NB-IOT

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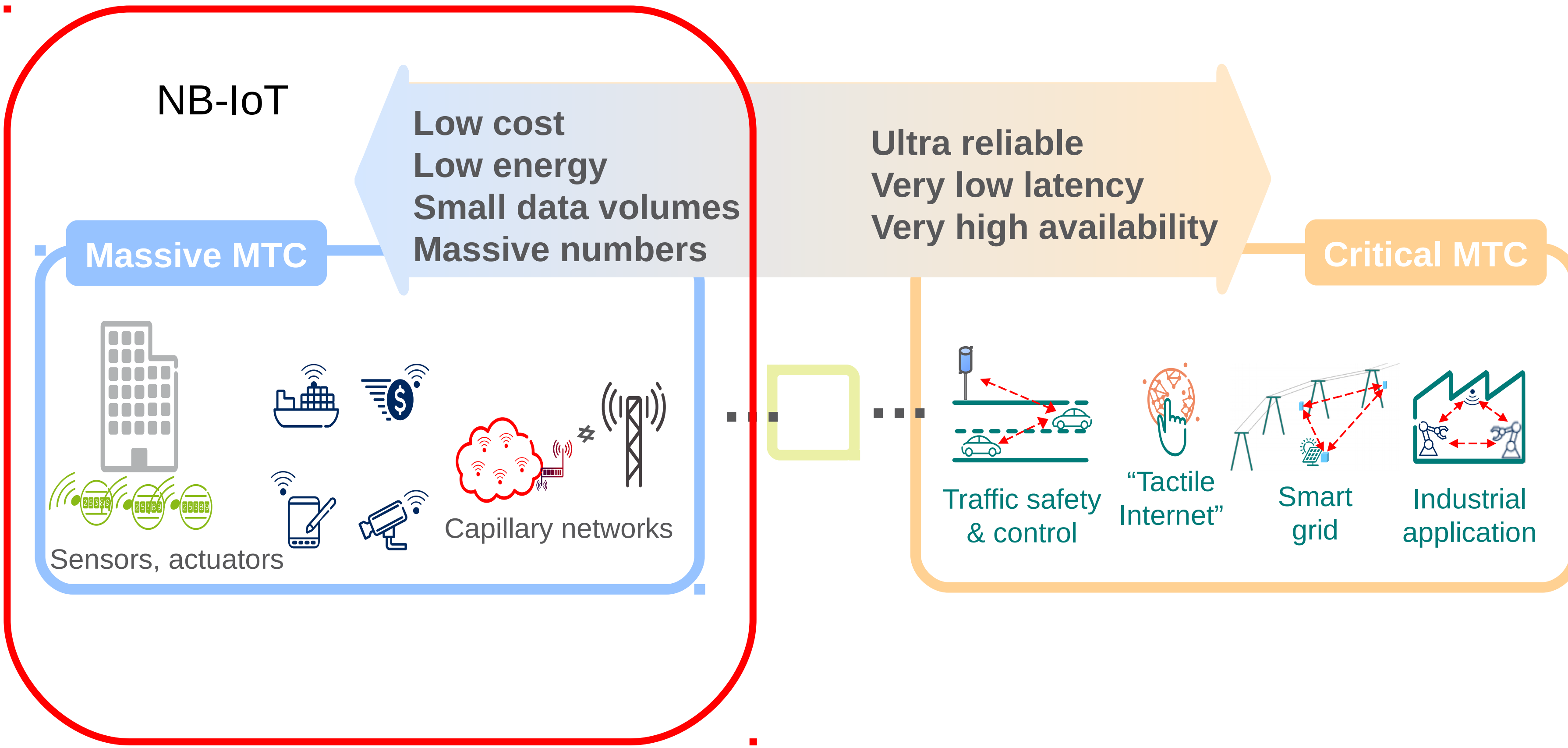
NB-IoT targeted use cases



NB-IoT Design targets

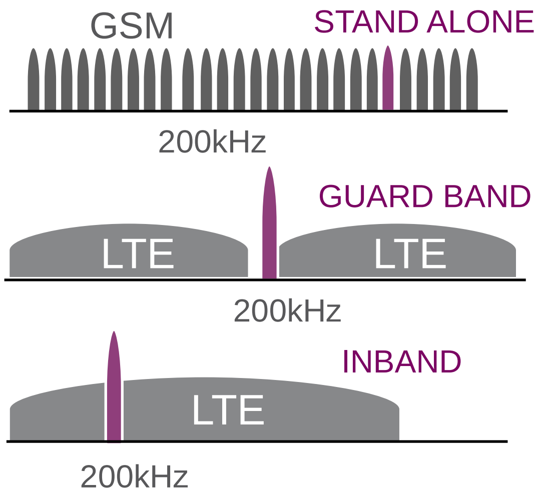
- NB-IoT targets the low-end “Massive MTC” scenario:

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

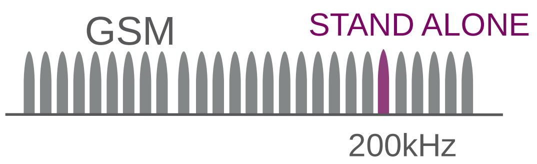
- Targeting implementation in an existing 3GPP network
- Applicable in any 3GPP defined (licensed) frequency band – standardization in release 13
- Three deployment modes
- Processing along with wideband LTE carriers implying OFDM secured orthogonality and common resource utilization
- User rates ranging from 300 bps up to 200 kbps

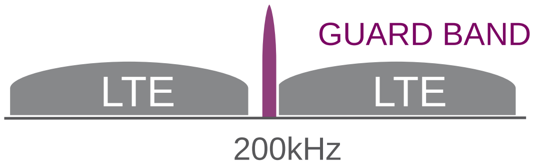


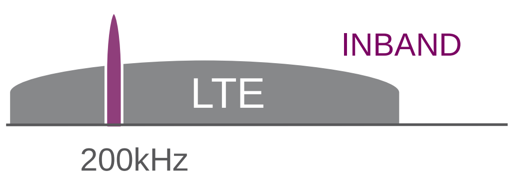
Device receives NB-IoT carrier
The capacity of NB-IoT carrier is shared by all devices
Capacity is scalable by adding additional NB-IoT carriers

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 up to 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
  - Maximum PDCP SDU size 1600 bytes
  - Extended Idle mode DRX with up to 3 h cycle, Connected mode DRX with up to 10.24 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
  - ~ 55000 devices per cell
  - 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

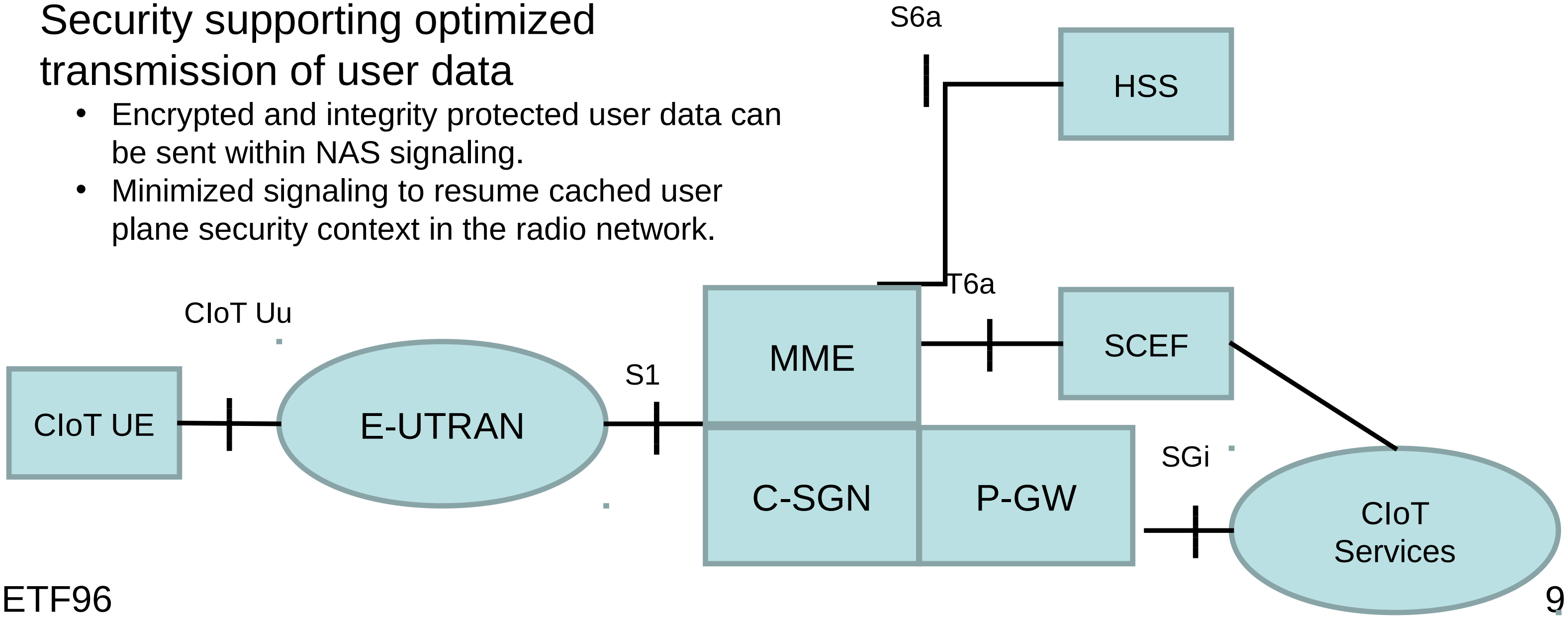
- Highest modulation scheme **QPSK**
- ISM bands vs licensed bands
  - NB-IoT currently works on licensed bands only
  - Narrowband operation (180 kHz bandwidth)
    - in-band (LTE), guard band (LTE) or standalone operation mode (e.g. refarm the GSM carrier at 850/900 MHz)
  - Half Duplex FDD operation mode with 60 kbps peak rate in uplink and 30 kbps peak rate in downlink
- > 10 year battery life time

Relevant L2 characteristics

- Maximum size of PDCP SDU and PDCP control PDU is 1600 bytes
- Multicast capabilities work in progress for 3GPP Release-14
- 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, data transfer over NAS signaling is also supported, which enables the usage of other delivery protocols than IP as well
  - Also AS optimization called RRC suspend/resume can be used to minimize the signaling needed to suspend/resume user plane connection.
- 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.
    - 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
Duty cycle	Up to 100%, no channel access restrictions
MTU	Max. PDCP SDU size 1600 B
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

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