployment Aspects
Feature activation



- **STEP 6** – CSS profile for first level coverage

Common Search Space profile for NB-IoT normal coverage-1 Properties

Maximum number of repetitions for NPDCCH common search space for RA:	r4
Offset for NPDCCH Common Search Space:	zero
Starting subframes of the NPDCCH Common Search Space for RA:	v2

Max number of repetitons 4 and starting subframes = 2, results in search space equal to 8 SF

- **STEP 7** – MAC profile for first level coverage

MAC profile for NB-IoT normal coverage-1 Properties

Logical channel SR prohibit timer for NB-IoT:	pp2
Retransmit BSR timer for NB-IoT:	pp64

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

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

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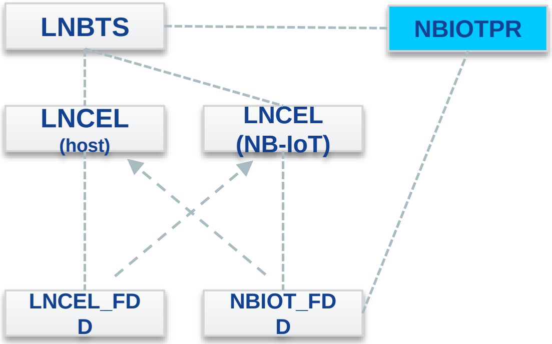
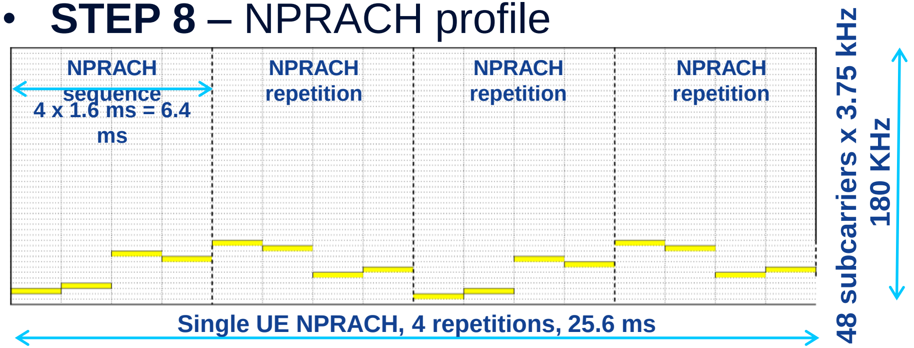
Deployment Aspects
Feature activation



- **STEP 8** – NPRACH profile



NPRACH profile for NB-IoT normal coverage-1 Properties

Max number of preamble attempts of NPRACH:	n5
NPRACH periodicity:	160ms
NPRACH start time:	8ms
NPRACH subcarrier offset:	n0
Number of repetitions per preamble attempt of NPRACH:	n4
Number of subcarriers of NPRACH:	n48

Max number of preamble attempts

NPRACH periodicty

Start time of the NPRACH resource in one period

NPRACH subcarrier offset; LTE3071=0 for 48 subcarriers

Preamble attempt per NPRACH

NPRACH preambles; LTE3071=48

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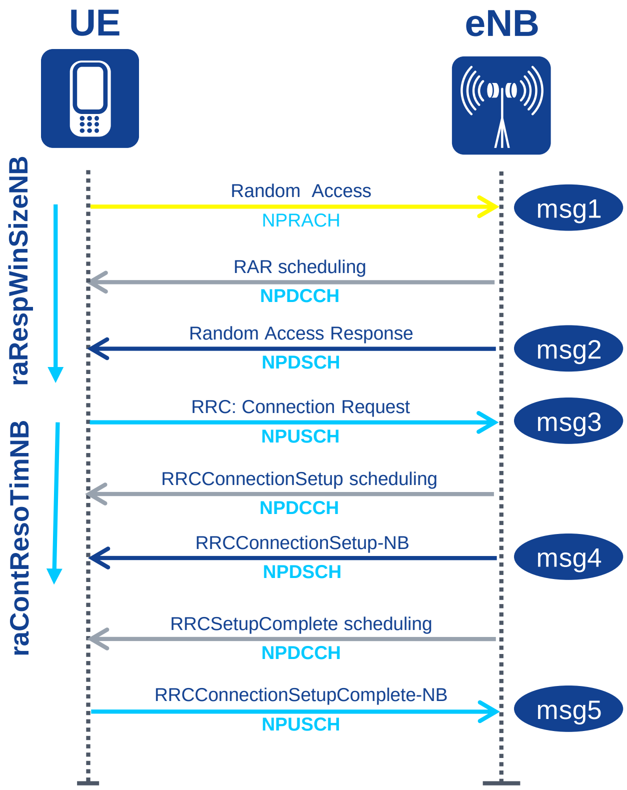
Deployment Aspects
Feature activation

- **STEP 9** – RACH profile

RACH profile for NB-IoT normal coverage-1 Properties

Contention resolution timer for NB-IoT: pp16 — **Contention resolution timer**

RA response window size for NB-IoT: pp10 — **RA response timer**



raContResoTimNB timer defines the maximum amount of time allowed for the contention resolution . The eNB sends RRCConnectionSetup-NB (msg4) over NPDSCH, inside the contention resolution timer. In case msg4 is not received within timer period, RACH access procedure is repeated, providing that **nprachMaxNumPreambleCE** settings is not reached

raRespWinSizeNB window size for the random access response. RAR (msg2) is sent over NPDSCH. RAR is expected inside the RAR response window.

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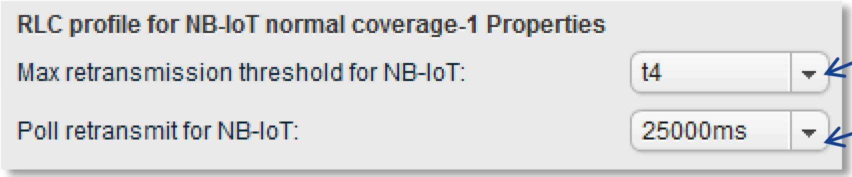
Deployment Aspects
Feature activation

- **STEP 10** – RLC profile

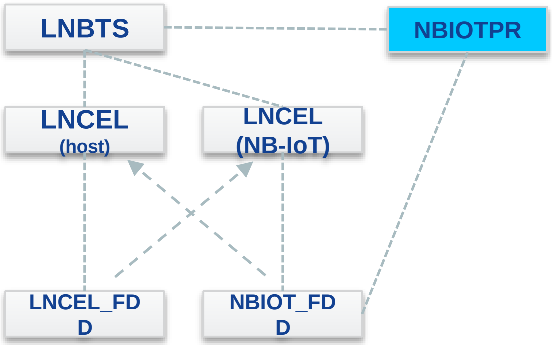


RLC retransmission threshold

Poll retransmit

maxRetxThreNB the maximum number of poll retransmission for the transmitting side of an AM RLC entity in NB-IoT. 3GPP: maxRetxThreshold-r13

tPollRetrNB
parameter specifies the parameter t-pollRetransmit-r13 of [36.331]. This timer is used by the transmitting side of an AM RLC entity in order to retransmit a poll. 3GPP: t-PollRetransmit-r13



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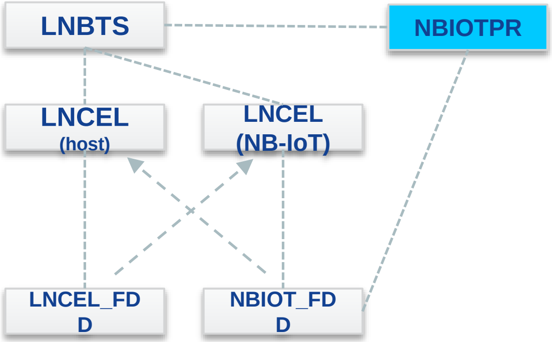
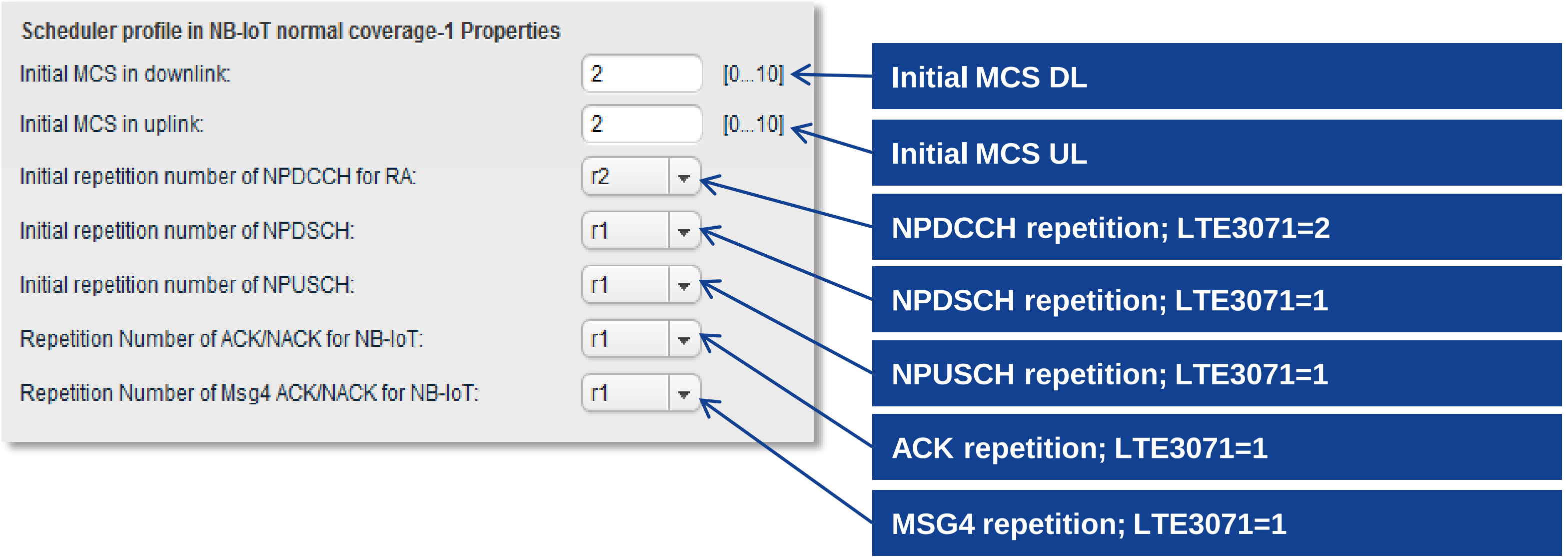
Deployment Aspects
Feature activation

- **STEP 11** – Scheduler profile





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Deployment Aspects
Supported configurations

- Inband NB-IoT cells don't require any additional BB HW, IQ data of inband NB-IoT cells is contained inside the IQ data of the host cell. **AirScale is not supported by LTE3071**. Supported NB-IoT configurations:

Single HW board (either FSMF or FBBA/C) within a Basic Cell Set
3*5/10/15/20MHz 2Tx/2Rx cells + 3 NB-IoT cells

2 HW boards (FSMF + FBBC/A) with extended Cell Set
6*5/10/15/20MHz 2Tx/2Rx cells + 6 NB-IoT cells OR

3 HW boards (FSMF + 2 FBBC/A) with XL-Cell-Set
9*5/10/15/20MHz 2Tx/2Rx cells + 9 NB-IoT cells OR

FZM
1*5/10/15/20MHz 2Tx/2Rx cells+ 1*NB-IoT 2Tx/2Rx cells

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Deployment Aspects
RF module

- Inband NB-IoT cells are transparent to the RF modules
- Inband NB-IoT and hosting LTE can be RF shared with GSM or WCDMA assuming first level RF sharing is supported for the hosting LTE cell itself
- **Only OBSAI and Nokia-CPRI** protocols are supported
- All the RF modules supporting 2Tx2Rx are feasible for inband NB-IoT, as listed by Supported Configurations xls. Please note bands restrictions for NB-IoT stated by 3GPP.

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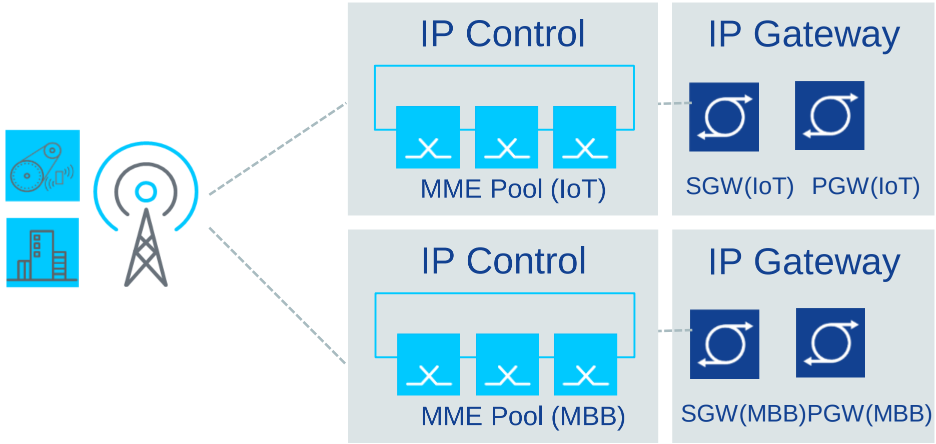
Deployment Aspects
S1 and MME

- NB-IoT traffic has different nature than the one coming from the legacy LTE users. A lot of small messages is not well suited for the network optimized towards mobile broadband.
- That is why it is suggested to provide separate core network optimized for IoT traffic
- Simplified core, lack of legacy specific features, e.g. Voice Support, VoLTE , allows for better utilization of resources.



MME type connected to eNB is indicated by ***LNMME: mmeRatSupport***

- only legacy LTE (‘WB-EUTRA MME’),
- only NB-IoT (‘NB-IoT MME’)
- both legacy LTE and NB-IoT (‘integrated MME’).

S1 for NB-IoT can be selected via two different methods:

- Dedicated S1 for NB-IoT UEs (i.e. NB-IoT gets its own separate S1 selected always)
- PLMN based S1 selection (Inband NB-IoT traffic is directed to same core as legacy LTE traffic of the hosting cell)

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Deployment Aspects
Alarms

- No new alarms are expected in LTE3071.
- One legacy alarm (Cell Setup Failure) will be re-used to indicate that host cell or inband NB-IoT cell was disabled.

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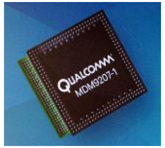
Deployment Aspects
Devices and chipsets for NB-IoT

- In general, commercial modules for both NB-IoT & Cat-M are expected **1Q17**

- **Main players:**
- **Intel** announced the XMM7115 **NB-IoT** chipset and the XMM7315 **Cat-M/NB-IoT**
- **Neul** NB-IoT chipset
- **Sequans** introduced Monarch **Cat-M** chipset, which will also support **NB-IoT**, partnering with **Gemalto** for commercial modules
- **Qualcomm** Cat-M chipset (**MDM9206**)



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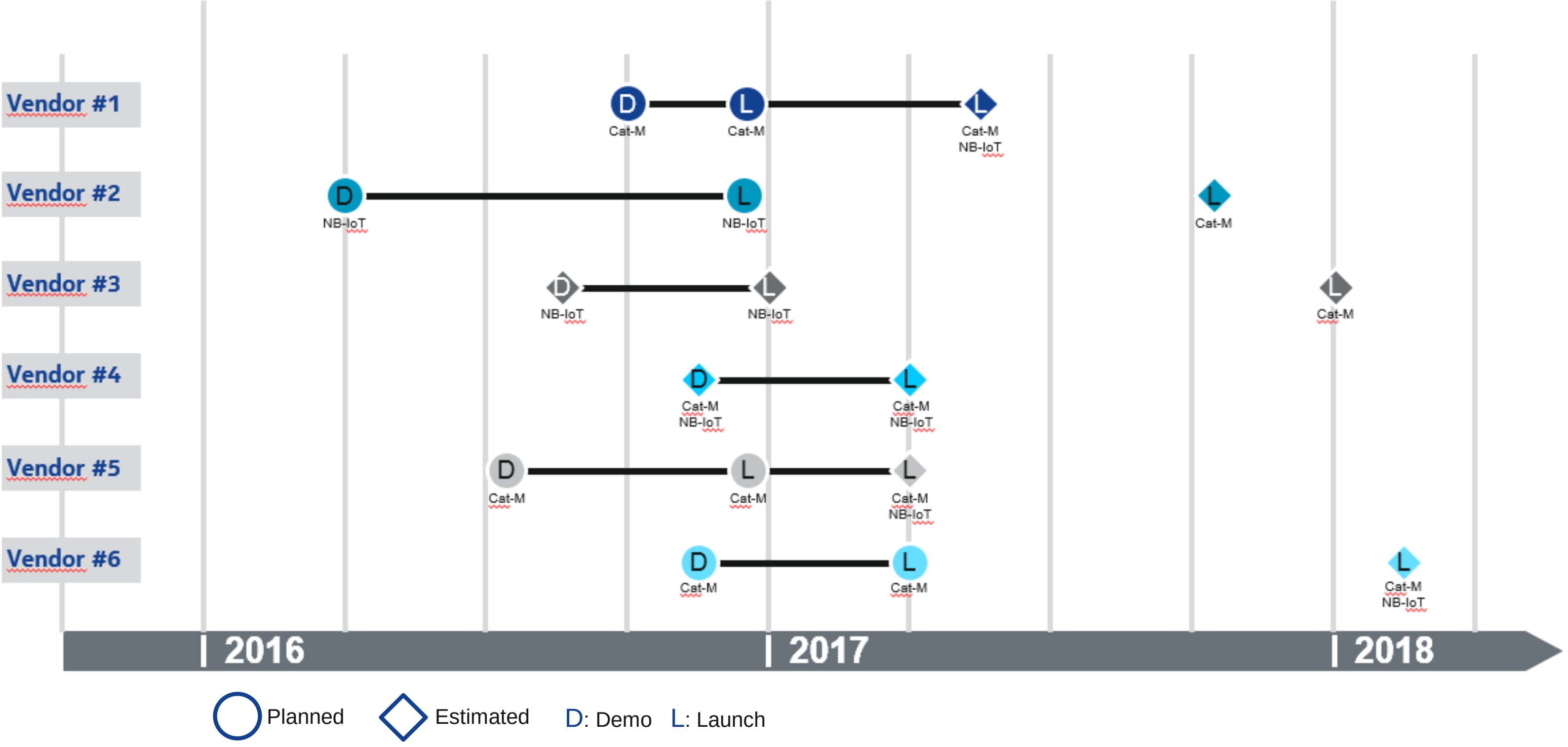
Deployment Aspects

Devices and chipsets for NB-IoT



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Let’s have a short coffee break!

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Dimensioning Aspects

Table of contents

Dimensioning

Dimensioning tools

NB-IoT Link budget tool

		Downlink	Uplink
General parameters	Operating band [MHz]	850	
	Sensors deployment	Stationary	
	NB-IoT carrier configuration	In-band	
	Legacy LTE channel bandwidth [MHz]	10	
	Legacy LTE DL transmission scheme	2Tx MIMO (TM2/3/4)	
Transmitting end	Tx antenna power [dBm]	43.0	23.0
	Antenna gain [dBi]	18.0	0.0
	Feeder loss [dB]	0.5	-
	DL NB-IoT Power Boosting [dB]	0.0	-
	Legacy cell power reduction per PRB [dB]	0.0	-
	Tx power increase [dB]	3.0	0.0
	Effective NB-IoT EIRP per user [dBm]	46.5	23.0
Receiving end	Feeder loss [dB]	-	0.5
	Antenna gain [dBi]	0.0	18.0
	Noise figure [dB]	5.0	3.0
	Additional gains [dB]	0.0	0.0
System overhead	Reference Signal (legacy LTE) [%]	9.52%	-
	PDCCH (legacy LTE) [%]	19.05%	-
	NB Primary Synchronization Signal (NPSS) [%]	7.20%	-
	NB Secondary Synchronization Signal (NSSS) [%]	3.93%	-
	NB Reference Signal (NRS) [%]	9.52%	-
	NB Broadcast Channel (NPBCH) [%]	5.95%	-
	SIB1-NB repetitions	4	-
	NB System Information Block 1 (SIB1-NB) [%]	0.77%	-
	SIB2-NB length [subframes]	8	-
	SIB2-NB repetition pattern [radio frames]	16	-
	SIB2-NB periodicity [ms]	2560	-
	SIB2-NB window length [ms]	160	-
	NB System Information Block 2 (SIB2-NB) [%]	0.19%	-
	Maximum number of NPDCCH repetitions (*R_max*)	16	-
	NPDCCH starting subframe period (*G*)	2	-
	NPDCCH repetition level	2	-
	NPDCCH overhead [%]	4.95%	-
	NPRACH periodicity [ms]	-	160
	NPRACH repetition level	-	4
	NPRACH overhead [%]	-	16.25%
	Additional overhead [%]	0.00%	0.00%
	Total system overhead [%]	**61.10%**	**16.25%**
Service	Message size [bytes]	10	200
	Number of NPDSCH subframes / NPUSCH Resource Units	4	4
	Number of NPUSCH tones per user	-	1
	Modulation and coding scheme (User defined)	0-QPSK	10-QPSK
	Residual BLER target	rBLER = 10%	
	Number of message repetitions	1	1
	Transport Block Size for NPDSCH / NPUSCH [bits]	88	680
	Number of TBSs required to send the message	1	3
	Estimated user throughput (single UE) [kbps]	**0.31**	**5.83**
	Modulation efficiency (data bits/modulated symbol)	0.34	1.81
	Effective Coding Rate	0.17	0.91
Channel	Channel model	Enhanced Pedestrian A 1Hz	
	NB-IoT transmission scheme	2Tx-1Rx	1Tx-2Rx
	Required SINR @ BLER10% [reference] [dB]	6.56	11.84
	Repetitions gain [dB]	0.00	0.00
	Required SINR at cell edge [dB]	6.56	11.84
	Interference Margin [dB]	3.00	3.00
	Number of received subcarriers [dB]	10.79	0.00
	Thermal noise density [dBm/Hz]	-173.93	
	Subcarrier bandwidth [kHz]	15	
	Noise power per subcarrier [dBm]	-132.17	
	Receiver sensitivity [dBm]	-109.82	-117.33
	Maximum Allowable Path Loss [dB] *(clutter not considered)*	**153.34**	**154.83**
	Link used for cell range calculations	Limiting link	
	RSRP (clutter not considered) [dBm]	-120.62	-122.11

NB-IoT Capacity calculator

MAR reports	Interarrival (h) / Share	24
		2
		1
		0.5
Traffic model	BHCA	0.47
	#UE	52547
	#UE attempts/cell/s	6.8
	UL message size (bytes)	200
NPRACH capacity	NPRACH periodicity [ms]	160
	NPRACH bandwidth (tones)	48
	RACH collision probability [%]	2.5
	NPRACH reception probability [%]	90
	max RACH load	1.2
	RACH attempts (from traffic model) [1/s]	7.6
	NPRACH occasions [1/s]	7.6
	Max # UEs (RACH)	**52733**
NPDCCH capacity	Maximum number of NPDCCH repetitions (*R_max*)	4
	NPDCCH starting subframe period (*G*)	2
	NPDCCH periodicity (search space length) [ms]	8
	NPDCCH occasion/s	125
	#DCI per UE call	12
	# UE/s (NPDCCH limit)	**8**
NPDSCH timing	NPDCCH transmission length [ms]	2
	NPDCCH -> NPDSCH gap [ms]	4
	TBS transmission time on NPDSCH [ms]	4
	NPDSCH -> NPUSCH (A/N) gap [ms]	12
	NPUSCH (A/N) length [ms]	2
	NPUSCH (A/N) / NPUSCH -> NPDCCH gap [ms]	3
	HARQ percentage [%]	10
	Total DL TBS transmission time [ms]	**30**
NPUSCH timing	NPDCCH transmission length [ms]	2
	NPDCCH -> NPUSCH gap [ms]	8
	TBS transmission time on NPUSCH [ms]	32
	NPUSCH -> NPDCCH (A/N) gap [ms]	3
	HARQ percentage [%]	10
	Total UL TBS transmission time [ms]	**50**
Call Setup timing	NPRACH transmission lenght [ms]	26
	NPDCCH scheduling time [ms]	8
	Number of NPDCCH per RACH procedure	3
	DL message transmission lenght [ms]	30
	UL message transmission lenght [ms]	50
	NPRACH reception probability	90
	Total Call setup time [ms]	**211**
UL settings	UL MCS (User defined)	3-QPSK
	TBS index	3
	Transport Block Size for NPUSCH [bits]	208
	UL BLER [%]	10
	Number of TBSs required to send the message	9
	NPUSCH transmission duration [ms]	446
	Average NB-IoT Call duration (including CS) [ms]	657
NPUSCH capacity	Average throughput per NB-IoT UE (Tx) [kbit/s]	3.59
	NPUSCH overhead [%]	16
	UL resources utilisation factor [%]	90
	Average number of UEs/Cell (TX)	**64398**

- Link budget calculates cell ranges taking into account LTE3071 parameterization and overheads.
- Capacity calculator estimates capacity of NPRACH, NPDCCH and NPUSCH channels. As expected that mobile originated traffic will be dominating, only UL data channels are considered.
- Tools are available here.

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NB-IoT coverage

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Dimensioning

Link Budget

- LTE3071 supports only first level coverage, in the range of legacy LTE. Further coverage enhancements are subject of subsequent FL17SP features.

		Downlink	Uplink
General parameters	Operating band [MHz]	900	
	Sensors deployment	Stationary	
	NB-IoT carrier configuration	In-band	
	Legacy LTE channel bandwidth [MHz]	10	
	Legacy LTE DL transmission scheme	2Tx MIMO (TM2/3/4)	
Transmitting end	Tx antenna power [dBm]	43.0	23.0
	Power per PRB [W]	0.40	-
	Antenna gain [dBi]	18.0	0.0
	Feeder loss [dB]	0.5	-
	DL NB-IoT Power Boosting [dB]	6.0	-
	Legacy Cell Power Reduction per PRB [dB]	0.1	-
	Tx power increase [dB]	3.0	0.0
	Effective NB-IoT EIRP per user [dBm]	52.5	23.0
Receiving end	Feeder loss [dB]	-	0.5
	Antenna gain [dBi]	0.0	18.0
	Noise figure [dB]	5.0	3.0
	Additional gains [dB]	0.0	0.0

Note that selected bands are allowed for NB-IoT within Rel 13

Only TM2 for LTE3071

Host legacy LTE cell power

DL power boosting up to 6 dB

Legacy cell power reduction due to power boost

EIRP per NB-IoT UE calculated from the PSD and power boost for 1PRB

Preliminary values

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Dimensioning

Link Budget

System overhead	Reference Signal (legacy LTE) [%]	9.52%	-
	PDCCH (legacy LTE) [%]	19.05%	-
	NB Primary Synchronization Signal (NPSS) [%]	7.20%	-
	NB Secondary Synchronization Signal (NSSS) [%]	3.93%	-
	NB Reference Signal (NRS) [%]	9.52%	-
	NB Broadcast Channel (NPBCH) [%]	5.95%	-
	SIB1-NB repetitions	4	-
	NB System Information Block 1 (SIB1-NB) [%]	0.77%	-
	SIB2-NB length [subframes]	8	-
	SIB2-NB repetition pattern [radio frames]	16	-
	SIB2-NB periodicity [ms]	2560	-
	SIB2-NB window length [ms]	160	-
	NB System Information Block 2 (SIB2-NB) [%]	0.19%	-
	Maximum number of NPDCCH repetitions (*R_max*)	4	-
	NPDCCH starting subframe period (*G*)	2	-
	NPDCCH repetition level	2	-
	Number of subscribers per cell	50000	-
	Subscriber BHCA	0.47	-
	NPDCCH overhead [%]	13.00%	-
	NPRACH periodicity [ms]	-	160
	NPRACH repetition level	-	4
	NPRACH overhead [%]	-	16.25%
	Additional overhead [%]	0.00%	0.00%
	Total system overhead [%]	**69.15%**	**16.25%**

numSib1RepNB

Depends on the SIB2 TBS: 56/120 bits TBS 2 subframes, remaining 8 subframes

sib2RepPatternNB

sib2PeriodicityNB

siWindowLenNB

npdcchMaxNumRepRa

npdcchStartSfRa; LTE3071=2

Assumed for NPDCCH overhead calculations

Assumed for NPDCCH overhead calculations

nprachPeriod

nprachNumRepPreamble

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Dimensioning
Link Budget

Service	Message size [bytes]	10	200
	Number of NPDSCH subframes / NPUSCH Resource Units	4	4
	Number of NPUSCH tones per user	-	1
	Modulation and coding scheme (User defined)	2-QPSK	2-QPSK
	Residual BLER target	rBLER = 10%	
	Number of message repetitions	1	1
	Transport Block Size for NPDSCH / NPUSCH [bits]	176	144
	Number of TBSs required to send the message	1	13
	Estimated user throughput (single UE) [kbps]	**0.50**	**2.11**
	Modulation efficiency (data bits/modulated symbol)	0.85	0.38
	Effective Coding Rate	0.42	0.19

LTE3071 supports only UE originated UL messages. Please align DL message size with limited links

There is no link adaptation for LTE3071, selected MCS is used for all the transmission. It impacts TBS size, and thus achievable throughputs and overheads

MCSs can be used to balance UL and DL links.

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Dimensioning
Link Budget

Channel	Channel model	Enhanced Pedestrian A 1Hz	
	NB-IoT transmission scheme	2Tx-1Rx	1Tx-2Rx
	Required SINR @ BLER10% [reference] [dB]	9.05	1.78
	Repetitions gain [dB]	0.00	0.00
	Required SINR at cell edge [dB]	9.05	1.78
	Interference Margin [dB]	3.00	3.00
	Thermal noise density [dBm/Hz]	-173.93	
	Subcarrier bandwidth [kHz]	15	
	Noise power per subcarrier [dBm]	-132.17	
	Receiver sensitivity [dBm]	-107.33	-127.39
	Maximum Allowable Path Loss [dB] ***(clutter not considered)***	**156.85**	**164.89**
	Link used for cell range calculations	Limiting link	
	RSRP (clutter not considered) [dBm]	-118.13	-126.17

LTE3071 supports only single antenna at UE and 2 antennas at eNB

DL is weaker since there is just single antenna at UE. MCS can be selected accordingly to balance links.

Allows for checking UL or DL cell ranges independently

Note: 3GPP Normal coverage pathloss (144dB) has different assumptions

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Dimensioning
Link Budget

		Dense Urban	Urban	Suburban	Rural (quasi)
Propagation	**Maximum Allowable Path Loss (limiting link) [dB]** ***(clutter not considered)***	**161.58**			
	eNB antenna height [m]	30	30	30	50
	Sensor antenna height [m]	0.5	0.5	0.5	0.5
	Average penetration loss [dB]	18.0	13.0	8.0	3.0
	Standard deviation outdoor [dB]	9.0	8.0	8.0	7.0
	Standard deviation of penetration loss [dB]	0.0	0.0	0.0	0.0
	Combined standard deviation [dB]	9.00	8.00	8.00	7.00
	Location probability				
	Cell area probability [%]	99.00%	99.02%	99.02%	99.02%
	Location / Cell edge probability [%]	96.90%	96.70%	96.70%	96.50%
	Log first level Fading margin [dB]	16.80	14.71	14.71	12.68
	Gain Against Shadowing [dB]	0.00	0.00	0.00	0.00
	Maximum Allowable Path Loss [dB] ***(clutter considered)***	**126.78**	**133.87**	**138.87**	**145.90**
	RSRP (clutter considered) [dBm]	-94.07	-101.15	-106.15	-113.18
	Intercept Point (w/o clutter correction) [dB]	128.16	128.16	127.56	124.50
	Slope 1 [dB]	35.22	35.22	35.22	33.77
	Slope 2 [dB]	39.92	39.92	39.92	38.11
	Clutter correction factor [dB]	3.00	0.00	-9.64	-23.01
	Cell Range [km]	**0.78**	**1.45**	**3.93**	**20.66**
	Inter Site Distance for 3-sector grid [km]	1.17	2.18	5.90	30.98

Differs from the legacy LTE, since IoT devices (e.g. Smart meters) are expected at lower heights

Improved NB-IoT coverage is not considered yet, since LTE3071 cope with first level coverage only

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Dimensioning
3GPP pathloss definition

- Normal pathloss (144 dB) 3GPP definition mentioned in the slideset refers to the Maximum Coupling Loss MCL
- MCL doesn’t consider antenna gain, feeder losses and other factors taken into account in the link budget for cell range estimation; this is just reference value
- For cell range estimation Maximum Allowable Pathloss MAPL is used, considering all the aspects above.

Channel	NB-PDSCH	NB-PUSCH
Data rate (kbps)	0.44	0.31
Transmitter		
Max Tx power (dBm)	46	23
(1) Actual Tx power (dBm)	35	23
Receiver		
(2) Thermal noise density (dBm/Hz)	-174	-174
(3) Receiver noise figure (dB)	5	3
(4) Interference margin (dB)	0	0
(5) Occupied channel bandwidth (Hz)	180,000	15,000
(6) Effective noise power = (2) + (3) + (4) + 10 log ((5)) (dBm)	-116.4	-129.2
(7) Required SINR (dB)	6.56	0.52
(8) Receiver sensitivity = (6) + (7) (dBm)	-109.9	-128.7
(9) Rx processing gain	0	0
(10) MCL = (1) -(8) + (9) (dB)	**144.9**	**151.7**

NOKIA simulated SINRs used for reference

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Dimensioning
3GPP pathloss definition

- The same numbers can obtained in NB-IoT LB when antenna gain, feeder loss and interference margin are aligned with 3GPP
- Note that 3GPP assumed 6dB power boost for NB-IoT

NB-IoT inband (LTE3071) Link budget v1.0

		Downlink	Uplink
General parameters	Operating band [MHz]	900	
	Sensors deployment	Stationary	
	NB-IoT carrier configuration	In-band	
	Legacy LTE channel bandwidth [MHz]	10	
	Legacy LTE DL transmission scheme	2Tx MIMO (TM2/3/4)	
Transmitting end	Tx antenna power [dBm]	43.0	23.0
	Antenna gain [dBi]	0.0	0.0
	Feeder loss [dB]	0.0	-
	DL NB-IoT Power Boosting [dB]	6.0	-
	Legacy cell power reduction per PRB [dB]	0.1	-
	Tx power increase [dB]	3.0	0.0
	Effective NB-IoT EIRP per user [dBm]	35.0	23.0
Receiving end	Feeder loss [dB]	-	0.0
	Antenna gain [dBi]	0.0	0.0
	Noise figure [dB]	5.0	3.0
	Additional gains [dB]	0.0	0.0
Service	Message size [bytes]	10	200
	Number of NPDSCH subframes / NPUSCH Resource Units	4	4
	Number of NPUSCH tones per user	-	1
	Modulation and coding scheme (User defined)	0-QPSK	0-BPSK
	Residual BLER target	rBLER = 10%	
	Number of message repetitions	1	1
	Transport Block Size for NPDSCH / NPUSCH [bits]	88	88
	Number of TBSs required to send the message	1	20
	Estimated user throughput (single UE) [kbps]	**0.21**	**1.39**
	Modulation efficiency (data bits/modulated symbol)	0.53	0.23
	Effective Coding Rate	0.27	0.23
Channel	Channel model	Enhanced Pedestrian A 1Hz	
	NB-IoT transmission scheme	2Tx-1Rx	1Tx-2Rx
	Required SINR @ BLER10% [reference] [dB]	6.56	0.52
	Repetitions gain [dB]	0.00	0.00
	Required SINR at cell edge [dB]	6.56	0.52
	Interference Margin [dB]	0.00	0.00
	Number of received subcarriers [dB]	10.79	0.00
	Thermal noise density [dBm/Hz]	-173.93	
	Subcarrier bandwidth [kHz]	15	
	Noise power per subcarrier [dBm]	-132.17	
	Receiver sensitivity [dBm]	-109.82	-128.65
	Maximum Allowable Path Loss [dB] ***(clutter not considered)***	**144.84**	**151.65**
	Link used for cell range calculations	Limiting link	
	RSRP (clutter not considered) [dBm]	-123.62	-130.43

0 dB antenna gain aligned with 3GPP MCL

0 dB feeder loss aligned with 3GPP MCL

0 dB interference margin aligned with 3GPP MCL

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NB-IoT capacity

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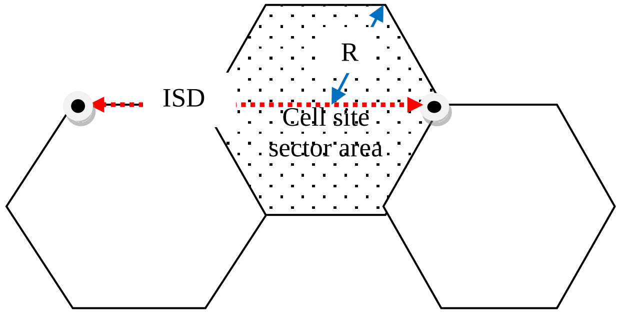
Dimensioning
NB-IoT Capacity Target

- NB-IoT was defined by 3GPP taking into account typical inter site distance and household density for urban area. Each location should handle up to 40 IoT devices.
- Capacity target is 52547 devices within a cell site sector



Case	Household Density per Sq km	Inter-site Distance (ISD) (m)	Number of devices within a household	Number of devices within a cell site sector
Urban	1517	1732 m	40	52547

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Dimensioning

3GPP IoT traffic model (45.820 Annex E)

Report type	Packet size	Inter-arrival time
Mobile Autonomous Reporting (MAR) exception reports → E.g. smoke detectors, power failure notifications from smart meters, tamper notifications etc.	**UL:** 20 bytes	**Months to years** (reaction time up to 10 second latency)
Mobile Autonomous Reporting (MAR) periodic reports → E.g. smart utility (gas/water/electric) metering reports, smart agriculture etc.	**UL**: 20 - 200 bytes Pareto distributed **DL:** Ack	40%: Once per day 40%: Once every 2 hours 15%: Once per hour 5%: Once per 30 min => **Mean = 0.47 times per hour**
Network originated reports → E.g. trigger the device to send an uplink report as a result of the network command e.g. request for a smart meter reading	**DL:** 20 bytes **UL:** 20 – 200 bytes Pareto distributed	40%: Once per day 40%: Once every 2 hours 15%: Once per hour 5%: Once per 30 min => **Mean = 0.47 times per hour**
Software update/reconfiguration model → Software updates or patches of Cellular IoT devices. Rare, but large payload sizes expected for complete software updates	**DL:** 200 - 2000 bytes Pareto distributed	**180 days**

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Dimensioning
Traffic model

- As **paging is not supported in LTE3071**, only UE initiated **Mobile autonomous reporting MAR** are expected. Network cannot initiate connection for a NB-IoT cell.
- 3GPP target of 50k UE served per cell is fulfilled under 45.820 traffic model, where distribution of messages size and their periodicity is defined. Generally NB-IoT supports infrequent, small messages.
- From 3GPP distribution of MAR reports **0.47 BHCA** is obtained with Pareto distributed **message size of 20-200 bytes**.
- Number of attempts during BH:

$$Attempts/cell/s = \frac{\#UE \cdot BHCA}{3600} = \frac{52547 \cdot 0.47}{3600} = 6.8$$

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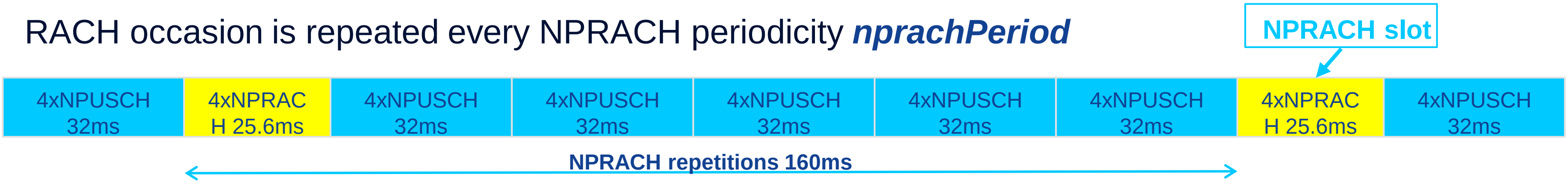
Dimensioning
NPRACH capacity

- 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, 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 is repeated every NPRACH periodicity ***nprachPeriod***



$$RACH\ occasions/s = \left(\frac{-1}{nprachPeriod\ [s]}\right) 48 \cdot \ln\left(1 - \frac{P_{coll}}{100}\right)$$

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Dimensioning
NPRACH capacity

- 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 2.5% (48 preambles, NPRACH repetition every 160 ms).

NPRACH capacity	NPRACH periodicity [ms]	160
	NPRACH bandwidth (tones)	48
	RACH collision probability [%]	2.5
	NPRACH reception probability [%]	90
	RACH attempts (from traffic model) [1/s]	7.6
	NPRACH occasions [1/s]	7.6
	Max # UEs (RACH)	**52733**

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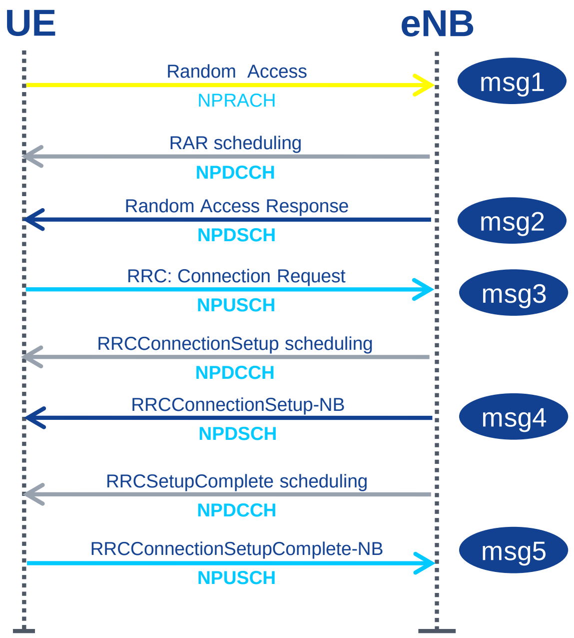
Dimensioning

NPDCCH capacity

- NPDCCH is used for UL and DL scheduling during call setup and further message transmission.
- Call setup requires at least 3 NPDCCH messages,
- When transmitted UL message is fragmented into TBSs, each NPUSCH scheduling needs separate DCI, so additionally #TBS NPDCCHs are needed, without HARQ repetition
- In UL direction 11 UEs can be scheduled simultaneously, providing that they are using different subcarriers, hence scheduling of another subcarrier transmission might occur during transmission on the previously selected subcarrier



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Dimensioning

NPDCCH capacity

- Single UE can be scheduled during each search space. Example Rmax=4, 8 SF for search space.

FN	0										1									
SFN	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
Excluded	MIB				SIB1	PSS				SSS	MIB					PSS				
Search space																				
NPDCCH occasion		1	2	1			2		1			2	1	2			1	2	1	2

FN	2										3									
SFN	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
Excluded	MIB				SIB1	PSS				SSS	MIB					PSS				
Search space																				
NPDCCH occasion		1	2				1	2	1			2	1	2	1		2	1	2	

- Max NPDCCH repetition can be 4, 8 or 16 subframes, what corresponds search spaces of 8, 16 and 32 subframes respectively. Maximum number of scheduled UEs:

$$Max\ UE_{NPDCCH}\# = \frac{\frac{1000}{Rmax \cdot G}}{3 + \#TBS}$$

- Additional overhead for common channels have to be considered as well.

G	2	2	2	*npdcchStartSfRa*
Rmax	4	8	16	*npdcchMaxNumRepRa*
Search space [SF]	8	16	32	
DCI # /s	125	63	31	1000/(search space [ms])
# scheduled UEs /s (w/overhead)	8	4	2	(0.75*DCI/s)/12

Example: Message size 200 bytes, MCS3, TBS size 208 bits, #TBS=9

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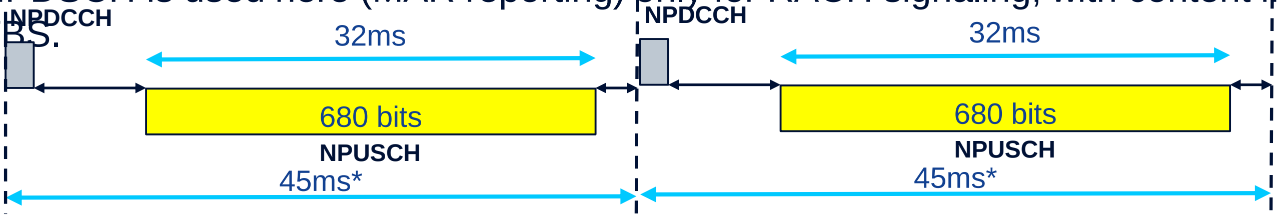
Dimensioning

Total MAR message transmission time

- Average NB-IoT Call duration:

$$T= T_{CS} + T_{Tx}$$

  - T_{CS} call setup time to establish the RRC connection
  - T_{Tx} time for data transfer
- Each scheduled UL and DL transmission follows timings for NPDSCH (27ms) and NPUSCH (45ms)
- In case message content does not fit into the single TBS (max 680 bits @MCS10) it is split into subsequent transmissions, hence total transmission time is multiplication of the single NPDSCH/NPUSCH process duration. It is assumed that the issue is only for NPUSCH since NPDSCH is used here (MAR reporting) only for RACH signaling, with content fitting into single TBS.



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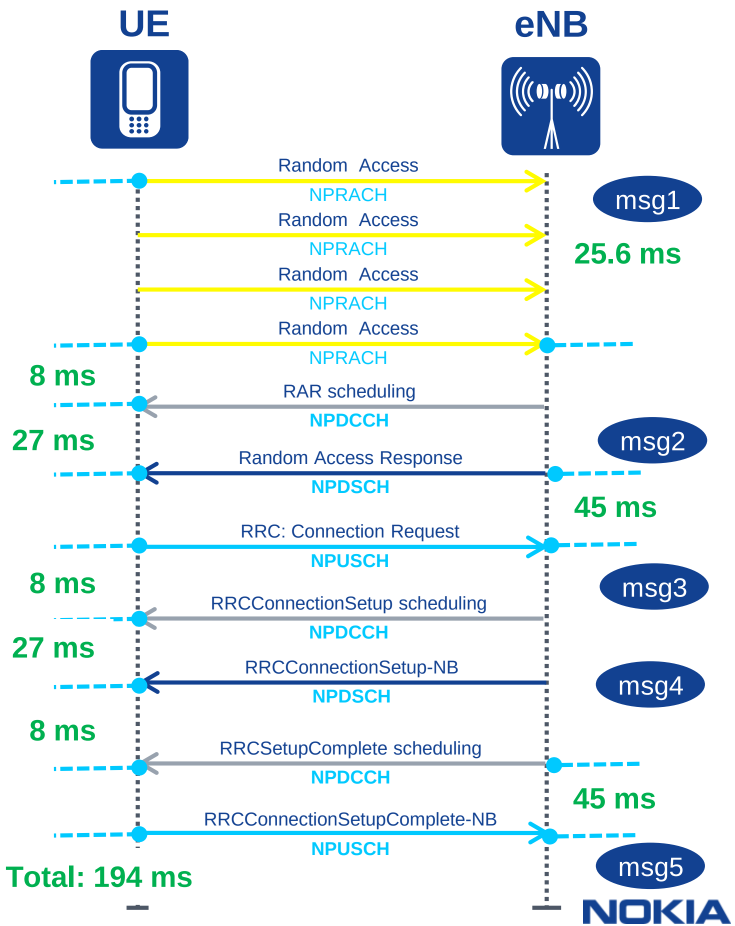
Dimensioning
Call setup time

- 27 ms is needed for the whole NPDSCH message, including NPDCCH time, 45 ms for NPUSCH
- Each NPDCCH have to be scheduled in the separate search space
- Total 194 ms for RACH procedure (without HARQ and NPRACH repetitions)



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Dimensioning

Call setup time

- NPRACH sequence can be repeated up to ***nprachMaxNumPreambleCE*** settings (default 5), we can assume certain probability for correct NPRACH reception P_{NPRACH} which impacts average time for NPRACH.

$$T_{NPRACH} = (25.6 \cdot P_{NPRACH}) + (2 \cdot 25.6 \cdot (1 - P_{NPRACH}) \cdot P_{NPRACH}) + (3 \cdot 25.6 \cdot (1 - P_{NPRACH})^2 \cdot P_{NPRACH}) \; .... = 25.6 \cdot P_{NPRACH} \cdot 1/[1-(1- P_{NPRACH})^2] = 25.6/P_{NPRACH}$$

- **Assuming P_{NPRACH} = 90%, T_{NPRACH} = 28.4 ms**
- The same approach can be selected for HARQ procedure for NPUSCH and NPDSCH:
- **P_{NPUSCH} = 90%, T_{NPUSCH} = 45 / 0.9 = 50 ms**
- **P_{NPDSCH} = 90%, T_{NPDSCH} = 27 / 0.9 = 30 ms**

- Hence modified RACH procedure time: **211 ms**

NPDCCH transmission length [ms]	2
NPDCCH -> NPDSCH gap [ms]	4
TBS transmission time on NPDSCH [ms]	4
NPDSCH -> NPUSCH (A/N) gap [ms]	12
NPUSCH (A/N) length [ms]	2
NPUSCH (A/N) / NPUSCH -> NPDCCH gap [ms]	3
HARQ percentage [%]	10
Total DL TBS transmission time [ms]	**30**
NPDCCH transmission length [ms]	2
NPDCCH -> NPUSCH gap [ms]	8
TBS transmission time on NPUSCH [ms]	32
NPUSCH -> NPDCCH (A/N) gap [ms]	3
HARQ percentage [%]	10
Total UL TBS transmission time [ms]	**50**
NPRACH transmission lenght [ms]	26
NPDCCH scheduling time [ms]	8
Number of NPDCCH per RACH procedure	3
DL message transmission lenght [ms]	30
UL message transmission lenght [ms]	50
NPRACH reception probability	90
Total Call setup time [ms]	**211**

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Dimensioning

Total MAR message transmission time

- 3GPP specifies MAR message size Pareto distributed, with 20-200 bytes size. For simplification only the worst case **200 bytes** will be considered.
- NPUSCH TBS size depends on the UL MCS selected, number of TBSs to be transmitted can be then calculated, taking into account BLER

$$\#TBS = \frac{8 \cdot Message_{UL}[bytes] \cdot (1 + \frac{BLER}{100})}{TBS_{size}[bits]}$$

- Having number of needed TBSs one can easily calculate Ttx taking into account transmission process duration: $T_{TX}\,[ms] = \#TBS \cdot T_{NPUSCH}\,[ms]$

Traffic model	BHCA	0.47
	#UE	52547
	#UE attempts/cell/s	6.8
	UL message size (bytes)	200
UL settings	UL MCS (User defined)	2-QPSK
	TBS index	1
	Transport Block Size for NPUSCH [bits]	144
	UL BLER [%]	10
	Number of TBSs required to send the message	13
	NPUSCH transmission duration [ms]	644
	Average NB-IoT Call duration (including CS) [ms]	855

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

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Dimensioning

NPUSCH capacity

- Average throughput for NB-IoT UE can be estimated taking into account amount of data to be transmitted and total time needed for the transmission (with call setup and TBS fragmentation)

$$Average\_UE\_througphut[kbps] = \frac{8 \cdot Message_{UL}[bytes]}{T_{CS} + \#TBS \cdot T_{TX}}$$

- NB-IoT capacity in terms of served subscribers in BH can be estimated considering average time of resources occupation by single UE. Providing that NPDCCH and NPRACH limits are met NPUSCH resources should be analyzed assuming certain utilization factor (11 subcarriers available for NPUSCH). NPRACH overhead should be considered as well.

$$NPRACHoverhead = \frac{1}{NPRACH_{Perodicity}[ms]} \cdot 25.6\ [ms]$$

$$\#UE\_BH = \frac{11 \cdot 3600 \cdot (1 - NPRACH_{overhead}) \cdot UL_{utilisation}}{T_{CS}[s] + (\#TBS \cdot T_{TX}[s])}$$

Average throughput per NB-IoT UE (Tx) [kbit/s]	3.59
NPUSCH overhead [%]	16
UL resources utilisation factor [%]	90
Average number of UEs/ Cell (TX)	**64398**

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Energy Savings Aspects

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Energy Savings Aspects
Battery life – PA efficiency impact

- 45.820 model
- Battery capacity: 5Wh

Mode	Power Consumption @ 23dBm with PA efficiency		
	40%	45%	50%
transmitting current drawn	589mW	533mW	489mW
receiving current drawn	90mW	90mW	90mW
idle current	2.4mW	2.4mW	2.4mW
power save current	15µW	15µW	15µW

Source: T&I simulations

	Battery life (years)		
PA efficiency	40%	45%	50%
Packet size, reporting interval	MCL 144 dB	MCL 144 dB	MCL 144 dB
50 bytes, 2 hours	18,9	19,2	19,4
200 bytes, 2 hours	17,4	17,7	18,0
50 bytes, 1 day	35,1	35,2	35,2
200 bytes, 1 day	34,6	34,7	34,8

- >10 year battery life met for all scenarios

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Performance Aspects

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Dimensioning
New counters

- There are new, NB-IoT specific counters defined for monitoring of the feature performance
- 20 counters in total, considering the following aspects:
  - RRC connection establishment
  - S1-Connection Establishments
  - Number of RRC connected Cat-NB1 UE
  - UE movement idle state reason
  - MAC PDU volume
  - NB-IoT resources and time
- Measurement 8066 – LTE NB-IoT has to be started

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Performance Aspects
New counters

Counter name	Description
NB_IOT_RRC_CONN_MAX (M8066C0) #LTE NB-IoT	This counter represents the highest value for number of NB-IoT UEs in RRC_CONNECTED state over the measurement period. **Trigger event:** This counter is updated after each sampling interval with the peak number of NB-IoT UEs in RRC_CONNECTED state during the measurement period. **Granularity:** 1 sec **Use case:** **Maximum number of RRC connected NB UEs** Monitoring of the number of RRC connected for NB UEs in the same way as LTE_5242b, LTE_5842a for legacy UEs.

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Performance Aspects
New counters

Counter name	Description
NB_IOT_RRC_CONN_SUM (M8066C1) #LTE NB-IoT	This counter provides the sum of sampled values for measuring the number of simultaneously RRC Connected NB-IoT UEs. This counter divided by the denominator NB_IOT_DENOM_RRC_CONN_UE provides the average number of RRC Connected NB-IoT UEs per cell. **Trigger event:** This counter is updated after each sampling interval with the sample taken from the number of NB-IoT UEs in RRC_CONNECTED state. **Granularity:** 1 sec **Use case:** **Average number of RRC connected NB UEs** Monitoring of the number of RRC connected for NB UEs in the same way as LTE_5242b, LTE_5842a for legacy UEs. $\text{Average number of RRC connected NB UEs} = \frac{NB\_IOT\_RRC\_CONN\_SUM}{NB\_IOT\_RRC\_CONN\_UE\_DENOM}$

Performance Aspects
New counters

Counter name	Description
NB_IOT_RRC_CONN_ESTAB_ATT (M8066C2) #LTE NB-IoT	This counter provides the number of attempted RRC Connection Establishment procedures. From UE's point of view, the transition from ECM-IDLE to ECM-CONNECTED is started. **Trigger event:** The counter is updated on the receipt of an RRC:ConnectionRequest-NB message. **Use case:** **RRC Connection Setup Success Ratio** The KPI proposed is monitoring RRC Connection Setup Success Ratio in the same way as LTE_5218f for non NB UEs. Impact: due to limited UE power, some setup degradations may happen more often for SRB1bis during RRC Connection Setup procedure. $\text{RRC Connection Setup Success Ratio related to NB UEs} = \frac{NB\_IOT\_RRC\_CONN\_ESTAB\_SUCC}{NB\_IOT\_RRC\_CONN\_ESTAB\_ATT} \times 100\%$

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Performance Aspects

New counters

Counter name	Description
NB_IOT_RRC_CONN_ESTAB_SUCC (M8066C3) #LTE NB-IoT	This counter provides the number of successful completions of an RRC connection establishment. **Trigger event:** The counter is updated on the receipt of an RRC:ConnectionSetupComplete-NB message. **Use case:** **RRC Connection Setup Success Ratio** The KPI proposed is monitoring RRC Connection Setup Success Ratio in the same way as LTE_5218f for non NB UEs. Impact: due to limited UE power, some setup degradations may happen more often for SRB1bis during RRC Connection Setup procedure. $\text{RRC Connection Setup Success Ratio related to NB UEs} = \frac{NB\_IOT\_RRC\_CONN\_ESTAB\_SUCC}{NB\_IOT\_RRC\_CONN\_ESTAB\_ATT} \times 100\%$

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Performance Aspects
New counters

Counter name	Description
NB_IOT_S1_SIGN_CONN_ESTAB_ATT (M8066C4) #LTE NB-IoT	This counter provides the number of attempted UE-associated logical S1-connection establishments from eNB to MME **Trigger event:** This counter is updated on the transmission of an S1AP:INITIAL UE MESSAGE by the eNodeB to the MME. **Use case:** **Logical S1 Signaling Connection Success Ratio** Above KPI is monitoring logical S1 Signaling Connection Success Ratio between eNB and MME for NB UEs in the same way as LTE_5526a for non NB UEs. Also it is used for pricing purposes. $$\text{Logical S1 Signaling Connection Success Ratio} = \frac{NB\_IOT\_S1\_SIGN\_CONN\_ESTAB\_SUCC}{NB\_IOT\_S1\_SIGN\_CONN\_ESTAB\_ATT} \times 100\%$$

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Performance Aspects
New counters

Counter name	Description
NB_IOT_S1_SIGN_CONN_ESTAB_SUCC (M8066C5) #LTE NB-IoT	This counter provides the number of successful UE-associated logical S1-connection establishments from eNB to MME. **Trigger event:** The counter is updated on receipt by the eNB of the first message from MME which succeeds INITIAL UE MESSAGE message on a UE-associated logical S1-connection. **Use case:** **Logical S1 Signaling Connection Success Ratio** Above KPI is monitoring logical S1 Signaling Connection Success Ratio between eNB and MME for NB UEs in the same way as LTE_5526a for non NB UEs. Also it is used for pricing purposes. $\text{Logical S1 Signaling Connection Success Ratio} = \frac{NB\_IOT\_S1\_SIGN\_CONN\_ESTAB\_SUCC}{NB\_IOT\_S1\_SIGN\_CONN\_ESTAB\_ATT} \times 100\%$

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Performance Aspects
New counters

Counter name	Description
NB_IOT_RRC_CONN_UE_DENOM (M8066C6) #LTE NB-IoT	This counter provides the number of samples taken for counter NB_IOT_RRC_CONN_SUM. It is used as the denominator for the average calculation. **Trigger event:** This counter is incremented by value 1 when the number of RRC connected NB-IoT UEs - provided by a single sample - is added to counter NB_IOT_RRC_CONN_SUM. **Use case:** **Average number of RRC connected NB UEs** Monitoring of the number of RRC connected for NB UEs in the same way as LTE_5242b, LTE_5842a for legacy UEs. $\text{Average number of RRC connected NB UEs} = \dfrac{\mathit{NB\_IOT\_RRC\_CONN\_SUM}}{\mathit{NB\_IOT\_RRC\_CONN\_UE\_DENOM}}$

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Performance Aspects

New counters

Counter name	Description
NB_IOT_UE_CTX_REL_UE_INACTIVE (M8066C7) #LTE NB-IoT	This counter provides the number of transitions to ECM_IDLE due to "user inactivity" **Trigger event:** The counter is updated on transmission of an S1AP:UE CONTEXT RELEASE REQUEST message sent by the eNB to the MME with release cause "user inactivity". **Use case:** **Abnormal UE movement to idle state** There is no possibility to monitor E-RAB Drop Ratio, because no data radio bearer is going to be established, but at least with this counter operator will be able to see any abnormal UE movement to ECM-Idle state.

$$\text{E-UTRAN UE Transaction to ECM-IDLE State Drop Ratio for NB IOT UE} = \frac{\mathit{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT} + \mathit{NB\_IOT\_UE\_CTX\_REL\_MME\_INIT} - \mathit{NB\_IOT\_UE\_CTX\_REL\_UE\_INACTIVE} - \mathit{NB\_IOT\_UE\_CTX\_REL\_DETACH} - \mathit{NB\_IOT\_UE\_CTX\_REL\_NORMAL}}{\mathit{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT} + \mathit{NB\_IOT\_UE\_CTX\_REL\_MME\_INIT}} \times 100\%$$

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Performance Aspects
New counters

Counter name	Description
NB_IOT_UE_CTX_REL_DETACH (M8066C9) #LTE NB-IoT	This counter provides the number of transitions to ECM_IDLE due to UE detach. **Trigger event:** The counter is updated on receipt of of an S1AP:UE CONTEXT RELEASE COMMAND sent by the MME to the eNB with release cause "detach" **Use case:** **Abnormal UE movement to idle state** There is no possibility to monitor E-RAB Drop Ratio, because no data radio bearer is going to be established, but at least with this counter operator will be able to see any abnormal UE movement to ECM-Idle state.

$$\text{E-UTRAN UE Transaction to ECM-IDLE State Drop Ratio for NB IOT UE} = \frac{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT + NB\_IOT\_UE\_CTX\_REL\_MME\_INIT - NB\_IOT\_UE\_CTX\_REL\_UE\_INACTIVE - NB\_IOT\_UE\_CTX\_REL\_DETACH - NB\_IOT\_UE\_CTX\_REL\_NORMAL}{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT + NB\_IOT\_UE\_CTX\_REL\_MME\_INIT} \times 100\%$$

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Performance Aspects

New counters

Counter name	Description
NB_IOT_UE_CTX_REL_NORMAL (M8066C10) #LTE NB-IoT	This counter provides the number of transitions to ECM_IDLE due to normal call release. **Trigger event:** The counter is updated on receipt of of an S1AP:UE CONTEXT RELEASE COMMAND sent by the MME to the eNB with release cause "Normal release" **Use case:** **Abnormal UE movement to idle state** There is no possibility to monitor E-RAB Drop Ratio, because no data radio bearer is going to be established, but at least with this counter operator will be able to see any abnormal UE movement to ECM-Idle state.

$$\text{E-UTRAN UE Transaction to ECM-IDLE State Drop Ratio for NB} = \frac{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT + NB\_IOT\_UE\_CTX\_REL\_MME\_INIT - NB\_IOT\_UE\_CTX\_REL\_UE\_INACTIVE - NB\_IOT\_UE\_CTX\_REL\_DETACH - NB\_IOT\_UE\_CTX\_REL\_NORMAL}{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT + NB\_IOT\_UE\_CTX\_REL\_MME\_INIT} \times 100\%$$

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Performance Aspects

New counters

Counter name	Description
NB_IOT_UE_CTX_REL_ENB_INIT (M8066C11) #LTE NB-IoT	This counter provides the number of transitions to ECM_IDLE due to any kind of RAN reasons. Note: this includes the more specific release causes as well. **<u>Trigger event:</u>** The counter is updated on transmission of an S1AP: UE CONTEXT RELEASE REQUEST message sent by the eNB to the MME - irrespective of the release cause. **<u>Use case:</u>** **Abnormal UE movement to idle state** There is no possibility to monitor E-RAB Drop Ratio, because no data radio bearer is going to be established, but at least with this counter operator will be able to see any abnormal UE movement to ECM-Idle state.

$$\text{E-UTRAN UE Transaction to ECM-IDLE State Drop Ratio for NB IOT UE} = \frac{\mathit{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT} + \mathit{NB\_IOT\_UE\_CTX\_REL\_MME\_INIT} - \mathit{NB\_IOT\_UE\_CTX\_REL\_UE\_INACTIVE} - \mathit{NB\_IOT\_UE\_CTX\_REL\_DETACH} - \mathit{NB\_IOT\_UE\_CTX\_REL\_NORMAL}}{\mathit{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT} + \mathit{NB\_IOT\_UE\_CTX\_REL\_MME\_INIT}} \times 100\%$$

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Performance Aspects

New counters

Counter name	Description
NB_IOT_UE_CTX_REL_MME_INIT (M8066C12) #LTE NB-IoT	This counter provides the number of transitions to ECM_IDLE due to any kind of EPC reasons. Note: this includes the more specific release causes as well. **Trigger event:** The counter is updated on receipt of of an S1AP:UE CONTEXT RELEASE COMMAND sent by the MME to the eNB - irrespective of the release cause. **Use case:** **Abnormal UE movement to idle state** There is no possibility to monitor E-RAB Drop Ratio, because no data radio bearer is going to be established, but at least with this counter operator will be able to see any abnormal UE movement to ECM-Idle state.

$$\text{E-UTRAN UE Transaction to ECM-IDLE State Drop Ratio for NB} = \frac{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT + NB\_IOT\_UE\_CTX\_REL\_MME\_INIT - NB\_IOT\_UE\_CTX\_REL\_UE\_INACTIVE - NB\_IOT\_UE\_CTX\_REL\_DETACH - NB\_IOT\_UE\_CTX\_REL\_NORMAL}{NB\_IOT\_UE\_CTX\_REL\_ENB\_INIT + NB\_IOT\_UE\_CTX\_REL\_MME\_INIT} \times 100\%$$

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Performance Aspects
New counters

Counter name	Description
NB_IOT_RRC_CONN_TIME_SUM (M8066C13) #LTE NB-IoT	This counter provides the total time of NB-IoT UEs in RRC_CONNECTED state, i.e. from the establishment of an RRC connection to its release. **Trigger event:** The counter is updated on the transmission of an RRCConnectionRelease-NB message by the time difference between this RRCConnectionRelease-NB message and the corresponding RRCConnectionSetupComplete-NB message. **Use case:** **Average session duration of NB UEs** The total time in the numerator of the formula considers only NB UEs which have successfully completed RRC Connection Setup procedure. $\text{Logical S1 Signaling Connection Success Ratio} = \frac{NB\_IOT\_RRC\_CONN\_TIME\_SUM}{NB\_IOT\_RRC\_CONN\_ESTAB\_SUCC} \times 100\%$

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Performance Aspects

New counters

Counter name	Description
NB_IOT_MAC_PDU_VOL_UL (M8066C14) #LTE NB-IoT	This counter provides the size of transport blocks scheduled on NPUSCH. The volume of MAC PDUs is considered. **Trigger event:** The counter is updated when such a MAC PDU is scheduled in UL. Retransmissions are included. **Use case:** **MAC PDU volume related to NB UEs in UL and DL** **Utilization Ratio in DL/UL** The above two KPIs proposed are monitoring MAC PDU volume and PRB Utilization Ratio for NB UEs in the same way as NPO KPIs for non NB UEs. Both of these KPIs can be used to monitor MAC PDU available throughput (MAC PDU volume / measurement period / PRB Utilization Ratio).

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Performance Aspects

New counters

Counter name	Description
NB_IOT_MAC_PDU_VOL_DL (M8066C15) #LTE NB-IoT	This counter provides the size of transport blocks scheduled on NPDSCH. The volume of MAC PDUs is considered. **Trigger event:** The counter is updated when such a MAC PDU is scheduled in DL. Retransmissions are included. **Use case:** **MAC PDU volume related to NB UEs in UL and DL** **Utilization Ratio in DL/UL** The above two KPIs proposed are monitoring MAC PDU volume and PRB Utilization Ratio for NB UEs in the same way as NPO KPIs for non NB UEs. Both of these KPIs can be used to monitor MAC PDU available throughput (MAC PDU volume / measurement period / PRB Utilization Ratio).

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Performance Aspects
New counters

Counter name	Description
NB_IOT_RESOURCES_USED_UL (M8066C16) #LTE NB-IoT	This counter provides the number of concurrently used NB-IoT subcarriers in UL, which are measured during a 1 millisecond interval and accumulated over the measurement period. **Trigger event:** This counter is updated after each 1 ms interval, in which UL resources for NB-IoT UEs were reserved. It is incremented by the number of subcarriers (granularity of 3.75 kHz) used in parallel by any NB-IoT UE. (15 kHz subcarriers result in an increment of 4 per interval). Note: In case of NB-IoT inband mode, this 1 ms interval corresponds to a subframe of the hosting WB cell, i.e. a subframe containing one or more host PRBs allocated to NB-IoT UEs. These PRBs are considered unusable from host cell perspective.

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Performance Aspects
New counters

Counter name	Description
NB_IOT_TIME_RESERVED_UL (M8066C17) #LTE NB-IoT	This counter provides the number of 1 millisecond intervals, in which UL resources for NB-IoT UEs were configured (NPRACH) or allocated (NPUSCH) in the cell. **Trigger event:** This counter is updated after each 1 ms interval, in which UL resources for NB-IoT UEs were configured or allocated. Note: In case of NB-IoT inband mode, this 1 ms interval corresponds to a subframe of the hosting WB cell, i.e. contains one or more host PRBs allocated to NB-IoT UEs, which are considered unusable from host cell perspective. **Use case:** **Utilization Ratio in UL** PRB Utilization Ratio for NB UEs in the same way as NPO KPIs for non NB UEs. It can be used to monitor MAC PDU available throughput (MAC PDU volume / measurement period / PRB Utilization Ratio). $\text{Utilization Ratio in UL} = \frac{NB\_IOT\_TIME\_RESERVED\_UL}{NB\_IOT\_RRC\_CONN\_TIME\_SUM} \times 100\%$

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Performance Aspects
New counters

Counter name	Description
NB_IOT_RESOURCES_USED_DL (M8066C18) #LTE NB-IoT	This counter provides the number of concurrently used NB-IoT PRB in DL, which are measured during a 1 millisecond interval and accumulated over the measurement period. **Trigger event:** This counter is updated after each 1 ms interval, in which DL resources for NB-IoT UEs were reserved. It is incremented by the number of PRB (granularity of 180 kHz) used in parallel by any NB-IoT UE. Note: In case of NB-IoT inband mode, this 1 ms interval corresponds to a subframe of the hosting WB cell, i.e. a subframe containing one or more host PRBs allocated to NB-IoT UEs. These PRBs are considered unusable from host cell perspective.

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Performance Aspects
New counters

Counter name	Description
NB_IOT_RESOURCES_AVAIL_DL (M8066C19) #LTE NB-IoT	This counter provides the number of concurrently available NB-IoT PRBs in DL, which are measured during a 1 millisecond interval and accumulated over the measurement period. **Trigger event:** This counter is updated after each 1 ms interval, in which DL resources for NB-IoT UEs were reserved. It is incremented by the number of available PRBs (granularity of 180 kHz) in parallel by any NB-IoT UE. Note: In case of NB-IoT inband mode, this 1 ms interval corresponds to a subframe of the hosting WB cell, i.e. contains one or more host PRBs allocated to NB-IoT UEs, which are considered unusable from host cell perspective.

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Performance Aspects
LTE3071 NB-IoT

- Host cell performance monitoring after NB-IoT activation

Feature impact	How to measure
Decreased DL capacity in the host cell due to PRB resources reserved for NB-IoT inband cell When NB-IoT carrier is deployed, the number of PRBs available for PDSCH is reduced. Consequently, DL capacity is in such a case decreased. Effect will be visible only if the given cell has heavy UL load	**Average PDCP Layer Active Cell Throughput DL** LTE_5292d
Decreased UL capacity in the host cell due to PRB resources reserved for NB-IoT inband cell When NB-IoT carrier is deployed, the number of PRBs available for PUSCH is reduced. Consequently, UL capacity is in such a case decreased. Effect will be visible only if the given cell has heavy UL load	**Average PDCP Layer Active Cell Throughput UL** LTE_5289d

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Performance Aspects
LTE3071 NB-IoT

- Host cell performance monitoring after NB-IoT activation

Feature impact	How to measure
Decreased amount of mean/peak active UEs/RRC connected UEs served by the host cell. If Average/Maximum number of RRC connected users suggests that the AC limits will be soon met in the host cell, RRC connected limit for NB-IoT have to verified.	**Average number of active users per cell** (LTE_717a) **Maximum number of active users per cell** (LTE_718a) **Average of RRC connected users** (LTE_805a) **Maximum of RRC connected users** (LTE_806a)
Decreased UL peak UE throughput NB-IoT carrier consumes UL PRB resources what may impact UL peak throughput. Additionally, when allocation of UL NB-IOT carrier yields UL resources fragmentation, PUSCH is physically divided into several scheduling areas. Peak UE throughput will be decreased as one user can be scheduled in only one scheduling area at the same time	As there are no available counters or KPIs to check UE peak throughput, TTI traces need to be checked.

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Performance Aspects
Latency

- There is QoS constraints defined for transmission of MAR reports
- 3GPP states 10s of delay for transmission of Exception report (e.g. smoke detector or alarm
- Periodicity of such events is rare; it means that synchronisation and SI messages acquisition have to be counted as well

Example MCS0 vs MCS10 latency, 200 bytes UL message, no repetitions, default timings, no HARQ

Synchronisation and SI acquisition			
Synchronization	20		[ms]
MIB acquisition	640		[ms]
SIB1 acquisition	160		[ms]
SIB2 acquisition	160		[ms]
Call setup			
NPRACH waiting time	160		[ms]
NPRACH duration	26		[ms]
NPDCCH scheduling time	8		[ms]
NPRACH -> NPDCCH (RAR scheduling)	6		[ms]
DL: Random Access Response transmission	27		[ms]
UL: RRC Connectiion Request	45		[ms]
DL: RRC Connection Setup	27		[ms]
DL: RRC Connection Setup Complete	45		[ms]
Total call setup time	354		[ms]
UL Data transmission			
UL MCS	MCS0	MCS10	
NACK + DCI (UL grant)	26		[ms]
TBS size	88	680	[bits]
Number of TBSs required to send the message	20	3	
Average UL transmission time	900	135	[ms]
UL Data transmission			
Total UL message transmission time	2234	1469	[ms]

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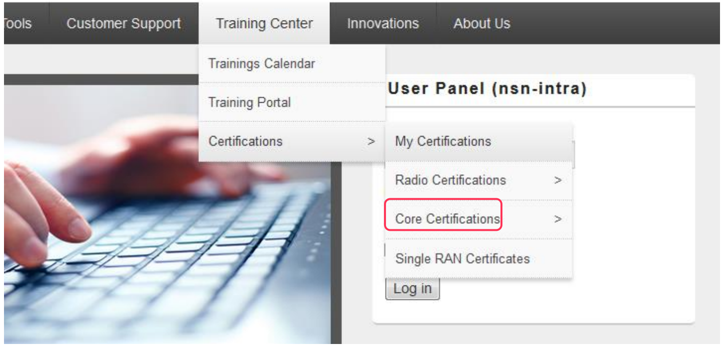

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Compliance Aspects

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Compliance Aspects

- NB-IoT technology has been standardized within Release 13 3GPP framework
- For more details please check 3GPP TS 45.820
- Only Cat-NB1 UE category has a possibility to support NB-IoT
- Legacy UEs cannot be handled by NB-IoT cell; nevertheless they can be served by legacy host LTE cell

A GLOBAL INITIATIVE

Cooperation between eNB and UE, needed for proper NB-IoT handling, is standardized by 3GPP

Compliance Aspects

Limitations / Simplification in Feature LTE3071 (comparing with 3GPP)

3GPP specification	Supported in LTE3071
In-band, guard-band and standalone deployment	In-band
Multiple PRBs can be used for NB-IoT	Single PRB can be used for NB-IoT
Uplink:15 kHz single tone and 3, 6, and 12 multi tones; 3.75 kHz single tone	Only 15kHz single tone NPUSCH is supported, 3.75kHz and 15kHz multi-tone NPUSCH (3,6,12) are out of scope
Idle mode mobility by cell re-selection	Cell selection
Coverage levels up to 164 dB supported	Only first level coverage (144dB MCL) is supported, coverage enhancements (154 and 164dB MCL) are not supported
Various transmission and reception schemes	Only 2T2R are supported in both host LTE and inband NB-IoT cells

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Compliance Aspects

Limitations / Simplification in Feature LTE3071 (comparing with 3GPP)

3GPP specification	Supported in LTE3071
Various configurations of subframes per TBS	Fixed number of subframes for NPDSCH is used Fixed number of resource unit for NPUSCH is used
Configurable downlink and uplink transmission gap	Fixed scheduling delay is used, Downlink and Uplink Transmission Gap is not supported
Dynamic TA alignment	Initial TA alignment
Dynamic downlink power control	Static downlink power
Dynamic uplink power control	Only uplink open loop power control (parameters broadcasted by SIB)

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Compliance Aspects

Limitations / Simplification in Feature LTE3071 (comparing with 3GPP)

3GPP specification	Supported in LTE3071
DRB and SRB can be used for data transmission	SRB can be used
NPRACH format 0 (CP length = 67 us) and format 1 (CP length = 267 us)	NPRACH format 1 (cell radius 35 km)
Repetitions on NPRACH, NPDSCH, NPDCCH, NPUSCH	No repetitions on NPDSCH and NPUSCH. Limited repetitions on NPRACH (can be up to 32) and NPDCCH (hard coded to 2)
Both Mobile Originated Calls and Mobile Terminated Calls (by paging) supported	Paging not supported
All the NB SIBs supported	SIBs other than SIB1-NB and SIB2-NB are not supported
Update of System Information with paging	System Information updates with paging is not supported
Idle DRX	Idle eDRX function is not supported

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Compliance Aspects
Limitations / Simplification in Feature LTE3071 (comparing with 3GPP)

3GPP specification	Supported in LTE3071
NPDCCH with 1 CCE	NPDCCH with 1 CCE is not supported
NPRACH and NPUSCH multiplexing in same TTI	NPRACH and NPUSCH multiplexing in same TTI is not supported
Valid subframes configuration	Configuration of valid subframe is not supported

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End-to-End Operability

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End-to-End Operability

- EPC core is suggested for optimized IoT-driven network operation
- The following **mandatory** features are needed for NB-IoT:
- EPC:
  - Small data transmission for IP devices
  - Small data transmission for non-IP devices
- SDM
  - NB-IoT ACCESS SUPPORT: HSS support for NB-IoT
  - SMALL DATA: Small data transmisson for non-IP devices
- Optionally for EPC:
  - BATTERY SAVING: Power saving mode
  - COVERAGE ENHANCEMENT: Coverage enhancement paging

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