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NB-IOT

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Narrow band IOT

Introduction :

- It is one of the LPWAN radio technology standard.
- It is a narrow band radio technology designed for IOT.
- It is one of the MIOT technologies standardized by 3GPP.

Deployment modes :

- Stand-alone as a dedicated carrier.
- In-band within the occupied BW of a wideband LTE carrier.
- Within the guard band of an existing LTE carrier.

Design targets of NB-IOT :

- Low cost devices
- High coverage
- Long device battery life
- Massive capacity

Transmission schemes

DL transmission scheme

DL transmission scheme :

- OFDMA with 15Khz sub-carrier spacing.
- Slot - 0.5 ms
- Sub frame - 1 ms
- Frame - 10 ms
- NB-IOT carrier uses an LTE PRB in the frequency domain.

UL transmission scheme

UL transmission scheme :

- The UL of NB-IOT supports both multi-tone & single-tone transmissions.
- Multi tone transmissions is based on 15KHz sub-carrier spacing.
- Single tone transmissions supports 15 KHz and 3.75 KHz.
- UL NB-IOT uses a total system bandwidth of 180 KHz.

Deployment options

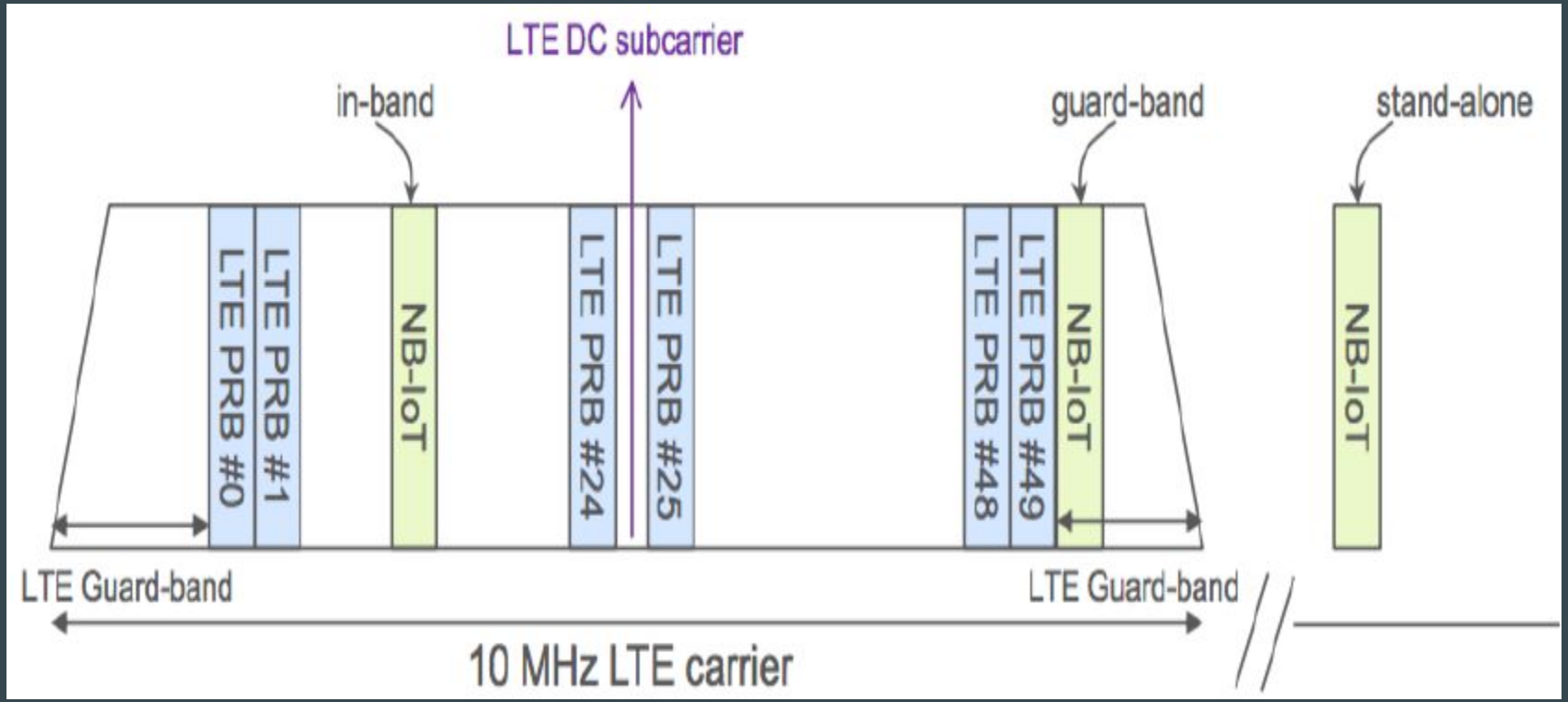
Deployment options :

- The deployment scenario, stand-alone, inband or guard band should be transparent to a UE when it is first turned on and searches for an NB-IOT carrier.
- NB-IOT UE is only required to search for a carrier on a 100 KHz raster.

Deployment options :

- An NB-IOT carrier that is intended for facilitating UE initial synchronization is referred to as an anchor carrier.
- In 10 MHz LTE carrier, the indexes of the PRB's that are best aligned with 100 KHz grid and can be used as an NB-IOT anchor carrier are 4,9,14,19,30,35,40,45.

Deployment options :



Narrow band IOT introduction

Introduction :

- New cellular radio access technology specified by 3GPP in rel-13.
- Used to address the fast expanding market for low power wide area connectivity.

Introduction :

- It provides improved indoor coverage, support for massive number of low throughput devices, low delay sensitivity, ultra low device cost, low device power consumption and optimized network architecture.
- It can be deployed “in-band” utilizing RB’s within a normal LTE carrier.
- It can be deployed in guard band or stand alone.

Guidelines :

- Support for IP traffic over control plane .
- Deployment of features : PSM, eDRX, paging, cell re-selection , support for extended coverage, power class , rate control mechanisms and SMS's.

NB-IOT data architecture

Architecture :

There are two main network attach options to support connectivity :

- Attach with PDN connection.
- Attach without PDN connection.

Architecture :

Data connectivity options :

- IP over control plane
- IP over user plane
- Non -IP over control plane
- Non -IP over user plane

Architecture :

- Control plane CIOT EPS optimisation transports user data or SMS messages via MME by encapsulating them in NAS.
- Non - IP allows for the use of protocols that have been optimised for a specific use.
- UDP is asynchronous , which reduces the time of the connection, while TCP will keep the connection open until an acknowledgement is received.

Architecture :

- In case of non-IP communication over the control plane, the MNO has two options either through PGW or by utilising SCEF.
- MNO should consider supporting IP traffic over control plane as a minimum requirement to start supporting roaming. This is the best solution for supporting devices that need to consume as little power as possible.

LTE NB-IOT E2E architecture :

- OSS SW upgrade
- HSS SW upgrade
- MME SW upgrade
- NB-IOT device
- NB-IOT SW upgrade
- Optional IOT platform
- SGW SW upgrade
- Common or dedicated VEPC

NB-IOT deployment bands

Deployment bands :

- Europe : B3 (1800) , B8 (900) , B20 (800).
- Commonwealth of independent states : B3 (1800) , B8 (900) , B20 (800).
- North America : none
- Asia pacific : B1 (2100) , B3 (1800) , B5 (850) , B8 (900) , B 18 (850), B20 (800) , B26 (850) , B28 (700).
- Sub - saharan Africa : B3 (1800) and B8 (900)
- Middle East and North Africa : B8 (900) and B20 (800)
- Latin America : B2 (1900) , B3 (1800) , B5 (850), B 28 (700).

NB-IOT feature deployment

Feature deployment :

- PSM configuration
- eDRX configuration
- Data transport in control plane CIOT EBS optimisation
- PRB configuration
- Deployment mode
- Paging
- SCEF deployment plans
- Cell reselection

Feature deployment :

- SMS without combined attach for NB-IOT only UE's.
- Coverage extension
- Class power
- Rate control

PSM configuration :

- It is designed to help IOT devices conserve battery power.
- The re-attach procedure consumes a small amount of energy, but the cumulative energy consumption of reattaches can become significant over the lifetime of a device.
- When a device initiates PSM with the network, it provides two preferred timers (T3324 and T3412).
- PSM time is the difference between these timers.

PSM configuration :

- It is a UE mechanism to reduce the energy used by the UE.
- The UE reports how often and for how long it needs to be active in order to transmit and receive data.
- PSM mode is similar to power off , but the UE remains registered with the network. When the UE becomes active again, there is no need to reattach or re-establish PDN connections.
- It is available for all LTE device categories.

eDRX configurations :

- Extended discontinuous reception is an extension of an existing LTE feature which can be used by IOT devices to reduce power consumption.
- eDRx cycle lengths : 20.48 secs - 175 min.
- Networks & devices negotiate when devices can sleep.

Other timers to consider :

- There are other timers that are needed to be considered by MNO while configuring the network.
- TAU, periodic TAU and IPX firewall timers.

TAU & periodic TAU :

- There is a direct relation between TAU and PSM.
- Devices that are constantly moving , particularly outside of the TA, would need to re-attach and consequently more signalling would be required.

IPX firewall timers :

- Employ a firewall on 3GPP S8 interface towards IPX network.
- These firewalls usually supervise the GTP tunnel (session).
- If no transfer by a SIM, GTP tunnel is deleted.

NB-IOT use cases

NB-IOT use cases :

Market potential for NB-IOT services :

- Agriculture
- Health care
- Safety & security
- Automotive & logistics
- Manufacturing
- Smart city
- Energy & utilities
- Retail
- Smart home

NB-IOT service categories :

- Smart metering (electricity, gas and water)
- Facility management services
- Intruder alarms and fire alarms for homes & commercial properties.
- Connected personal appliances measuring health parameters.
- Tracking of persons, animals or objects.
- Smart city infrastructure such as street lamps
- Connected industrial appliance such as welding machines or air compressor.

IOT public :

- Smart metering
- Alarms & event detectors
- Smart garbage bins

IOT industry :

- Logistics tracking
- Asset tracking
- Smart agriculture

IOT personal :

- Wearables
- Smart bicycle

Channels

Physical channels :

Downlink channels :

- NPSS
- NSSS
- NPBCH
- NPDCCH
- NPDSCH

Downlink physical channels :

	subframe number									
even numbered frame	0	1	2	3	4	5	6	7	8	9
	NPBCH	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NPSS	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NSSS
	subframe number									
odd numbered frame	0	1	2	3	4	5	6	7	8	9
	NPBCH	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NPSS	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NPDCCH or NPDSCH	NPDCCH or NPDSCH

Downlink physical channels ：

- NPSS is transmitted in subframe #5 in every 10ms frame, using the last 11 OFDM symbols in the subframe.
- To allow efficient implementation of NPSS detection, NB-IOT uses a hierarchical sequence.
- NSSS has 20ms periodicity and is transmitted in subframe #9 , using the last OFDMA symbols that consists of 132 RE's overall.

Downlink physical channels ：

- NPBCH carries MIB and it is transmitted in subframe #0 in every frame.
- NPDCCH carries scheduling information for both DL and UL data channels.
- NPDSCH carries data from the higher layers as well as paging message, system information and the RAR message.

Downlink physical channels :

- To reduce UE complexity, all DL channels use the LTE TBCC.
- Maximum transport block size of NPDSCH is 680 bits.
- In LTE without spatial multiplexing supports maximum TBS greater than 70000 bits.

Uplink channels :

- NPRACH
- NPUSCH

Uplink channels :

- NPRACH is a newly designed channel.
- One NPRACH preamble consists of 4 symbol groups.
- Each symbol with fixed symbol value 1 , is modulated on a 3.75 KHz tone.
- The waveform of NPRACH preamble is referred to as single tone frequency hopping.

NPUSCH formats :

NPUSCH has two formats :

- Format 1 : used for carrying UL data and uses the same LTE turbo code for error correction.
- Format 2 : used for signaling HARQ acknowledgement of NPDSCH and uses a repetition code for error correction.

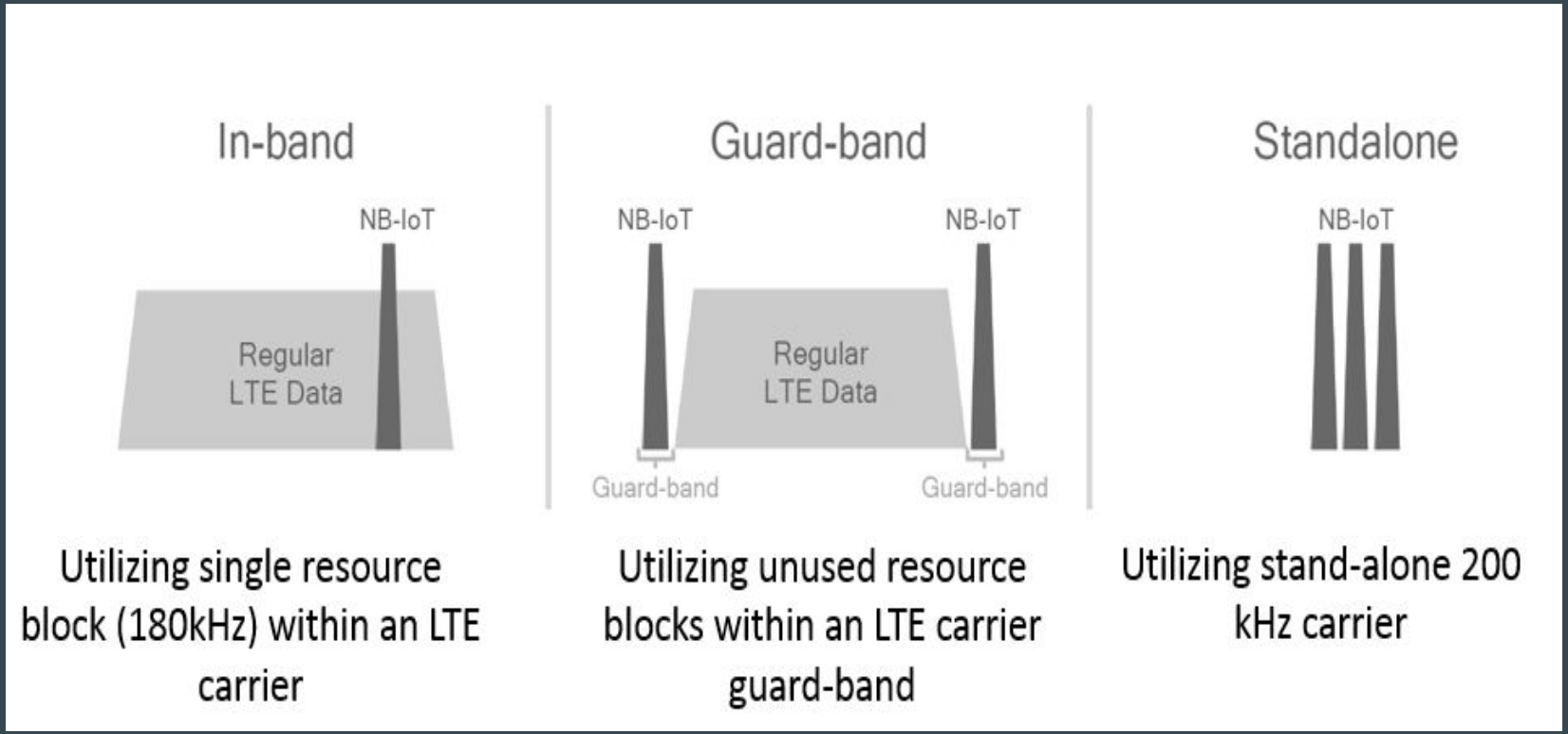
Deployment modes

Deployment mode :

MNO's surveyed by GSMA plan to deploy NB-IOT in all three deployment modes :

- Standalone deployment
- LTE guardband deployment
- LTE in-band deployment

Deployment mode :



Standalone mode :

- It mainly utilizes new bandwidth.
- The spectrum currently being used by GERAN systems as a replacement of one or more GSM carriers.
- It could be used in LTE system bands other than guard band.

Inband mode :

- It utilize resource blocks within a normal LTE carrier.

Guardband mode :

- It utilizes the unused resource bands within a LTE carrier guard band.

SCEF deployment plans :

- MME-SCEF interface
- Abstraction
- Monitoring events
- Network parameter configuration

Partial deployment of in-band NB-IOT :

- With partial deployment, NB-IOT devices cannot attach to the best cell if that cell does not support NB_IOT.
- NB-IOT may be deployed in only a fraction of all LTE cells.
- Non-NB IOT cells may either use the PRB used by NB-IOT for LTE or leave it unused.

3GPP standards for NB-IOT

Standards :

- Deployment : inband, guardband and stand alone.
- Coverage : 164 dB for standalone
- DL : OFDMA, 15 KHz tone spacing, 1 receiver
- UL : single tone, 15 KHz and 3,75 KHz spacing
  SCFDMA , 15 KHz tone spacing, turbo code.
- Bandwidth : 180 KHz
- Peak rate : DL - 50 kbps, UL - 50 kbps for multi-tone and 20 kbps for single tone.
- Duplexing : HD (type B) , FDD
- Power class : 23 dbm

Physical features ：

- Narrow band support of 180 KHz.
- Supports two modes for UL : single tone & multi tone.
- No support of turbo code for the DL
- Single transmission mode of SFBC for PBCH,PDSCH , PDCCH.
- New narrow band channels.

Radio protocol features :

- Single HARQ process.
- Only RLC AM mode with simplified status reporting.
- Two PDCP options
- Significantly reduced broadcast system information.

Main features enhancements :

- Support for multicast
- Power consumption
- Latency reduction
- Mobility and service continuity enhancements
- New power classes

Resource mapping

Resource mapping :

- NB-IOT is designed to allow a UE to learn the deployment mode (stand-alone, in-band or guard band) as well as cell identity (both NB-IOT and LTE) through initial acquisition.
- The UE can map NPDCCH and NPDSCH symbols to available RE's.

Resource mapping :

- NPSS, NSSS and NPBCH are used for initial synchronization and master information acquisition.
- These signals needs to be detected without knowing the deployment mode.

Cell search and initial acquisition procedure

Cell search & initial acquisition procedure :

- Synchronization is an important aspect in cellular communications.
- When a UE is powered on for the first time, it needs to detect a suitable cell to camp on, and for that cell , obtain the symbol, subframe and frame timing as well as synchronize to the carrier frequency.
- Due to the presence of multiple cells, the UE needs to distinguish a particular cells on the basis of an NB-PCID.

Cell search & initial acquisition procedure :

- Synchronization is achieved through the use of NPSS and NSSS.
- NPSS is used to obtain symbol timings.
- NSSS is used to obtain NB-PCID.

Random access

Random access :

Contention based random access procedure in NB-IOT consists of 4 steps :

- UE transmits a random access preamble.
- The network transmits a random access response.
- The UE transmits its identity to the network using scheduled resources.
- The network transmits contention resolution message.

Random access :

- To serve UE's in different coverage classes that have different ranges of path loss, the network can configure upto three NPRACH resource configurations in a cell.
- In each configuration, a repetition value is specified for repeating a basic random access preamble.

NPRACH deployments :

- Time domain : periodicity of NPRACH resource, and starting time of NPRACH resource in time.
- Frequency domain : frequency location and number of sub carriers.

Scheduling and HARQ operation

Scheduling & HARQ operation :

- Adaptive HARQ procedure is adopted to support scheduling flexibility.
- Scheduling command is conveyed through DCI (downlink control indicator) , which is carried by NPDCCH.
- NPDCCH may use aggregation levels 1 or 2 for transmitting a DCI.

Performance

Peak data rates :

- NDSCH peak data rate can be achieved by using the largest TBS of 680 bits and transmitting it over 3ms.
- This gives 226.7 kbps peak layer 1 data rate.

Coverage :

- Coverage extension is achieved by trading off data rate through increasing the number of repetitions.
- NPUSCH with 15 KHz single tone gives a L1 data rate of approx 20 bps when configured with the highest repetition factor i.e 128 and lowest modulation & coding scheme.
- NPDSCH gives a L1 data rate of 35 bps when configured with repetition factor 512 and lowest modulation & coding scheme.

Device complexity :

NB-IOT enables low complexity UE implementation by designs as :

- Significantly reduced TBS for both UL & DL.
- Support only one redundancy version in the DL.
- Support only single stream transmissions in both UL & DL.
- A UE requires single antenna.
- Allow only half duplex FDD operation.

Latency and battery life time ：

- NB-IOT targets latency insensitive applications.
- NB-IOT aims to support long battery life.
- For some applications, it is designed to allow less than 10 seconds latency.

Capacity ：

- NB-IOT with one PRB supports more than 52500 UE's per cell.
- NB-IOT supports multi-carrier operation.
- More IOT capacity can be added by adding more NB-IOT carriers.

NB-IOT key features

Key features :

- Better coverage
- 10+ years battery life
- Support for massive number of connections.

DONAS :

NB-IOT small data transport data over NAS

- Cost efficient small data transfer through minimized signalling.
- Suitable for infrequent small data transfer.

RACH message optimization :

- The message could be any as RRC connection request, RRC connection reconfiguration complete or an RRC connection re-establishment depends on the cause which initiated the RACH procedure.
- In the worse RF condition, the message's coverage may be improved with RLC segmentation for fragmenting this handover complete message.

Thanks...