NB-IoT presentation for IETF LPWAN

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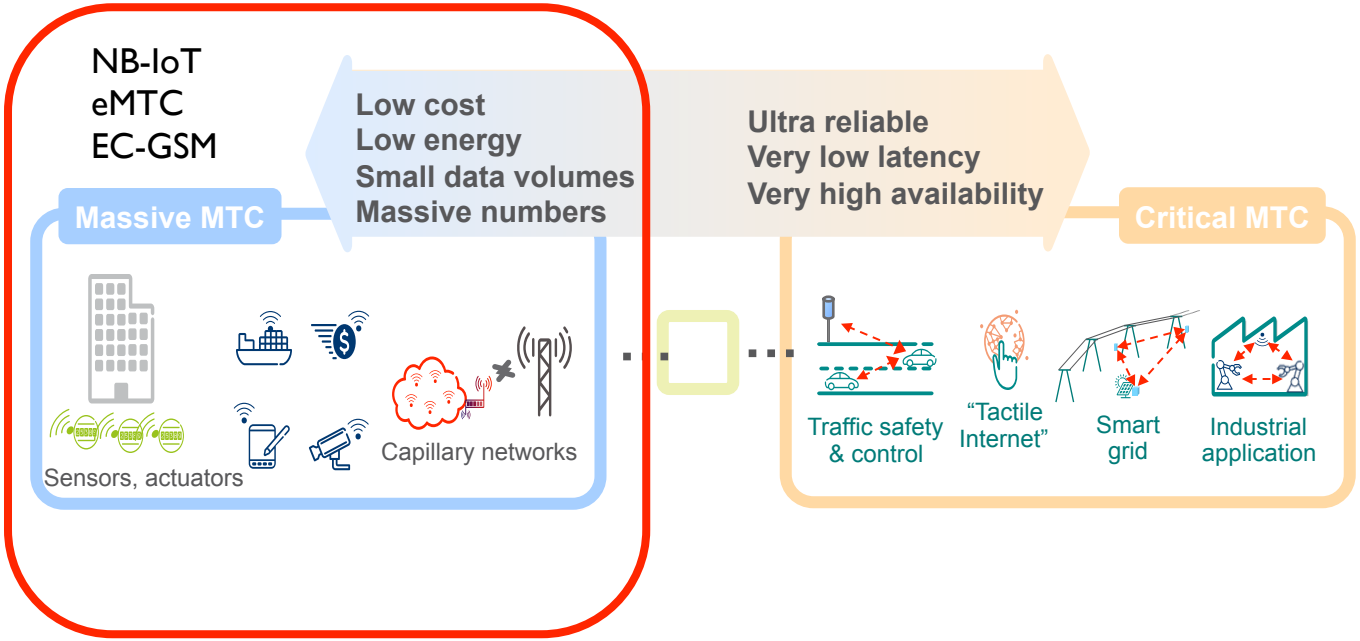
NB-IoT targeted use cases



NB-IoT Design targets

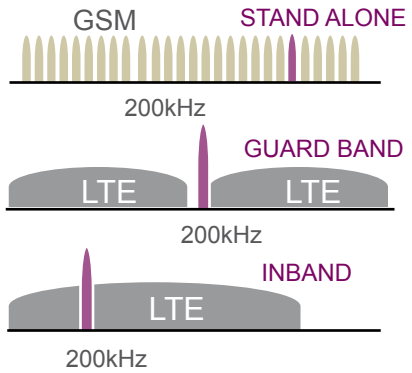
- NB-IoT targets the low-end "Massive MTC" scenario:

Low device cost/complexity:	<$5 per module
Extended coverage:	164 dB MCL, 20 dB better compared to GPRS
Long battery life:	>10 years
Capacity:	40 devices per household, ~55k devices per cell
Uplink report latency :	<10 seconds

Basic Technical Characteristics

NB-IoT

- Targeting implementation in an existing 3GPP network
- Applicable in any 3GPP defined (licensed) frequency band – standardization in release 13
- Three deployment modes
- Processing along with wideband LTE carriers implying OFDM secured orthogonality and common resource utilization
- Maximum user rates 30/60 (DL/UL) kbps



The capacity of NB-IoT carrier is shared by all devices
Capacity is scalable by adding additional NB-IoT carriers

NB-IoT overview

- M2M access technology contained in 200 kHz with 3 deployments modes:
  - **Stand-alone** operation
  - Operation in LTE "**guard band**'
  - Operation within wider LTE carrier (aka **inband**)
- L1:
  - FDD only & half-duplex User Equipment (UE)
  - Narrow band physical downlink channels over 180 kHz (1 PRB)
  - Preamble based Random Access on 3.75 kHz
  - Narrow band physical uplink channel on single-tone (15 kHz or 3.75 kHz) or multi-tone (n*15 kHz, n = [3,6,12])
  - Maximum transport block size (TBS) 680 bits in downlink, 1000 bits in uplink
- L2, L3:
  - Single-process, adaptive and asynchronous HARQ for both UL and DL
  - Data over Non Access Stratum, or data over user plane with RRC Suspend/ Resume
  - MTU size 1500 bytes
  - Extended Idle mode DRX with up to 3 h cycle, Connected mode DRX with up to 9.216 s cycle
  - Multi Physical Resource Block (PRB)/Carrier support

NETWORK DEPLOYMENT

- Maximum coupling loss 164 dB which has been reached with assumptions given in the table below, which shows the link budget for uplink
  - Urban: deep in-building penetration
  - Rural: long range (10-15 km)

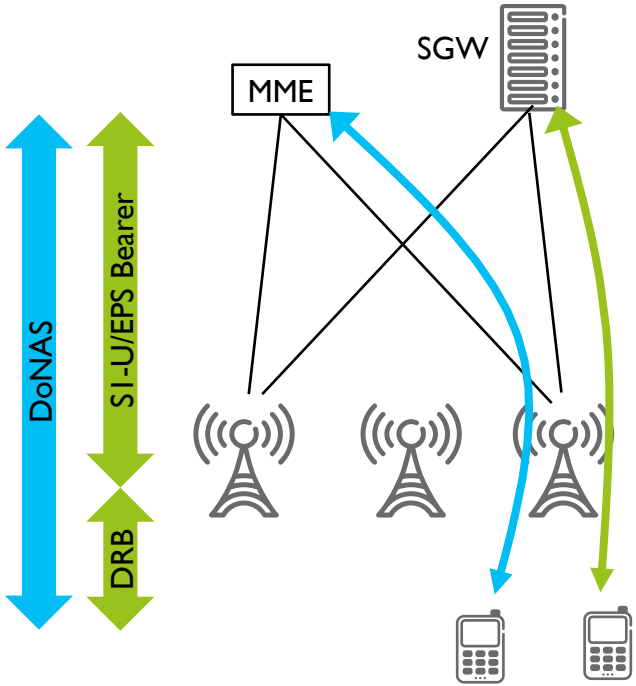
Numerology	15 kHz	3.75 kHz
(1) Transmit power (dBm)	23.0	23.0
(2) Thermal noise density (dBm/Hz)	-174	-174
(3) Receiver noise figure (dB)	3	3
(4) Occupied channel bandwidth (Hz)	15000	3750
(5) Effective noise power = (2) + (3) + 10*log ((4)) (dBm)	-129.2	-135.3
(6) Required SINR (dB)	-11.8	-5.7
(7) Receiver sensitivity = (5) + (6) (dBm)	-141.0	-141.0
(8) Max coupling loss = (1) - (7) (dB)	164.0	164.0

Relevant L1 characteristics

- Highest modulation scheme **QPSK**
- ISM bands vs licensed bands
  - NB-IoT currently specified on licensed bands only
  - Narrowband operation (180 kHz bandwidth)
    - in-band (LTE), guard band (LTE) or standalone operation mode (e.g. refarm the GSM carrier at 850/900 MHz)
  - Half Duplex FDD operation mode with 60 kbps peak rate in uplink and 30 kbps peak rate in downlink
- Maximum transmission block size 680 bits in DL, 1000 bits in UL (In Rel-13)
- Use repetitions for coverage enhancements, up to 2048 reps in DL, 128 reps in UL data channels
- > 10 year battery life time

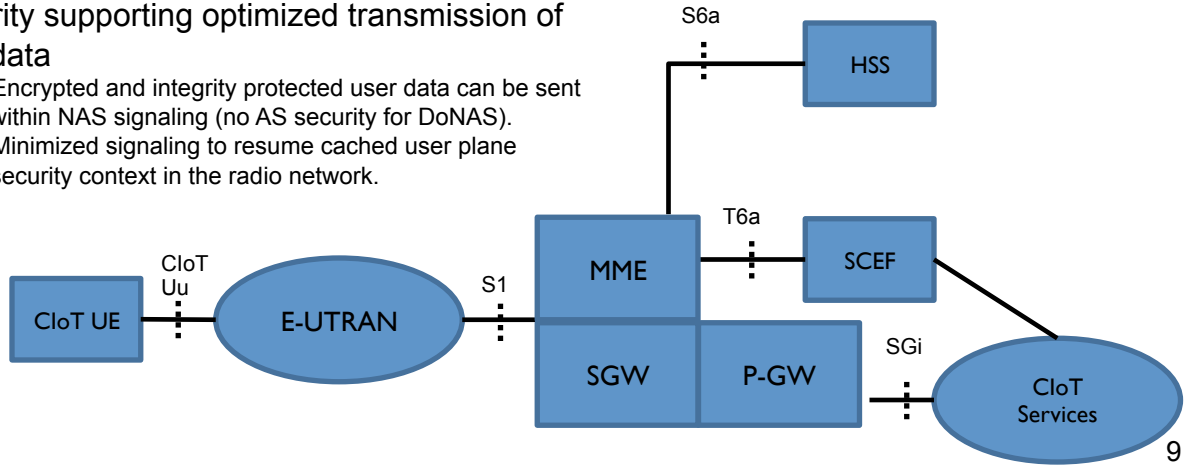
Relevant L2 characteristics

- Supported MTU size is 1500 bytes for both, NAS and AS solutions
- Error correction, concatenation, segmentation and reassembly in RLC Acknowledged Mode
  - Error correction through ARQ
  - Segmentation to segment the SDUs from PDCP into the transmission block sizes for physical layer
- Non-access stratum (NAS) and Access stratum (AS)
  - NAS is a set of protocols used to convey non-radio signaling between the UE and the core network, passing transparently through radio network. The responsibilities of NAS include authentication, security control, mobility management and bearer management
  - AS is the functional layer below NAS, working between the UE and radio network. It is responsible for transporting data over wireless connection and managing radio resources.
  - In NB-IoT, an optimization for data transfer over NAS (DoNAS) signaling is also supported,
  - Also AS optimization called RRC suspend/resume can be used to minimize the signaling needed to suspend/resume user plane connection.
  - Non-IP support, which enables the usage of other delivery protocols than IP as well
- L2 security
  - Authentication between UE and core network.
  - Encryption and integrity protection of both AS and NAS signaling.
  - Encryption of user plane data between the UE and radio network.
  - Key management mechanisms to effectively support mobility and UE connectivity mode changes.



NB-IoT system architecture

- Architecture is based on evolved Packet Core (EPC) used by LTE
- Cellular IoT User Equipment (CIoT UE) is the mobile terminal
- evolved UMTS Terrestrial Radio Access Network (E-UTRAN) handles the radio communications between the UE and the EPC, and consists of the evolved base stations called eNodeB or eNB
- NB-IoT security properties
  - Authentication and core network signaling security as in normal LTE
  - Security supporting optimized transmission of user data
    - Encrypted and integrity protected user data can be sent within NAS signaling (no AS security for DoNAS).
    - Minimized signaling to resume cached user plane security context in the radio network.



Summary for NB-IoT

	NB-IoT
Deployment	In-band & Guard-band LTE, standalone
Coverage (MCL)	164 dB
Downlink	OFDMA, 15 KHz tone spacing, TBCC, 1 Rx
Uplink	Single tone: 15 KHz and 3.75 KHz spacing, SC-FDMA: 15 KHz tone spacing, Turbocode
Bandwidth	180 KHz
Highest modulation	QPSK
Link peak rate (DL/ UL)	DL: ~30 kbps UL: ~60 kbps
Duplexing	HD FDD
MTU size	1500 B
TBS	Max. transmission block size 680 bits in DL, 1000 bits in UL, min. 16 bits
Repetitions	Up to 2048 repetitions in DL and 128 repetitions in UL data channels
Power saving	PSM, extended Idle mode DRX with up to 3 h cycle, Connected mode DRX with up to 10.24 s cycle
UE Power class	23 dBm or 20 dBm

UE categories for massive MTC

	Rel-8 Cat-4	Rel-8 Cat-1	Rel-12 Cat-0	Rel-13 Cat-M1	Rel-13 NB-IOT
Supported duplex modes	FD-FDD / TDD	FD-FDD / TDD	HD-FDD / FD-FDD / TDD	HD-FDD / FD-FDD / TDD	HD-FDD
DL link peak rate [Mbps]	150	10	0.375 / 1	0.3 / 0.8	~0.03*
UL link peak rate [Mbps]	50	5	0.375 / 1	0.375 / 1	~0.06**
Highest DL modulation scheme	64QAM	64QAM	64QAM	16QAM	QPSK
Highest UL modulation scheme	16QAM	16QAM	16QAM	16QAM	QPSK
Max number of DL spatial layers	2	1	1	1	1
Number of receive antennas	2	2	1	1	1
UE bandwidth [MHz]	20	20	20	1.080	0.180
Maximum transmit power [dBm]	23	23	23	20 or 23	20 or 23

* DL system peak rate: 0.23 Mbps **UL system peak rate: 0.25 Mbps

WORK IN PROGRESS, TO BE DONE

- Further enhancements for NB-IoT (and eMTC) are being worked on for next 3GPP Release.
- These enhancements include the following topics
  - Positioning
  - Multicast
    - Support multi-cast downlink transmission (e.g. firmware or software updates, group message delivery) for NB-IoT
  - Non- Anchor PRB enhancements
  - Mobility and service continuity enhancements
  - New Power Class(es)
    - Evaluate and, if appropriate, specify new UE power class(es) (e.g. 14dBm), and any necessary signaling support, to support lower maximum transmit power suitable for small form-factor batteries, with appropriate MCL relaxations compared to Rel-13