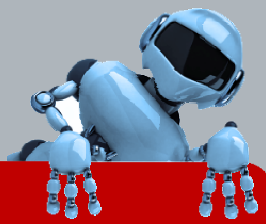
Internet of Things - IoT
System Design Challenges and Testing Solutions

Lothar Walther

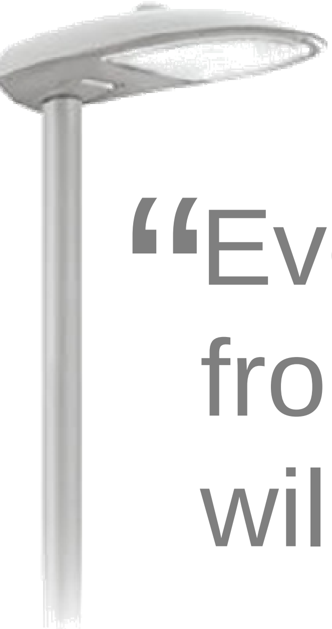
Training Center
Rohde & Schwarz, Germany

ROHDE&SCHWARZ

Outline



- The Internet of dogs, lights and doors
- Sigfox, LoRa and more
- LTE-A Pro: eMTC, NB-IoT
- What’s next on the way to 5G



“Everything that benefits
from being connected
will be connected” *Ericsson, 2010*

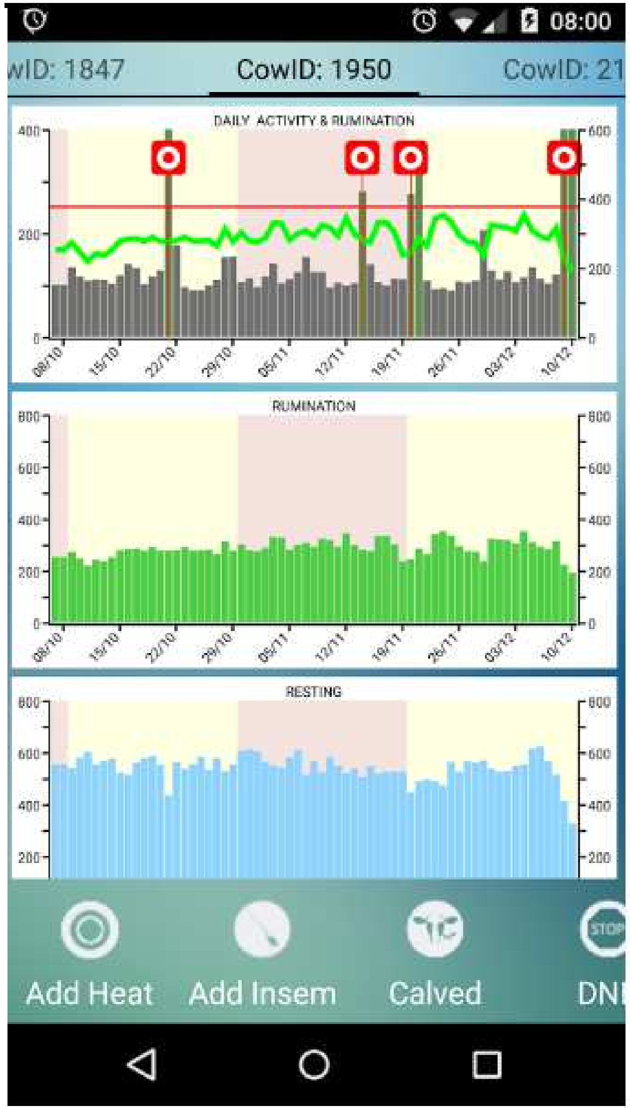
Wearables


tractive
PET TRACKING


BATCH07B
Edit Safe Zone
Klosterneuburg
VIENNA
Schwechat
Brunn am Gebirge
6,7 km
Eisenstadt
Activate Safe Zone

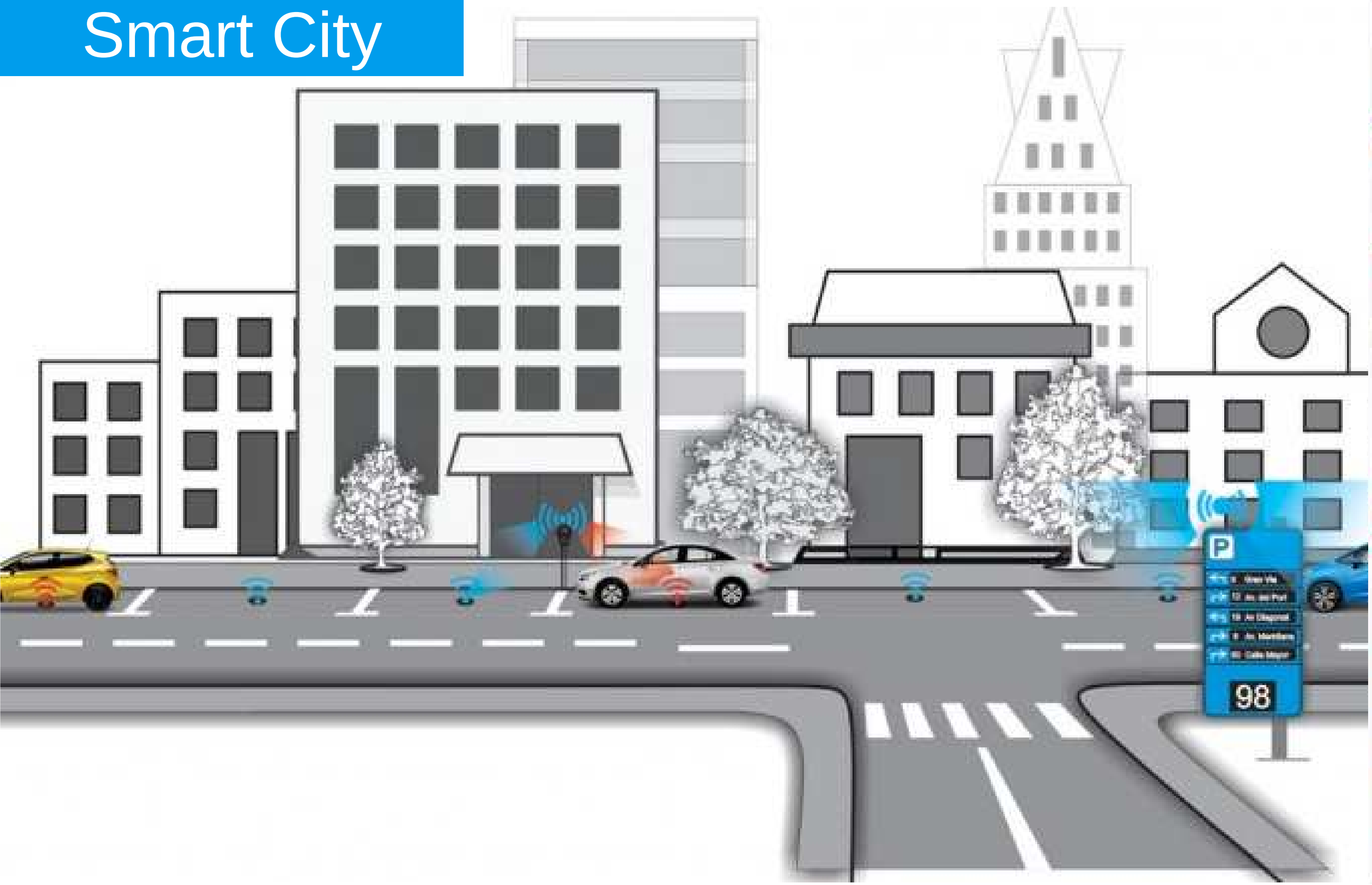
Smart Herd


MooMonitor +
Health & Fertility Monitoring


08:00
wID: 1847
CowID: 1950
CowID: 21
DAILY ACTIVITY & RUMINATION
RUMINATION
RESTING
Add Heat
Add Insem
Calved

Smart City

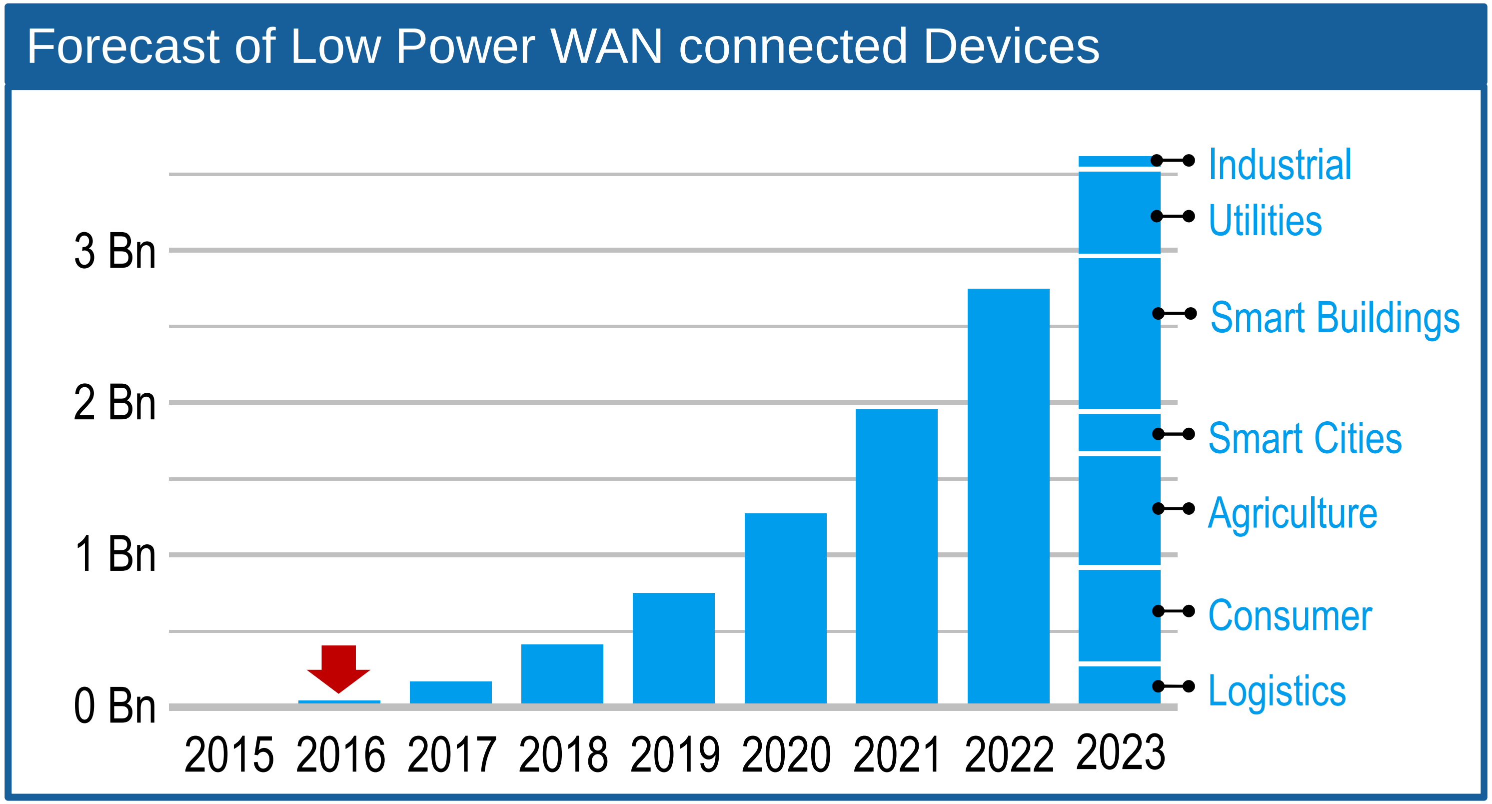
Smart City



P
98

GARAGE
PRICE
PARKING GARAGE
ON STREET PARKING
No Vacant Parking Space Available
YOUR LOCATION

Low-power wide-area networks (LP-WAN) will enable applications which sense literally Everything Everywhere Anytime



The *SIX L's* characterizing LP-WANs, or

10 € devices capable of 10 km range with 10-year battery lifetime

Low Power
Battery powered devices requiring 10+ years lifetime

Low Cost
Communication modules for 5 Euro and even less

Long Range
Covering large areas with low number of base stations

Large Scale
Several thousands of devices per gateway or base station

Low Throughput
From 100 bps to some few kbps; short message once per hour, day or week, ….

Low Responsiveness
Relaxed requirements regarding responsiveness of a device

Outline

- The Internet of dogs, lights and doors
- Sigfox, LoRa and more
- LTE-A Pro: eMTC, NB-IoT
- What’s next on the way to 5G

LAN and PAN technology becoming more important

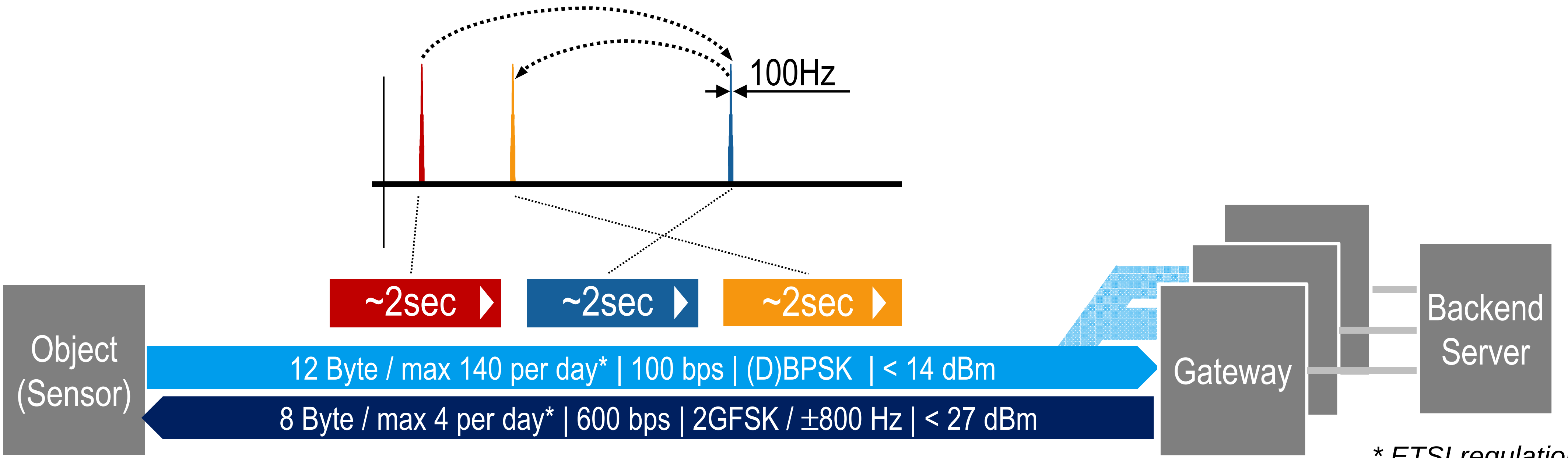
Bluetooth and especially BLE become important in the **Smart Home** market with features like Mesh

Wi-Fi 802.11n/ac/ax stay relevant.
Future of "Wi-Fi HaLow" and "White Wi-Fi" still unclear

ZigBee ecosystem becomes stronger due to cooperation with enocean and Thread

Example: Sigfox designed as LP-WAN sensor network

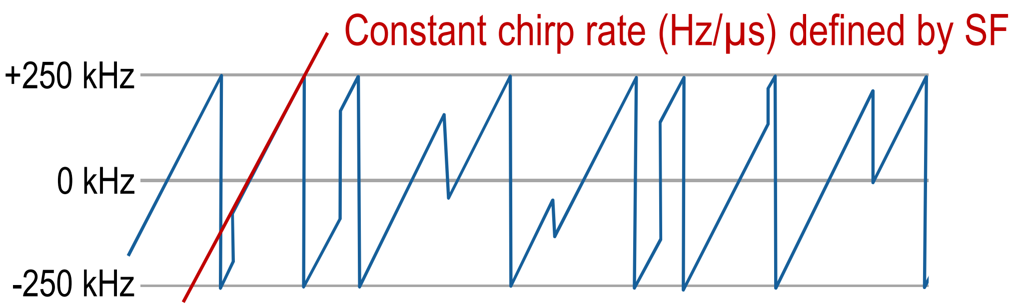
Ultra Narrow Band Modulation (100 Hz / 600 Hz)	Redundant uplink Transmission (2x repetitions)	Pseudo–random frequency hopping (3 out of 320 ch.)	Short messages UL: 12 Byte DL: 8 Byte	No passive RX mode (RX window after TX)

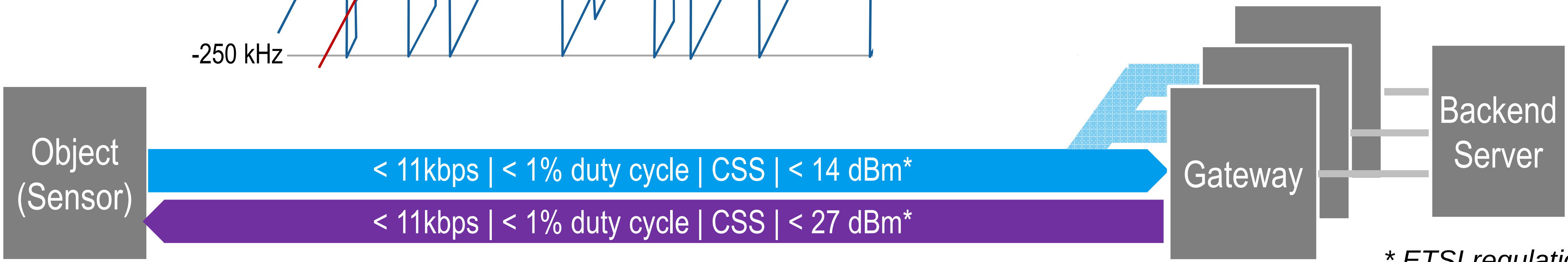


* *ETSI regulation*

Another prominent example: LoRaWAN™

- Chirped Spread Spectrum (125/250/500 kHz)
- Multiple Gateways simultaneously receiving
- Pseudo–random frequency hopping (after each TX)
- Data Rate Adaption (spreading factor/ bandwidth)
- Different RX mode options (Class A/B/C)



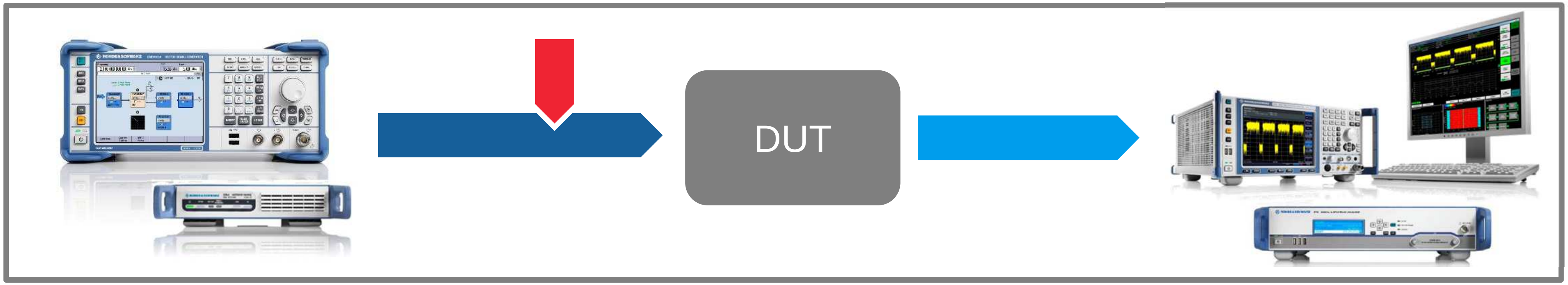


* *ETSI regulation*

LP-WAN technologies in ISM/SRD bands shaking the market

	sigfox	LoRaWAN	INGENU	WEIGHTLESS-N	WEIGHTLESS-W	WEIGHTLESS-P
Technique	Ultra Narrow Band (UNB)	Chirp Spread Spectrum	DSSS RPMA	Ultra Narrow Band (UNB)	DSSS	Narrow Band (NB)
Modulation	UL: DBPSK DL: GFSK	Frequency Chirps	UL:DBPSK DL:DBPSK	UL:DBPSK DL: -	16-QAM…. DBPSK	GMSK, QPSK
Channel BW (UpLink)	ETSI: 100 Hz FCC: 600 Hz	125 kHz 250 kHz 500 kHz	1 MHz	200 Hz	6/7/8 MHz	12.5 kHz
Band	ISM/SRD < 1 GHz	ISM/SRD < 1 GHz	ISM/SRD 2.4 GHz	ISM/SRD < 1 GHz	TV white space 470-790 MHz	ISM/SRD < 1 GHz
Driver	sigfox	SEMTECH	INGENU	nwave	neul	M2COMM

Typical RF parametric measurements to ensure desired performance as well as pre-conformance



Typical RX Measurement
- Receiver sensitivity
- Receiver blocking
- Adjacent channel selectivity
- Spurious response rejection
- …..

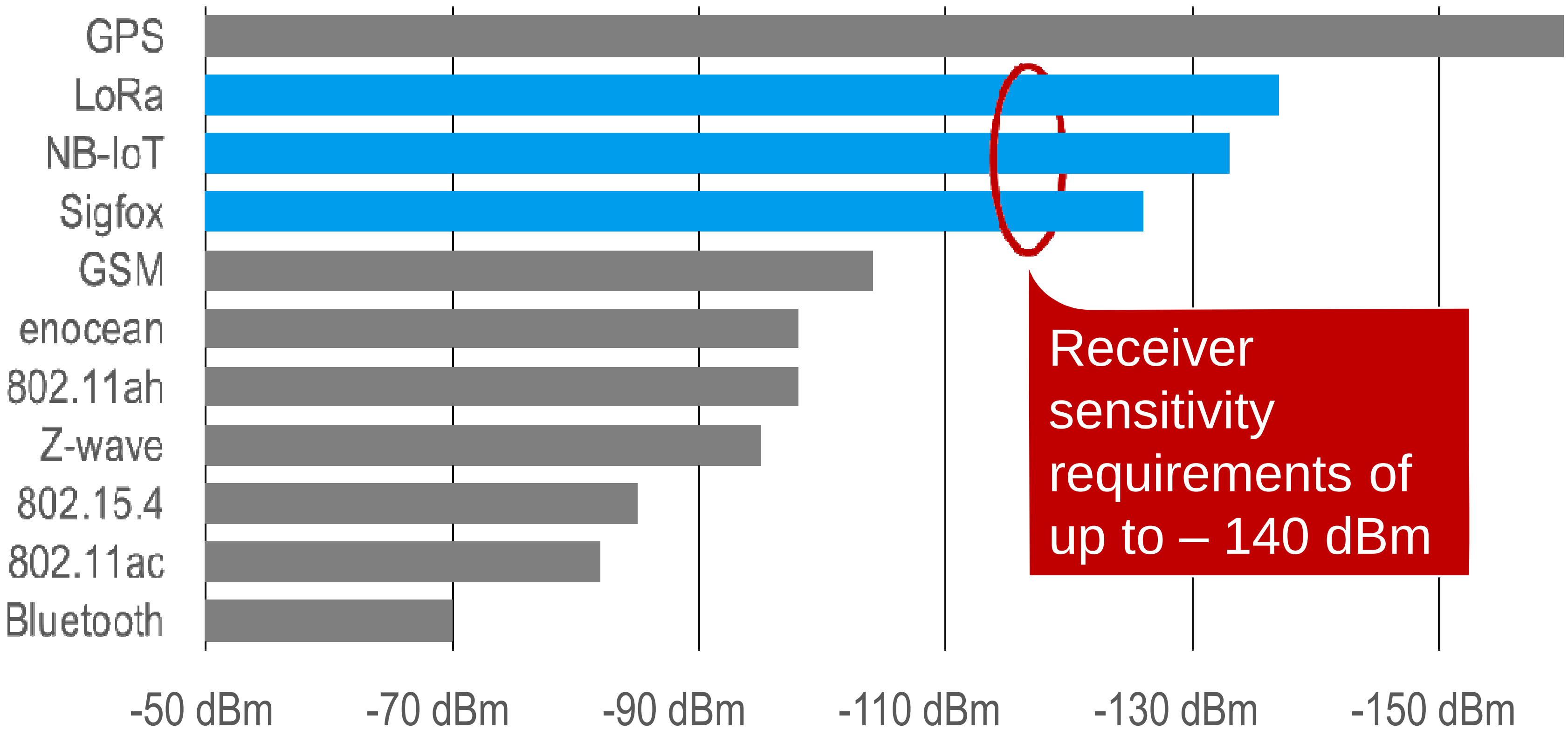
RF Performance

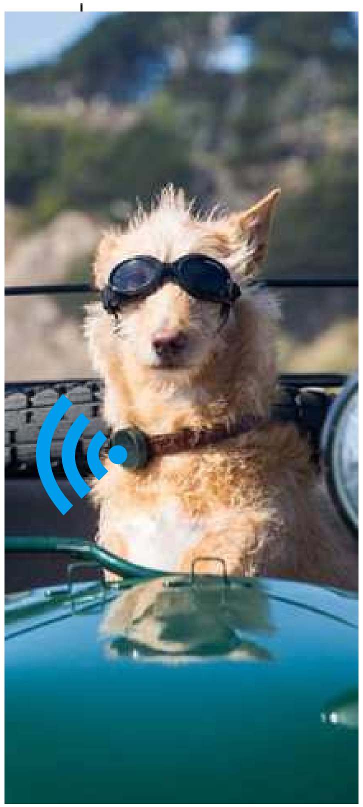
Standard Conformance

Regulatory Conformance

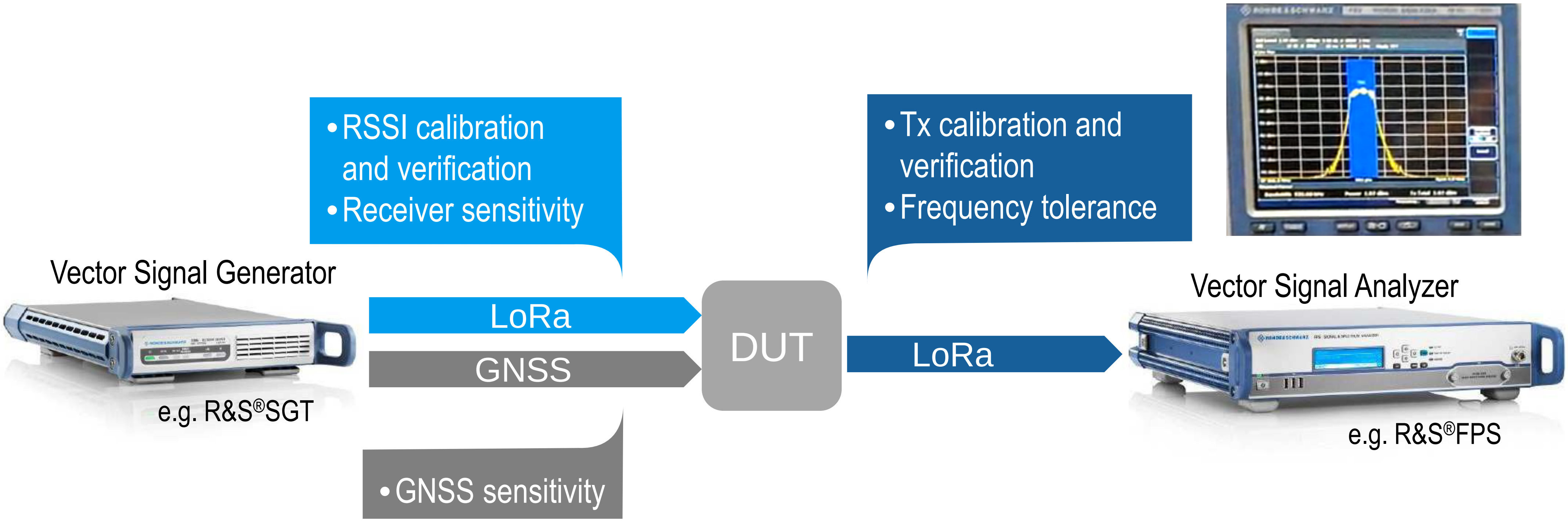
Typical TX Measurements
- Spectrum emission mask
- Power
- Frequency Error
- Error Vector Magnitude
- …..

Receiver sensitivity and Tx power are very critical





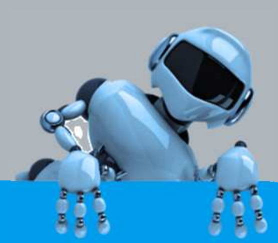
Example: Calibration and Verification of LoRaWAN Gateway



Outline

The Internet of dogs, lights and doors

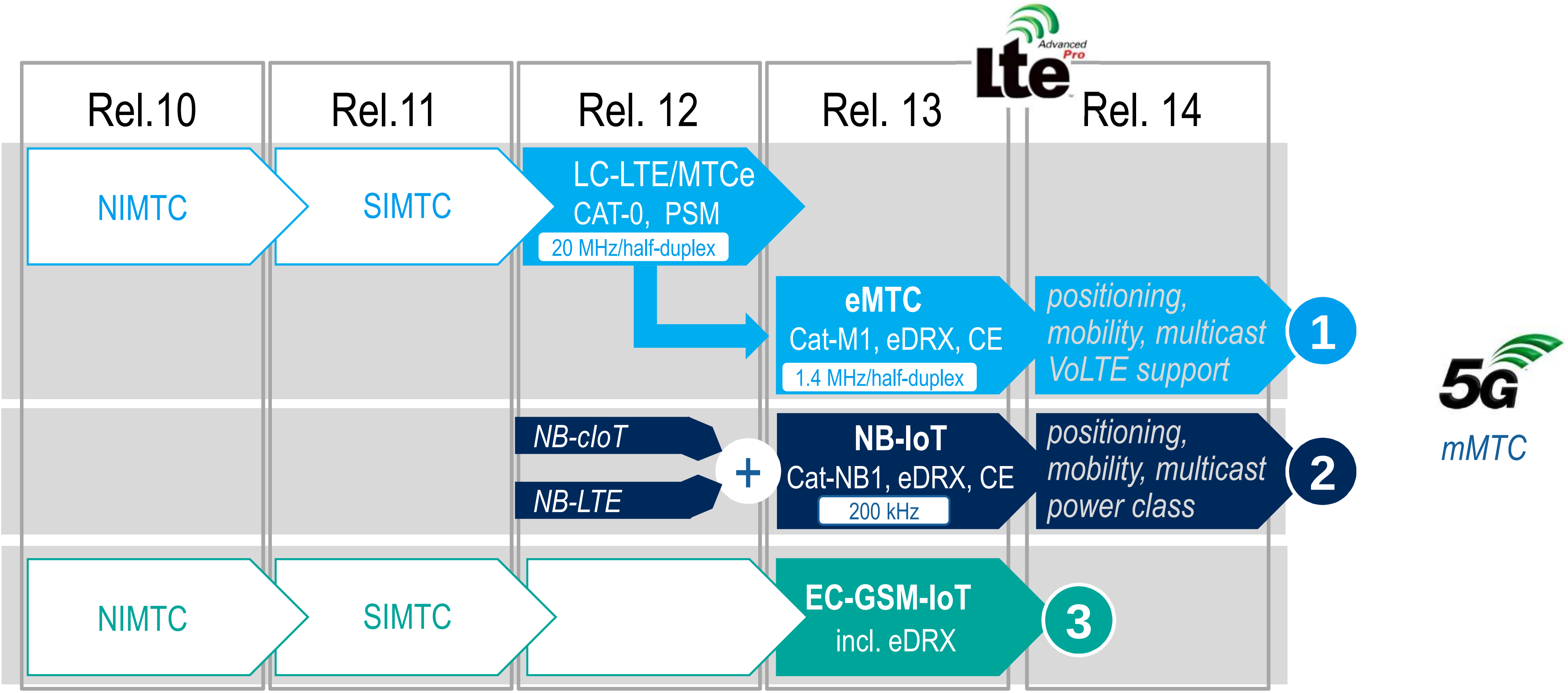
Sigfox, LoRa and more



LTE-A Pro: eMTC, NB-IoT

What's next on the way to 5G

Three LP-WAN technologies specified by 3GPP



Status of NB-IoT – GSA report June 2016: GSA is forecasting 75 Bn connected things by 2025

7 Commercial **Cat-1** Networks by June 2016

2 Cat-M1 Networks are being trialed with one planned

January 23, 2017: Vodafone has confirmed its first commercially available NB-IoT network is now operational in Spain

9 Operators trailing pre Cat-NB1 standard networks

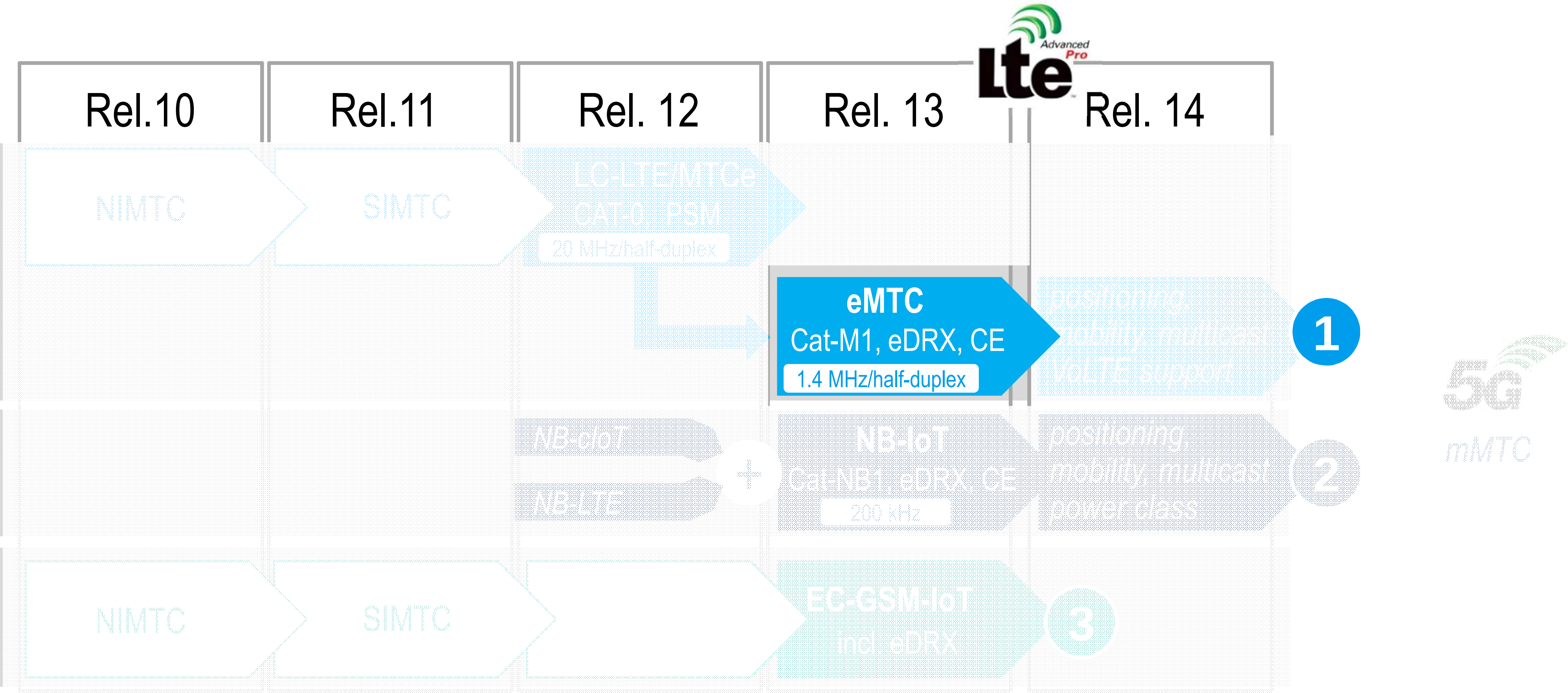
24 Operators are committed to deploying NB-IoT

20 Commercial NB-IoT Networks are forecasted by E2017

3GPP ecosystem is trying to address the LP-WAN market as well

	LTE Cat 1	LTE Cat 0	LTE Cat M1	NB-IoT (Cat NB1)	EC-GSM-IoT
Deployment	In-band LTE	In-band LTE	In-band LTE	In-band LTE Guard-band LTE Standalone	In-band GSM
Downlink	OFDMA [15 kHz]	OFDMA [15 kHz]	OFDMA [15 kHz]	OFDMA[15 kHz]	TDMA/FDMA
Uplink	SC-FDMA [15 kHz]	SC-FDMA [15 kHz]	SC-FDMA [15 kHz]	Single tone [15/3.75 kHz] SC-FDMA [15 kHz]	TDMA/FDMA
Peak rate	DL: 10 Mbps UL: 5 Mbps	DL: 1 Mbps UL: 1 Mbps	DL: 1 Mbps UL: 1 Mbps	DL: 250 kbps UL: 20 kbps (ST)	DL: 70/240 kbps UL: 70/240 kbps
UE receiver BW	20 MHz	20 MHz	1.4 MHz	200 kHz	200 kHz
Duplex mode	Full-duplex FDD/TDD	Full/Half-duplex FDD/TDD	Full/Half-duplex FDD/TDD	Half-duplex FDD	Half-duplex
UE transmit power	23 dBm	23 dBm	23 or 20 dBm	23 or 20 dBm	33 or 23 dBm
Power saving	PSM, eDRX	PSM, eDRX	PSM, eDRX	PSM, eDRX	PSM, eDRX

eMTC / CAT-M1


Rel.10
Rel.11
Rel. 12
Rel. 13
Rel. 14
NIMTC
SIMTC
LC-LTE/MTCe
CAT-0, PSM
20 MHz/half-duplex
eMTC
Cat-M1, eDRX, CE
1.4 MHz/half-duplex
positioning,
mobility, multicast
VoLTE support
1
NB-cIoT
NB-LTE
+
NB-IoT
Cat-NB1, eDRX, CE
200 kHz
positioning,
mobility, multicast
power class
2
5G
mMTC
NIMTC
SIMTC
EC-GSM-IoT
incl. eDRX
3

eMTC Operating Bands

Band Number	F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}	Duplex Mode
1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
5	824 MHz	–	849 MHz	869 MHz	–	894MHz	FDD
7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
11	1427.9 MHz	–	1447.9 MHz	1475.9 MHz	–	1495.9 MHz	FDD
12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	FDD
13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	FDD
18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	FDD
19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	FDD
26	814 MHz	–	849 MHz	859 MHz	–	894 MHz	FDD
27	807 MHz	–	824 MHz	852 MHz	–	869 MHz	FDD
28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	FDD
31	1710 MHz	–	1780 MHz	2110 MHz	–	2200 MHz	FDD[4]
39	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
41	2496 MHz	-	2690 MHz	2496 MHz	-	2690 MHz	TDD

[4] The range 2180-2200 MHz of the DL operating band is restricted to E-UTRA operation when carrier aggregation is configured.

Further LTE Physical Layer Enhancements for MTC (eMTC)

Quick facts

- RAN1 Work item (follow-up to Rel-12 MTC)
- Started September 2014
- Completed March 2016
- **Main** topics of the Work Item

Low complexity
- 1.4 MHz bandwidth
- Reduced max. Tx power
- Reduced number of transmission modes

LTE **coverage improvement** (15dB for FDD) by
- Repetition of PHY channels
- Skipping of channels

“not extending coverage for given data rate, but coverage is extended by reducing the data rate”

⇨ **Low-cost UEs (LC)**
⇨ **BL: Bandwidth reduced low complexity**
⇨ **“BL UEs”**

⇨ **UEs operating in coverage enhancement**
⇨ **“UEs in CE”**

BL UEs also support CE

CE can also be used by “regular” R13 UEs

eMTC Properties - Overview

UE Cat. M1	Coverage Enhancement -Repetition-
1.4 MHz bandwidth (tunable)	PBCH / MIB
No legacy PCFICH, PDCCH, PHICH	MPDCCH
SIB1-BR	Cross-subframe scheduled PDSCH
New power class (20 dBm) and CE operation optional	PUCCH
CEMode A (and CEModeB)	PUSCH
Only TM1/2/6 for CRS + TM9 for DM-RS based demodulation	PRACH multiple attempts and repetition levels

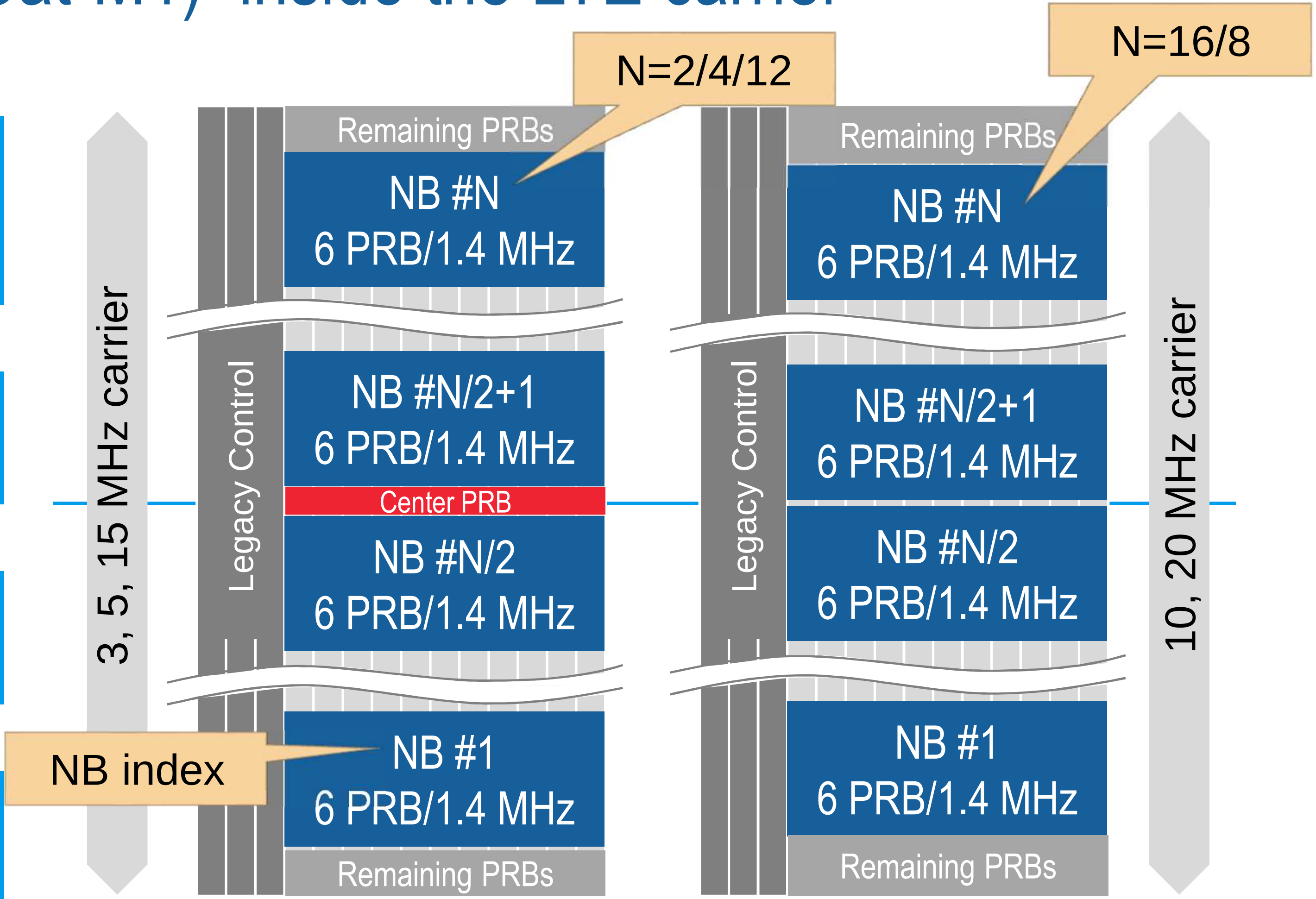
Narrowbands (eMTC; Cat-M1) inside the LTE carrier

Frequency retuning (e.g. after cell search) to multiple narrowbands to support scalable resource allocation

Frequency hopping between narrow-bands for coverage enhancement

Guard Period for retuning:
2 OFDM Symbols (created by UE)

TDD: same set of narrowbands for UL and DL



CE Modes A and B → PDSCH / PUSCH repetition

SIB2
→ cell specific

DCI
→ UE specific

pd(u)sch-maxNumRepetitionCEmodeA	{n1,n2,n3,n4}
Not configured	{1,2,4,8}
16	{1,4,8,16}
32	{1,4,16,32}

pd(u)sch-maxNumRepetitionCEmodeB	{n1,n2,n3,n4,n5,n6,n7,n8}
Not configured	{4,8,16,32,64,128,256,512}
192	{1,4,8,16,32,64,128,192}
256	{4,8,16,32,64,128,192,256}
384	{4,16,32,64,128,192,256,384}
512	{4,16,64,128,192,256,384,512}
768	{8,32,128,192,256,384,512,768}
1024	{4,8,16,64,128,256,512,1024}
1536	{4,16,64,256,512,768,1024,1536}
2048	{4,16,64,128,256,512,1024,2048}

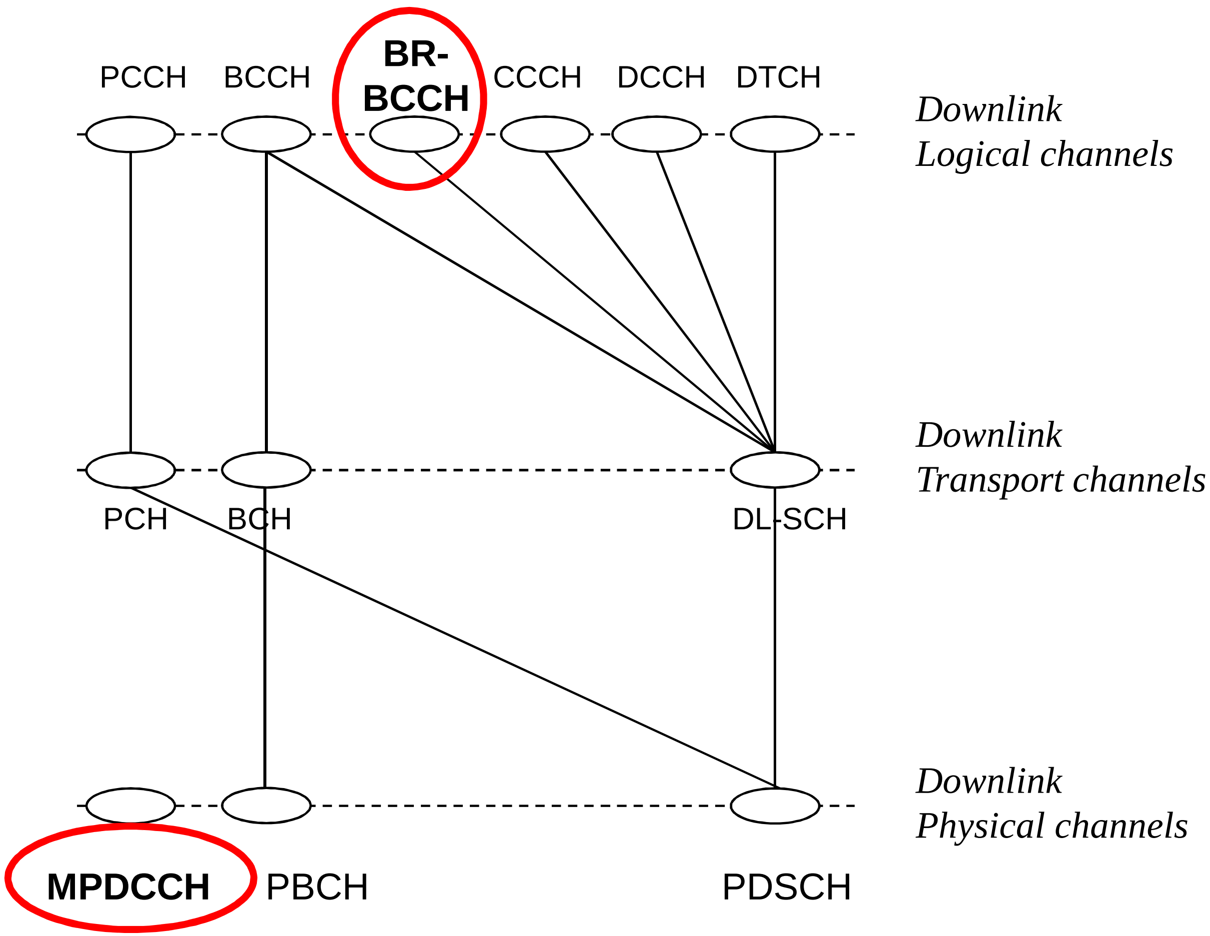
CE Modes A and B → PUCCH repetition

	CEModeA	CEModeB
RRC Signalling	{1,2,4,8}	{4, 8,16,32}

CE Modes A and B

	CEModeA	CEModeB
connected	mandatory max 8 HARQ processes (FDD) max 7 HARQ processes (TDD, depends on UL/DL configuration) FDD: PUCCH formats 1, 1a, 2, 2a TDD: PUCCH formats 1, 1a, 1b, 2, 2a	optional if B is supported, UE implicitly supports also A max 2 HARQ processes (UL, DL, TDD, FDD) max. TBS=936 No SRS No TPC No SPS No TM6 No periodic/aperiodic reporting PUCCH formats 1, 1a
idle	≙ PRACH coverage enhancement level 0 / 1	≙ PRACH coverage enhancement level 2 / 3
	“compensates for: -3dB lower UE power, only single receive antenna”	“provides full coverage extension : 15dB higher MCL”

eMTC: Downlink Channels



eMTC: Downlink

Physical Channel	Monitored RNTI	Associated Transport Channel	Modulation Scheme
PBCH	N/A	BCH	QPSK
MPDCCH	SI-RNTI	DL-SCH	QPSK
	P-RNTI	PCH	QPSK
	RA-RNTI	DL-SCH	QPSK
	Temporary C-RNTI		
	C-RNTI	DL-SCH	QPSK
PDSCH	N/A	DL-SCH	QPSK/16QAM

Signals
PSS
SSS
CRS
DMRS

no change, use legacy

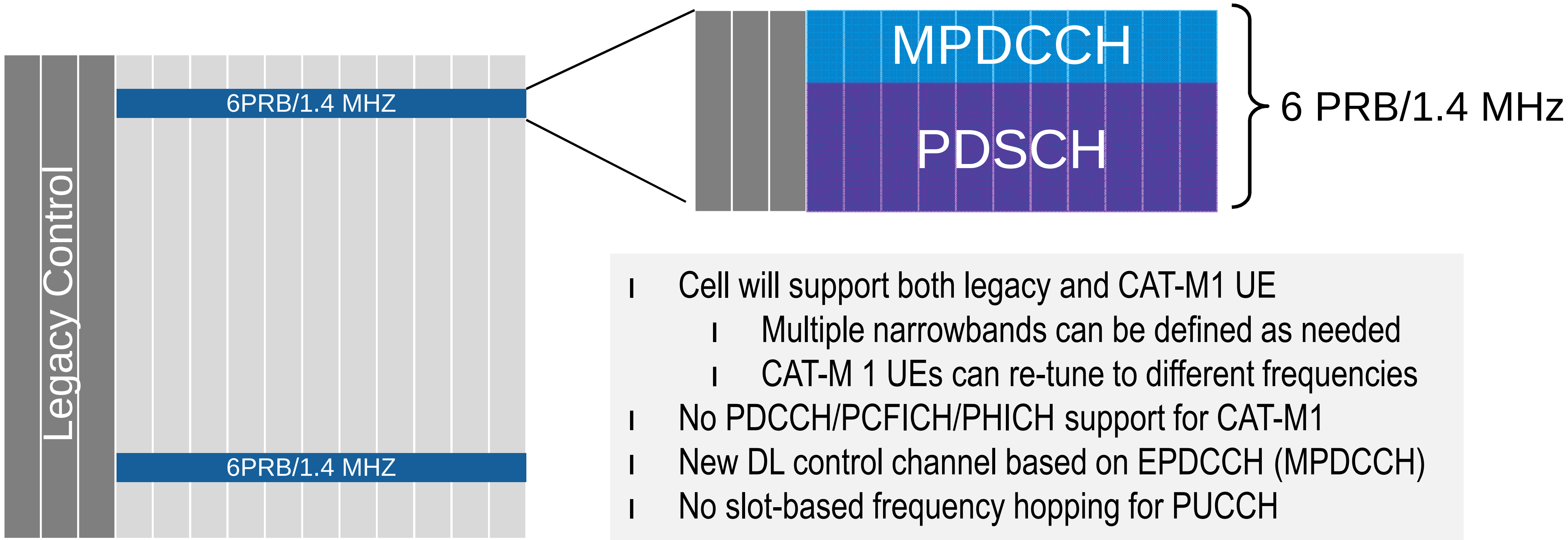
may have to be received more often under bad radio conditions, increases cell search time, decreases HO performance

System Information - MIB

Scheduling of SIBs
without
Control Channel

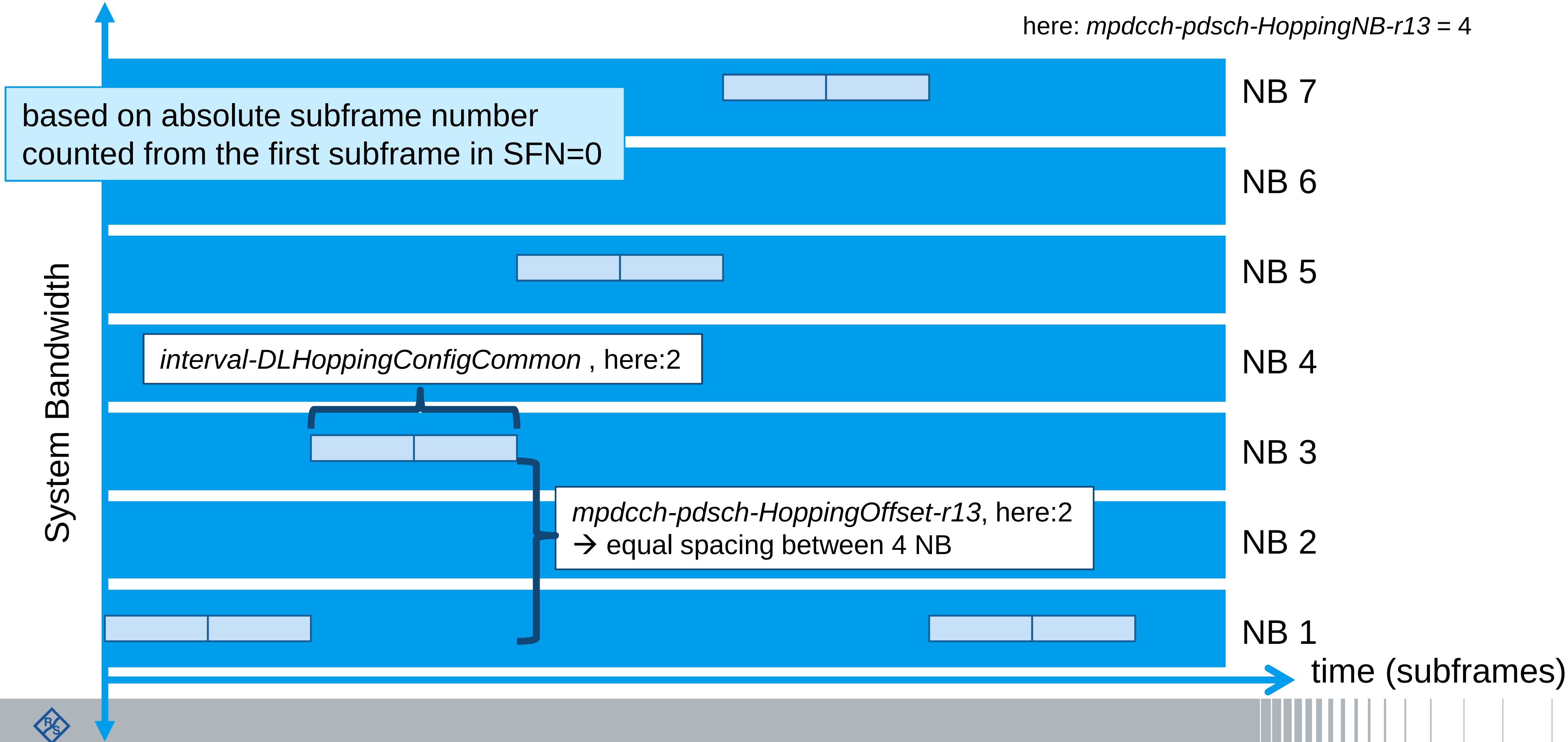
```
-- ASN1START

MasterInformationBlock ::= SEQUENCE {
  dl-Bandwidth                   ENUMERATED {
                                 n6, n15, n25, n50, n75, n100},
  phich-Config                   PHICH-Config,
  systemFrameNumber              BIT STRING (SIZE (8)),
  schedulingInfoSIB1-BR-r13      INTEGER (0..31),
  spare                          BIT STRING (SIZE (5))
}

-- ASN1STOP
```

LTE CAT-M1 – 1.4 MHz DL channel support

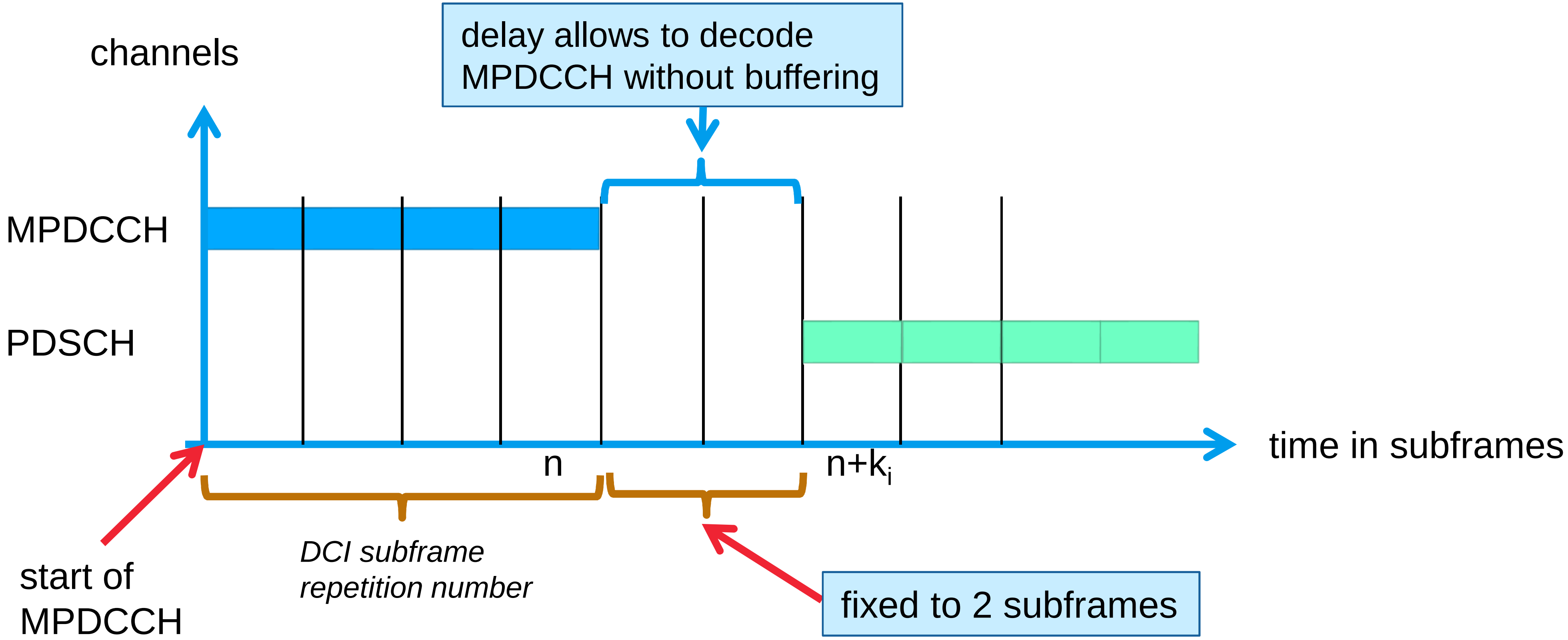


- Cell will support both legacy and CAT-M1 UE
  - Multiple narrowbands can be defined as needed
  - CAT-M 1 UEs can re-tune to different frequencies
- No PDCCH/PCFICH/PHICH support for CAT-M1
- New DL control channel based on EPDCCH (MPDCCH)
- No slot-based frequency hopping for PUCCH

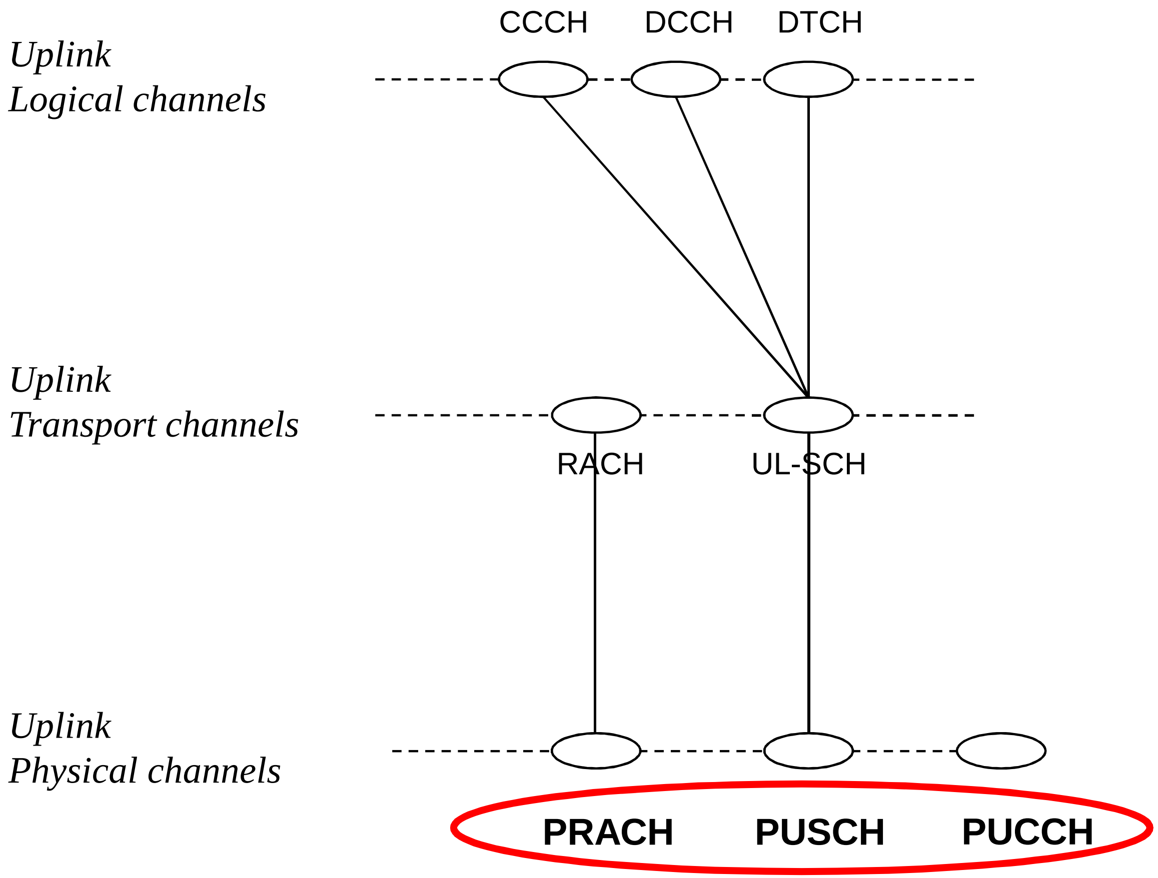
MPDCCH - Frequency Hopping



PDSCH Cross Subframe scheduling



eMTC: Uplink Channels



eMTC: Uplink

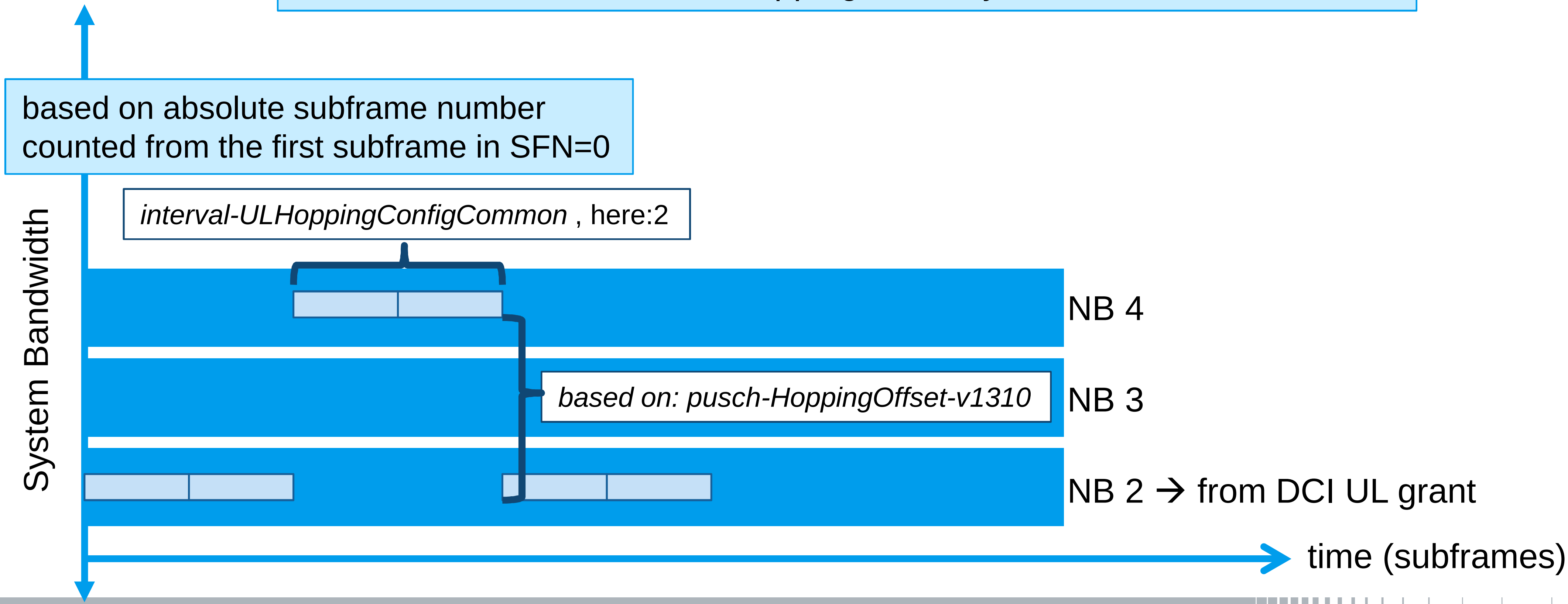
Physical Channel	Transport Channel	Modulation Scheme
PUSCH	UL-SCH	QPSK / 16-QAM → CEModeA
		QPSK → CEModeB
PUCCH	UCI	depends on format
PRACH	RACH	N/A

Signal
DMRS
SRS

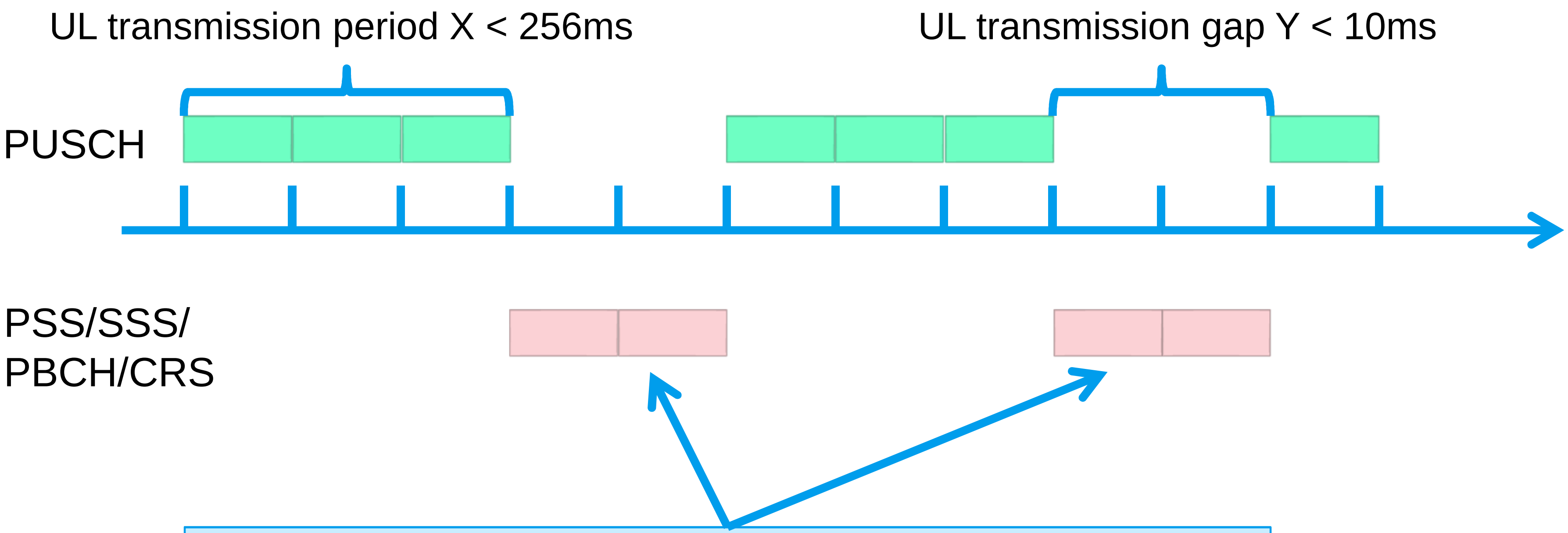
no changes

PUSCH - Frequency Hopping

similar to MPDCCH/PDSCH-hopping, but only between 2 narrowbands



eMTC: Uplink Transmission Gaps



UE tunes to DL during UL transmission gaps in order to keep frequency synchronised (for long UL transmissions)

NB-IoT / CAT-NB1

NB-IoT

Objectives

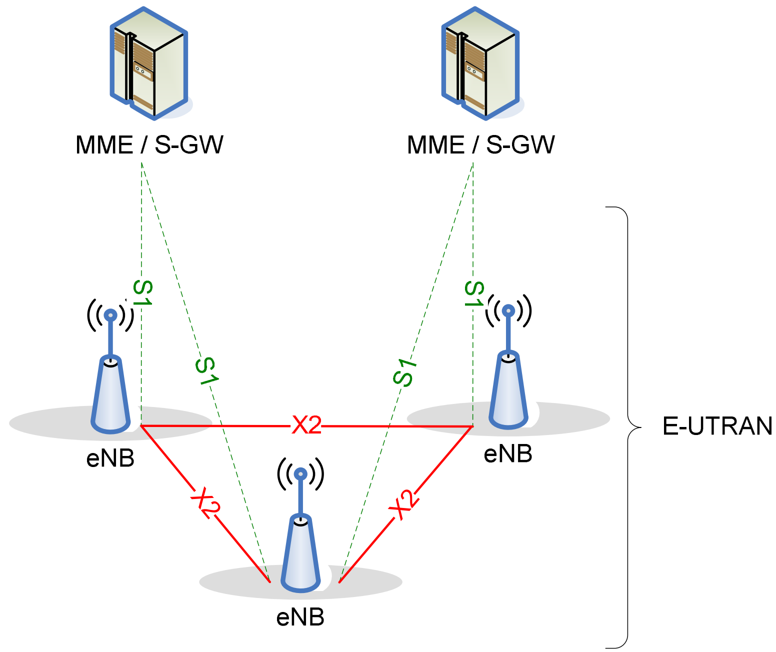
- Improved indoor coverage: extended coverage of 20 dB
- Support of massive number of low throughput devices
  (e.g. 40 MTC devices per household) → 52547 devices per cell (“standard”) sector
- Reduced complexity
- Things that cost less than a 2G device
- Improved power efficiency: more than 10 years battery life time (@200bytes per day)
- Relaxed delay characteristics: ~10 sec.

NB-IoT Architecture

Requirements:
Following architecture requirements shall be supported:

- minimize system signalling load especially over Radio interface
- appropriate security to EPS system
- improve battery life
- support delivery of IP data
- support delivery of non-IP data
- support of SMS

General Architecture not changed

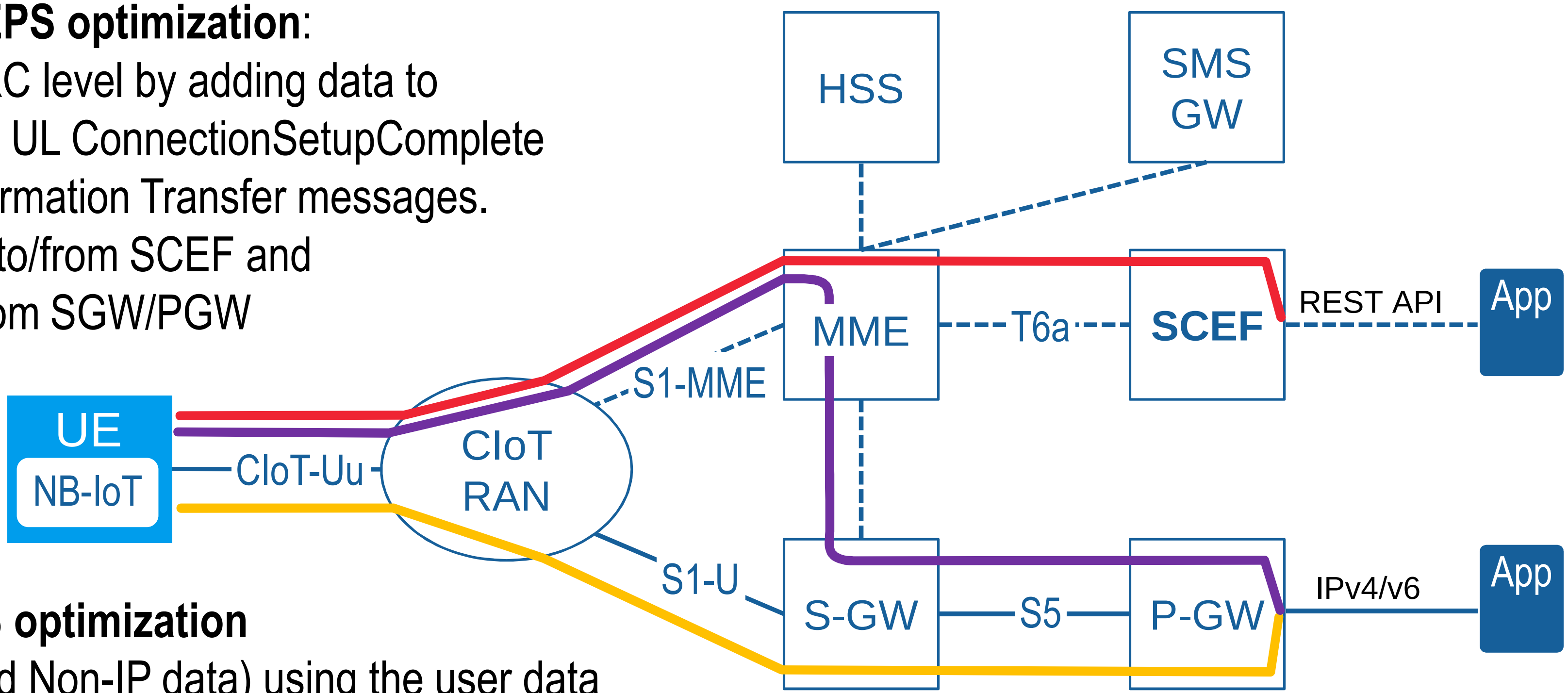


X2: no handover,
but resume to other eNB

NB-IoT Architecture: Optimized to support transfer of small data ⇨ Minimize signaling load over the radio interface

Control Plane CIoT EPS optimization:
Data Exchange on RRC level by adding data to ConnectionSetup or in UL ConnectionSetupComplete message or using Information Transfer messages.

- non-IP messages to/from SCEF and
- IP messages to/from SGW/PGW



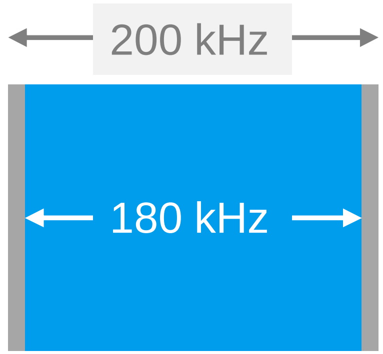
User Plane CIoT EPS optimization
Data Exchange (IP and Non-IP data) using the user data plane via radio bearers

NB-IoT Operating Bands

Band Number	F_{UL_low} – F_{UL_high}			F_{DL_low} – F_{DL_high}			Duplex Mode
1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
5	824 MHz	–	849 MHz	869 MHz	–	894MHz	FDD
8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	FDD
13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	FDD
17	704 MHz	–	716 MHz	734 MHz	–	746 MHz	FDD
18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	FDD
19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
26	814 MHz	–	849 MHz	859 MHz	–	894 MHz	FDD
28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	FDD
66	1710 MHz	–	1780 MHz	2110 MHz	–	2200 MHz	FDD[4]

[4] The range 2180-2200 MHz of the DL operating band is restricted to E-UTRA operation when carrier aggregation is configured.

NB-IoT: Physical Operations



UE RF **Bandwidth will be 180 kHz** for both downlink and uplink. (1 PRB)

Downlink

OFDMA with 15kHz subcarrier spacing

Uplink

multi-tone transmissions
- SC-FDMA based
- 15 kHz subcarrier spacing

→ **optional**

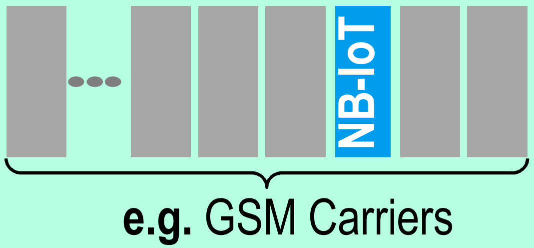
single tone transmissions
- 3.75 kHz or 15 kHz subcarrier spacing

→ **mandatory**

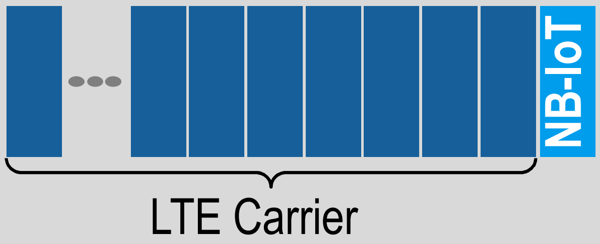
Only **FDD in half-duplex mode** TypeB, **no TDD** (in Rel. 13)

NB-IoT: Physical Operations

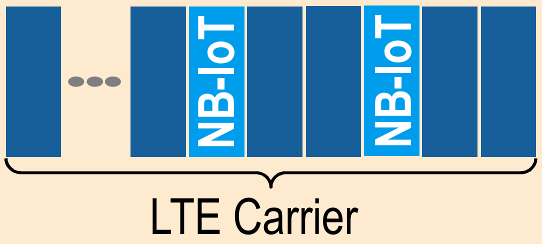
‘Stand-alone operation’
e.g. refarm existing GSM carriers



‘Guard operation’
in guard-band of LTE carrier
capacity of LTE Carrier unchanged

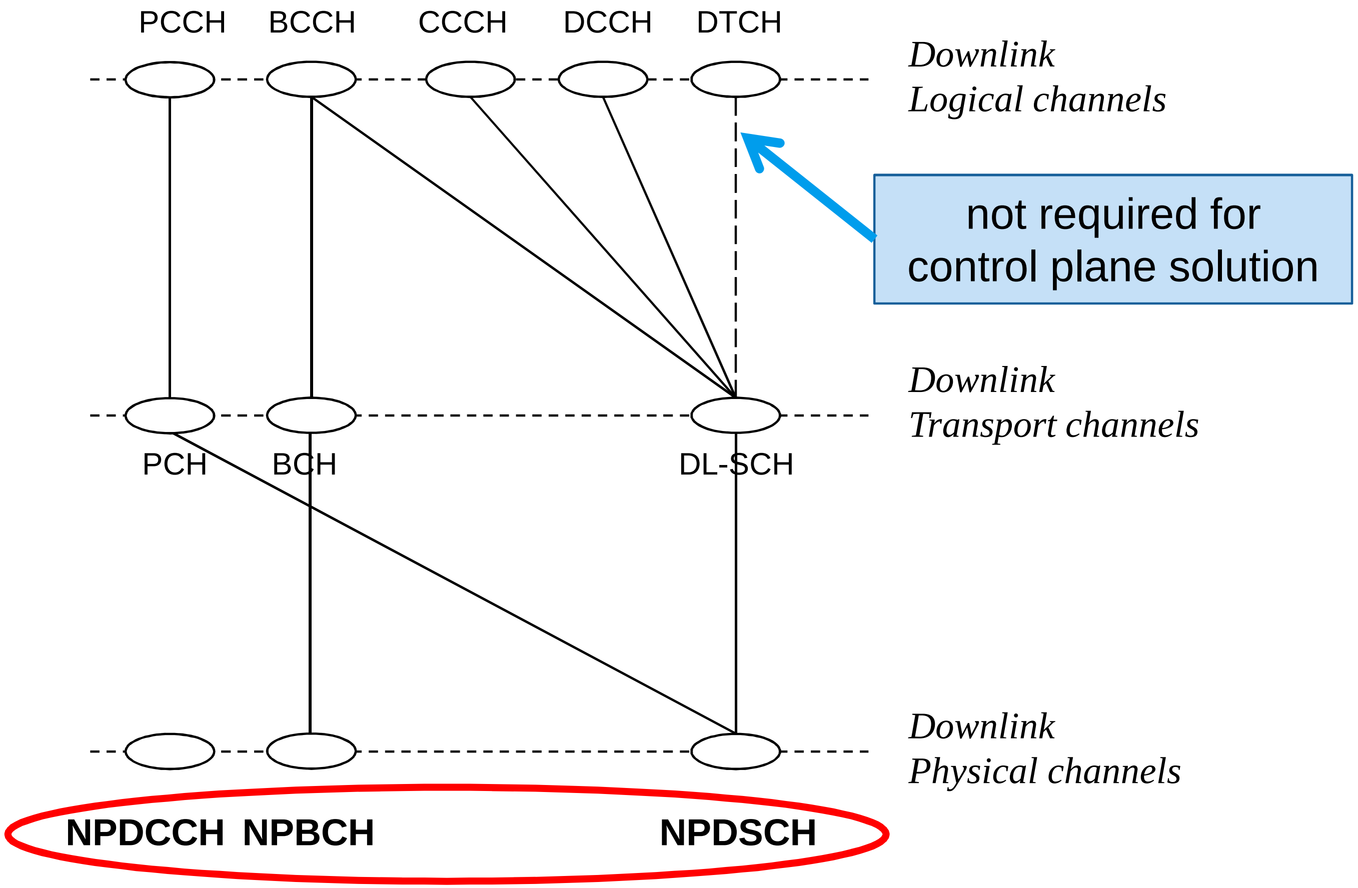


‘In-band operation’
use RB of a regular LTE carrier.
Flexible assignments of resources between LTE and NB-IoT.



CRS of the LTE cell may be used by the NB-IoT UE

NB-IoT: Downlink Channels



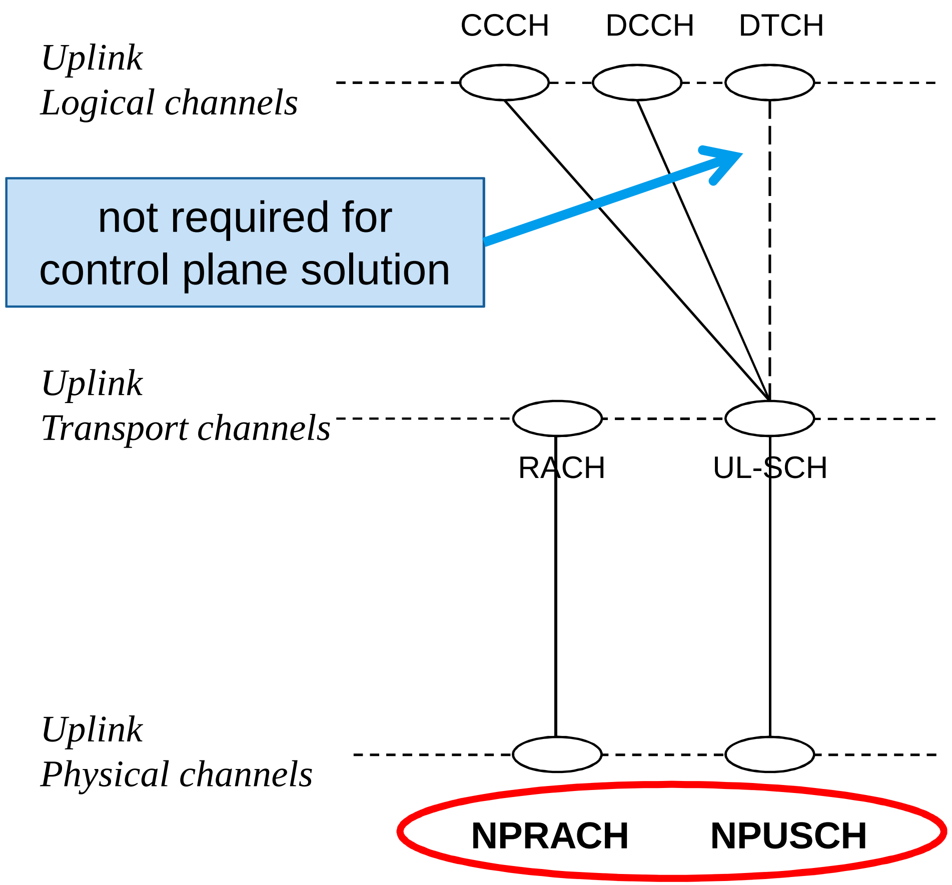
No support for:
LTE Sidelink
Multicast Channels
PFCICH
PHICH

NB-IoT: Downlink

Physical Channel	Monitored RNTI	Transport Channel	Modulation Scheme
NPBCH	N/A	BCH	QPSK
NPDCCH	SI-RNTI	DL-SCH	QPSK
	P-RNTI	PCH	QPSK
	RA-RNTI	DL-SCH	QPSK
	Temporary C-RNTI		
	C-RNTI	DL-SCH	QPSK
NPDSCH	N/A	DL-SCH	QPSK

Signals	
NPSS	only one sequence !
NSSS	504 sequences (NB-PCID)
NRS	1 or 2 ports

NB-IoT: Uplink Channels



No support for:
PUCCH

NB-IoT: Uplink

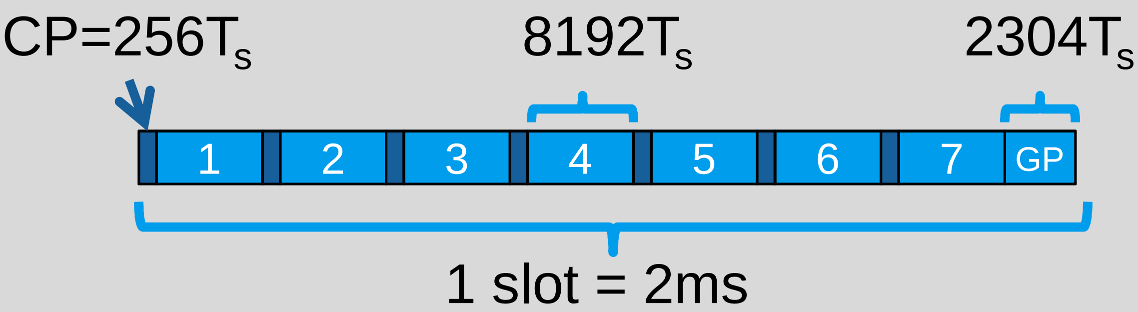
Physical Channel	Transport Channel	N_{sc}^{UL}	Modulation Scheme
NPUSCH Format 1	UL-SCH	1	π/2 BPSK, π/4 QPSK
		>1	QPSK
NPUSCH Format 2	UCI	1	BPSK
NPRACH	RACH	1	

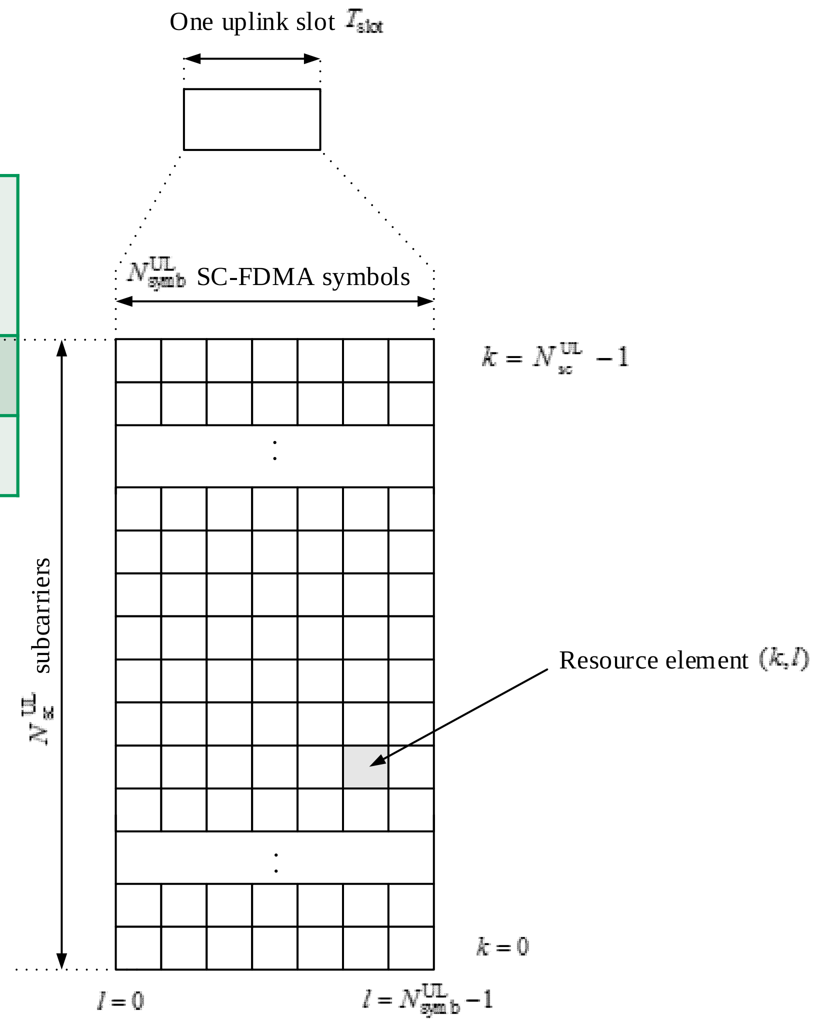
Signal	Constellation
DMRS	matching PUSCH modulation

NB-IoT: NPUSCH

Subcarrier spacing	Symbol duration	N	N_{sc}^{UL}	T_{slot}	T_{slot}	slots per radio frame
$\Delta f = 3.75\,\text{kHz}$	266,6µs	8192	48	61440 T_s	2,0ms	5
$\Delta f = 15\,\text{kHz}$	66,6µs	2048	12	15360 T_s	0,5ms	20

$\Delta f = 3.75\,\text{kHz}$ T_s~32ns





NB-IoT: NPUSCH

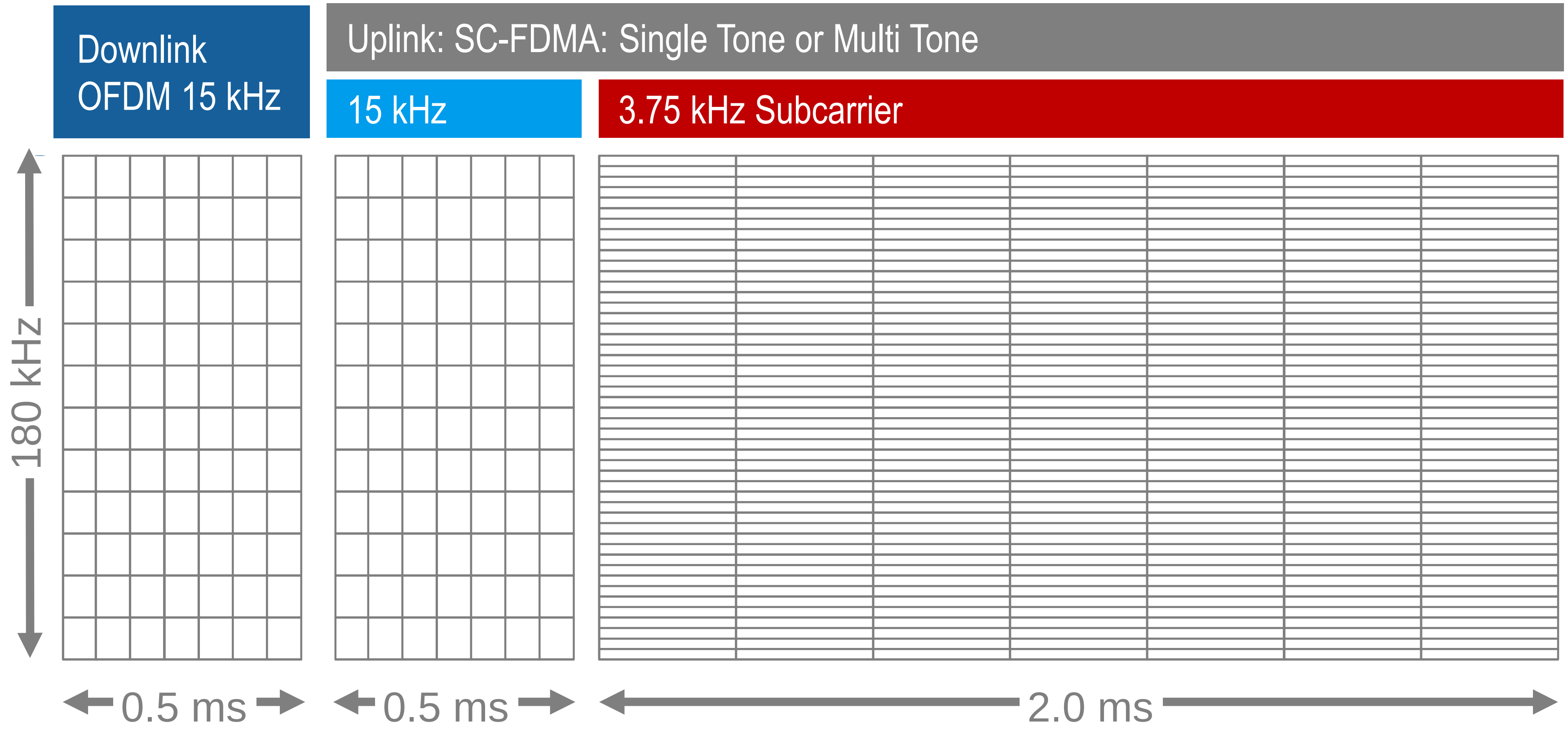
New definition: Resource Unit, RU

Resource units are used to describe the mapping of the NPUSCH to resource elements.
NPUSCH can be mapped to one or more than one resource unit.

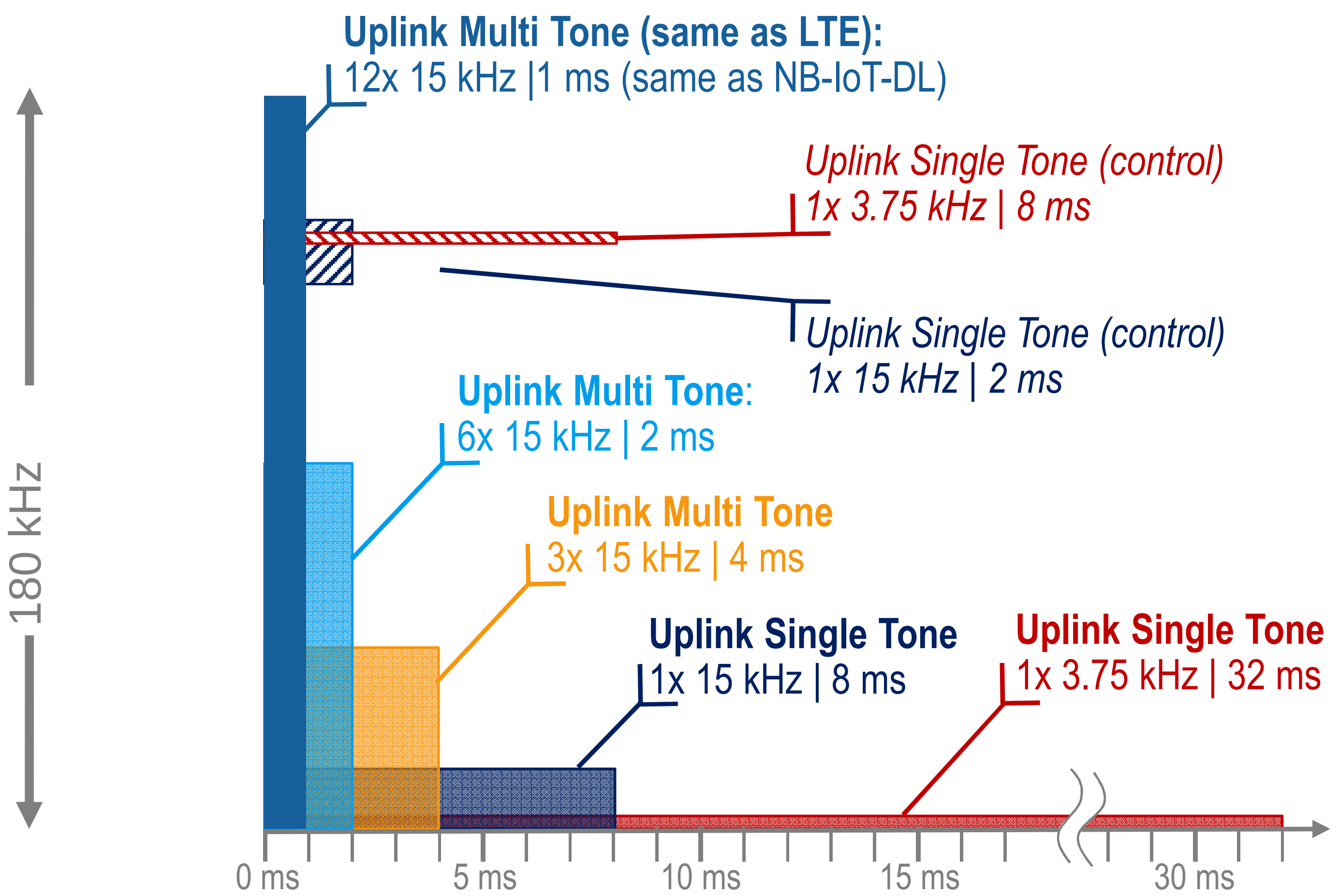
$$RU = N_{symb}^{UL} * N_{slots}^{UL} \text{ consecutive SC-FDMA Symbols} \times N_{sc}^{RU} \text{ consecutive subcarriers}$$

NPUSCH format	usage	Δf	N_{sc}^{RU}	N_{slots}^{UL}	N_{symb}^{UL}	T_{slot} [ms]	T_{RU} [ms]
1	UL-SCH	3.75 kHz	1	16	7	2	32
		15 kHz	1	16		0,5	8
			3	8		0,5	4
			6	4		0,5	2
			12	2		0,5	1
2	UCI	3.75 kHz	1	4		2	8
		15 kHz	1	4		0,5	2

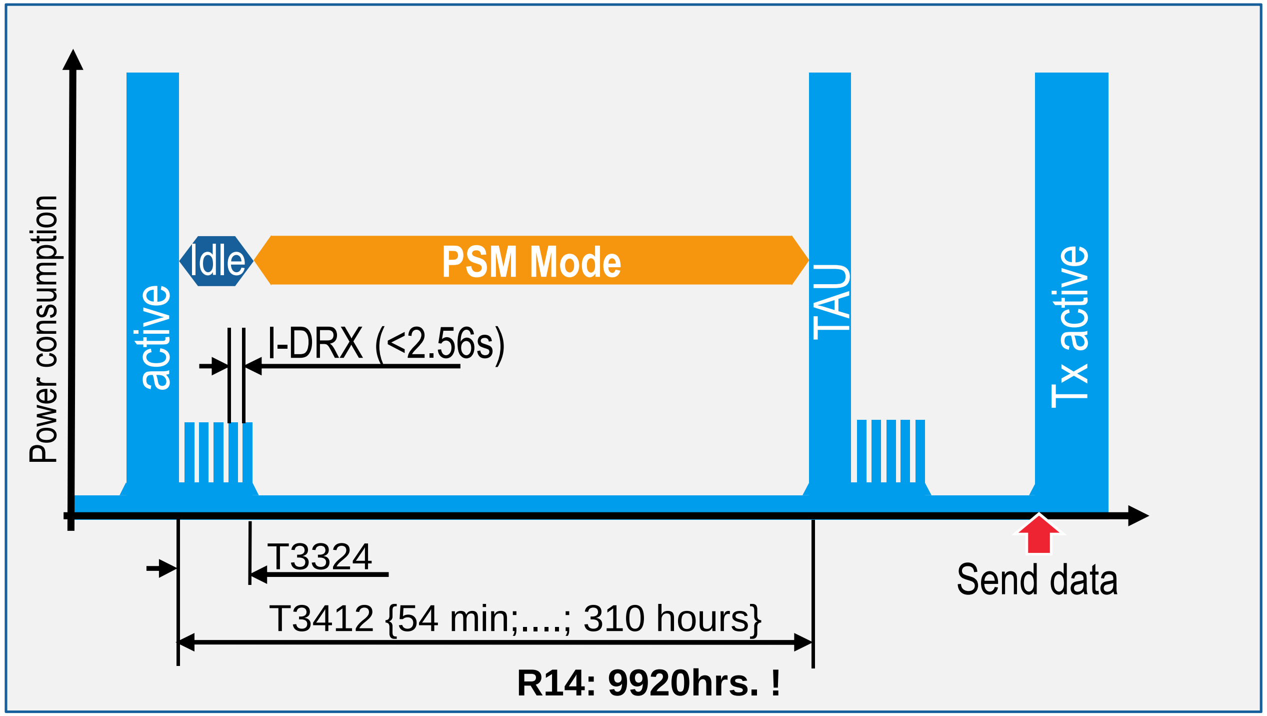
Frame and Slot Structure – NB-IoT – 7 symbols per slot

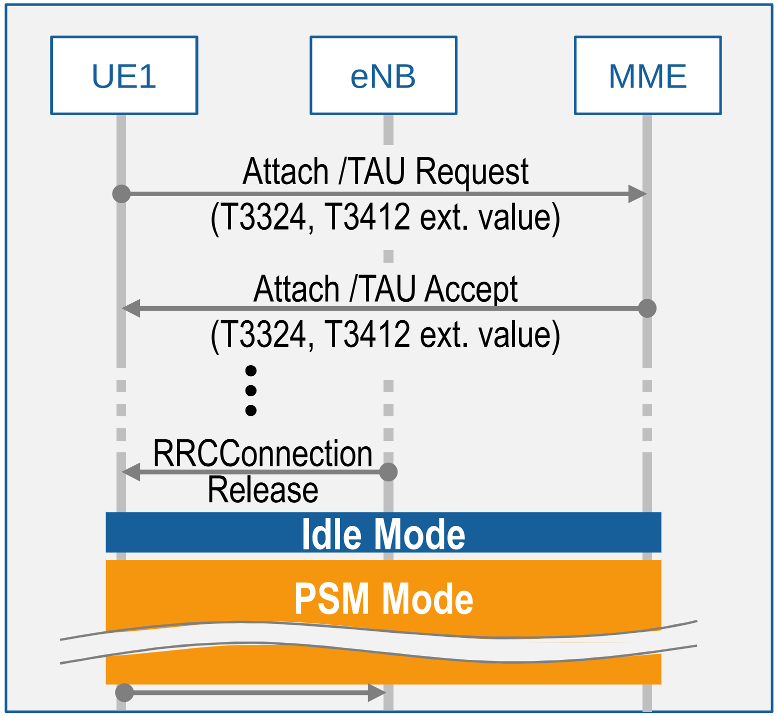


Frame and Slot Structure



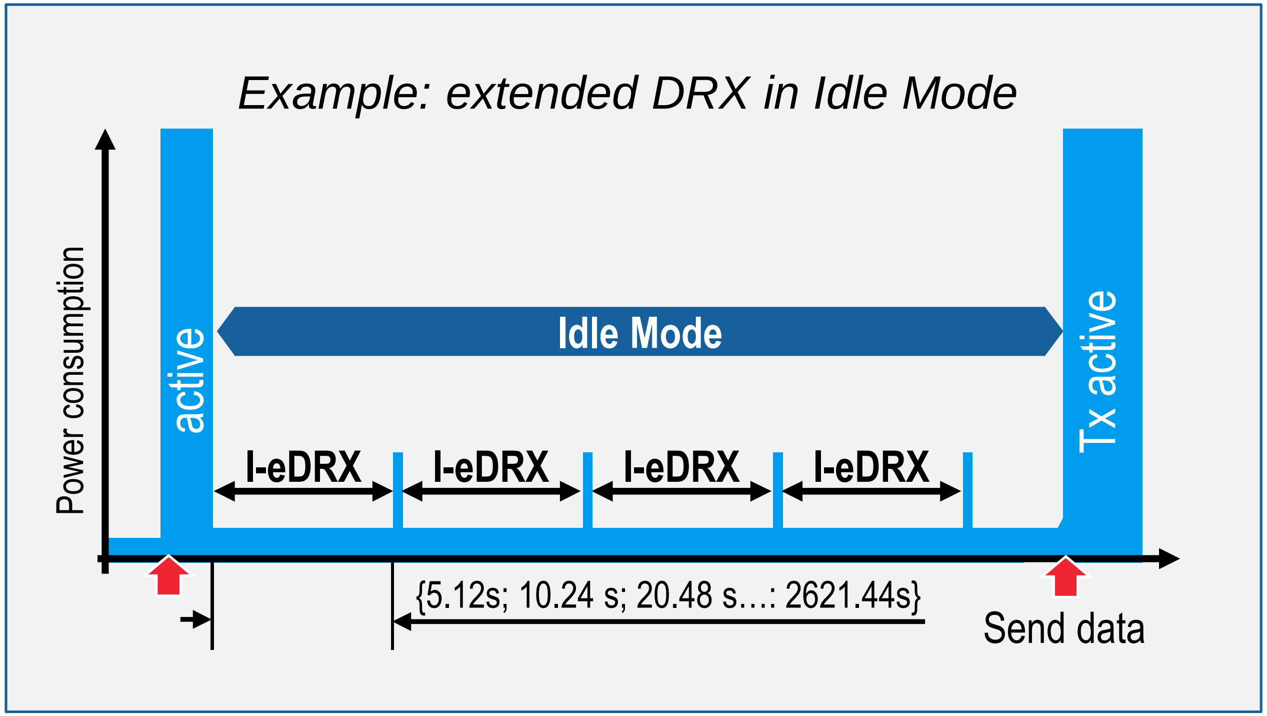
Power Saving Mode (PSM)

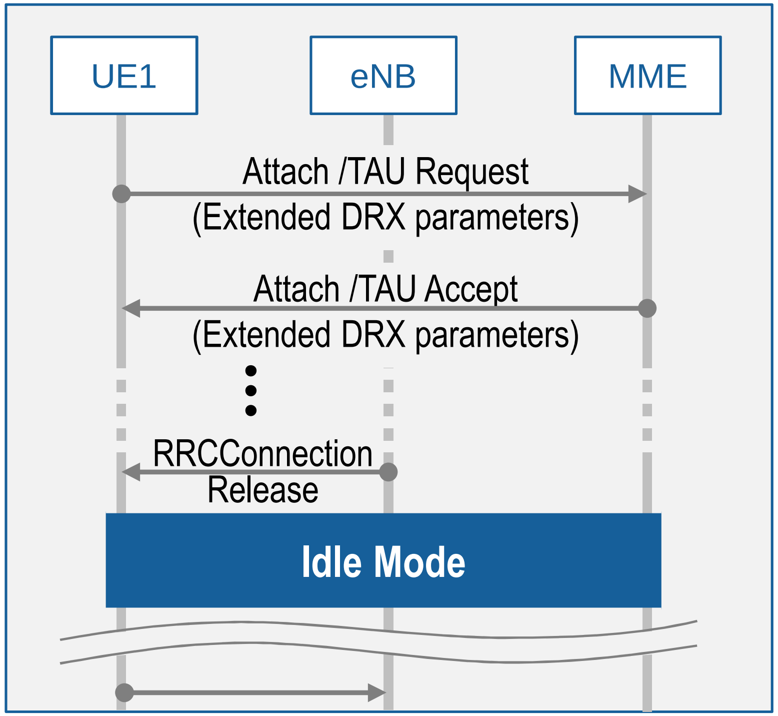




PSM Mode: UE remains registered with the network and there is **no need to re-attach or re-establish PDN connections** – saves power, but UE isn't reachable in PSM Mode

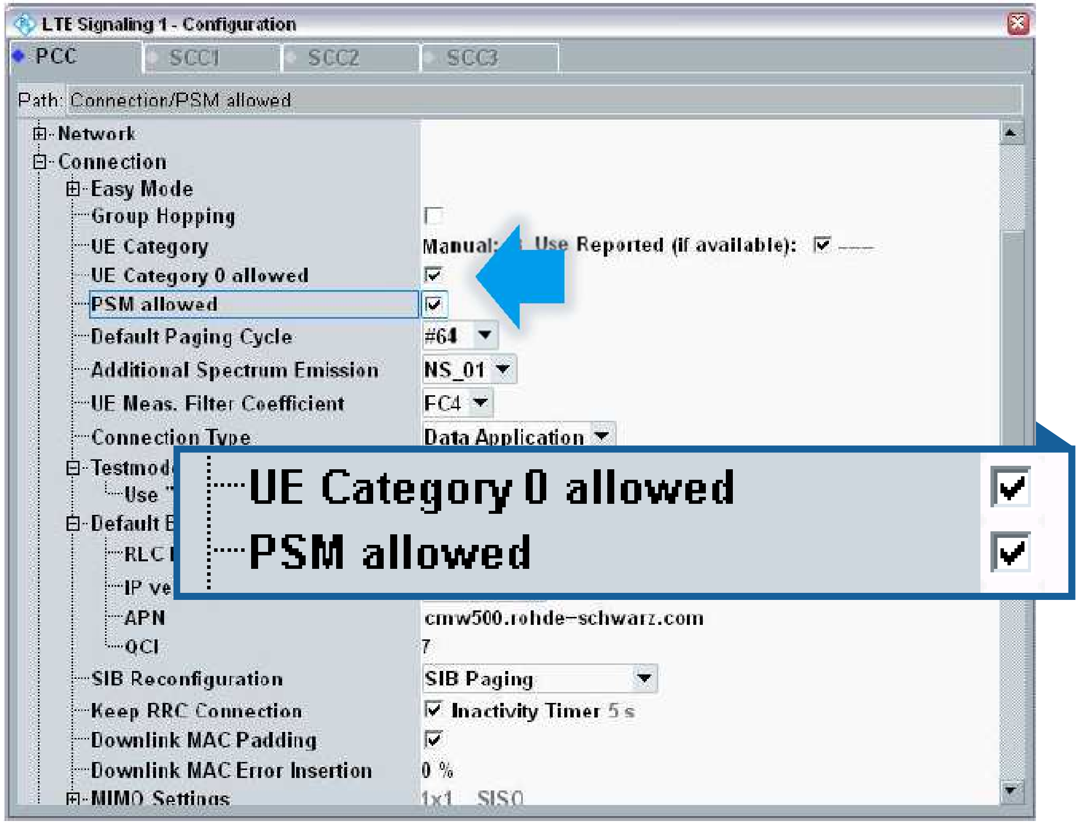
Extended DRX in idle (I-eDRX) and connected (C-eDRX) mode





For devices with infrequently uplink data transmission, energy consumption can be reduced significantly by longer cycles for discontinuous reception (DRX).

LTE Cat-0 and Power Saving Mode Testing with R&S®CMW500



Cat-0 device testing like any LTE device:

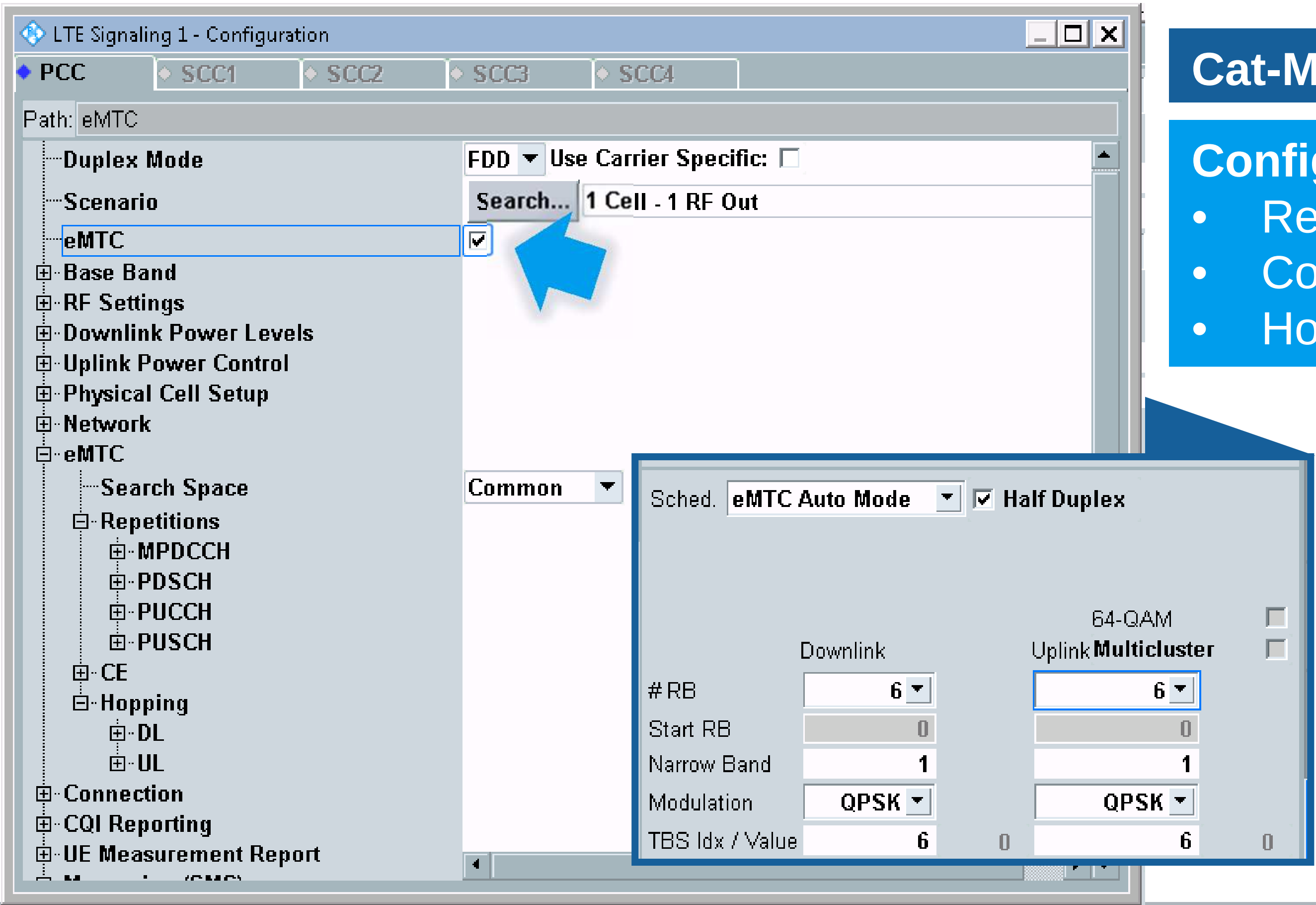
- IE in SIB1 “category0Allowed”
- Half-duplex by TTI based scheduling

Test of Power Saving Mode:

- support of related timer (T3324)
- device in PSM mode not reachable

R&S®CMW500

eMTC / LTE Cat-M1 Testing with R&S®CMW500



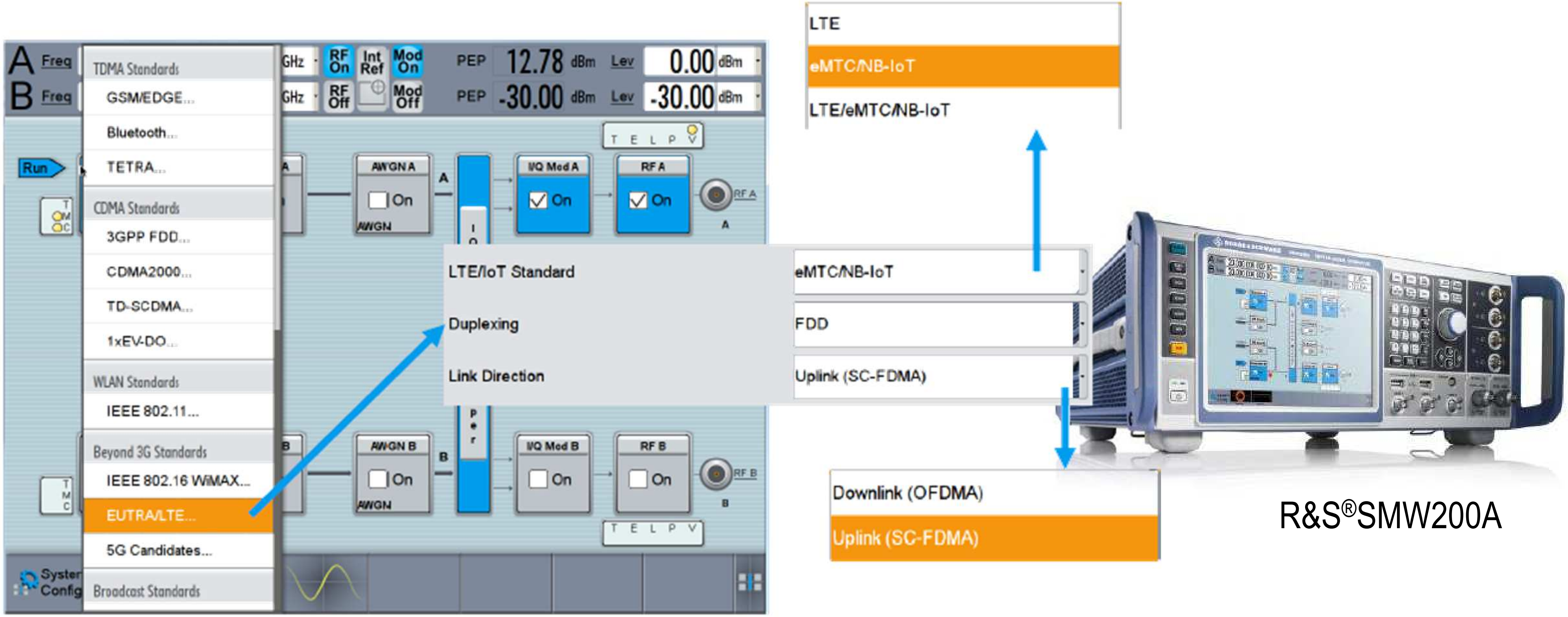
Cat-M1 device testing like any LTE device

Configuration of:

- Repetitions
- Coverage Enhancement levels
- Hopping

R&S®CMW500

eMTC / NB-IoT support – Signal Generation with R&S®SMW200A



Narrow Band IoT measurement application with R&S®VSE

Operates w/ RTO, FPS, FSW and FSV/FSVA

UL and DL measurements

Demodulation measurements (EVM)

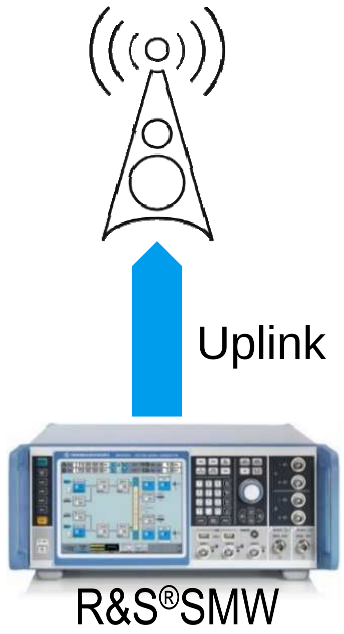
Spectral measurements (ACLR, SEM)

R&S®VSE

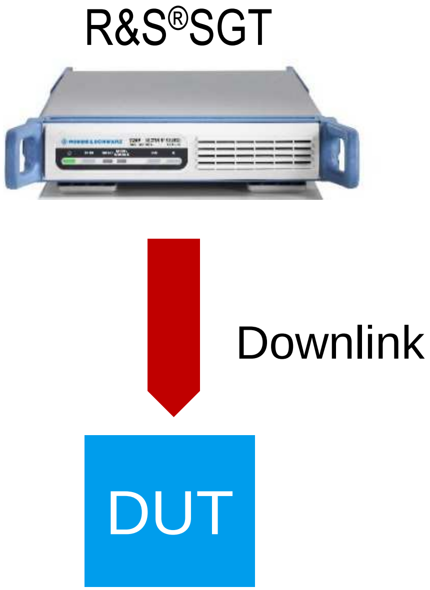
NB-IoT/eMTC Test application with R&S signal generators

From High-End to Low-cost solutions

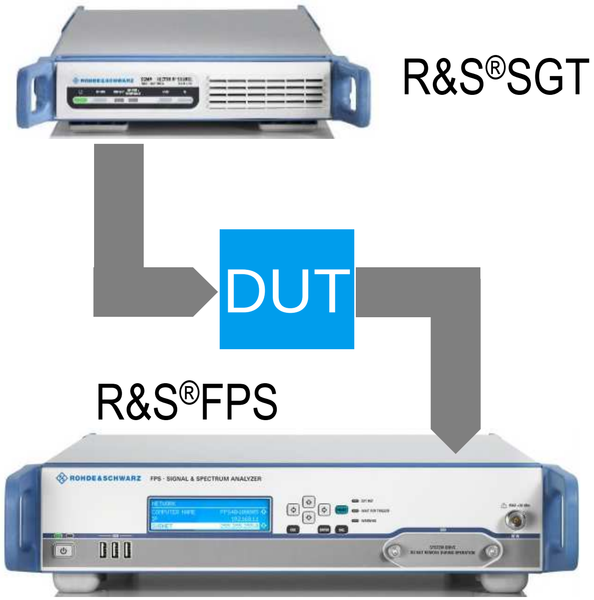
BS Receiver Test



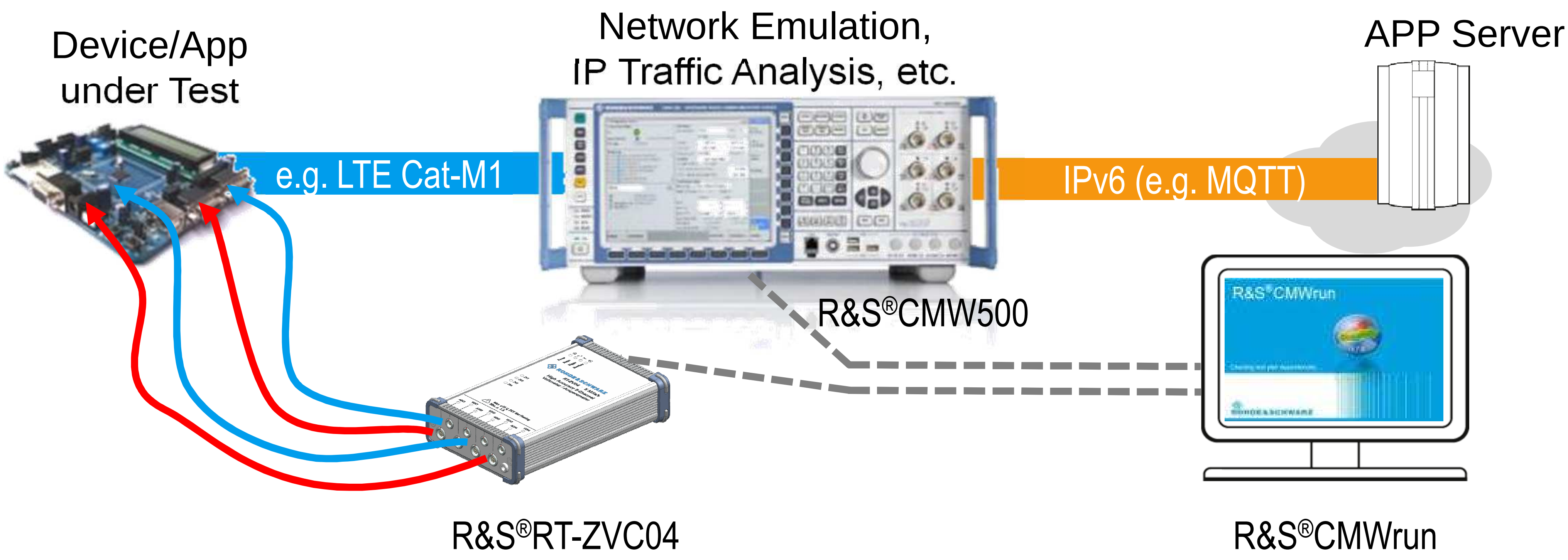
Module / Device Test



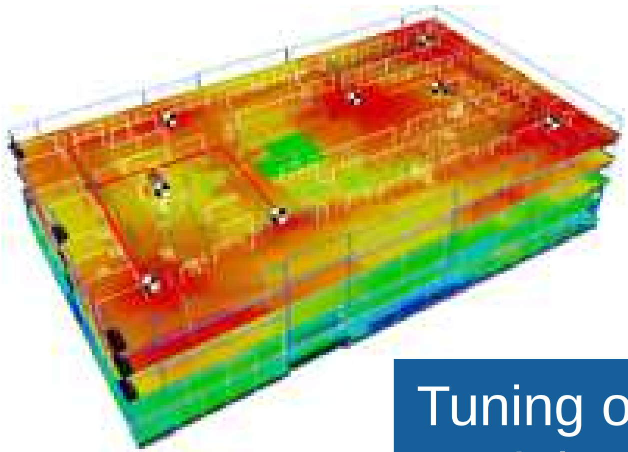
Component Test



Analyzing/optimizing Power Consumption in e2e environment



NB IoT – Mobile Network Testing Challenges



Coverage / Pathloss measurements in all basements of a city ?

Validation of co-existence with existing networks, i.e. LTE and GSM

Tuning of coverage models used in network planning tools

NB IoT Network Scanners by Rohde&Schwarz

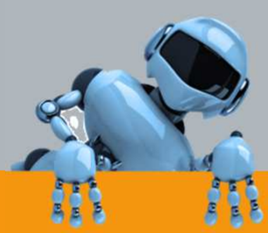
e.g. R&S®TSMA

Outline

The Internet of dogs, lights and doors

Sigfox, LoRa and more

LTE-A Pro: eMTC, NB-IoT



What's next on the way to 5G

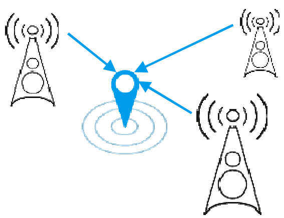
Rel. 14: feMTC e.g. for wearables like smart watches

New UE Category: CAT-M2

CAT	TBS DL [bits]	TBS UL [bits]	Buffer [bytes]	BW
M2	4008	4008	100000	5 MHz in CE A 1.4 MHz in CE B
M1	1000	1000 or **2984**	20000 or **40000**	1.4 MHz

If UE indicates: *ce-pusch-nb-maxTbs-r14* (in CE Mode A)

Rel. 14: feMTC e.g. for wearables like smart watches

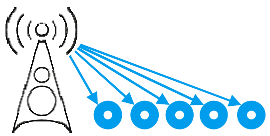


Positioning

E-CID: RSRP / RSRQ measurements

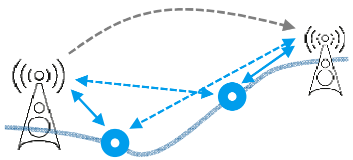
E-CID: Rx-Tx time difference

Observed Time Difference Of Arrival (OTDOA)



Multicast for FW update und group messages

Extended Rel. 13 Single-cell Point-to-Multipoint (SC-PTM)



Mobility and service continuity enhancements

Standard support for inter-frequency measurements

VoLTE

VoLTE for half-duplex communication

Higher Data Rate for audio/voice streaming

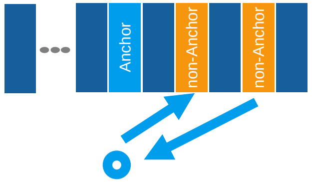
For example by HARQ-ACK bundling , 10 HARQ processes or larger maximum TBS

Rel. 14: eNB-IoT Enhancements e.g. for tracking applications

New UE Category: CAT-NB2

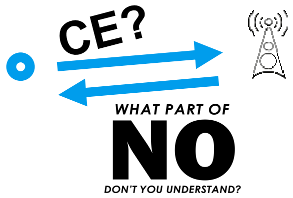
CAT	TBS DL [bits]	TBS UL [bits]	Buffer [bytes]
NB2	2536	2536	8000
NB1	680	1000	4000

New Power Class: 14dBm



Multi-PRB (non-anchor PRB enhancements)

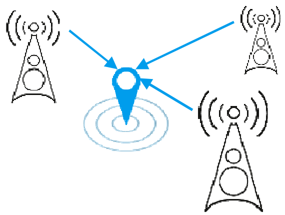
NPRACH and paging on a non-anchor NB-IoT PRB



Coverage Enhancement Authorization

not all networks (PLMN) allow UE to use Coverage Enhancement Feature.
(Applies also to LTE UE)

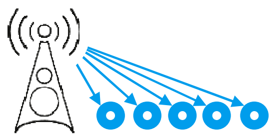
Rel. 14: eNB-IoT - Optional Features



Positioning

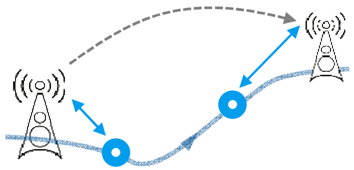
E-CID / OTDOA , capability / assistance data transfer via LPP

(N)RSRP / (N)RSRQ / Rx-Tx time difference / (N)RSTD measurements in idle mode only



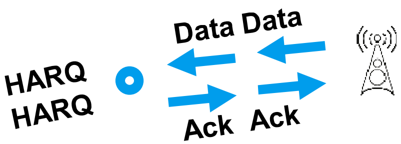
Multicast for FW update and group messages

Extended Rel. 13 Single-cell Point-to-Multipoint (SC-PTM)



Mobility and service continuity enhancements

Connected Mode Mobility via RRC re-establishment



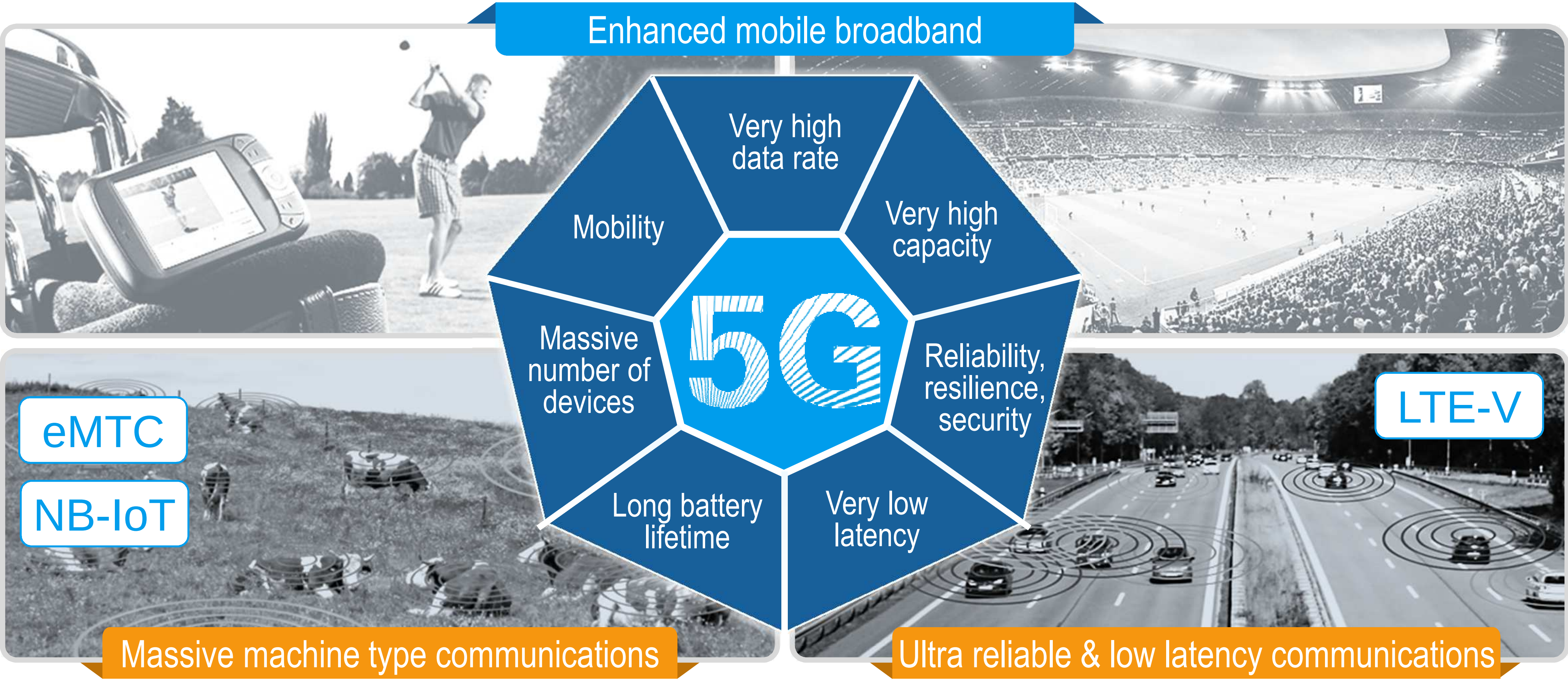
2 HARQ Processes

Support part of UE capability information, enabled via RRC signaling

Release Assistance (rai)

Support part of UE capability information, indicated by UE via BSR=0

5G networks will enable the Internet of Things of the future



Your Partner in testing the Internet of Things

Thanks for your attention.

LTE- Advanced (3GPP Rel.11) Technology Introduction

White Paper

The LTE technology as specified within 3GPP Release 8 was first commercially deployed by end 2009. Since then the number of commercial networks is strongly increasing around the globe. LTE has become the fastest developing mobile system technology. As other cellular technologies LTE is continuously worked on in terms of improvements. 3GPP groups added technology components into so called releases. Initial enhancements were included in 3GPP Release 9, followed by more significant improvements in 3GPP Release 10, also known as LTE-Advanced. Beyond Release 10 a number of different market terms have been used. However 3GPP reaffirmed that the naming for the technology family and its evolution continues to be covered by the term LTE-Advanced. I.e. LTE-Advanced remains the correct description for specifications defined from Release 10 onwards, including 3GPP Release 12. This white paper summarizes improvements specified in 3GPP Release 11 with focus on the air interface.

ROHDE&SCHWARZ

https://www.rohde-schwarz.com/applications/lte-advanced-3gpp-rel.11-technology-introduction-application-note_56280-42753.html

LTE- Advanced (3GPP Rel.12) Technology Introduction

White Paper

This white paper summarizes significant additional technology components based on LTE, which are included in 3GPP Release 12 specifications. The LTE technology as specified within 3GPP Release 8 was first commercially deployed by end 2009. Since then the number of commercial networks is strongly increasing around the globe. LTE has become the fastest developing mobile system technology ever. As other cellular technologies LTE is continuously worked on in terms of improvements. 3GPP groups added technology components according to so called releases. Initial enhancements were included in 3GPP Release 9, followed by more significant improvements in 3GPP Release 10, also known as LTE-Advanced. Beyond Release 10 a number of different market terms have been used. However 3GPP reaffirmed that the naming for the technology family and its evolution continues to be covered by the term LTE-Advanced. Therefore LTE-Advanced remains the correct description for specifications defined from Release 10 onwards, including 3GPP Release 12.

ROHDE&SCHWARZ

https://www.rohde-schwarz.com/applications/lte-advanced-3gpp-rel.12-technology-introduction-white-paper-application-note_56280-108294.html

Narrowband Internet of Things

Whitepaper

As part of Release 13, 3GPP has specified a new radio interface, the *Narrowband Internet of Things* (NB-IoT). NB-IoT is optimized for machine type traffic. It is kept as simple as possible in order to reduce device costs and to minimize battery consumption. In addition, it is also adapted to work in difficult radio conditions, which is a frequent operational area for certain machine type communication devices. Although NB-IoT is an independent radio interface, it is tightly connected with LTE, which also shows up in its integration in the current LTE specifications.

In this whitepaper we introduce the NB-IoT technology with an emphasis on the tight connection to LTE.

Note:

Visit our homepage for the most recent version of this application note (www.rohde-schwarz.com/appnote/1MA266).

NarrowBand_IoT – 1MA266_0e

J. Schlienz, D. Raddino

Whitepaper

ROHDE&SCHWARZ

https://www.rohde-schwarz.com/de/applikationen/application-note_56280-314242.html