THE CONTINUING 5G TECHNOLOGY EVOLUTION – 5G ADVANCED TOWARDS 6G

AN INTRODUCTION INTO SELECTED 5G ADVANCED TECHNOLOGIES

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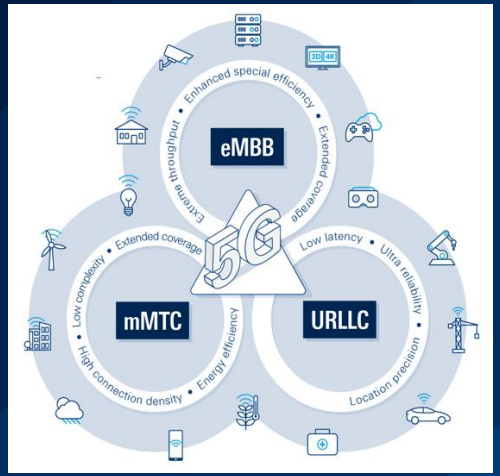
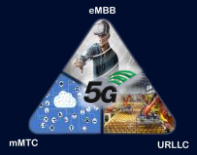
Technology Manager Wireless



ROHDE&SCHWARZ
Make ideas real

3GPP 5G ADVANCED EVOLUTION



5G NR

| Release 15

| Release 16

| Release 17

5G NR Advanced
Release 18

Release 19

Release 20

6G research kick off

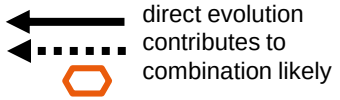
6G workshop
March 2025

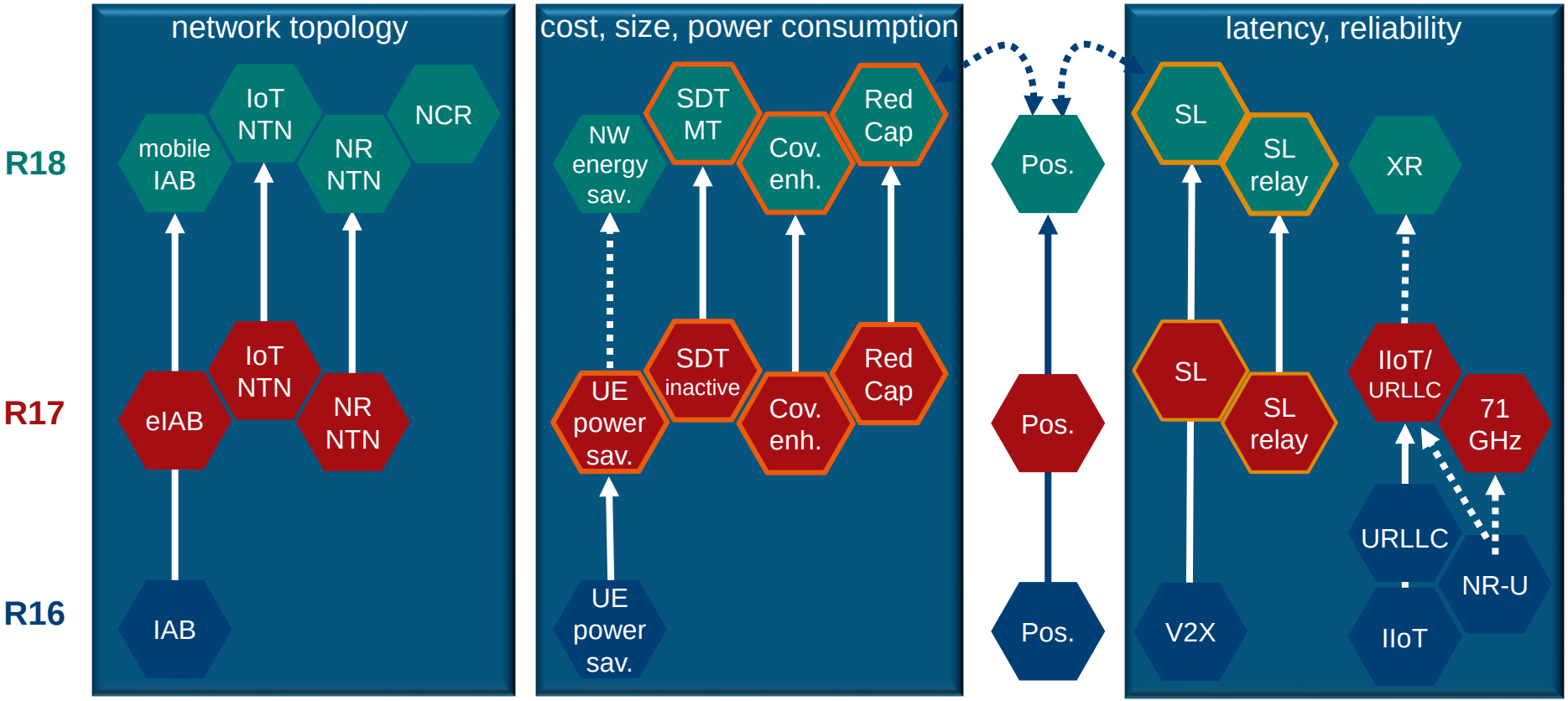
Release 18 5G Adv.	Release 19 5G Adv	Release 20 6G Studies	Release 21 6G Normative

Duration open

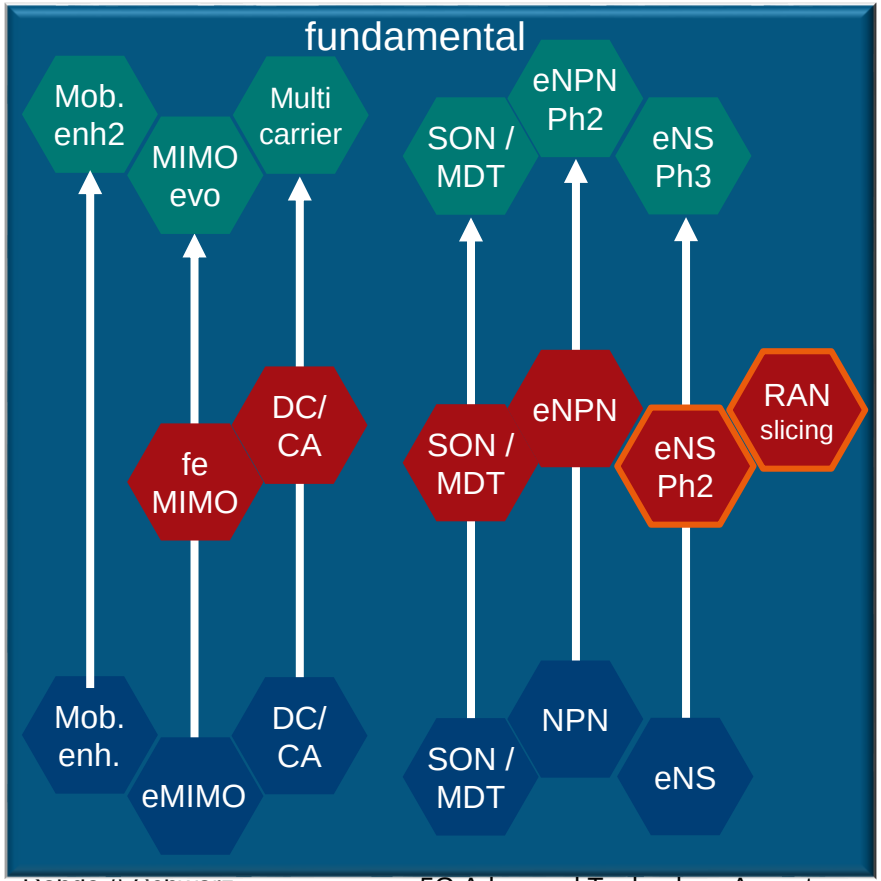
2018 2020 2022 2024 2026 2028 2030

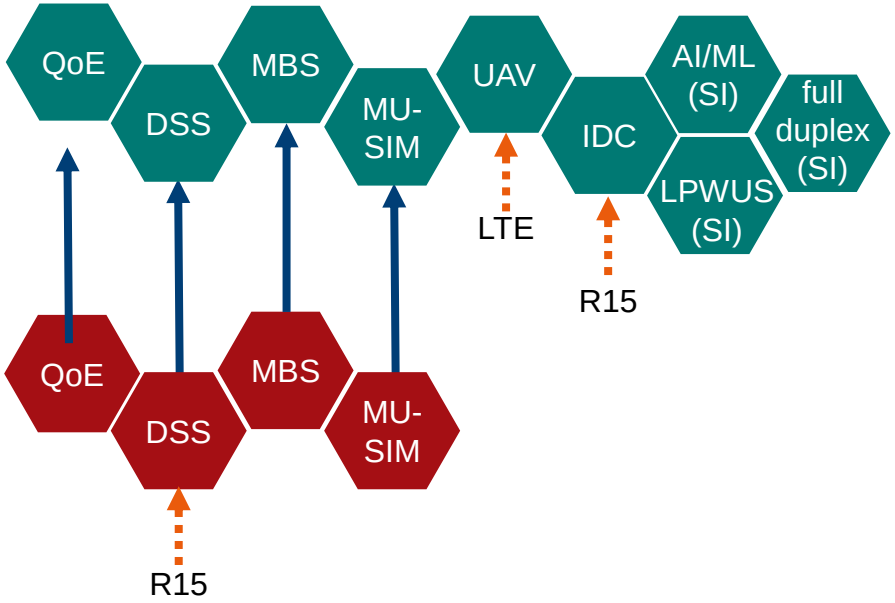
3GPP REL-16 TO REL-18 TOPICS AND RELATIONS

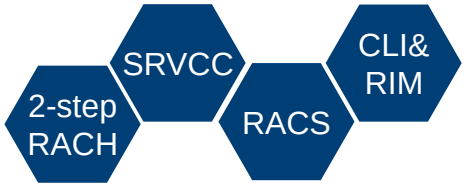




3GPP REL-16 TO REL-18 TOPICS AND RELATIONS







direct evolution
contributes to
combination likely

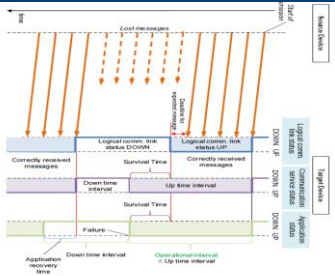
5G evolution

INDUSTRIAL IoT & NON-PUBLIC NETWORKS (NPN)

5G TIME SENSITIVE NETWORKS (TSN) - INTEGRATION

Deterministic network: 5G measures ingress-egress latency and sync with external networks.

New KPI: Survival time



5G or PTP external as time reference

5GS Bridge

Control plane

UDM NEF AMF SMF PCF TSN AF

TSN based application

TSN based application

DS-TSN translator

UE

DS-TSN translator

UE

UPF

NW-TSN translator

TSN bridge

TSN bridge

5GS time synchronization

TSN time synchronization

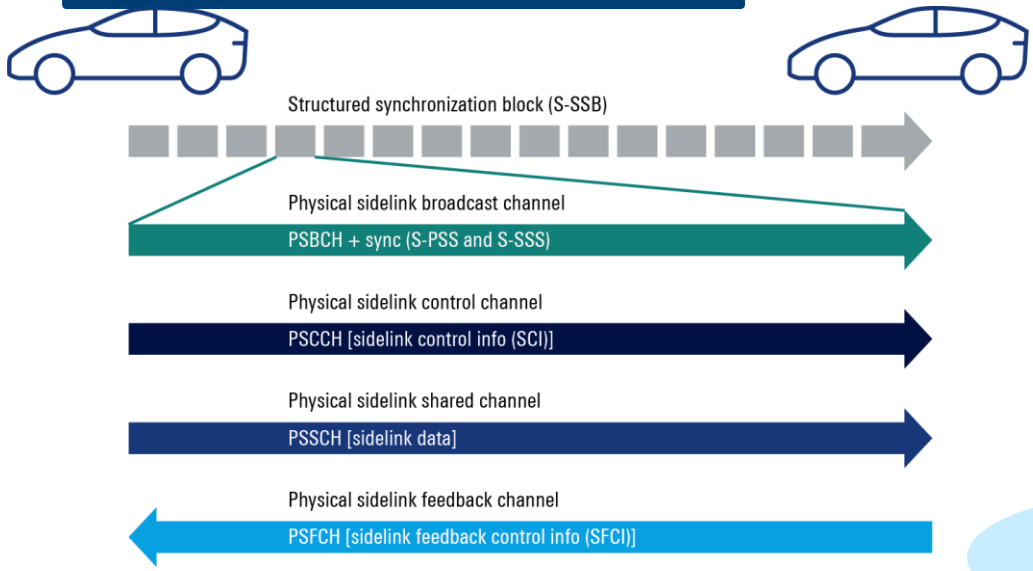
Enhancements on time error budget estimation to reduce uncertainty

The ongoing evolution of 5G

NR-V2X: SIDELINK ENHANCEMENTS + RELAY

5G NR SIDELINK – CHANNEL STRUCTURE

Improved flexibility due to sidelink control info.
Various numerologies to copy the tremendous flexibility of 5G NR, also to 5G NR V2X

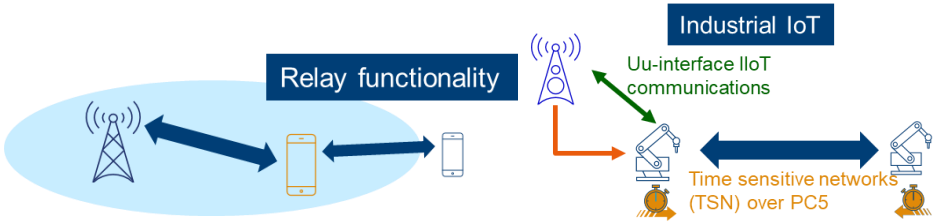


Release 16 sidelink with focus on automotive!

Release 17 sidelink with focus on battery consumption!

Release 17 sidelink with focus on uRLLC!

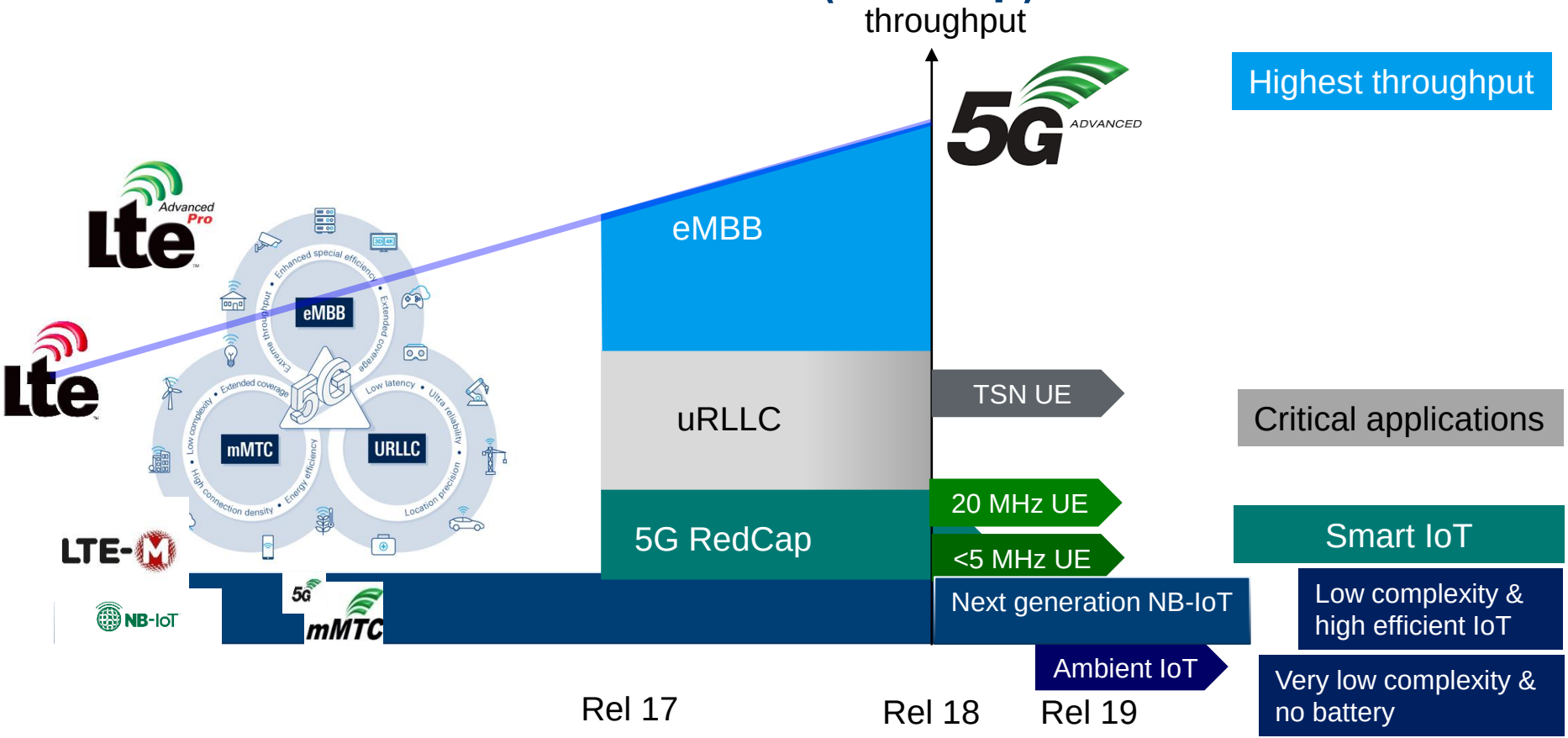
Release 17 sidelink with focus on public safety!



The ongoing evolution of 5G

REDUCED CAPABILITY (RedCap) + POWER SAVING ASPECTS

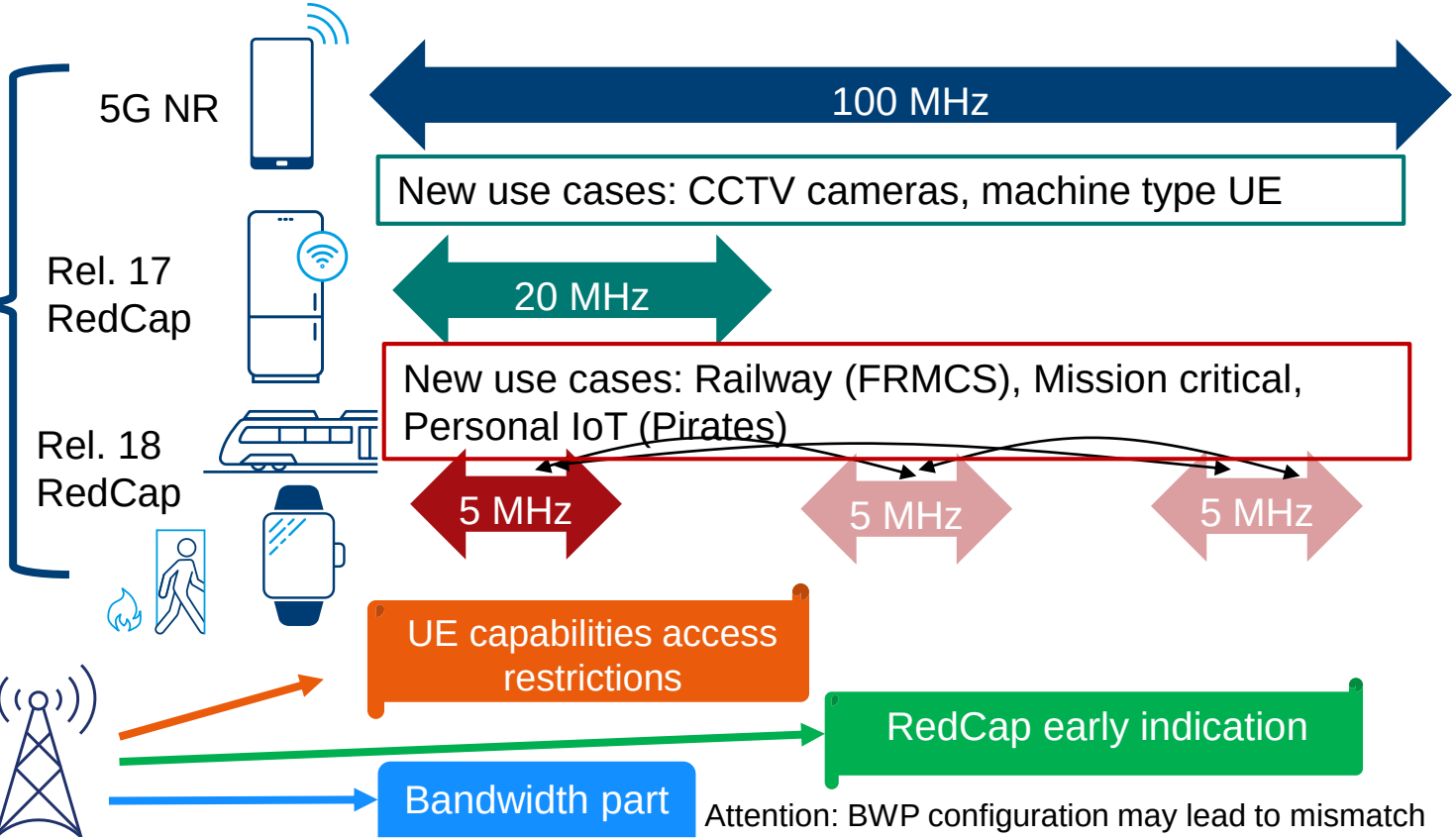
5G NR: REDUCED CAPABILITIES (RedCap)



REDUCED CAPABILITIES ASPECTS & EVOLUTION

- 20MHz bandwidth
- Half-duplex
- 1 antenna
- 256QAM optional
- No dual connectivity

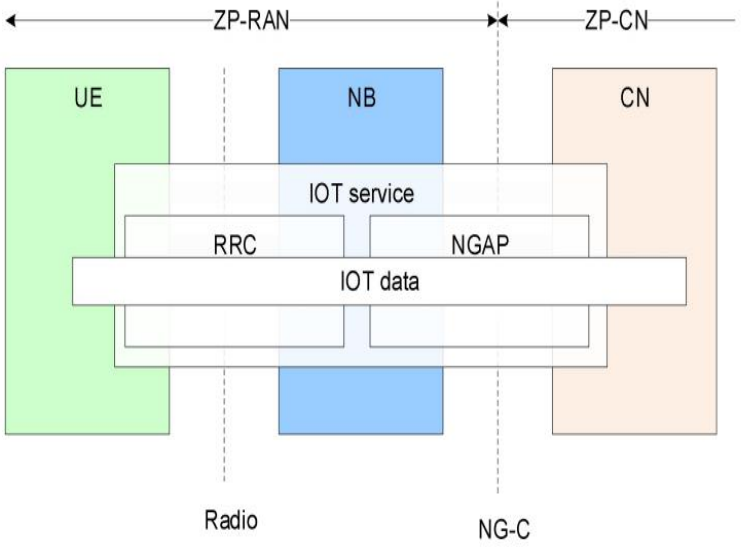
Coexistence

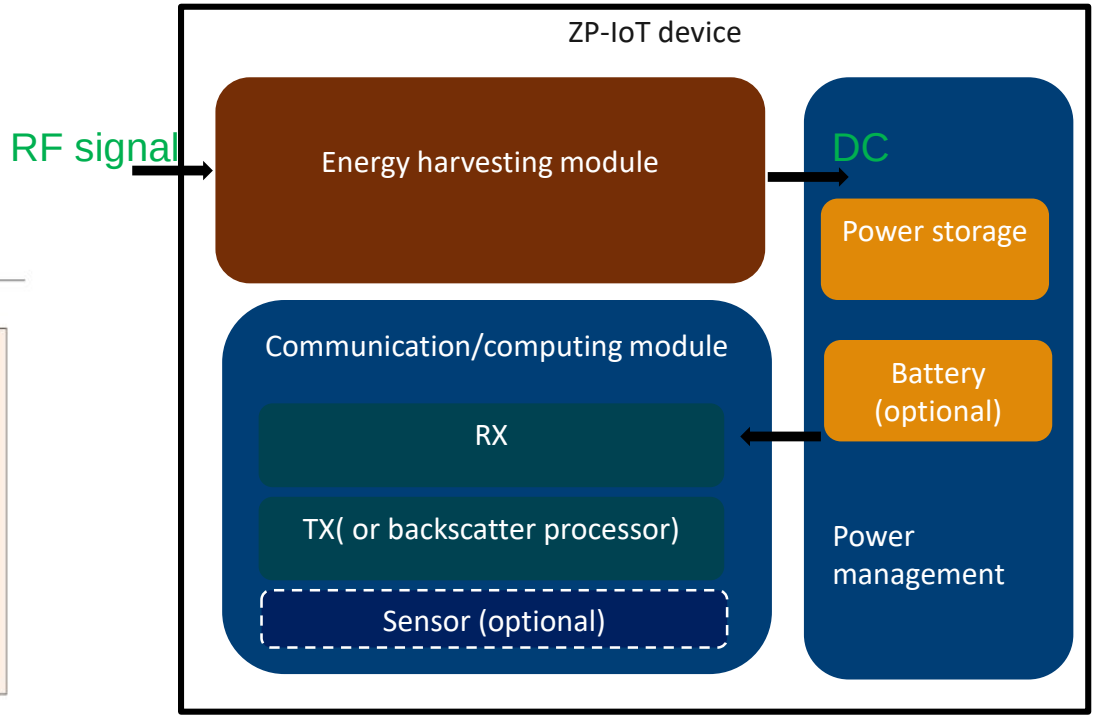


Network must operate in standalone 5G (SA)

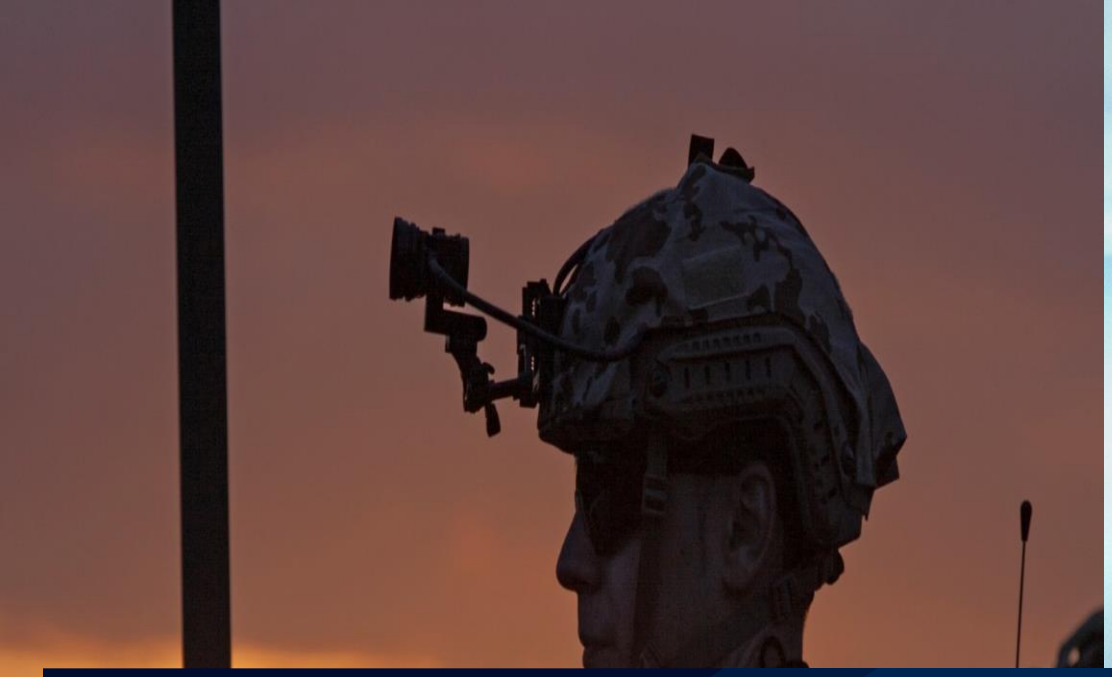
KEY COMPONENT OF ZP-IOT DEVICE

Lightweight protocol stack
- Non-IP protocol
- Integration of control plane and user plane
- Simplified user plane and control plane
- Synchronization procedure
- Simplified security mechanism





- Rx is receiver including RF units and baseband
- Tx part could be transmitter or backscatter processor



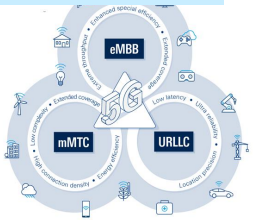
5G radio technoloy aspects

MISSION CRITICAL COMMUNICATIONS

5G TECHNOLOGY ASPECTS SUPPORTING MISSION CRITICAL COMMUNICATIONS

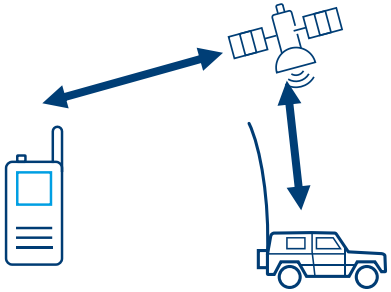
5G supports mission critical communications due to the plethora of features

5G service flexibility

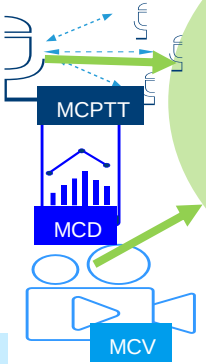


5G sidelink enabling device to device & relay

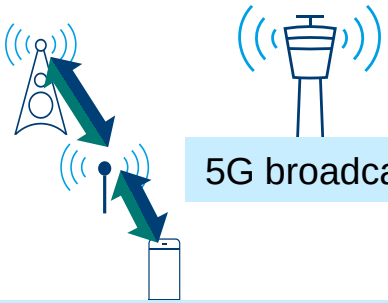
5G NTN ubiquituous coverage



New MCX services:
Voice, video, data

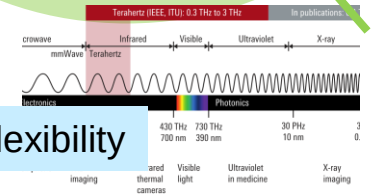


5G broadcast



Integrated access backhaul:
Dynamic deployment

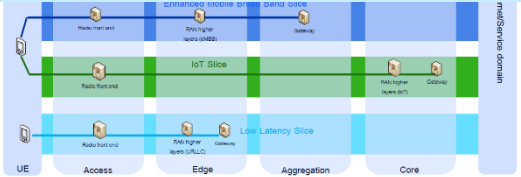
Spectrum flexibility



5G QoS concept

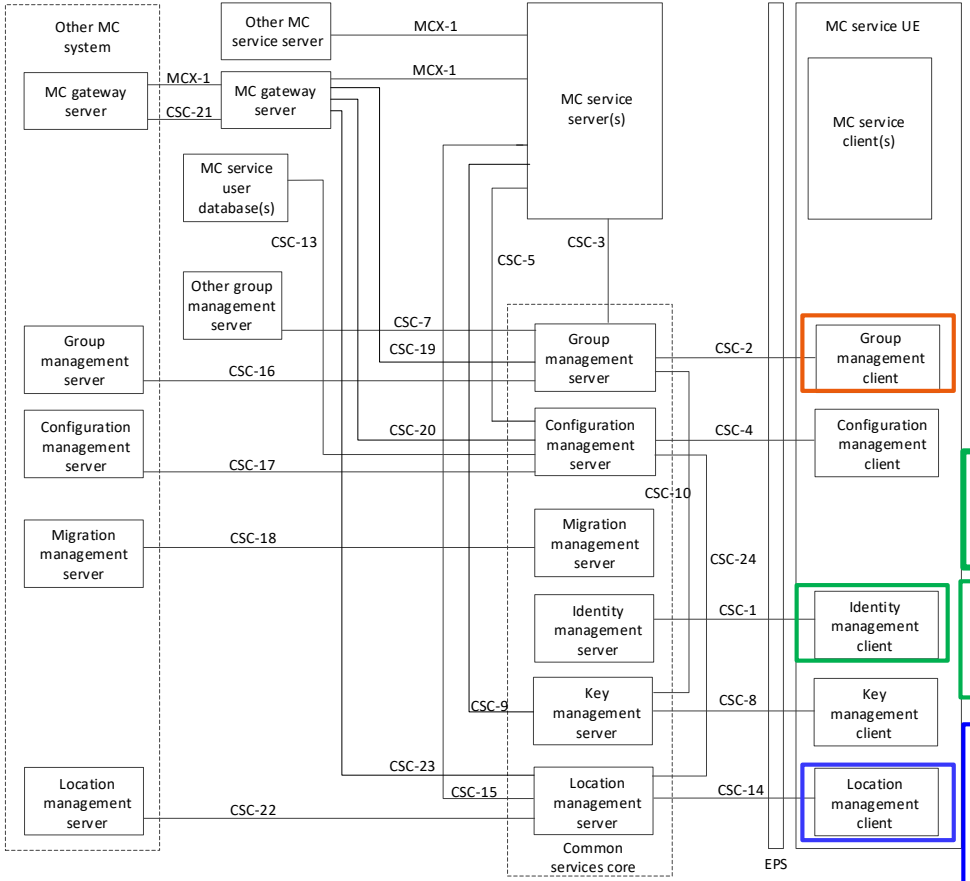
Prio	Latency	Bit rate	BLER

Sophisticated QoS management & NW slicing



Cloud native core

5G MISSION CRITICAL COMMUNICATIONS (MCX)



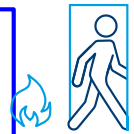
MCX introduces a „complex“ functional model. Just some aspects of reaching out to a MCX-UE

A MCX-UE is called because it belongs to a group

A MCX-UE is addressed by its name (e.g. phone number)

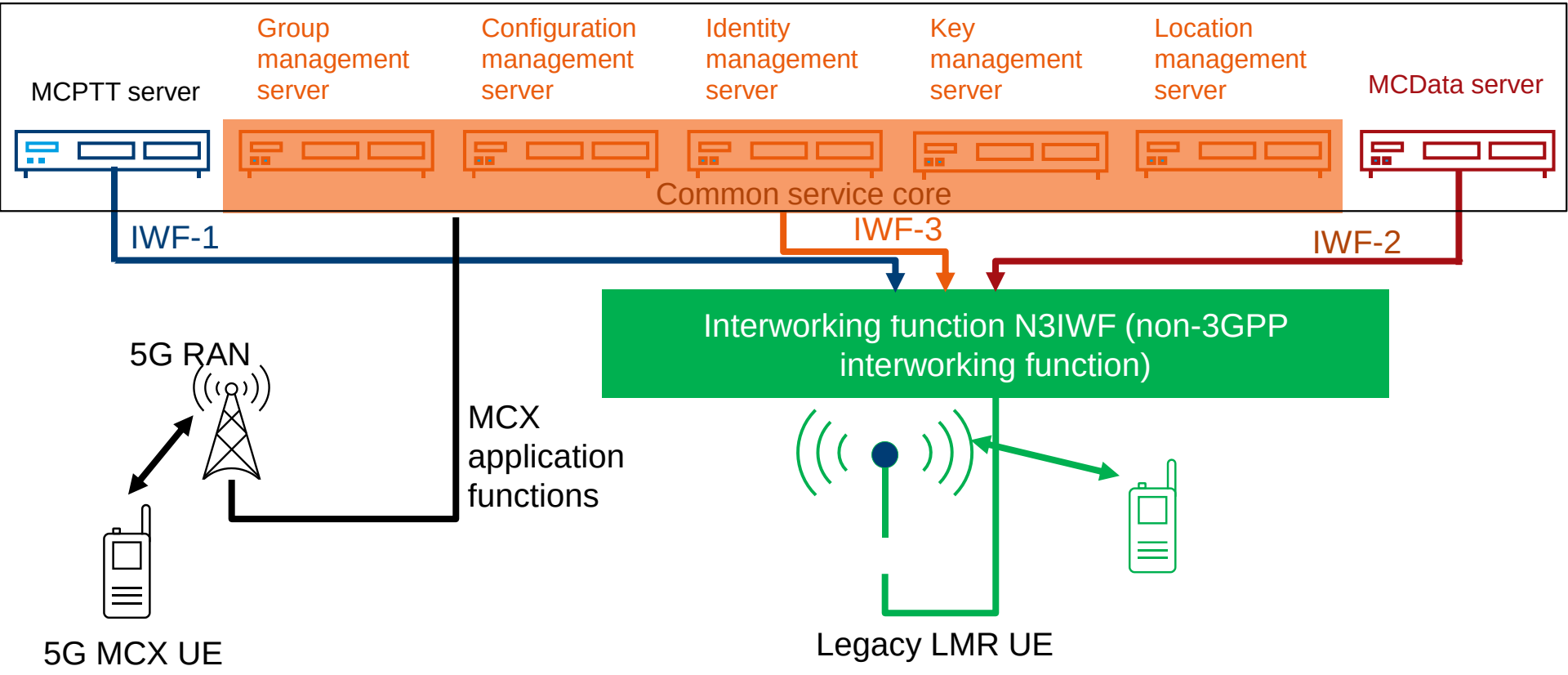
A MCX-UE is addressed by its function (e.g. education, profession)

A MCX-UE is addressed based on its location



5G AND LMR INTERWORKING VIA N3IWF

LMR is widely deployed and transition is only gradually possible: 3GPP defines interworking concept

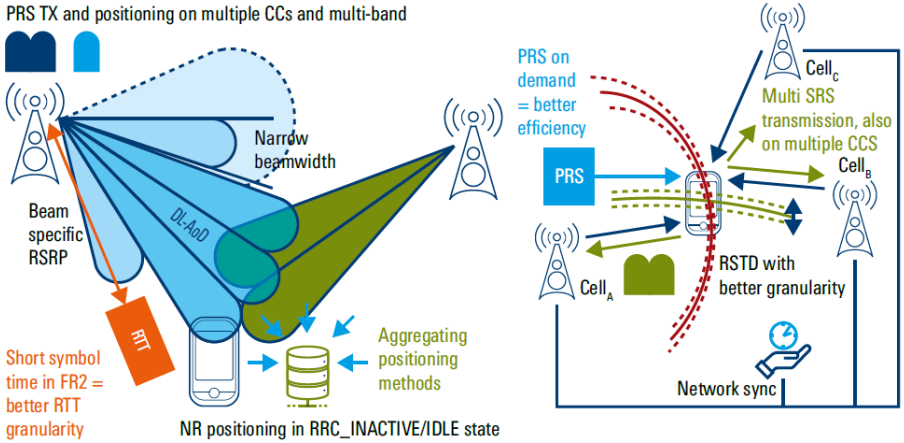


The ongoing evolution of 5G

POSITIONING ENHANCEMENTS

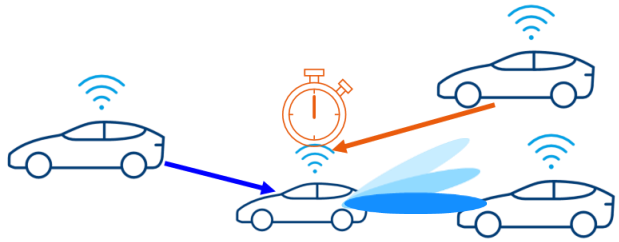
POSITIONING METHODOLOGIES - EVOLUTION

RAT based positioning methodologies

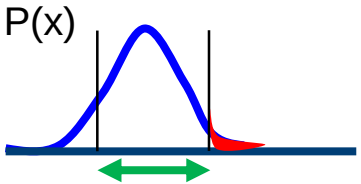


Enhance accuracy due to hybrid (e.g. GNSS, UWB, Bluetooth)

Differential positioning, e.g. sidelink RTT and AoD methodologies or hybrid with UWB

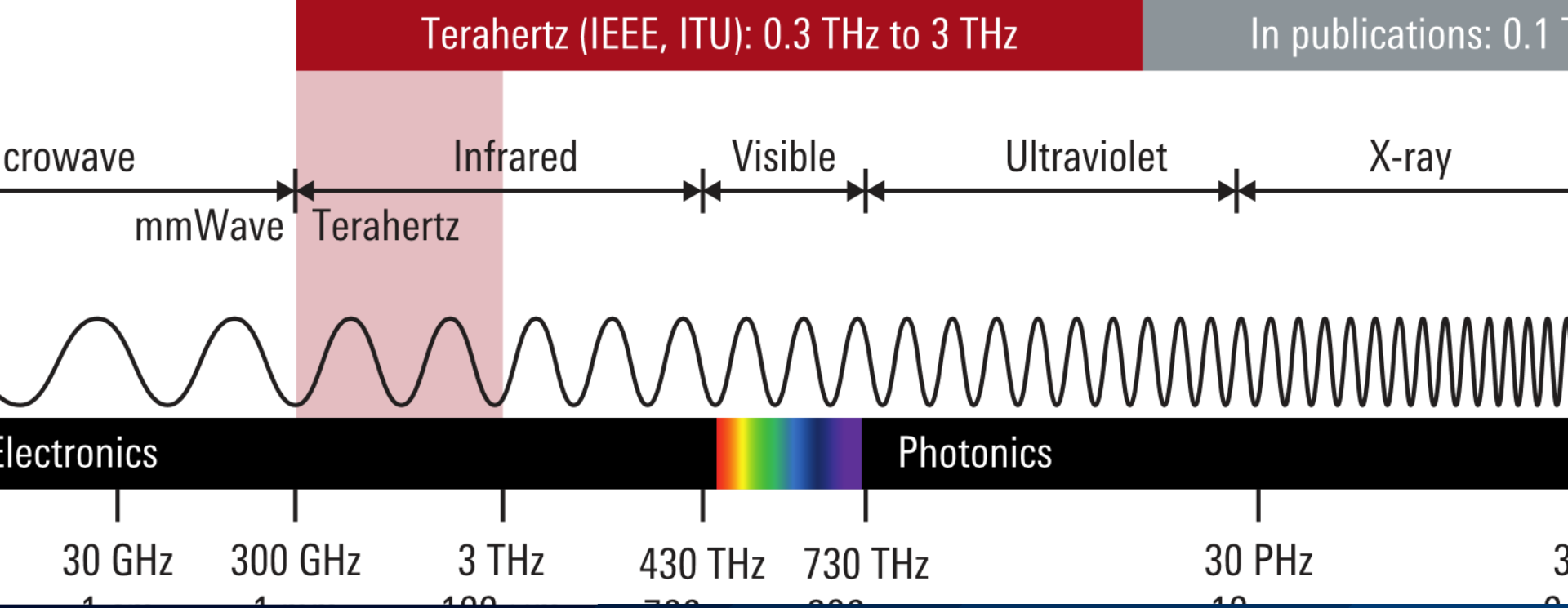


Positioning integrity & verification (e.g. AI, statistics, two-factor authentication)



Confidence interval, mean score, error distribution (sigma)

Rel. 17 => GNSS integrity → Rel. 18 => any RAT integrity → UE or LMF based integrity; Indoor

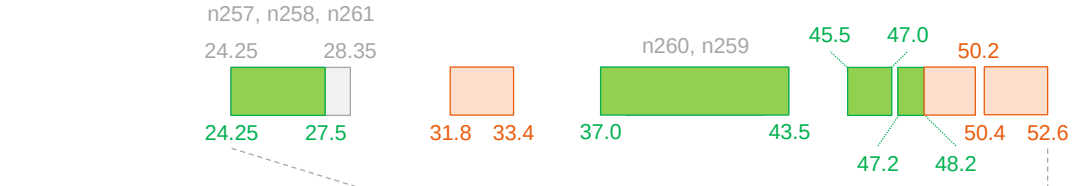


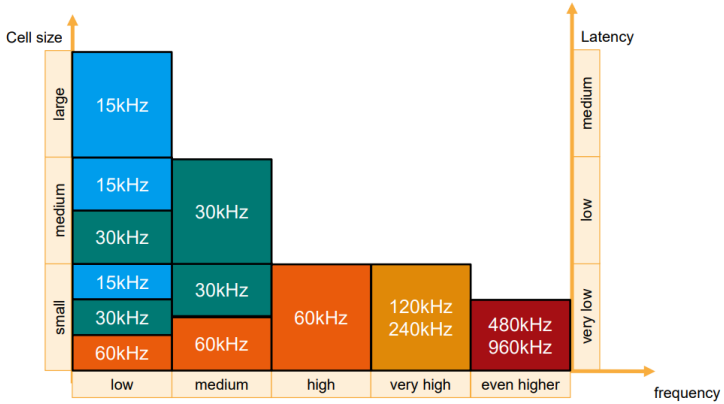
The ongoing evolution of 5G

EXTENSION OF FREQUENCY RANGE 2: FR2-2

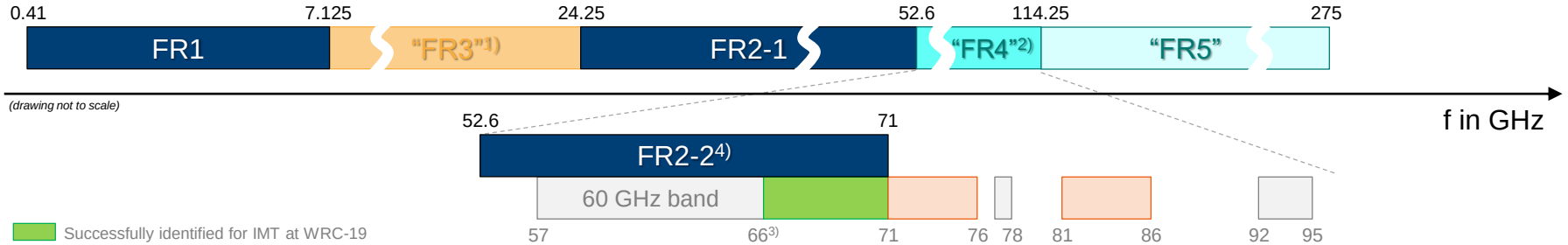
SPECTRUM FOR 5G NR AND 5G ADVANCED

Operating Band	Uplink (UL) operating band BS receive UE transmit			Downlink (DL) operating band BS transmit UE receive			Duplex Mode
	F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}	
n263	57000 MHz	-	71000 MHz	57000 MHz	-	71000 MHz	TDD (Note)
[n264]	66000 MHz	-	71000 MHz	66000 MHz		71000 MHz	TDD (Note)
NOTE:	n263 unlicensed, n264 licensed						





For WRC-23
3.4 to 3.4, 3.6 to 3.8, 6.425 to 7.025, 7.025 to 7.125 and 10 to 10.5 GHz



Source: https://news.itu.int/wrc-19-agrees-to-identify-new-frequency-bands-for-5g/

New channel bandwidth of 2GHz possible

Non-terrestrial networks (NTN)

5G NTN FREQUENCY ASPECTS & ARCHITECTURE

5G NTN SPECTRUM & UE ASPECTS

FR1: NTN bands

Band	Region	Related bands	Band type	UL low MHz	UL high MHz	DL low MHz	DL high MHz
n253	EU	L-ext	FDD	1668.0	1675.0	1518.0	1525.0
n254	EU	L+53	FDD	1610.0	1626.5	2483.5	2500.0
n255	EU	n65	FDD	1626.5	1660.5	1525.0	1559.0
n256	NA	n24	FDD	1980.0	2010.0	2170.0	2200.0

FR2-1N: new NTN bands (R18). FR2-1N range 17.3 – 52.6GHz

Band	Region	Band type	UL low MHz	UL high MHz	DL low MHz	DL high MHz
n510	US	FDD	27500	28350	17300	20200
n511	US	FDD	28350	30000	17300	20200
n512	EU	FDD	27500	30000	17300	20200

„FR3“ bands Ku: requested in R19

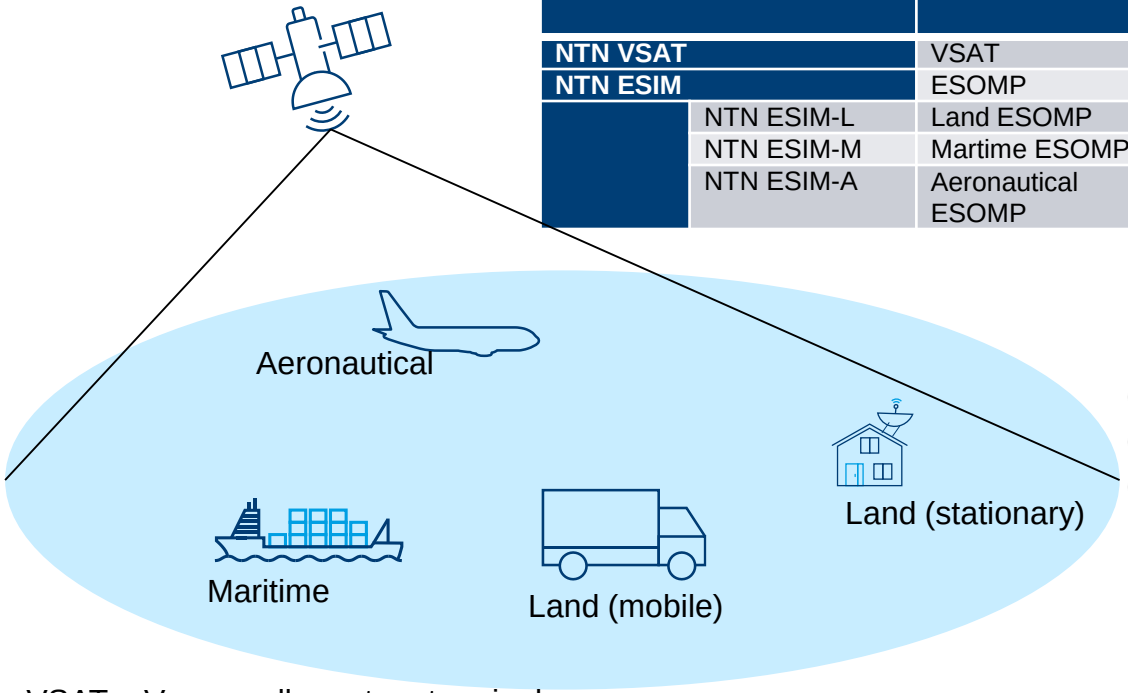
Band	Region	Band type	UL (Earth to space) GHz	DL (Space to Earth) MHz
Ku	Region 1	FDD	12.75 – 13.25 & 13.75 – 14.5	10.7 – 12.75
Ku	Region 2	FDD	12.75 – 13.25 & 13.75 – 14.5	10.7 – 12.7

UE aspects for NTN

Link level assumptions	FR1 NTN-UE or IoT-UE	FR2-1N VSAT UE
TX power	23dBm ± 2dB (200mW) (note: more likely 23 dBm + 2dB)	33 dBm (2W)
Antenna type	Omnidirectional	60cm aperture diameter
Antenna gain	TX/RX 0dBi	TX: 43.2 dBi / RX: 39.7 dBi
Noise figure	9 dB	1.2 dB
Polarization	Linear (dual polarized possible)	Circular polarized phased array antenna

NTN REL. 18 UE CATEGORY DISCUSSION (>10 GHZ)

Proposed naming in RAN4		CEPT	FCC	ACMA	Mobility	Satellite tracking feature
NTN VSAT		VSAT	Earth station	VSAT	No, fixed	No
NTN ESIM		ESOMP	ESIM	ESIM	Yes	Yes
	NTN ESIM-L	Land ESOMP	ESIM / VMES	ESIM-L		
	NTN ESIM-M	Martime ESOMP	ESIM / ESAA	ESIM-M		
	NTN ESIM-A	Aeronautical ESOMP	ESIM / ESV	ESIM-A		

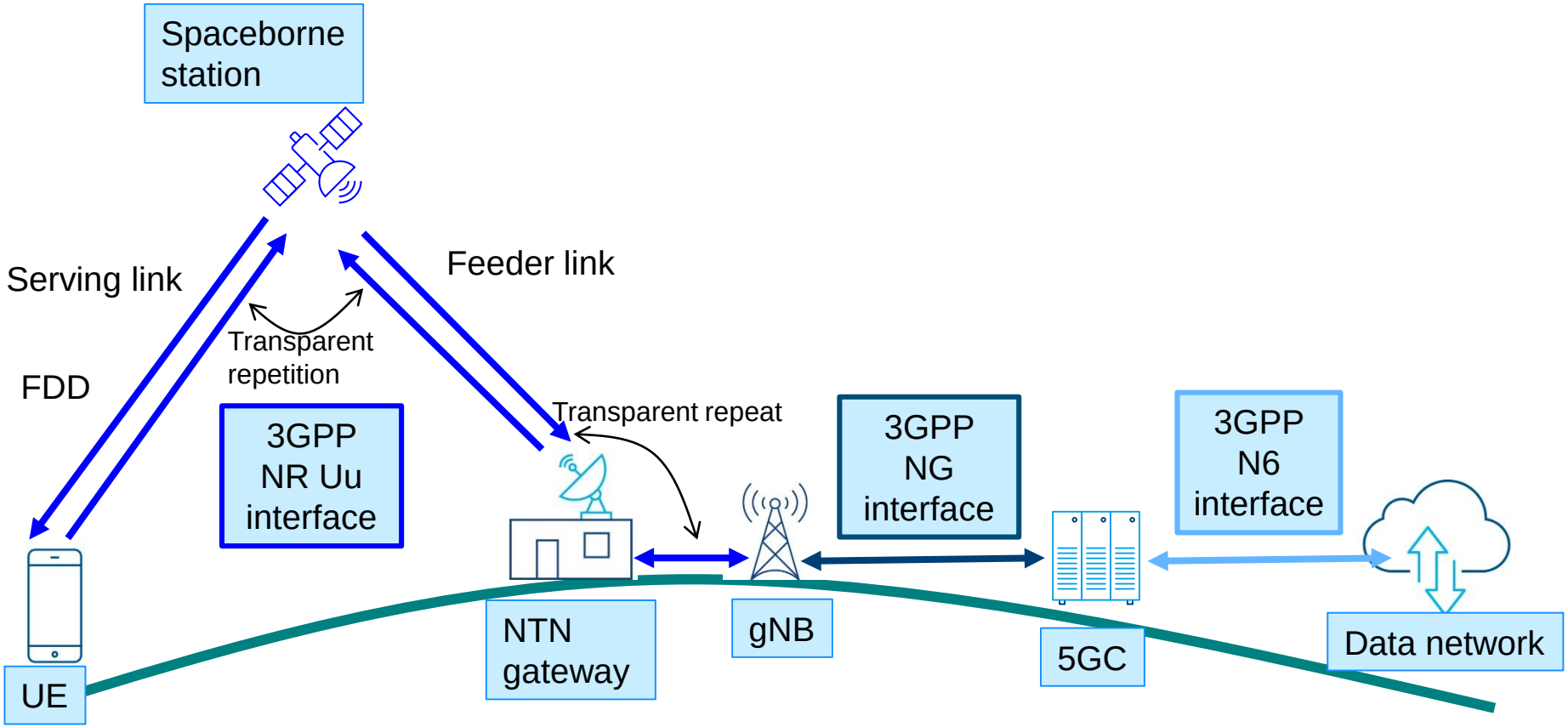


RRM discussions:
Case-1: Stationary UE for GSO
Case-2: Stationary UE for LEO
Case-3: Mobile UE for GSO

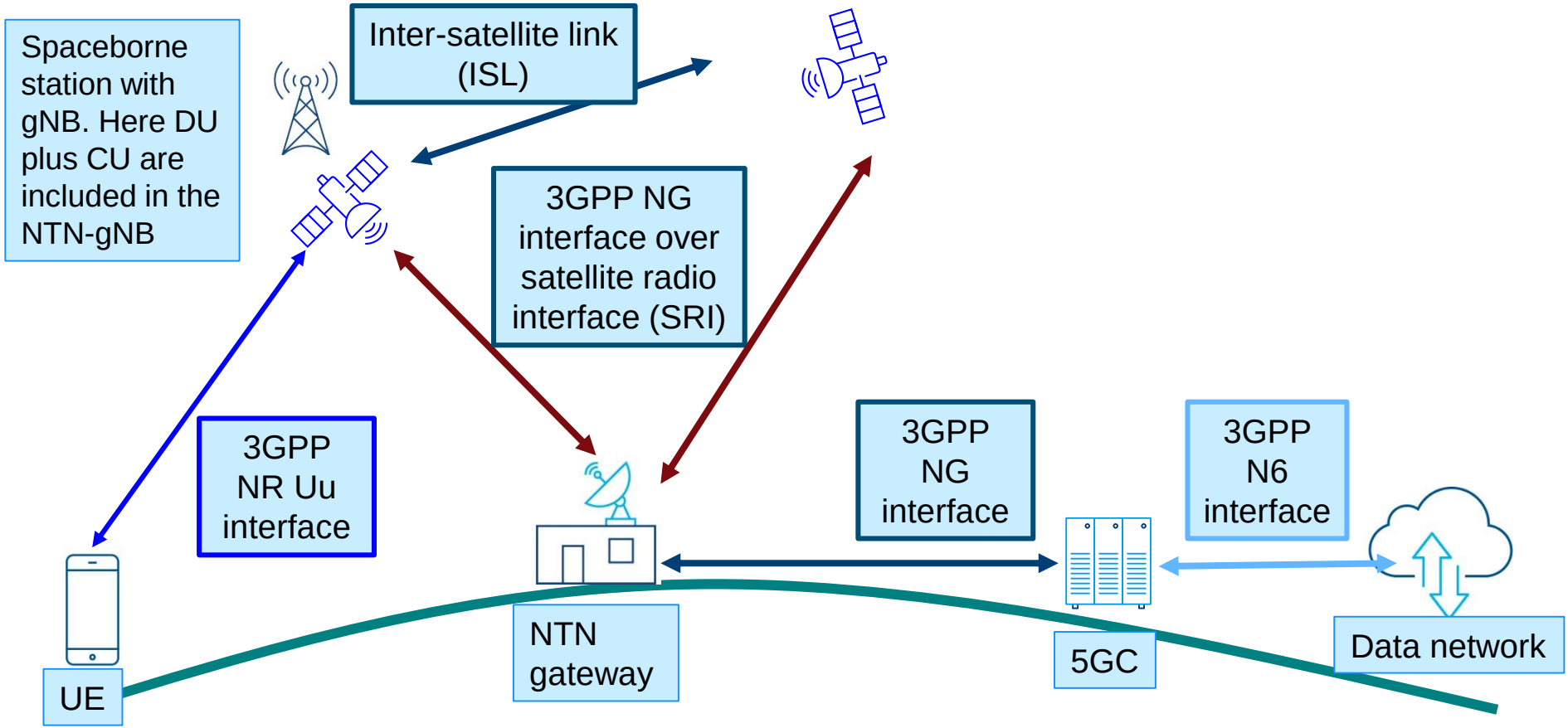
UE architectures:
Fully electronically-steered beam UEs (Type 1)
Fully mechanically-steered beam UEs (Type 2)

VSAT = Very small aperture terminal
ESIM = Earth station in motion
ESOMP = Earth station on mobile platform

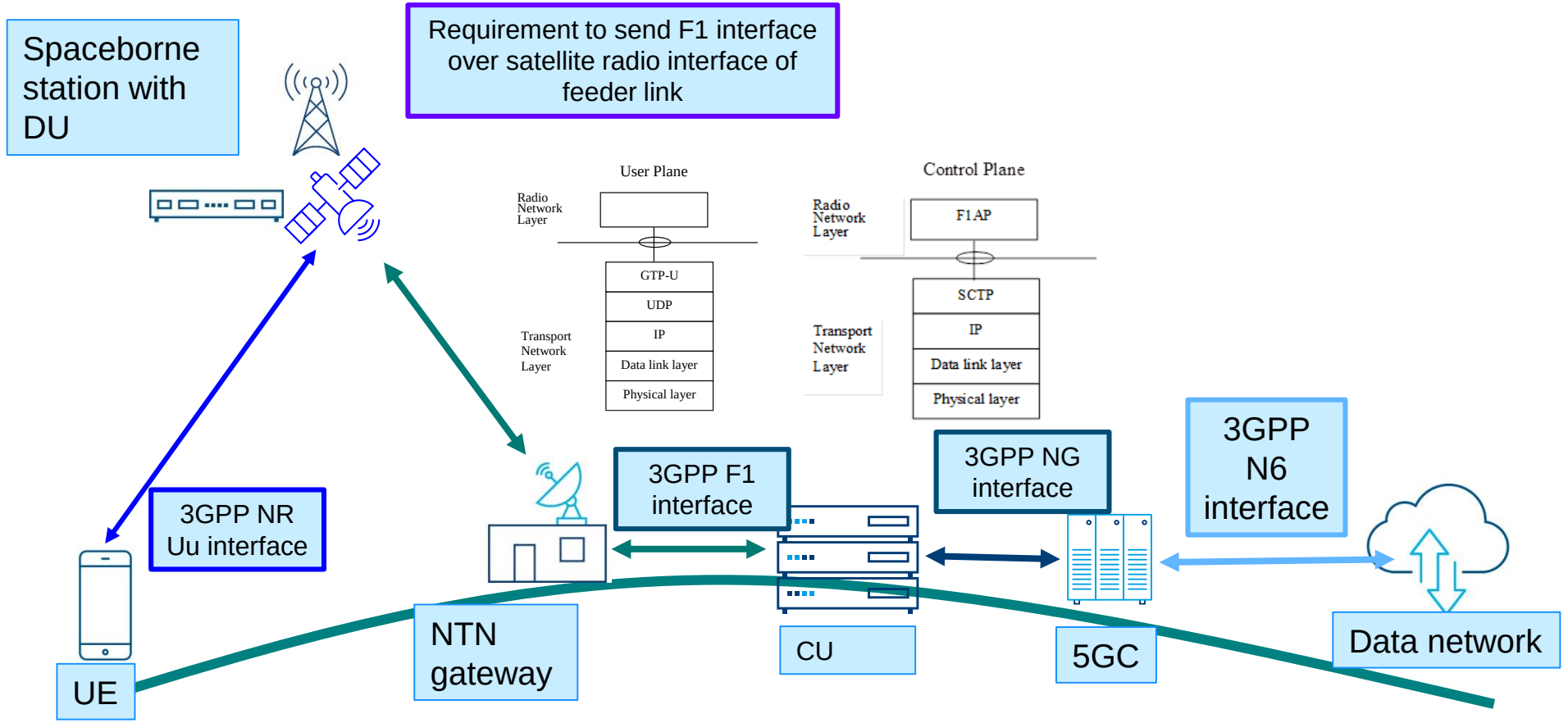
NTN: TRANSPARENT PAYLOAD ARCHITECTURE



NTN: REGENERATIVE PAYLOAD ARCHITECTURE



NTN: DISAGGREGATED ARCHITECTURE, DU-CU SPLIT



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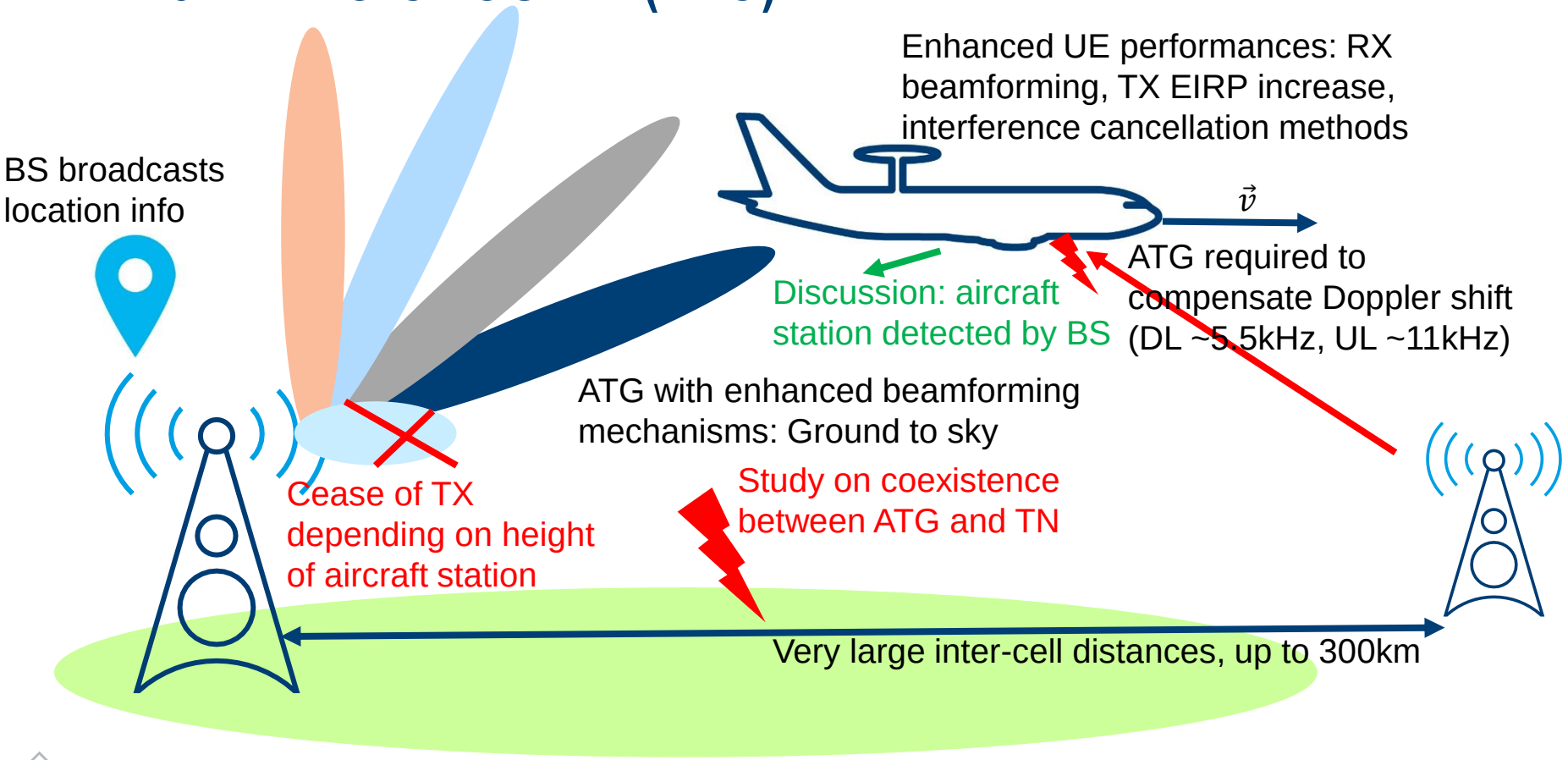
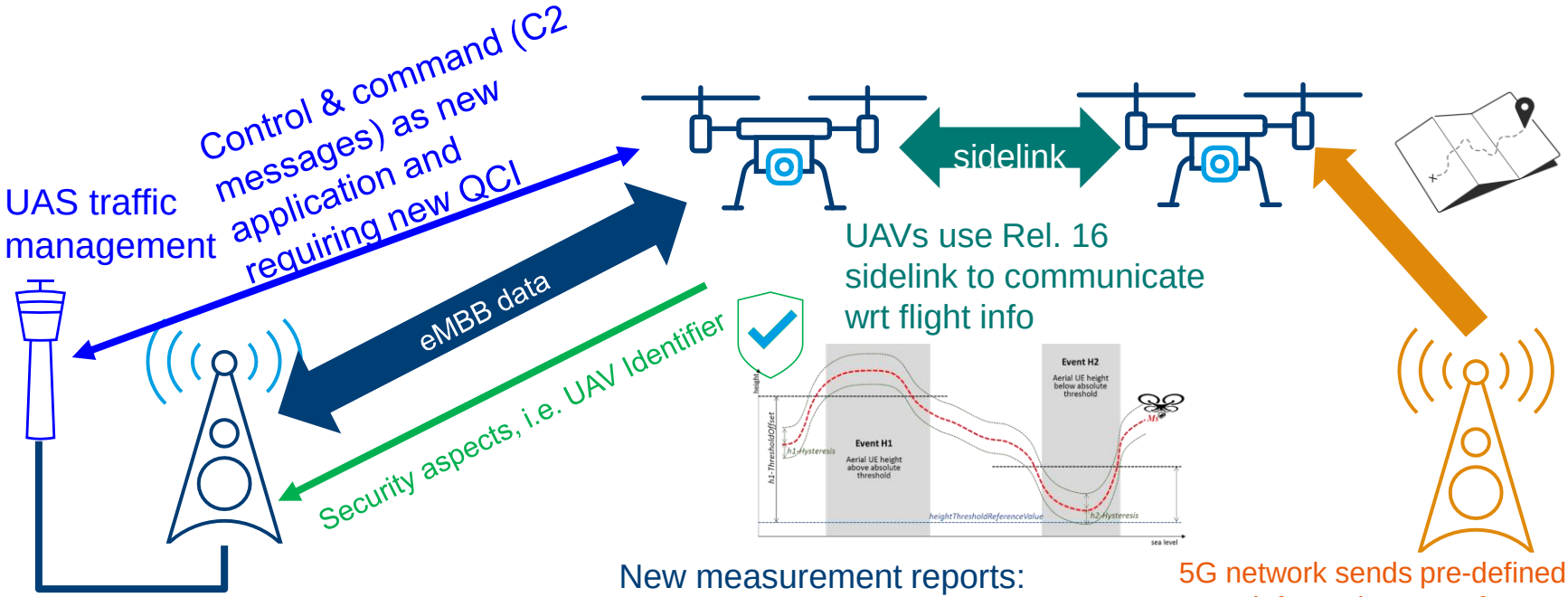
UNCREWED AERIAL VEHICLES (UAV) + AIR TO GROUND (ATG)

REL-18 AIR TO GROUND (ATG)



REL-18 UAV FLIGHT CONTROL ASPECTS

Three different methods for UAV flight control coordinated by 5G system



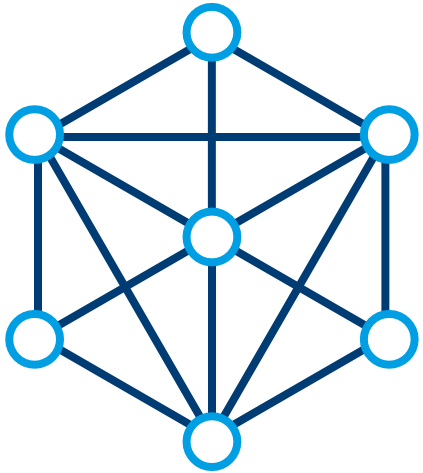
The ongoing evolution of 5G

SUSTAINABILITY & NETWORK ENERGY SAVING

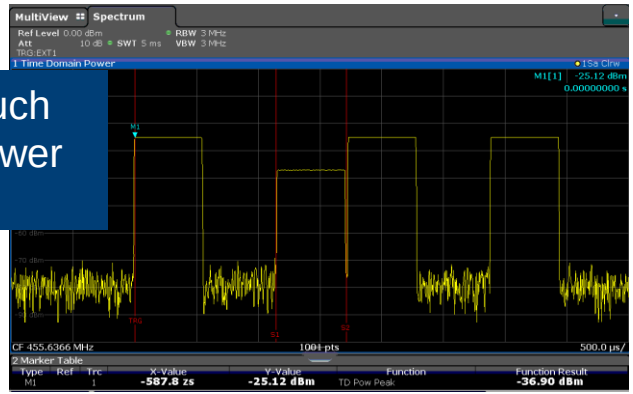
NETWORK ENERGY SAVING (NES)

ES = Energy saving
EE = Energy efficiency
EC = Energy consumption

1. NES affects the entire network



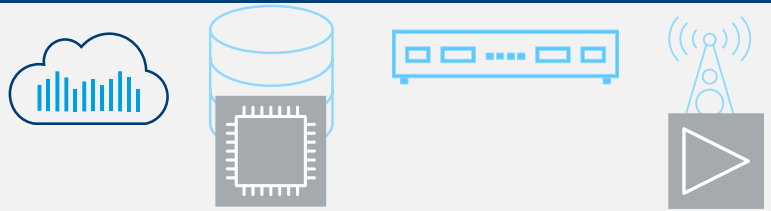
2. NES is much more than power ON/OFF



3. NES requires cooperation between RAN and UE

NETWORK ENERGY EFFICIENCY

Holistic approach: From cloud to component, energy saving methods in the entire 5G system



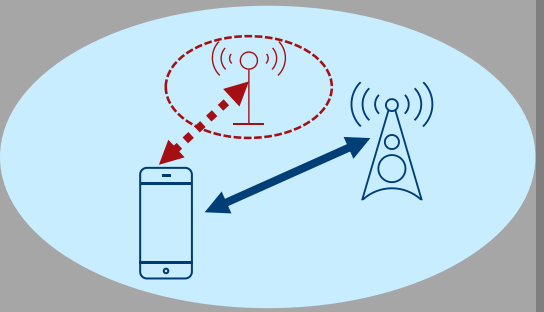
ETSI & 3GPP definition: Energy efficiency

$$EE_{MN,DV} = \frac{DV_{MN}}{EC_{MN}}$$

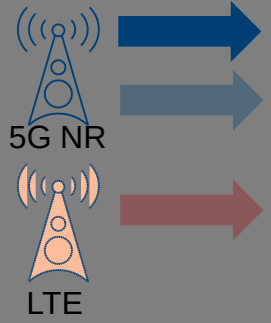
Data volume / energy consumption

$$EE_{MN,CoA} = \frac{CoA_{des.MN}}{EC_{MN}}$$

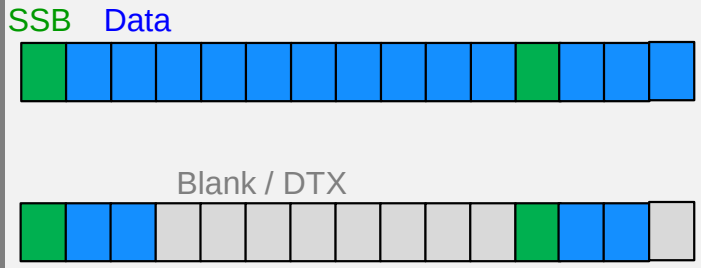
Designated coverage area / energy consumption



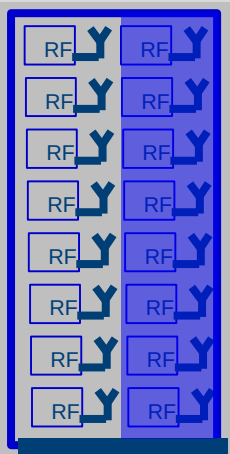
Turn on/off cells



Activate / de-activate carriers / RAT



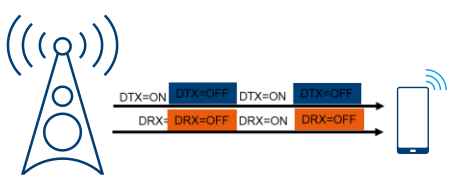
Advanced sleep mode (ASM)

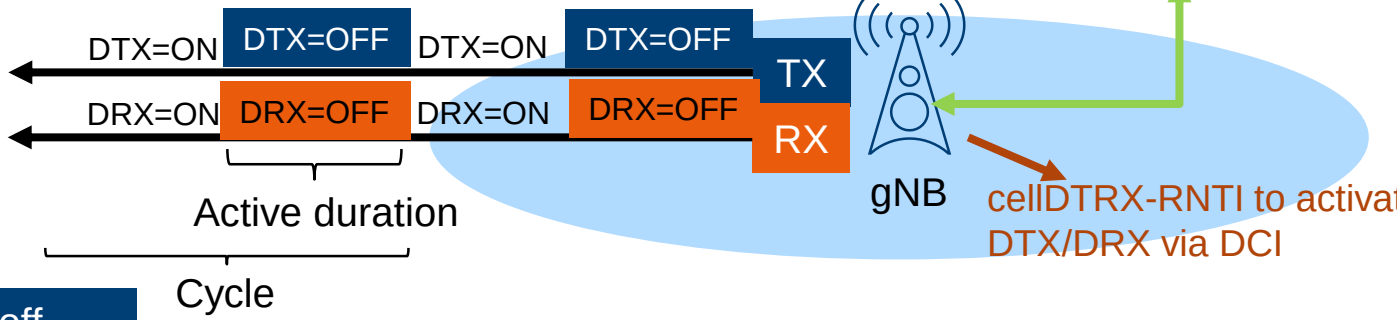


Turn on/off RF

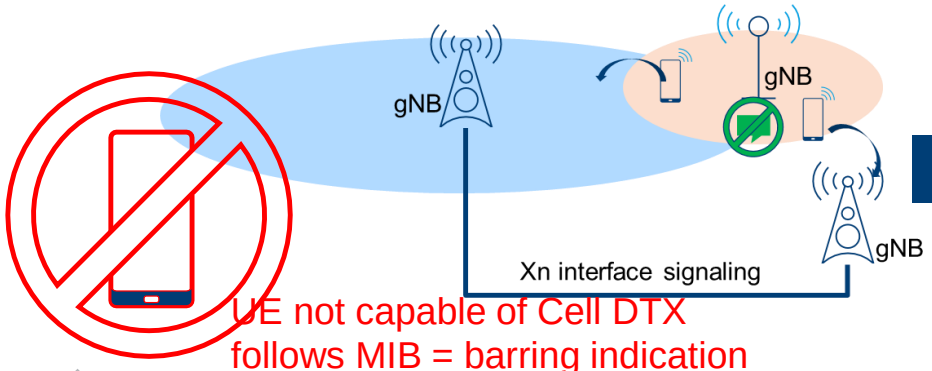
NES REL. 18 MECHANISMS

To facilitate gNB downlink RX and TX, UE can be configured with a periodic cell DTX/DRX pattern



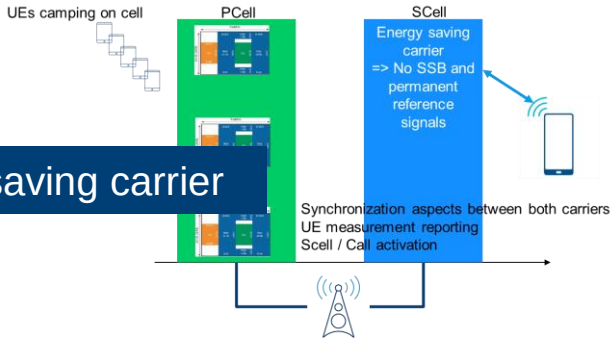


Intra/inter-system cell on/off



UE not capable of Cell DTX
follows MIB = barring indication

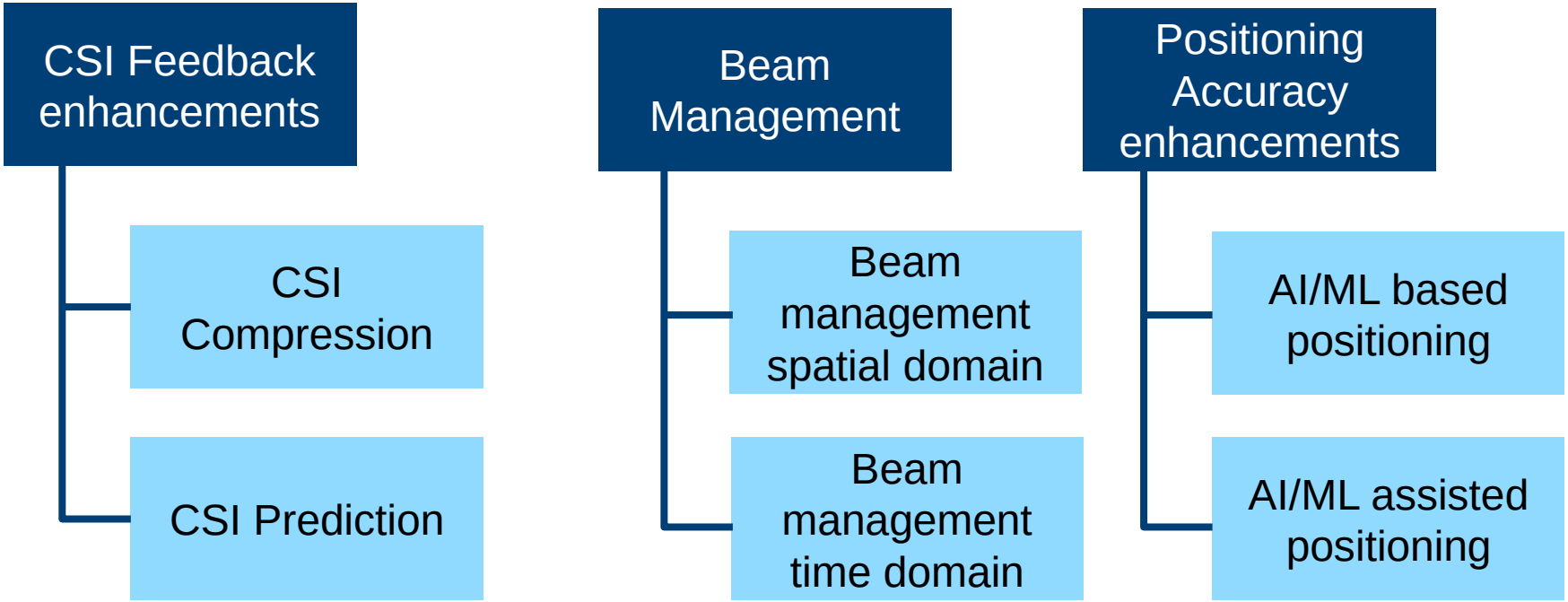
SCell energy saving carrier



The ongoing evolution of 5G

ARTIFICIAL INTELLIGENCE (AI) IN 5G

5G – FIRST AI – USE CASES

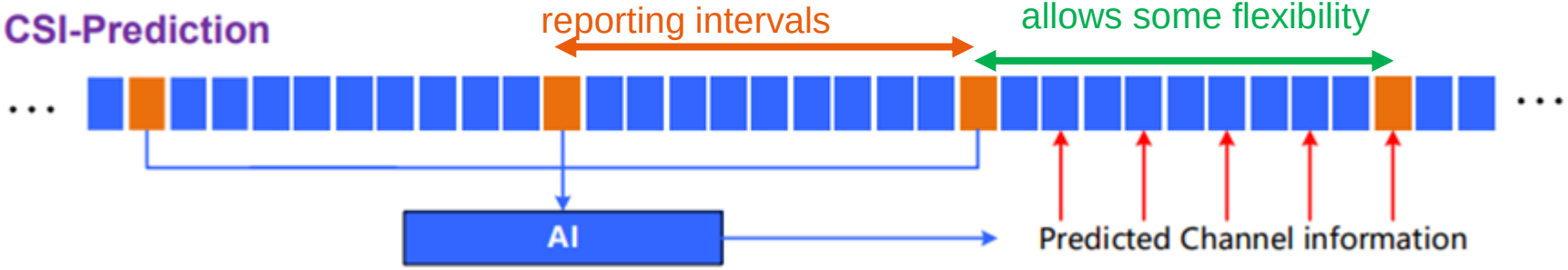


5G – AI FIRST USE CASES

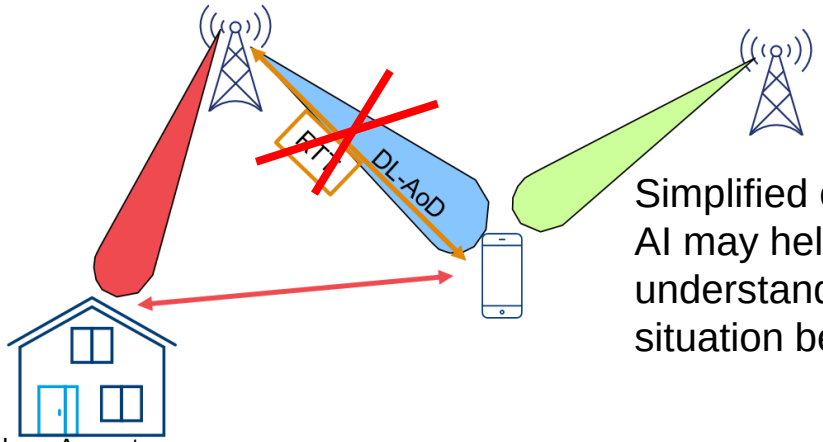
AI to learn channel, predict and reduce #CSI signals needed

Past: consider channel status as constant in between CSI reporting intervals

New: AI model predicts the „real“ channel conditions and allows some flexibility



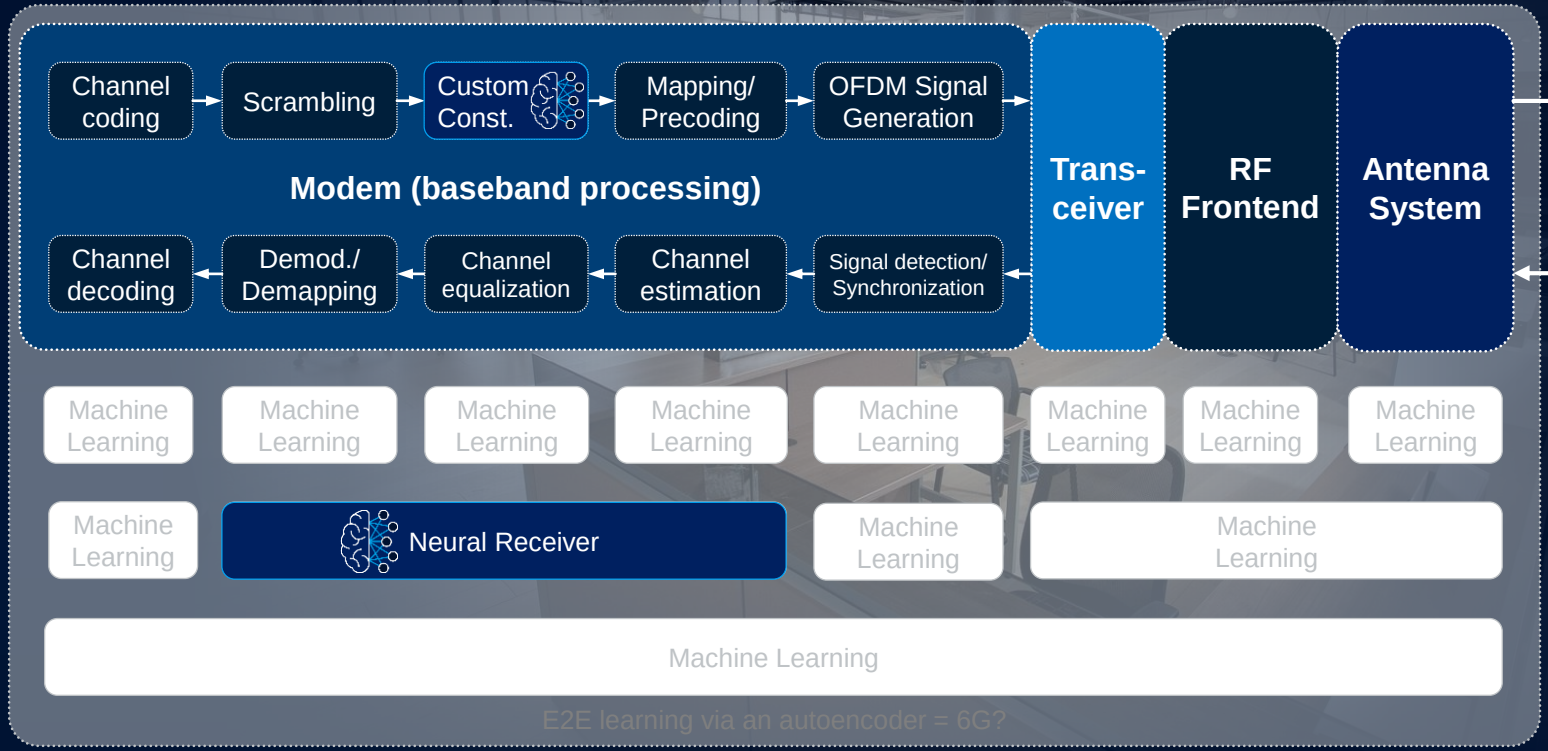
AI to enhance the position estimates + verify position determination



Simplified example: AI may help to understand the real situation better

TOWARDS AN AI-NATIVE AIR INTERFACE FOR 6G

ADVANCING THE NEURAL RECEIVER WITH CUSTOM CONSTELLATION



ML applied to individual processing blocks

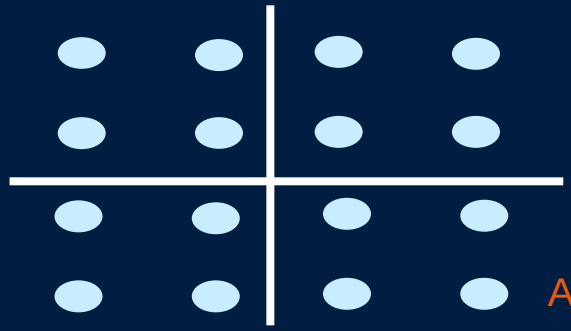
ML replaces multiple processing blocks

ML used to jointly optimize TX, RX and baseband processing;

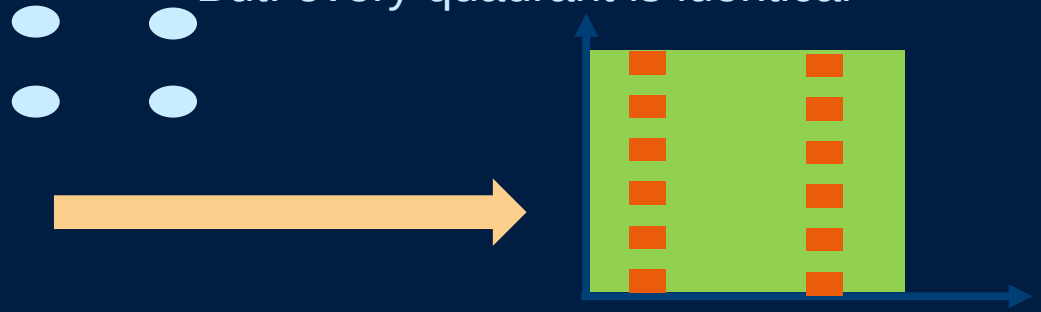
ML designs part of 6G PHY/MAC itself

Modulation scheme constellation aspects

Reminder 16QAM

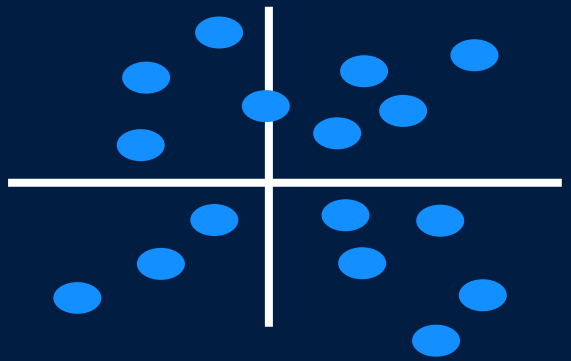


But: every quadrant is identical



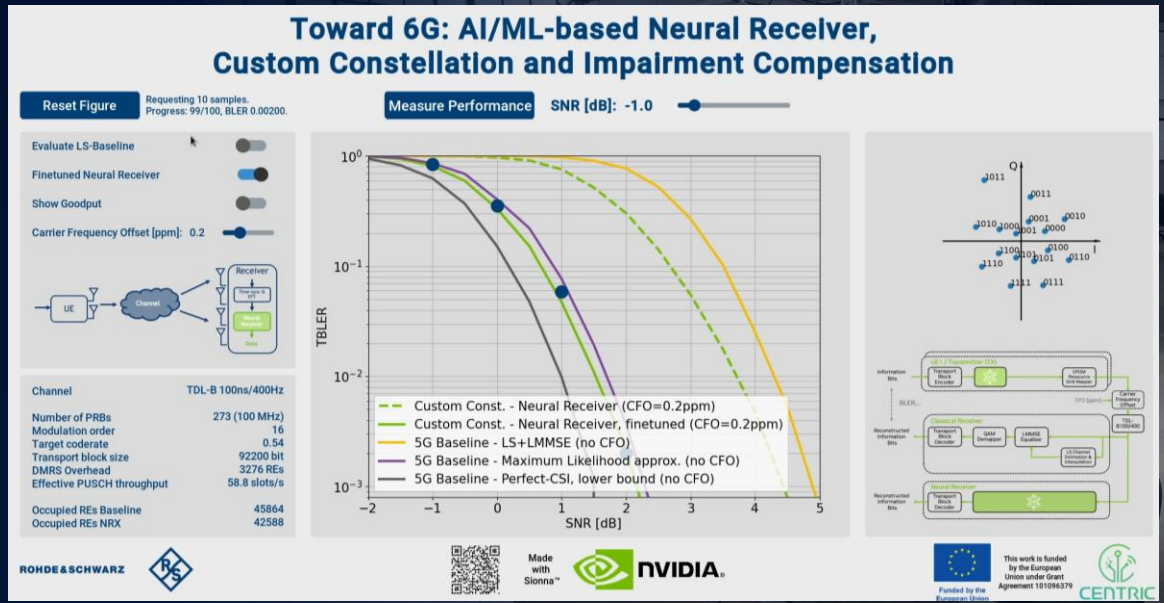
As radio channel (Fading) deteriorates the signal,
we need pilots, e.g. DMRS for channel estimation and equalization

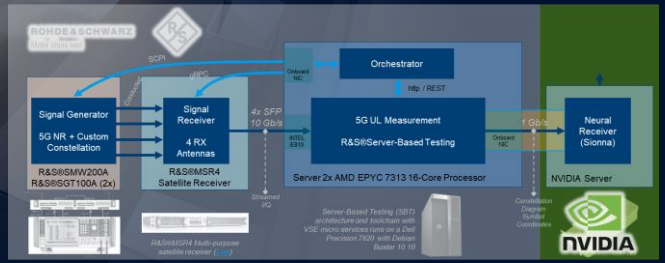
Idea: If we apply a scenario specific, pseudo-random looking constellation diagram, we may understand the constellation position as kind of reference signals



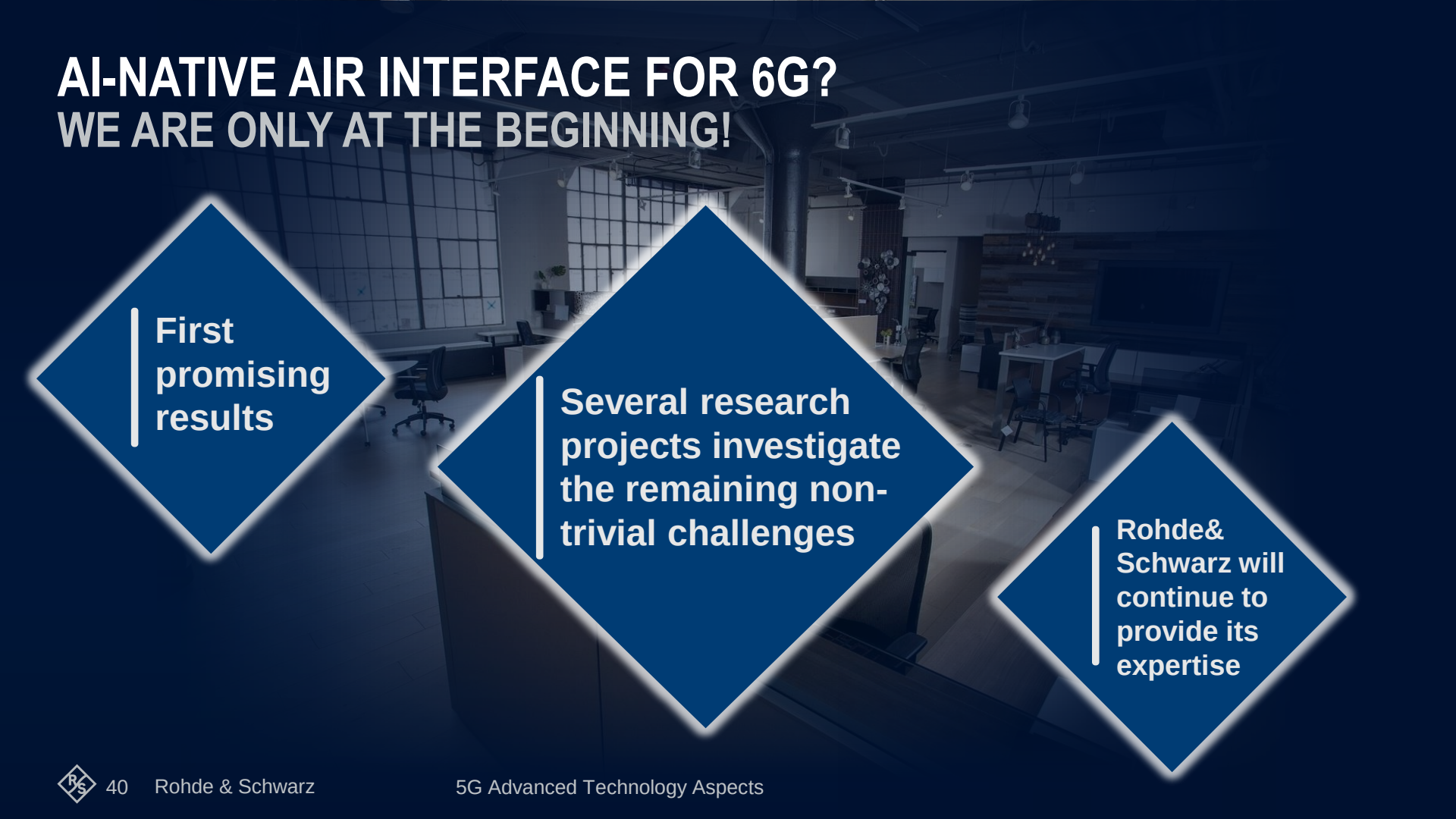
END-TO-END LEARNING TESTBED

Demoed @ MWC24





AI-NATIVE AIR INTERFACE FOR 6G?
WE ARE ONLY AT THE BEGINNING!



REL-19 : ITEMS (CORE)

Project (RAN1 Led)	WI/SI/Effort	Ref.
AI/ML - Air Interface	WI (4)	RP-234039
NR-MIMO Evolution	WI(2.5)	RP-234007
Evolution of duplex operation	WI(2.5)	RP-234035
Network energy savings	WI(2)	RP-234065
Low power WUS/WUR	WI(1.5)	RP-234056
ISAC	SI 2Q'24 (1)	RP-234069
Exploring study in new spectrum (7-24GHz)	SI 2Q'24 (1)	RP-234018
Ambient IoT	SI (3.5)	RP-234058

Project (RAN2 Led)	WI/SI/Effort	Ref.
Mobility Enhancements	WI(2)	RP-234036
Enhancements for XR	WI(2)	RP-234057
NTN (Non-Terrestrial Networks) evolution - NR	WI(2)	RP-234075
NTN (Non-Terrestrial Networks) evolution - IoT	WI(1)	RP-234070
AI/ML for Air Interface (Mobility)	SI(2)	RP-234055

Project (RAN3 Led)	WI/SI/Effort	Ref.
SON/MDT Enhancements	~1.5 TUs	RP-234038
AI/ML for NG-RAN	SI+WI(2)	RP-234054
Additional topological improvements	SI+WI(2)	RP-234041

- RAN4 Items will be defined in March 2024
- Additional LTE WI tbd in March 2024

Legend : WI Only ; SI only; SI + WI
Effort 1= 1 TU pro meeting

SUMMARY

- Deployment of 5G networks is in full swing! Clear evolution path provided by the industry's standardization organization
- Academia and key industry players are exploring the boundaries and started looking into next generation of wireless communication aka 6G
- New, challenging technology components may complement the existing concept of cellular networks or even provide revolutionary aspects
- Rohde&Schwarz is actively engaged in this phase of fundamental research, providing our expertise in test and measurement to make ideas real