THE ONGOING EVOLUTION OF 5G NEW RADIO

BEYOND RELEASE 15

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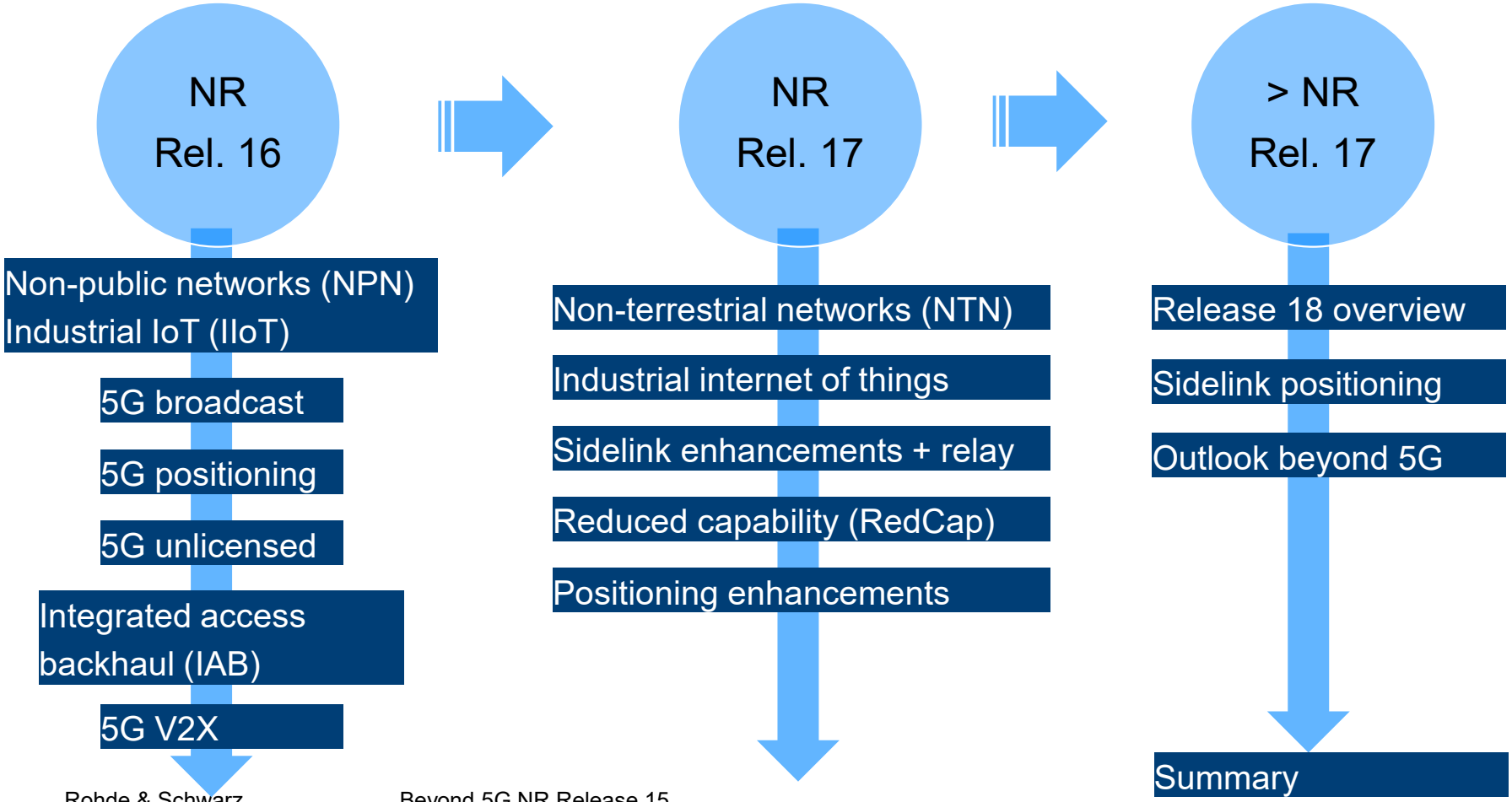
Make ideas real

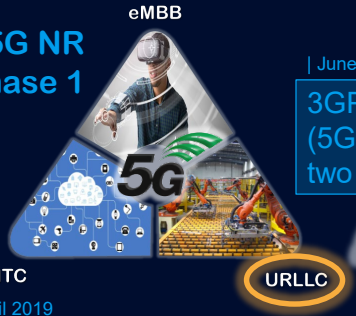
5G NR BEYOND RELEASE 15 - AGENDA



5G NR TECHNOLOGY EVOLUTION – THE NEXT PHASE

LTE LTE Advanced LTE Advanced Pro

5G NR Phase 1



| April 2019

1st 5G NR networks (FR1, FR2) launched; focus: eMBB

| June 2020

3GPP Release 16 (5G Phase 2); focus: two market verticals

5GACIA

5GAA Automotive Association

| Sep 2022

3GPP Release 17 (5G Phase 2+); focus: NTN, NR Light, FR2+

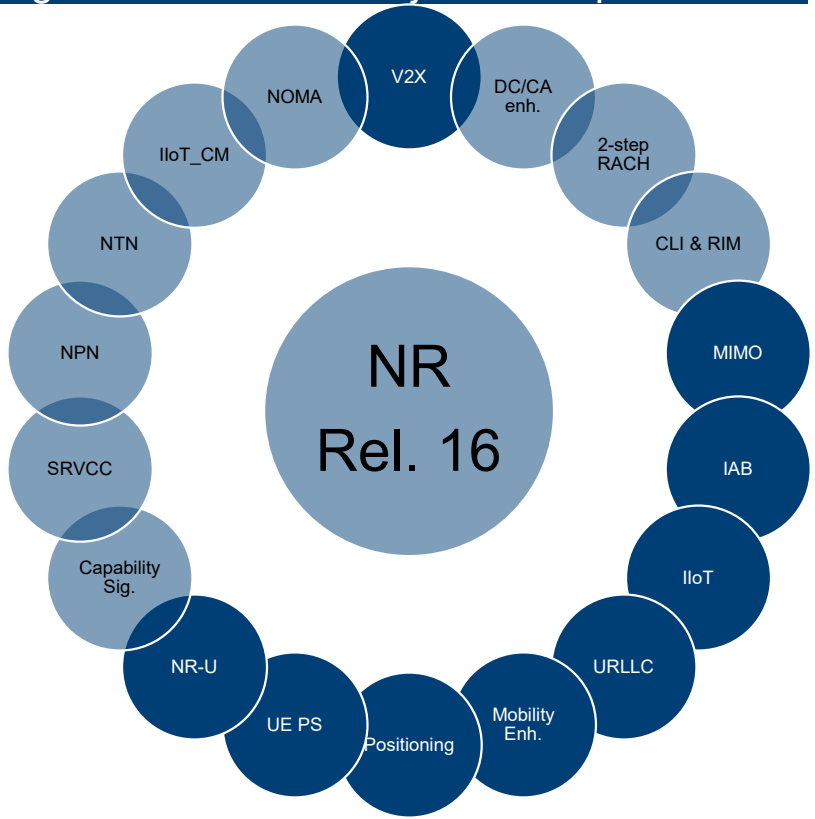
5G is a marathon, not a 100 m sprint…

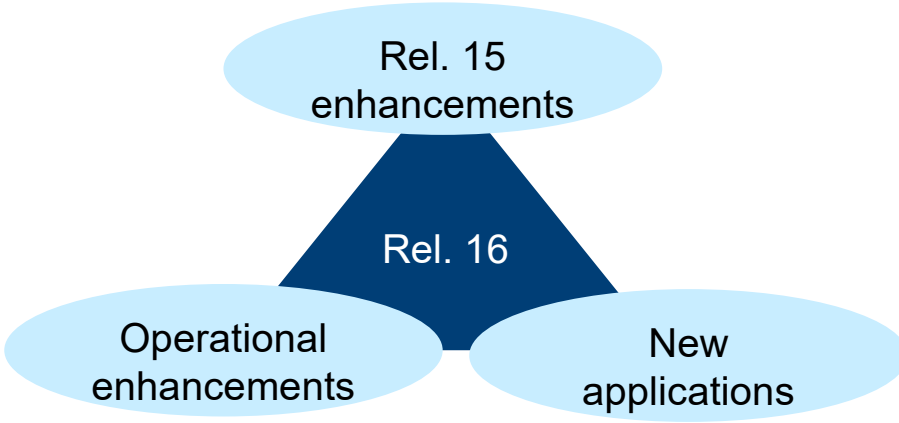
2018 2020 2022 2024 2026

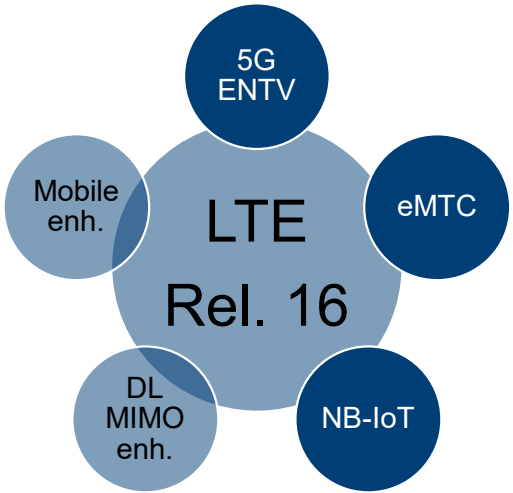
eMBB: enhanced Mobile Broadband
URLLC: Ultra-Reliable Low Latency Communication
mMTC: massive Machine Type Communication

3GPP REL. 16 TOPIC SUMMARY

Highlighted work items: major new aspects





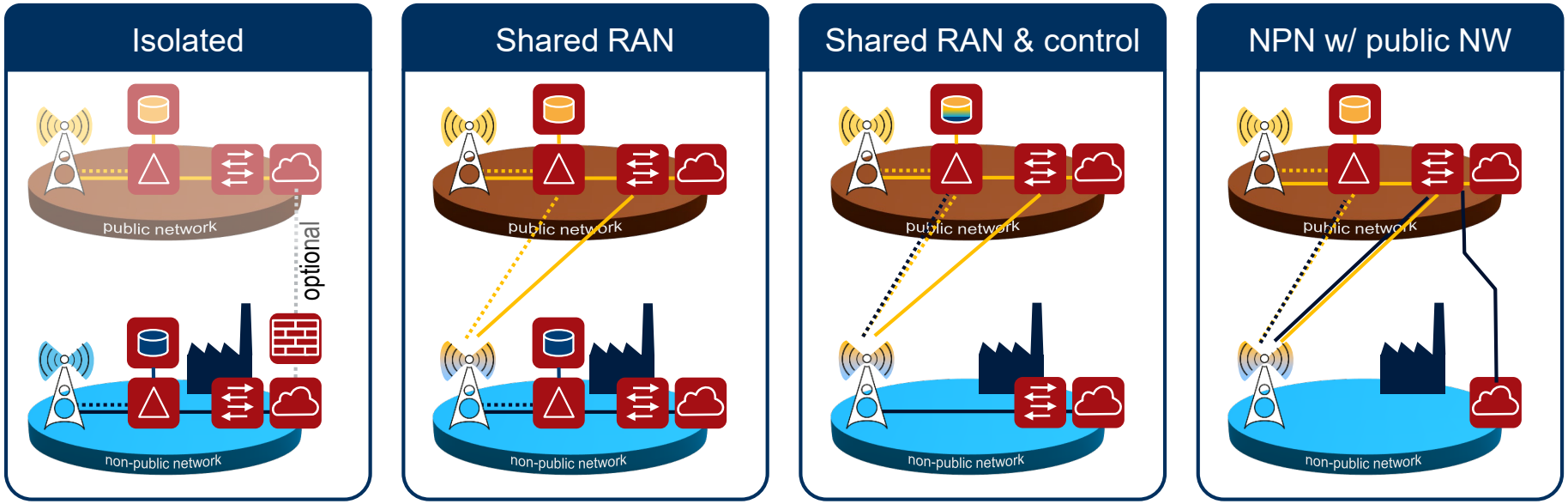


5G evolution, Releases 16 and 17

INDUSTRIAL IoT

INDUSTRY 4.0 SPECIFIC DEPLOYMENT SCENARIOS

5G-ACIA WP: 5G NON-PUBLIC NETWORKS (NPN) FOR INDUSTRIAL SCENARIOS

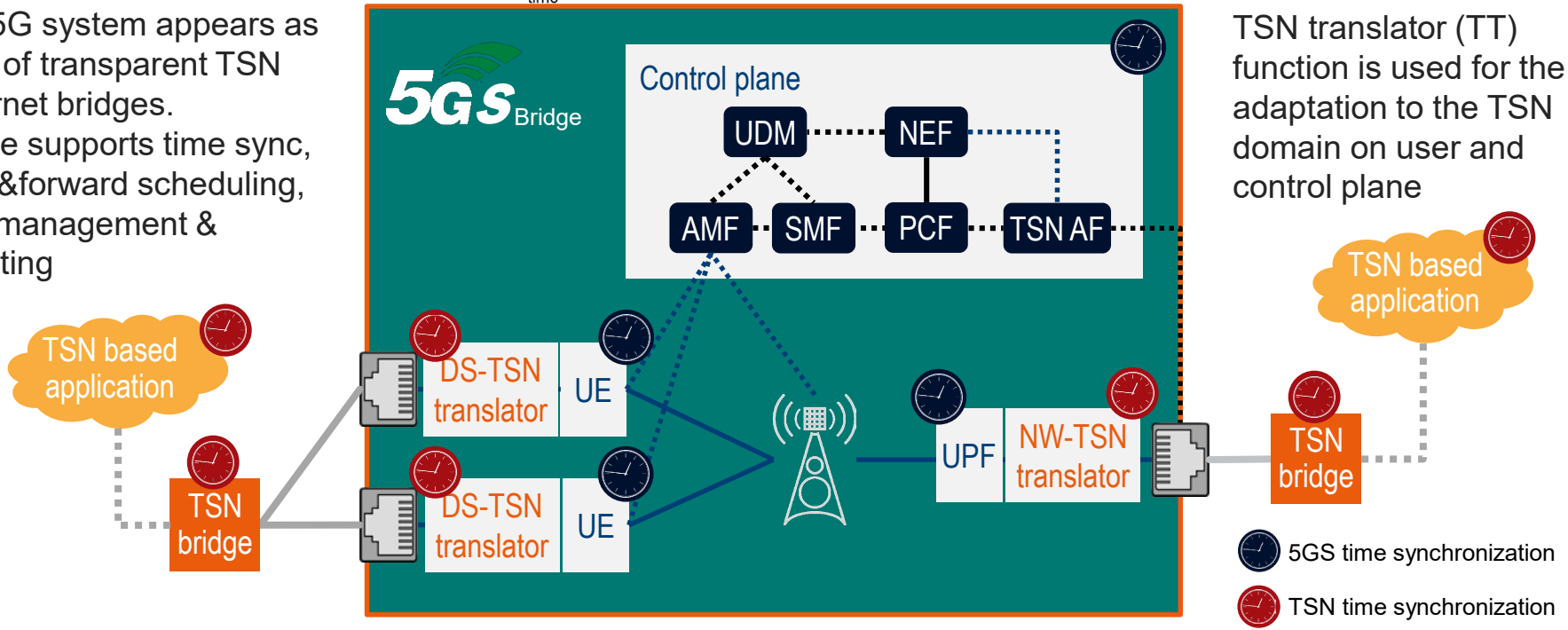


- Isolated NPN deployed on the organization's defined premises, such as a campus or a factory, offer high reliability and operation flexibility

5G INTEGRATION INTO AN ETHERNET: TSN ARCHITECTURE

The 5G system appears as a set of transparent TSN Ethernet bridges.
Bridge supports time sync, store&forward scheduling, jitter management & reporting

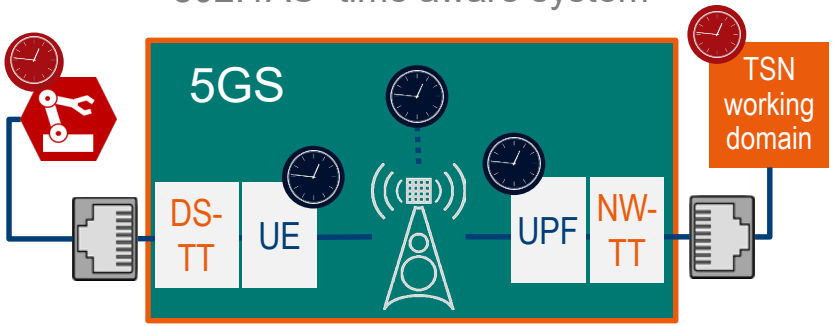
TSN translator (TT) function is used for the adaptation to the TSN domain on user and control plane



5G INTEGRATION INTO AN ETHERNET: TSN ARCHITECTURE
3GPP RELEASE 16 TECHNOLOGY COMPONENTS

Time synchronization

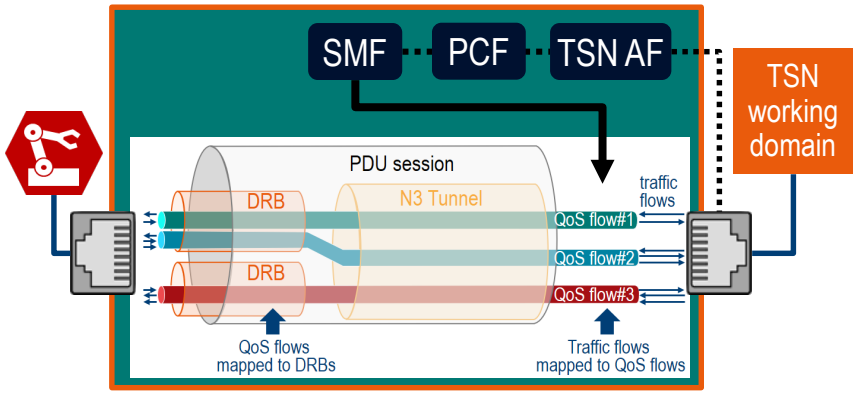
5GS can be considered as an IEEE 802.1AS “time aware system”



5GS calculates and adds the measured residence time between the TTs into the Correction Field (CF) of the synchronization packets of the TSN working domain (TS 23.501 - chapter 5.27.1).

gNB may signal 5G system time reference information to the UE using unicast or broadcast RRC signaling with a granularity of 10 ns

TSN traffic characteristic exchange

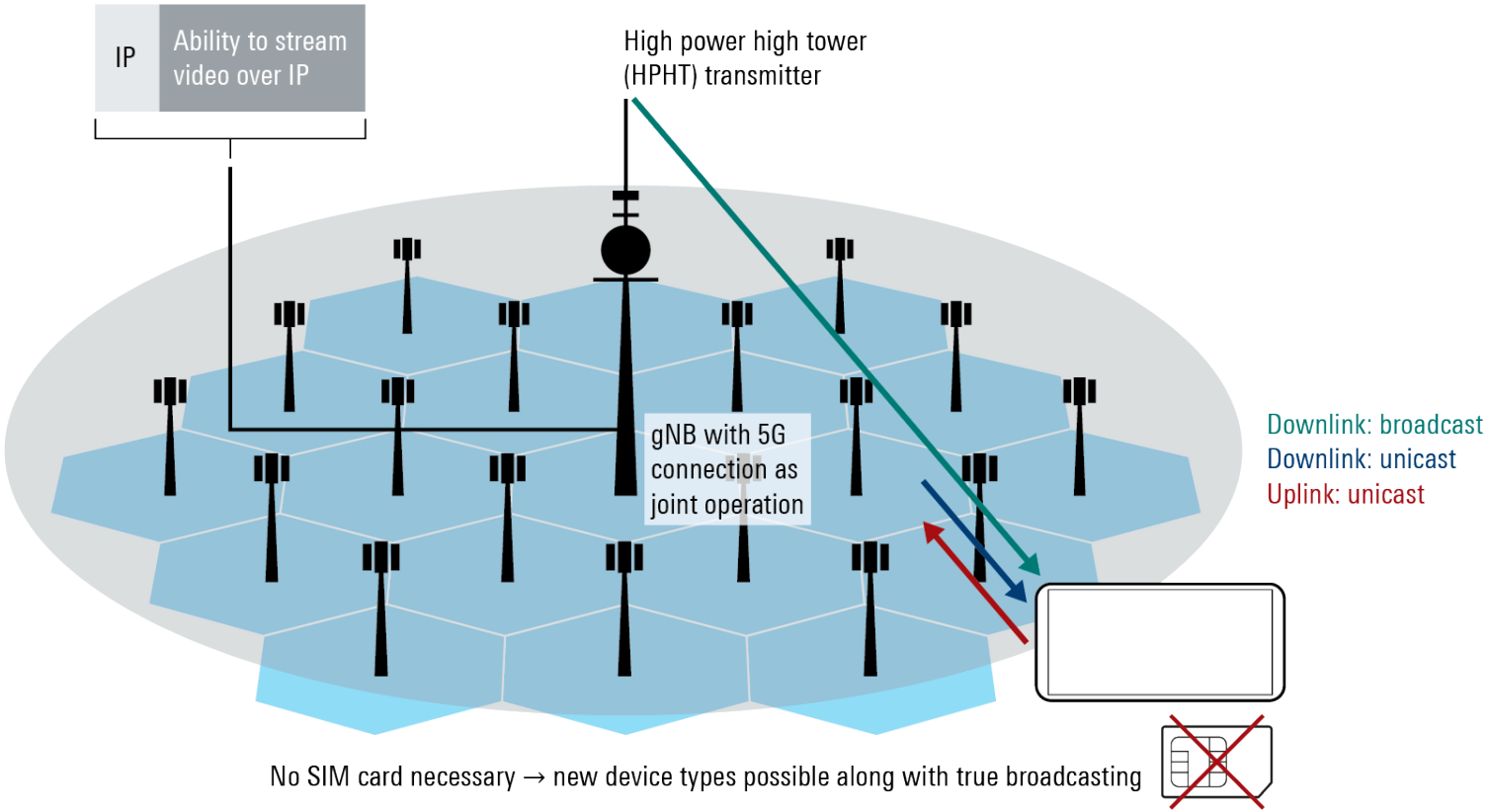


The knowledge of TSN traffic pattern is useful for the gNB to allow it to more efficiently schedule periodic, deterministic traffic flows either via Configured Grants, Semi-Persistent Scheduling or with dynamic grants.

5G evolution, Releases 16 and 17

5G BROADCAST

FEMBMS – FURTHER ENHANCED MBMS, REL. 14 FEATURE



5G BROADCAST TECHNOLOGY EVOLUTION

Traditional broadcast world

Rel. 14 FeMBMS

Rel. 15

Rel. 16 LTE-based 5G terrestrial broadcast

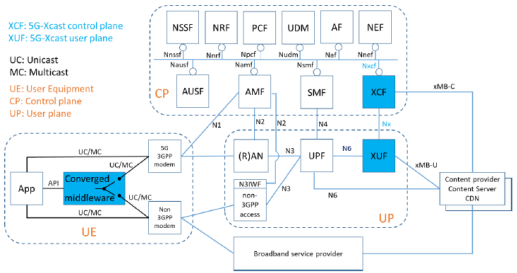
Converging worlds

Traditional cellular world

Rel. 15

Rel. 16

Rel. 17 Introduction of multicast + broadcast



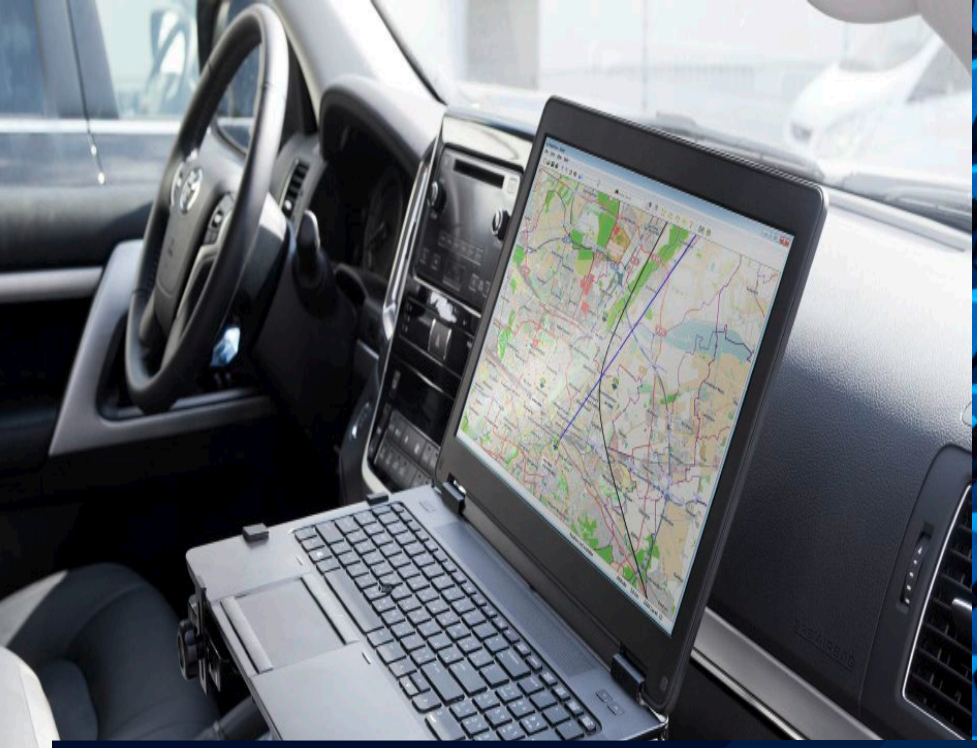
Rohde & Schwarz

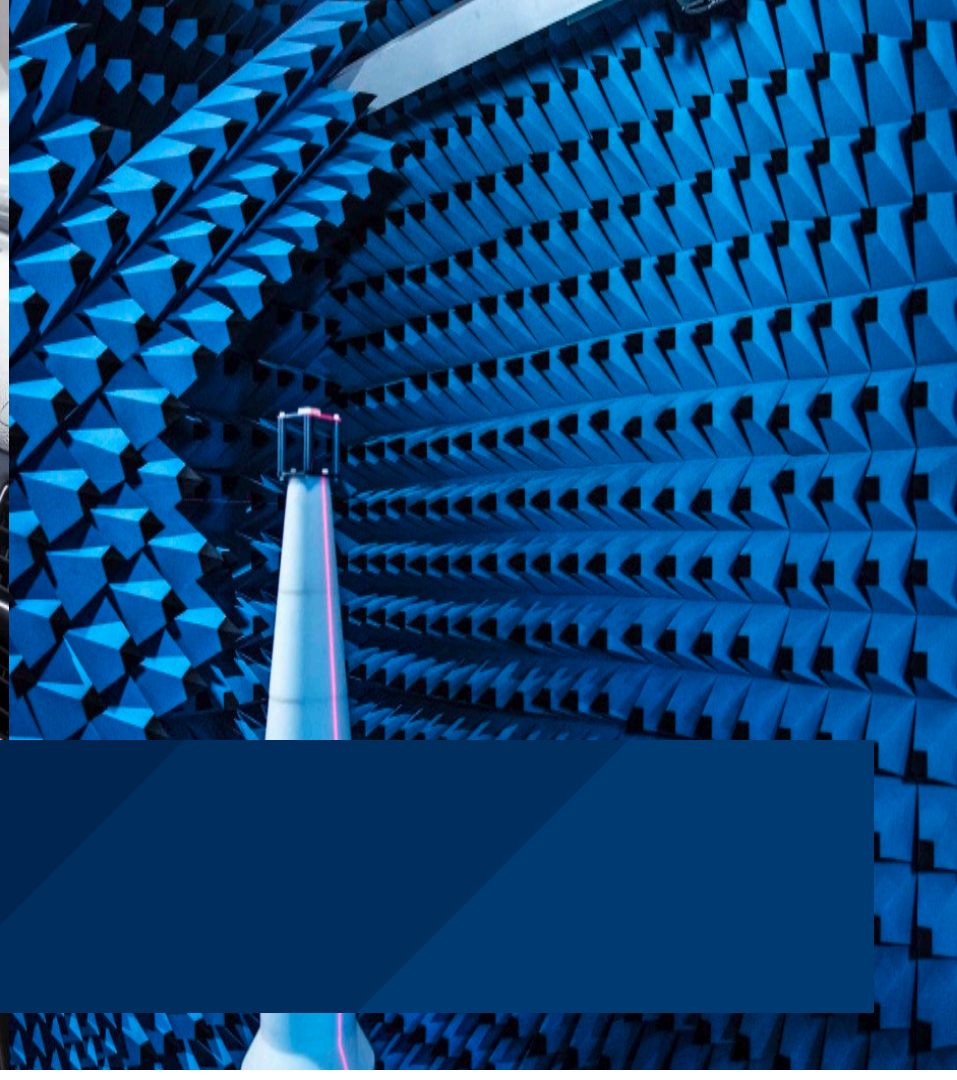
Impact on infrastructure to enable broadcast + multicast

Beyond 5G NR Release 15

	μ	Δf (Hz)	T_U (MS)	CP FRACTION	T_{CP} (MS)	T_S (MS)	SC_{RB}	ISD (km)
A	0	15000	66.67	~7%	4.7/5.1	0.07	12	1.4
B	0	15000	66.67	20%	16.67	0.08	12	5
C	-1	7500	133.33	20%	33.33	0.17	24	10
D	-2	3750	266.67	20%	66.67	0.33	48	20
E	-	2500	400.00	20%	100.00	0.50	72	30
F	-3	1875	533.33	20%	133.33	0.67	96	40
G	-	1250	800.00	20%	200.00	1.0	144	60
H	-	625	1600.00	20%	400.00	2.0	288	120
I	-	3333	300.00	10%	33.33	0.33	54	10
J	-	2045.45	488.88	2.22%	11.11	0.50	88	3.3
K	-	1022.72	977.78	2.22%	22.22	1.0	176	6.6
L	-	511.36	1955.56	2.22%	44.44	2.0	352	13.2
M	-	416.67	2400	4%	100	2.5	432	30
N	-	208.33	4800	4%	200	5.0	864	60
O	-	104.67	9600	4%	400	10.0	1728	120
P	-	217.39	4600	8%	400	5.0	828	120

5G Xcast: study on several numerologies to allow mix mode for several coverage scenarios

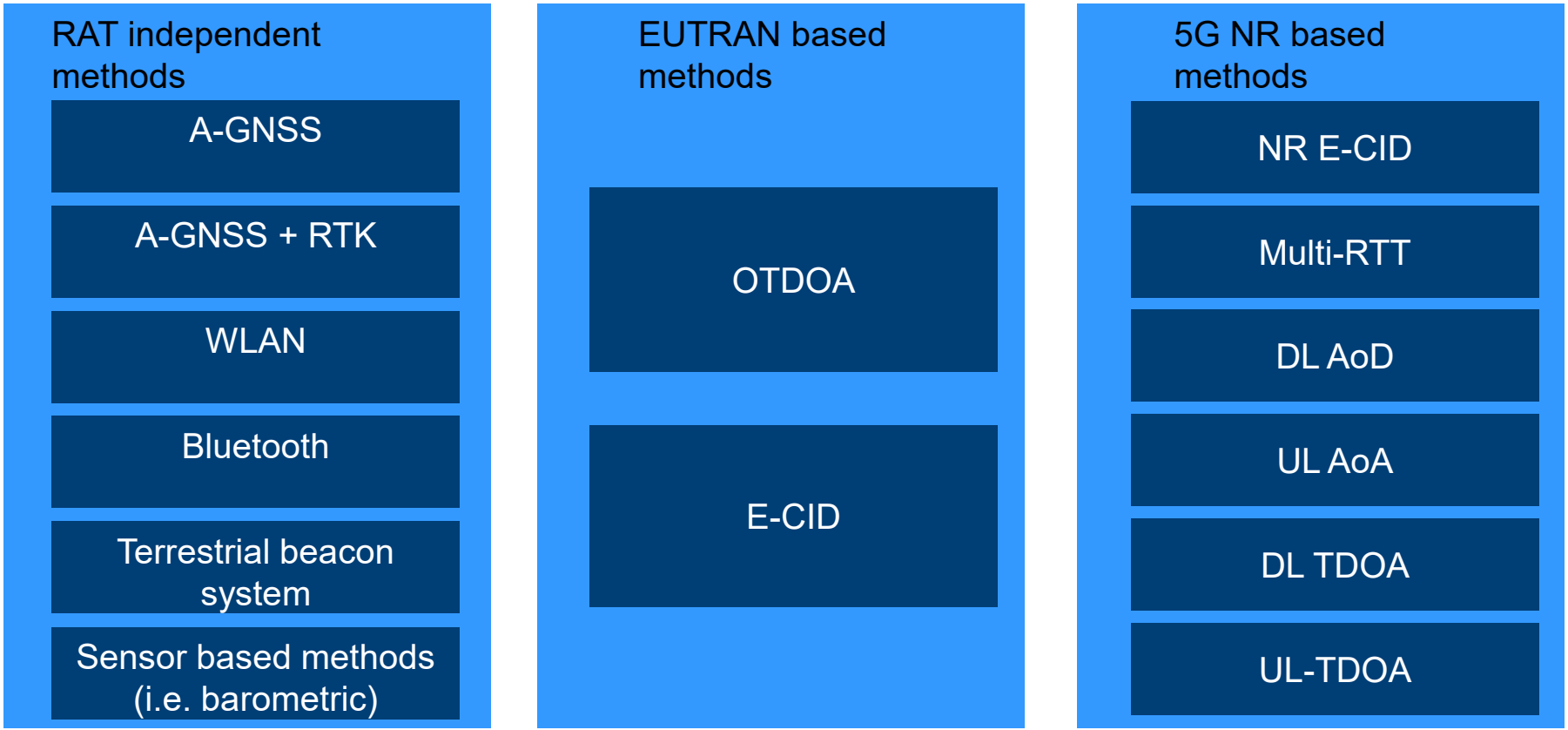




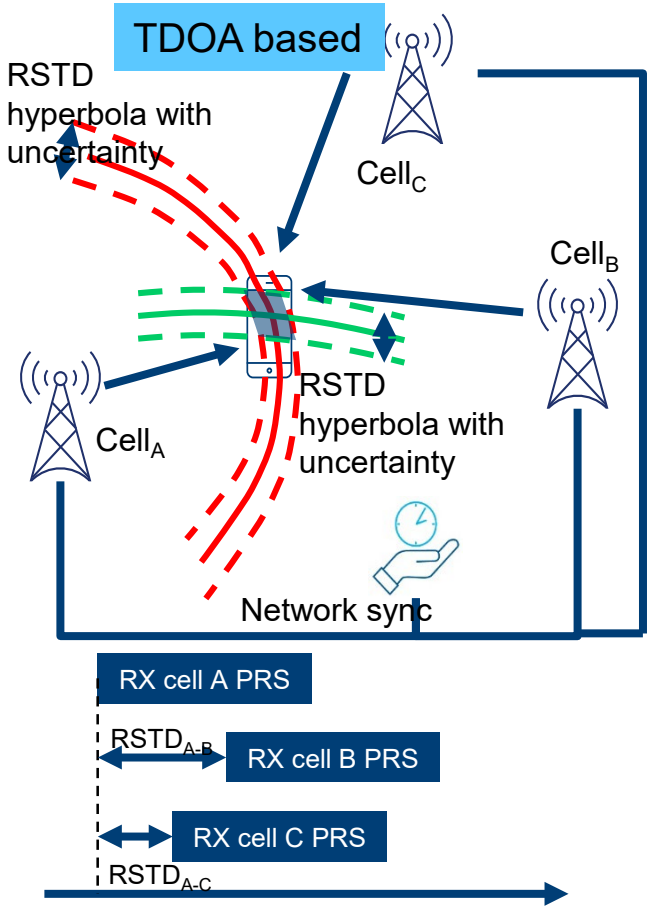
5G evolution, Releases 16 and 17

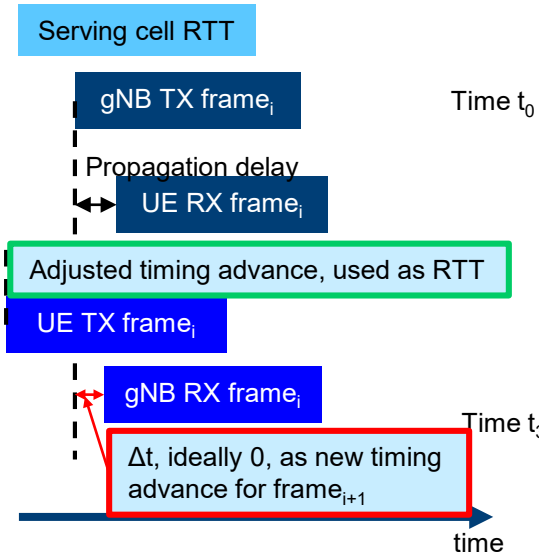
5G – POSITIONING

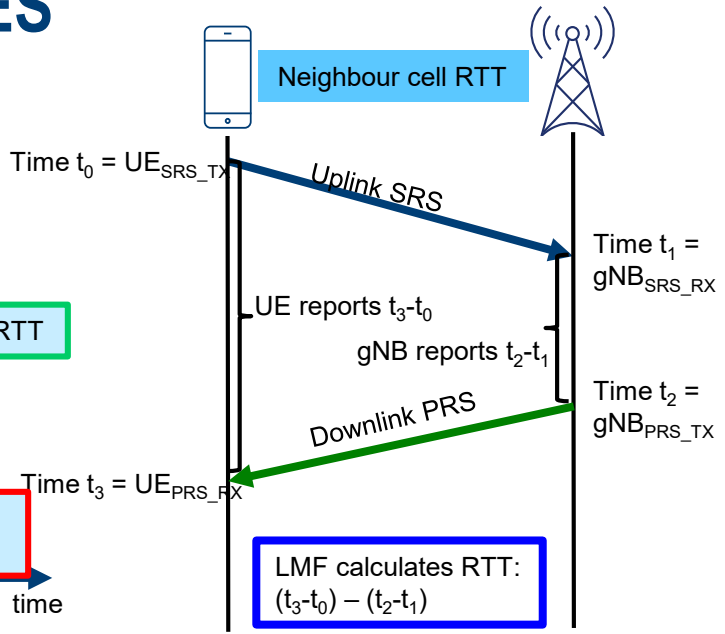
NR POSITIONING FLEXIBILITY

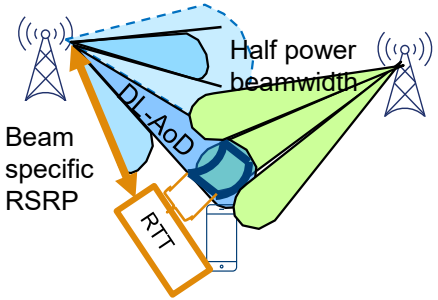


5G NR RAT BASED LBS TECHNOLOGIES









Angle based

REL. 16 POSITIONING REFERENCE SIGNALS (PRS)

$$r(m) = \frac{1}{\sqrt{2}}\left(1 - 2c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1 - 2c(2m+1)\right)$$

Pseudo-random sequence for PRS

dl-PRS-SequenceID

$$c_{init} = \left(2^{22}\left\lfloor \frac{n_{ID,seq}^{PRS}}{1024} \right\rfloor + 2^{10}\left(N_{symb}^{slot} n_{s,f}^{\mu} + l + 1\right)\left(2\left(n_{ID,seq}^{PRS} \bmod 1024\right) + 1\right) + \left(n_{ID,seq}^{PRS} \bmod 1024\right)\right) \bmod 2^{31}$$

PRS mapping on resource elements k,l

Frequency offset: dl-PRS-ReOffset

Subcarrier comb: dl-PRS-CombSizeN

$$a_{k,l}^{(p,\mu)} = \beta_{PRS} r(m)$$

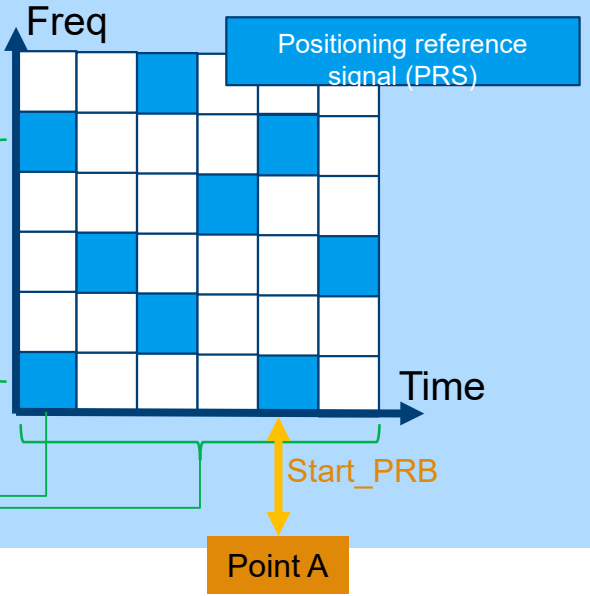
$$m = 0, 1, \ldots$$

$$k = mK_{comb}^{PRS} + \left(\left(k_{offset}^{PRS} + k'\right) \bmod K_{comb}^{PRS}\right)$$

$$l = l_{start}^{PRS}, l_{start}^{PRS} + 1, \ldots, l_{start}^{PRS} + L_{PRS} - 1$$

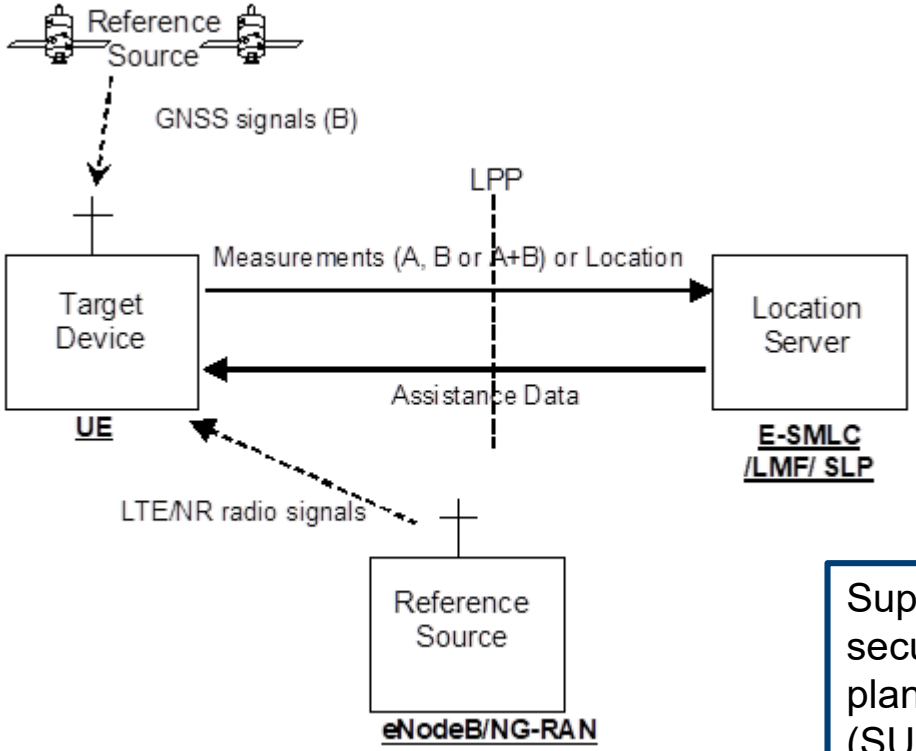
Qunatity of symbols: dl-PRS-NumSymbols

Symbol offset: dl-PRS-ResourceSymbolOffset



REL-16: NR POSITIONING – COOPERATION WITH LTE

Updating location positioning protocol (LPP) from LTE



Introducing location management function (LMF) in 5GC

Supporting secure user plane location (SUPL)

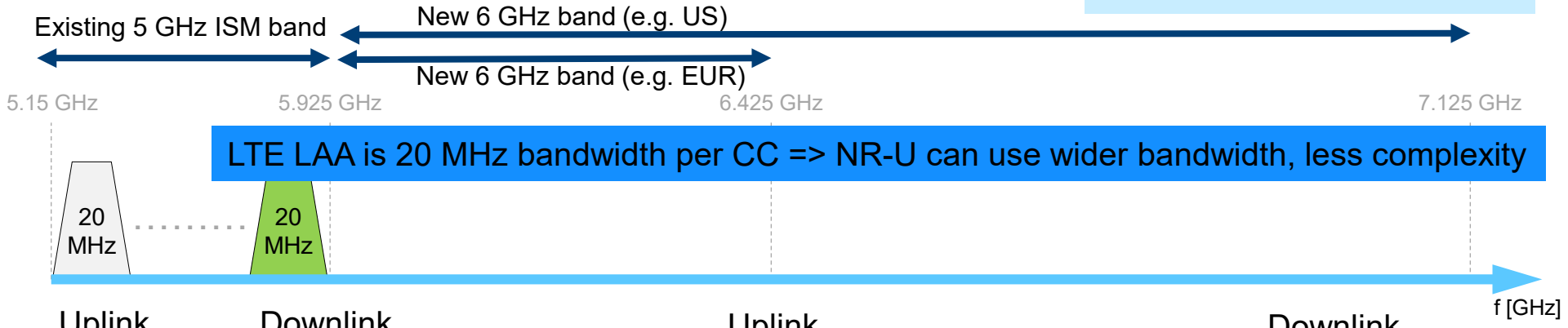
Source TS 37.355

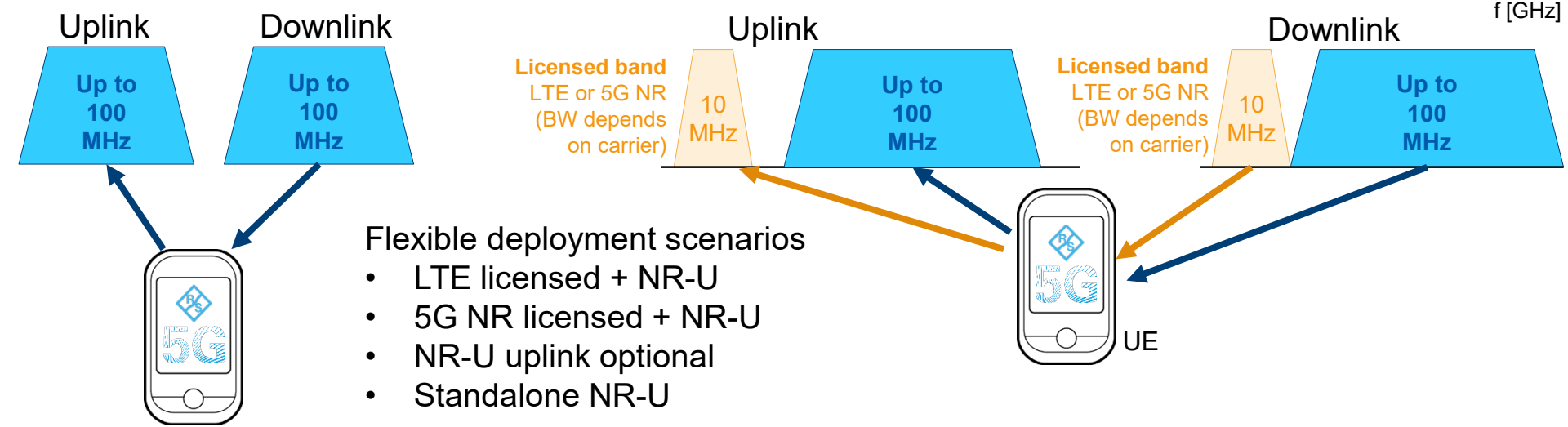
5G evolution, Releases 16 and 17

5G NR – UNLICENSED (NR-U)

5G NR IN UNLICENSED SPECTRUM (NR-U)

Outlook: NR-U in 57-71 GHz

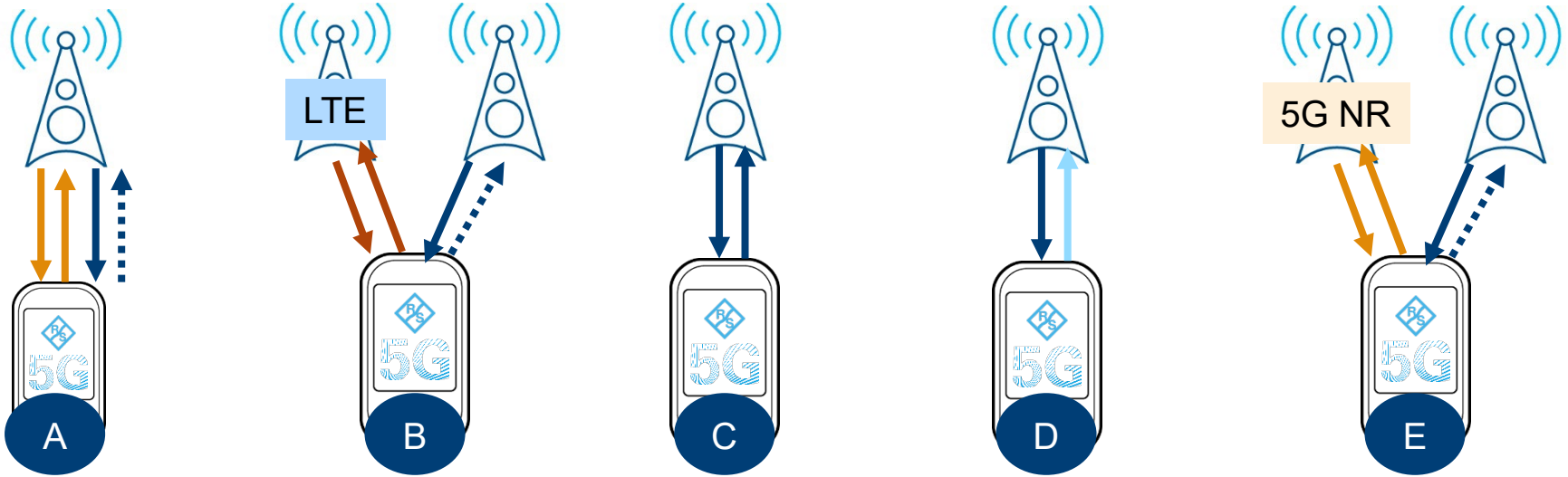




Flexible deployment scenarios

- LTE licensed + NR-U
- 5G NR licensed + NR-U
- NR-U uplink optional
- Standalone NR-U

REL. 16: NR ACCESS TO UNLICENSED SPECTRUM (NR-U)

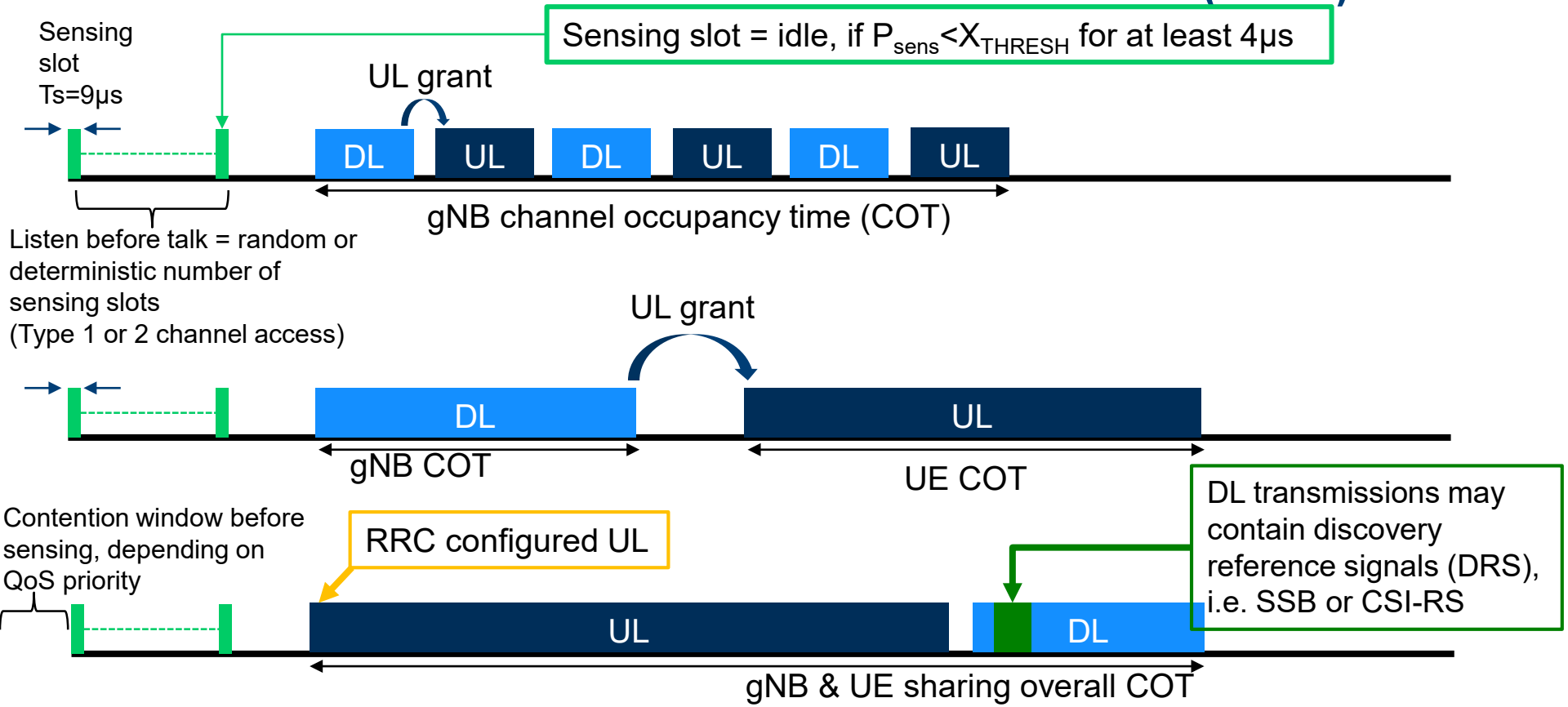


- Scenario A: Carrier aggregation between licensed band NR (PCell) and NR-U (SCell)
  - NR-U SCell may have both DL and UL, or DL-only
- Scenario B: Dual connectivity between licensed band LTE (PCell) and NR-U (PSCell)
- Scenario C: Stand-alone NR-U
- Scenario D: A stand-alone NR cell in unlicensed band and UL in licensed band
- Scenario E: Dual connectivity between licensed band NR and NR-U

Unlicensed
Licensed NR
Licensed LTE

Scenarios acc. TR 38.889

REL-16: NR ACCESS TO UNLICENSED SPECTRUM (NR-U)

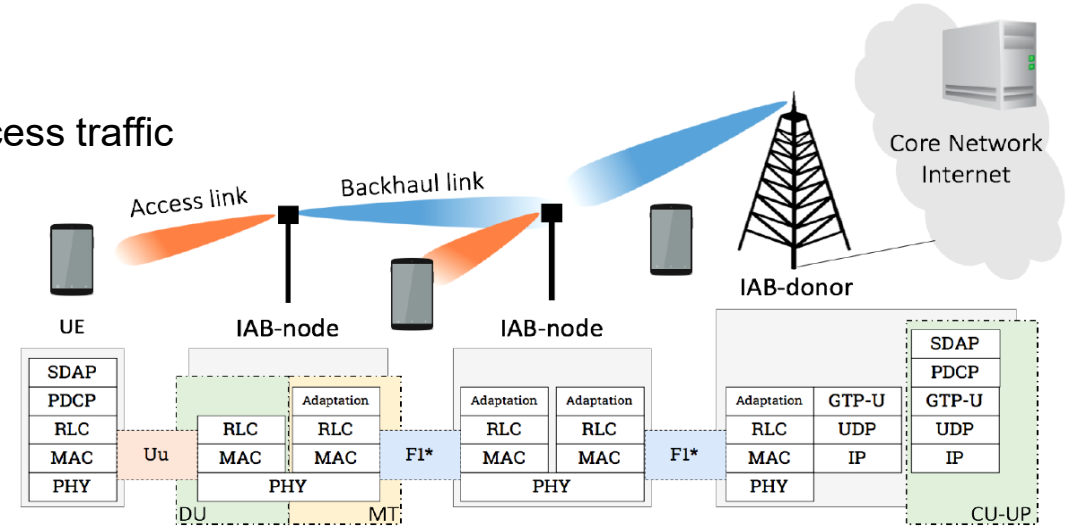


5G evolution, Releases 16 and 17

INTEGRATED ACCESS BACKHAUL (IAB) + ENH. MIMO

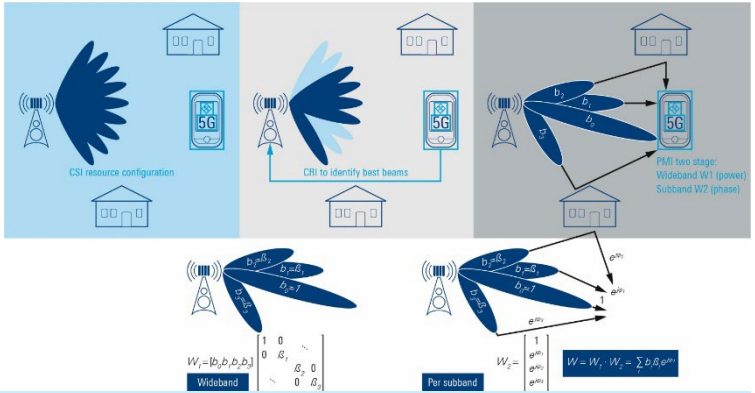
REL-16: NR INTEGRATED ACCESS AND BACKHAUL (IAB)

- Wireless backhaul links to relay the access traffic
- Enabling flexible and ultra-dense cell deployments at lower cost
- Multi-hops for the short range in mmWave

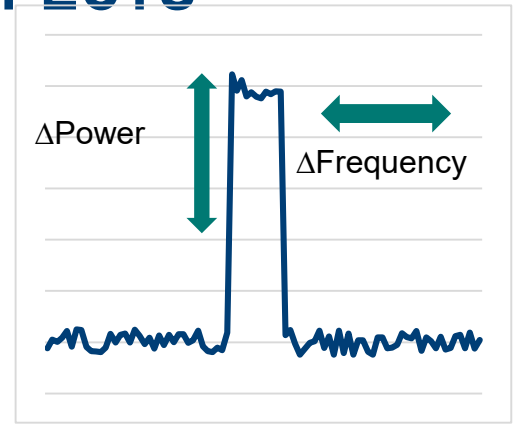


- Replaces the proprietary solutions in current (extensively used) wireless backhaul links (P2P, LOS)
- Motivated by larger bandwidths and native beamforming in NR (as opposed to LTE Rel-10 relays)
- Very beneficial for NR rollout and during the early phases of the initial growth

REL-16: NR eNR-MIMO = 5 ASPECTS

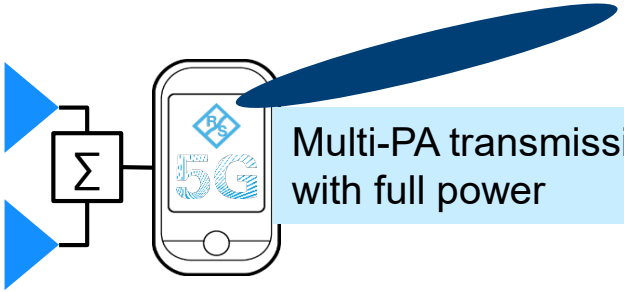


CSI enhancements, e.g. type II to close gap to near-ideal channel status info (CSI)

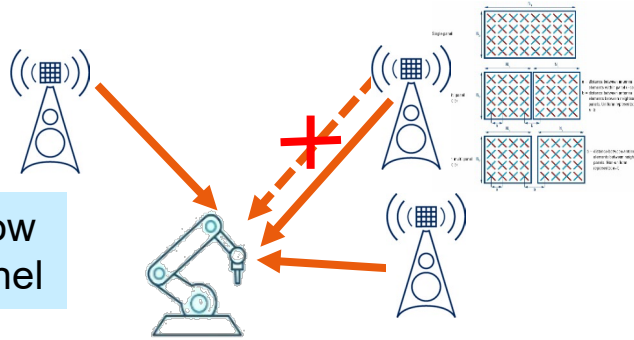


PAPR reduction

Multi-beam operation, including beam failure recovery & schemes for UL/DL beam selection



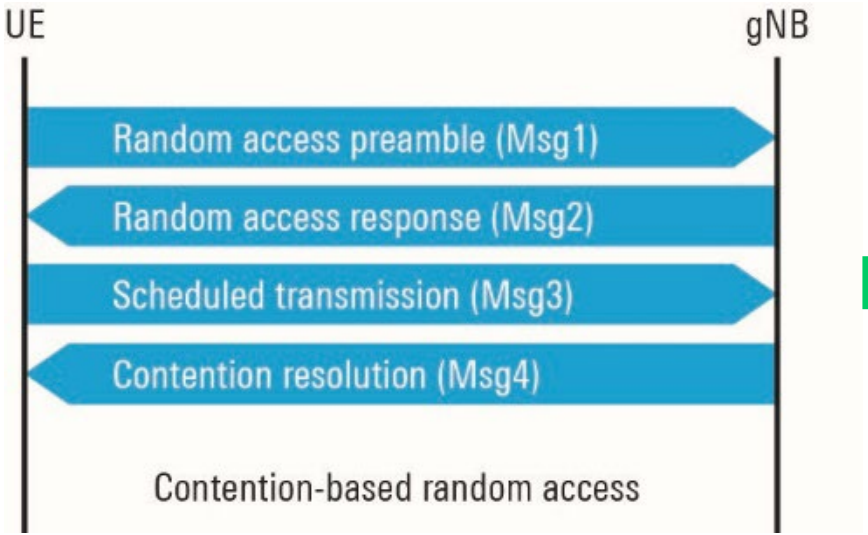
Multi-PA transmission with full power

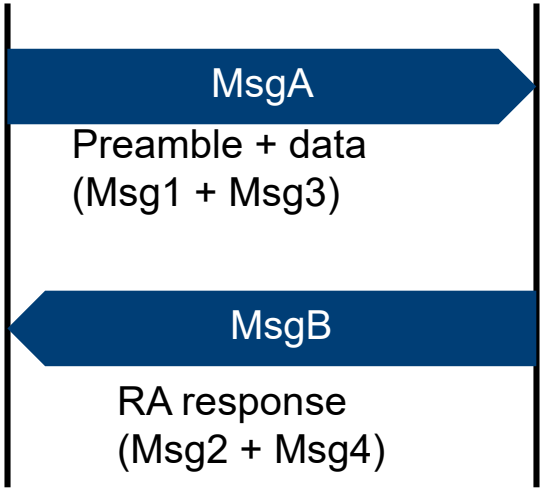


Multi-TRP scenario and allow larger size of multi-TRP/panel

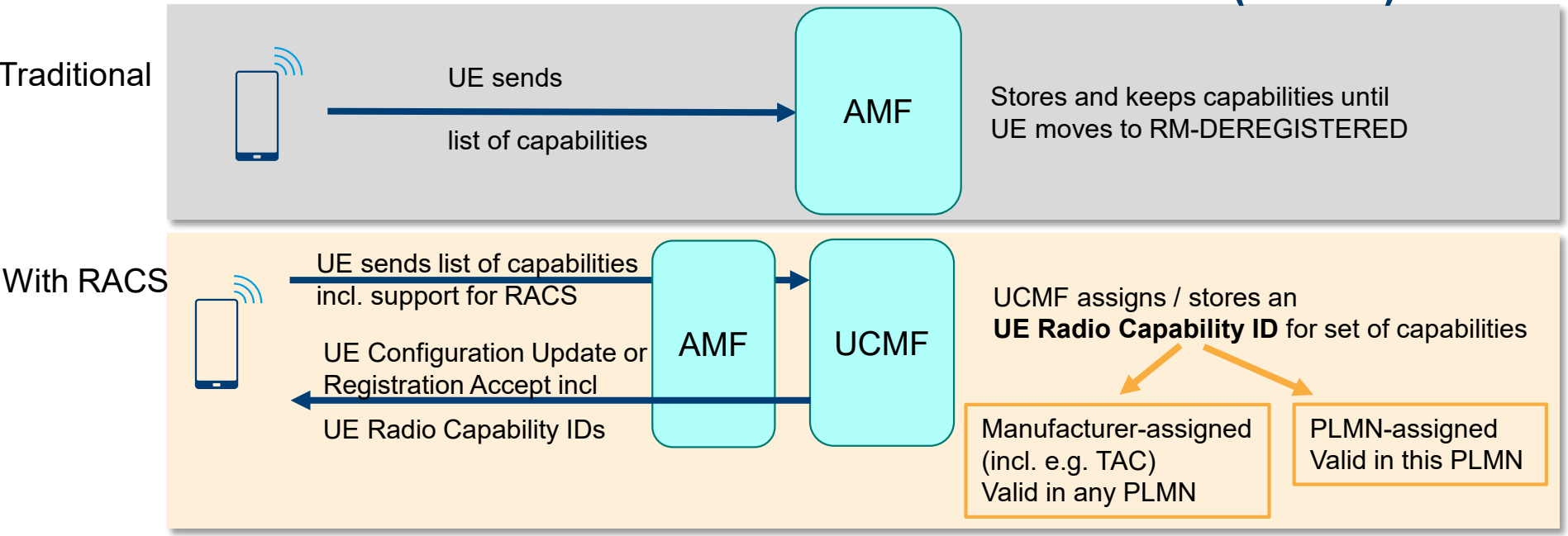
REL-16: NR 2-STEP RACH

Idea: change legacy 4-step RACH into 2-step RACH
Motivation: reduce latency and control signaling overhead





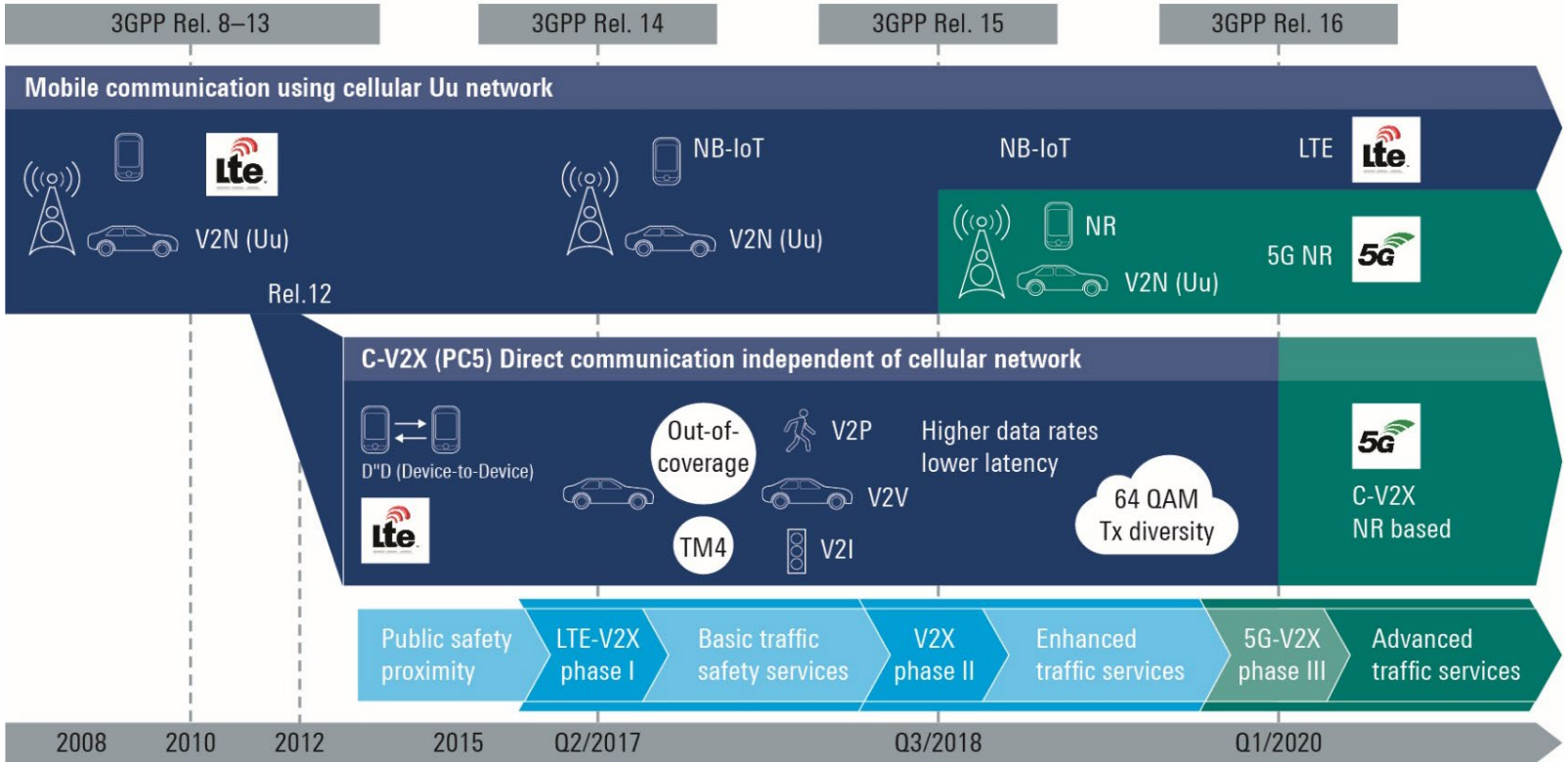
UE RADIO CAPABILITY SIGNALING OPTIMIZATION (RACS)



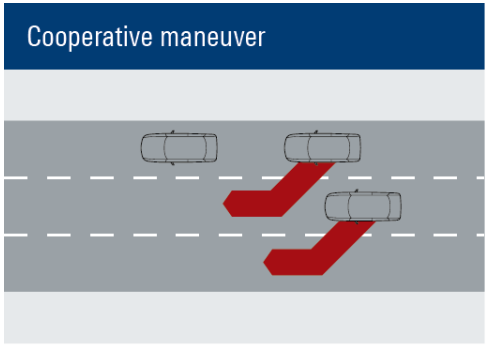
5G evolution, Releases 16 and 17

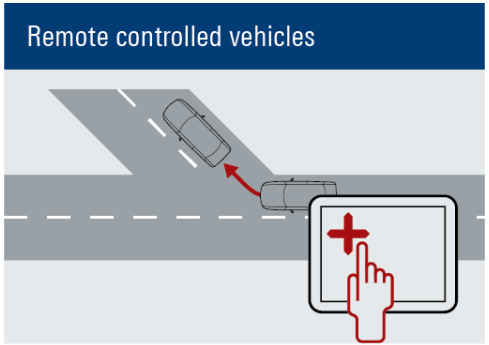
NR-V2X

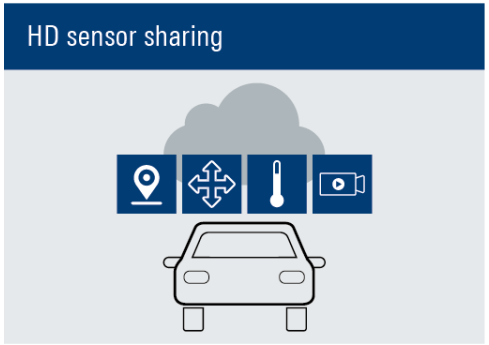
EVOLUTION OF 3GPP MOBILE COMMUNICATIONS STANDARD RELEASES 12 TO 16 FF RELEVANT FOR AUTOMOTIVE



3GPP RELEASE 16: PHASE III 5G NR V2X







- Flexible numerology
- Operates Multiple Input Multiple Output (MIMO) transmission
- Distance based Hybrid Automatic Repeat Request (HARQ)
- V2X communication in FR1 and FR2

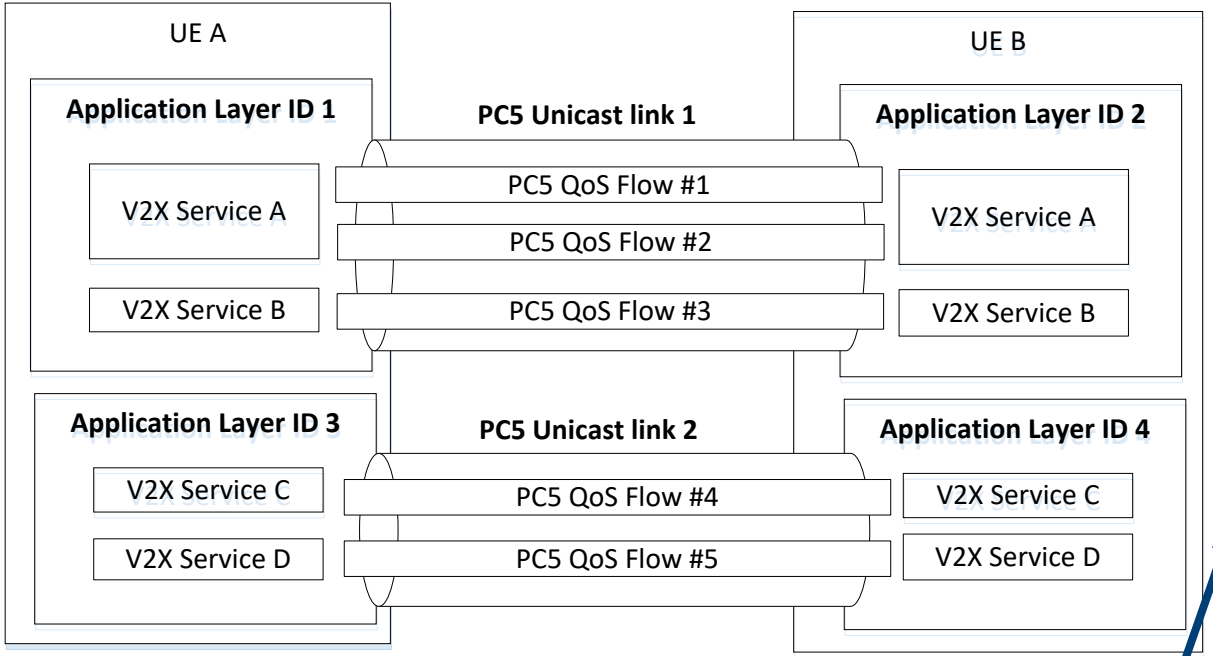
V2X PHYSICAL LAYER PARAMETERS

Parameter	LTE D2D (Rel. 12)	LTE V2X (Rel. 14)	LTE V2X (Rel. 15)	5G NR V2X (Rel. 16/17)
Frequency	all bands possible (e.g. FirstNet 700 MHz)	Target 5.9 GHz	Target 5.9 GHz	Target 5.9 GHz / FR1 but also FR2
Waveform	DFT-s-OFDM	DFT-s-OFDM	DFT-s-OFDM	CP-OFDM
Subcarrier spacing	15 kHz	15 kHz	15 kHz	NR numerologies 15/30/60/120 kHz
Cyclic prefix	Normal + extended	Normal	Normal	Normal + extended (only 60 kHz SCS)
Modulation	QPSK, 16QAM	QPSK, 16QAM	QPSK, 16QAM, 64 QAM	QPSK, 16QAM, 64 QAM, 256 QAM
Channel coding	Turbo code	Turbo code	Turbo code	LPDC (data) + polar (signaling) codes
Time scheduling	1 subframe = 1 ms	1 subframe = 1 ms	1 subframe = 1 ms	1 slot, slot duration flexible, slot aggregation possible
# DMRS symbols/TTI	2 per subframe	4 per subframe	4 per subframe	2–4 per slot
Data/control multiplex	TDM	FDM	FDM	TDM + FDM
HARQ	NA	NA	NA	RX UE reports to TX UE, TX UE reports to gNB
MIMO	Single layer	Single layer	TX + RX diversity	Up to 2 layers
Retransmissions	4 by default	Up to 2	Up to 2	Up to 32 (configurable + resource reservation)
Communication type	Groupcast, broadcast	Broadcast only	Broadcast only	Unicast, groupcast + broadcast
Carrier aggregation	No	No	Up to 8 CCs	No
Peak throughput	~7 Mbps	~32 Mbps	~72 Mbps	~200 Mbps (256 QAM)

THE 7 PILLARS OF 5G NR-C-V2X

1. CP-OFDM with multiple numerologies
2. Greater flexibility & higher throughput
3. Low latency slot structure (self-contained)
4. Broadcast, multicast and unicast
5. QoS management policy
6. Beamforming support
7. Channel structure: reliability + flexibility

NR V2X SIDELINK SUPPORTING QoS

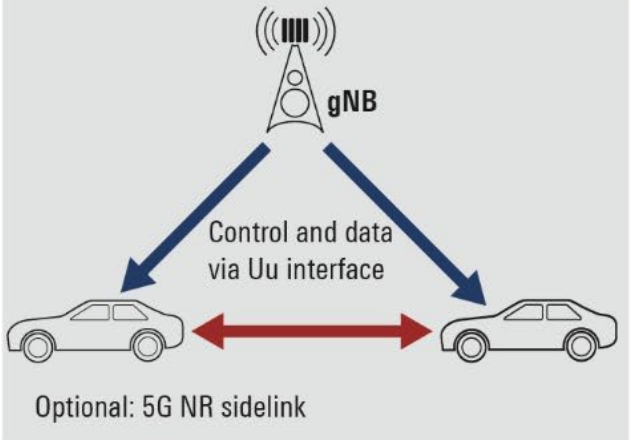


	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Service
21	GBR	3	20 ms	10^{-4}	1. N/A	2. 2000 ms	3. Platooning between UEs – Higher degree of automation; 4. Platooning between UE and R – Higher degree of automation
22	(NOTE 1)	4	50 ms	10^{-2}	5. N/A	6. 2000 ms	7. Sensor sharin higher degree of automation
23		3	100 ms	10^{-4}	8. N/A	9. 2000 ms	10. Information sharing for automat driving – between UEs or UE and RS higher degree of automation
55	Non-GBR	3	10 ms	10^{-4}	11. N/A	12. N/A	13. Cooperative l change – higher degree of automati
56		6	20 ms	10^{-1}	14. N/A	15. N/A	16. Platooning informative exchan – low degree of automation; 17. Platooning – information sharing with RSU
57		5	25 ms	10^{-1}	18. N/A	19. N/A	20. Cooperative l change – lower degree of automati
58		4	100 ms	10^{-2}	21. N/A	22. N/A	23. Sensor information sharing lower degree of automation
59		6	500 ms	10^{-1}	24. N/A	25. N/A	26. Platooning – reporting to an RSU
90	Delay Critical GBR	3	10 ms	10^{-4}	27. 2000 bytes	28. 2000 ms	29. Cooperative collision avoidance 30. Sensor sharin Higher degree of automation; 31. Video sharing higher degree of automation
91	(NOTE 1)	2	3 ms	10^{-5}	32. 2000 bytes	33. 2000 ms	34. Emergency trajectory alignmen 35. Sensor sharin Higher degree of automation

Not an eye chart ☺ but an example of the flexibility:
3GPP defines ~10 different QoS flow profiles for the NR V2X sidelink

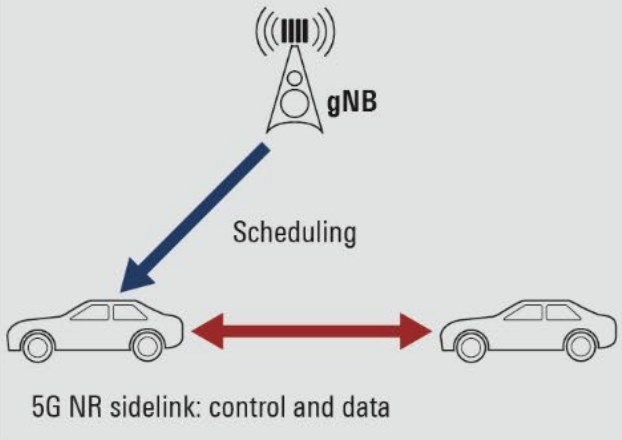
5G NR C-V2X COMMUNICATION MODES AT PHY LAYER

Uu based communication:
gNB optionally schedules sidelink,
data and control is sent over Uu-interface



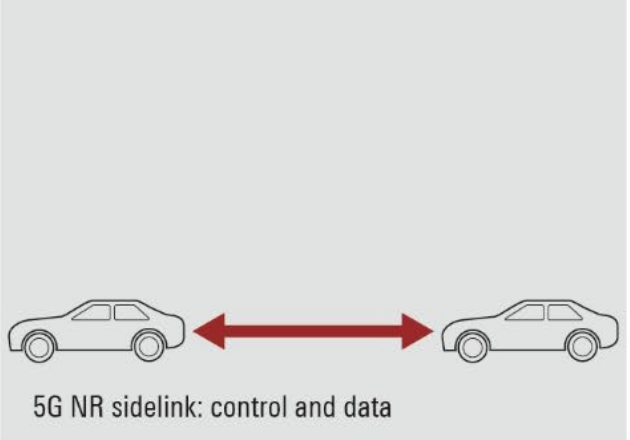
Optional: 5G NR sidelink

5G NR sidelink mode 1:
gNB schedules sidelink resources,
data and control is sent over 5G NR sidelink



5G NR sidelink: control and data

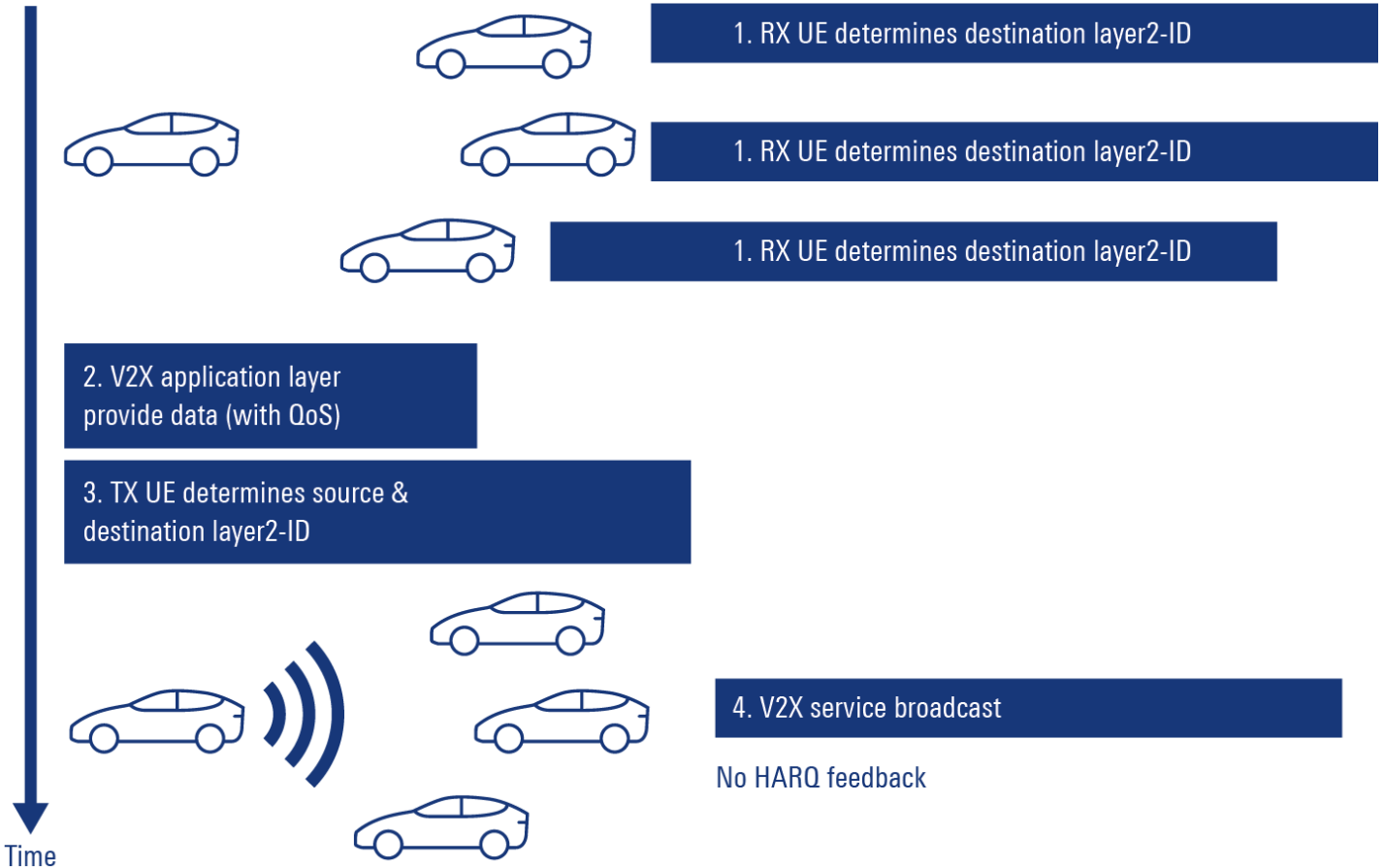
5G NR sidelink mode 2:
UEs autonomously select 5G NR sidelink resources
- Contention-based
- Channel structure required
- Synchronization aspects



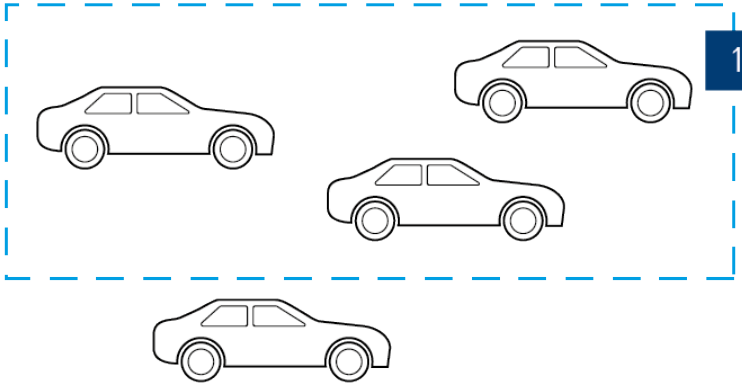
5G NR sidelink: control and data

Note: eNB can schedule NR or LTE sidelink. gNB can schedule NR or LTE sidelink

V2X PC5 INTERFACE PROCEDURE BROADCAST



V2X PC5 INTERFACE PROCEDURE GROUPCAST



1. V2X application layer carries out group management

2. V2X application layer provides data (group info)

3. TX UE determines source and destination layer 2-ID and RX UEs determine destination layer 2-ID

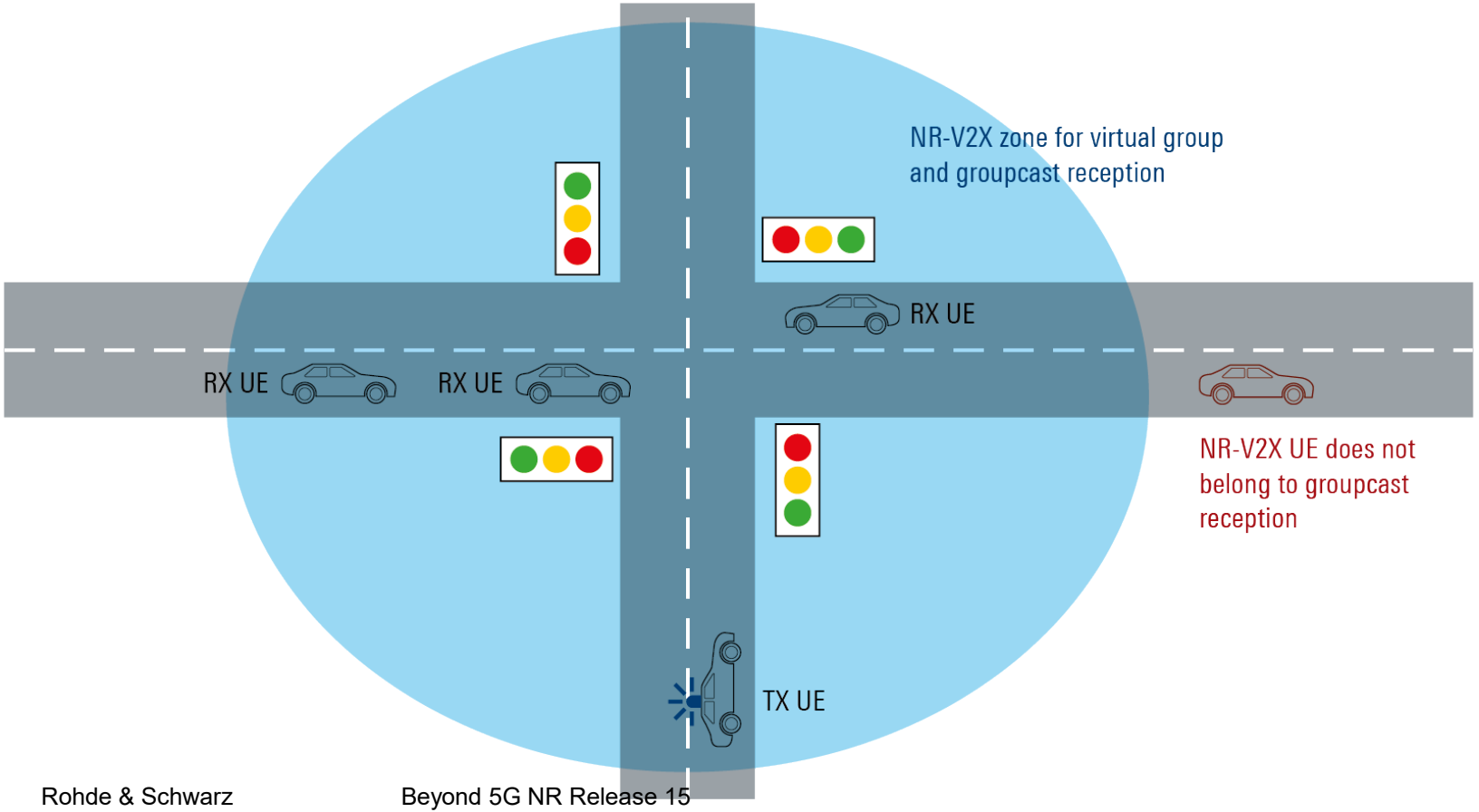
4. V2X service groupcast

HARQ feedback; only NACK are sent

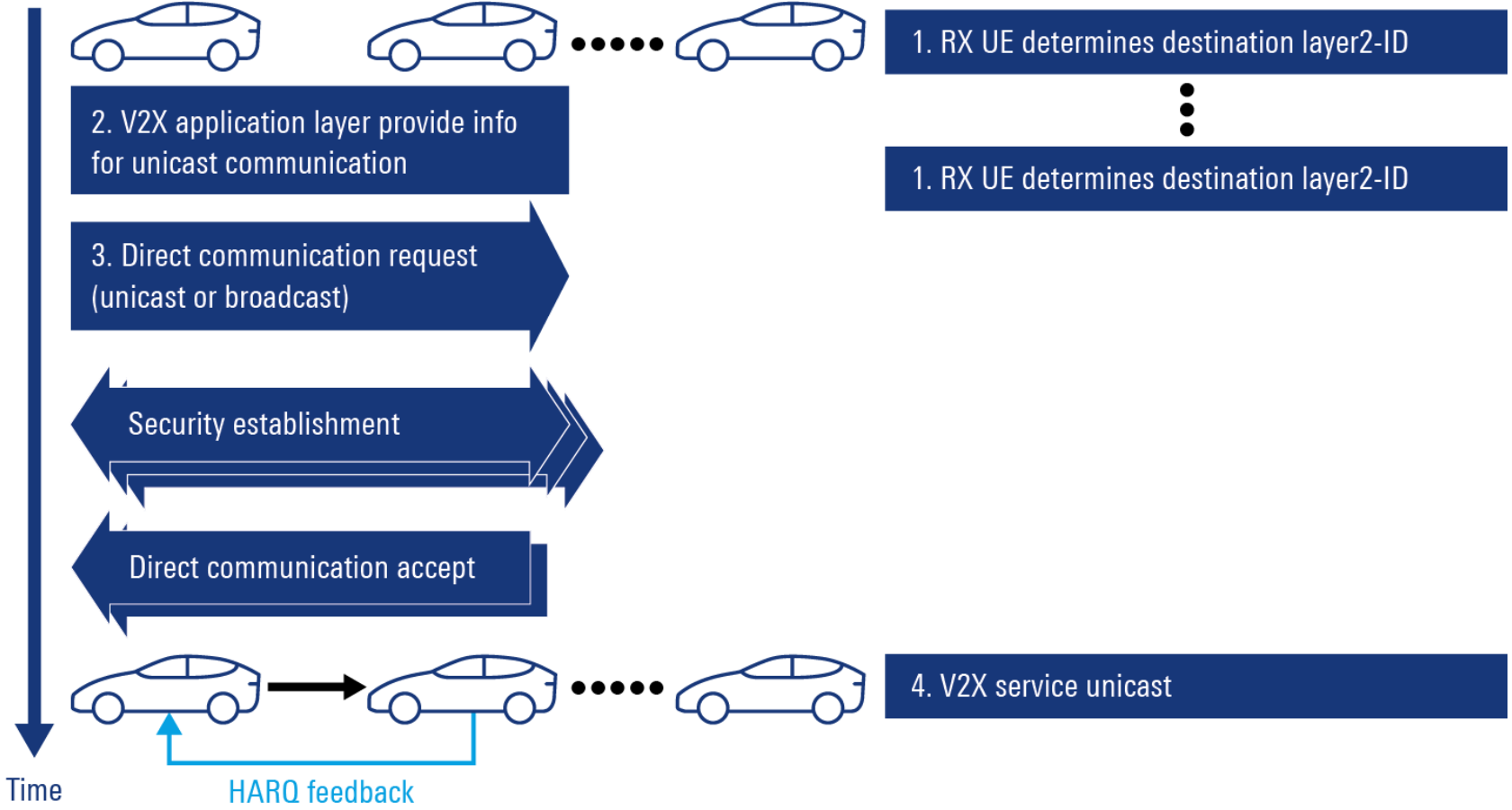
UE not belonging to group

Time

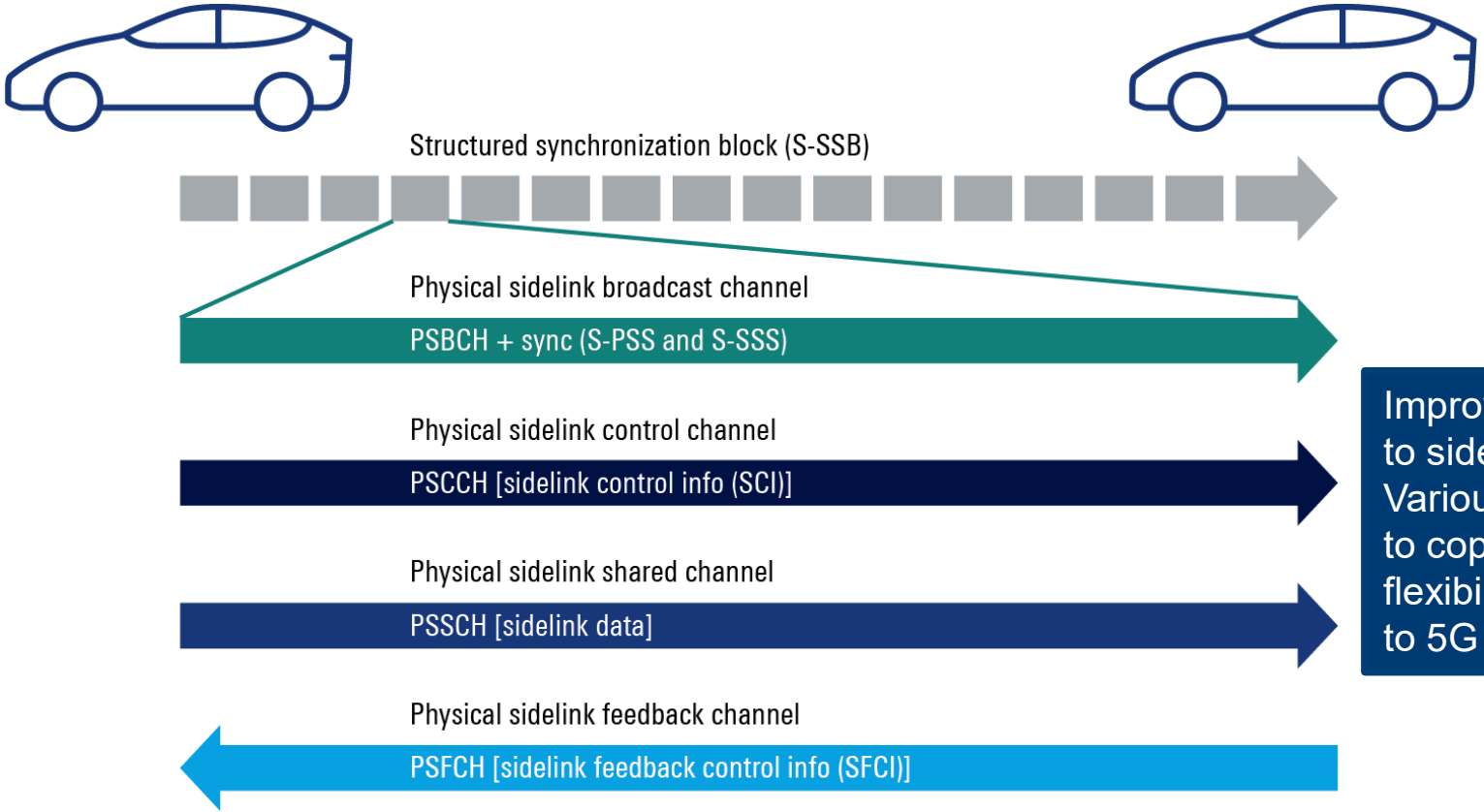
5G NR ZONE CONCEPT



V2X PC5 INTERFACE PROCEDURE UNICAST

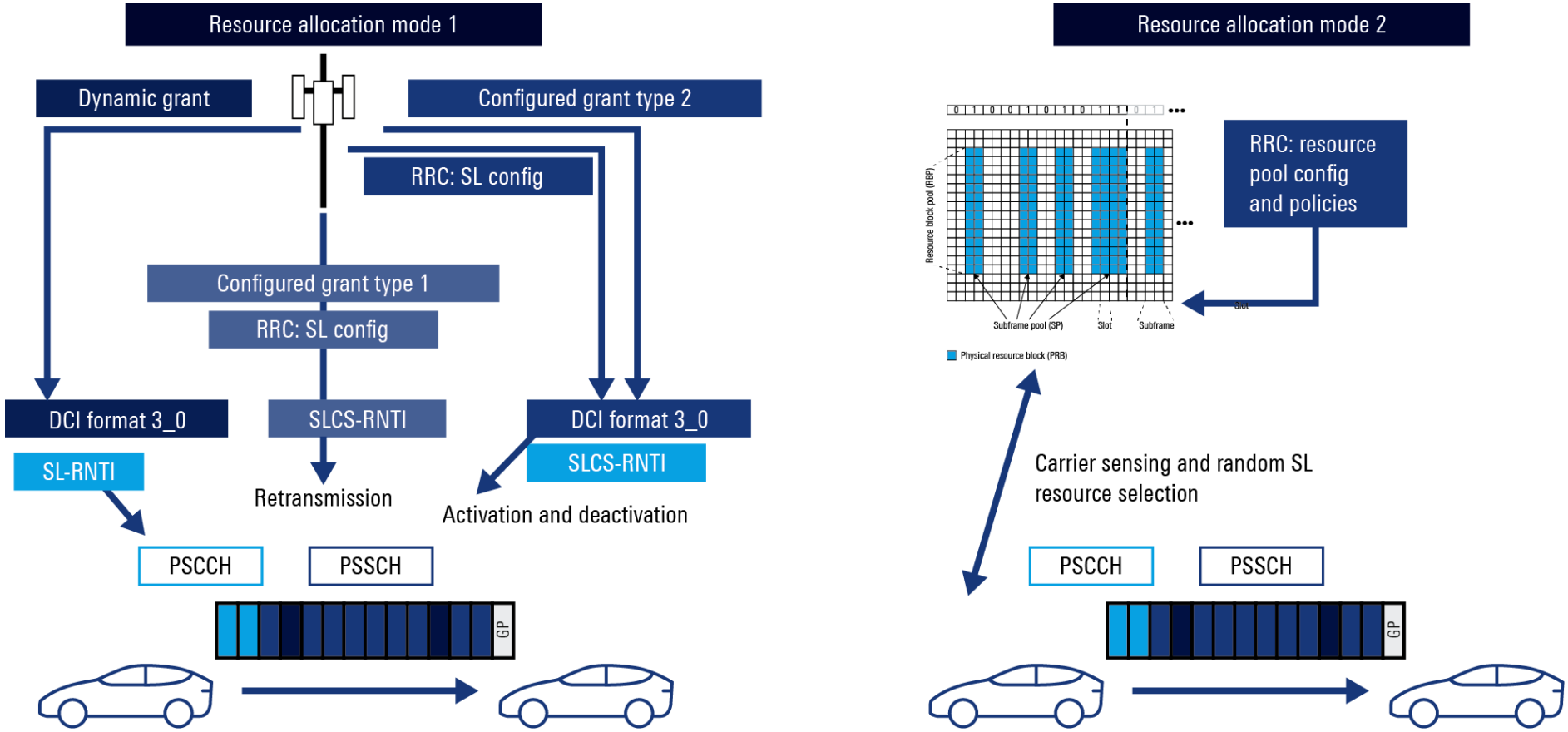


5G NR SIDELINK – CHANNEL STRUCTURE

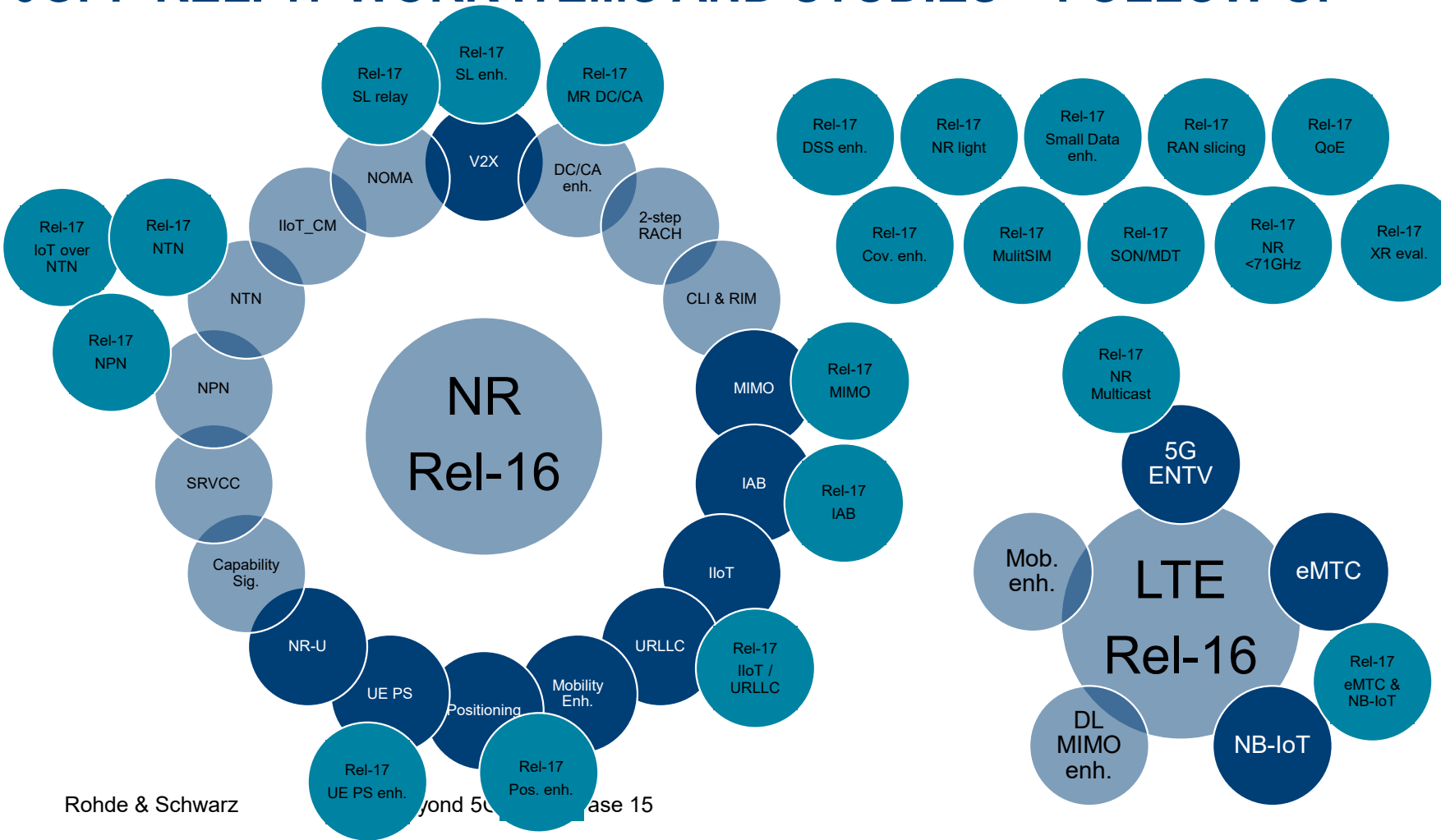


Improved flexibility due to sidelink control info. Various numerologies to copy the tremendous flexibility of 5G NR, also to 5G NR V2X

NR V2X SIDELINK RESOURCE SCHEDULING



3GPP REL. 17 WORK ITEMS AND STUDIES + FOLLOW-UP



5G evolution, Releases 16 and 17

NON-TERRESTRIAL NETWORKS

NON TERRESTRIAL NETWORK APPLICATIONS

ETSI TR 103 612: Mobile/fixed communication network in the frequency range 6425 to 7125 MHz

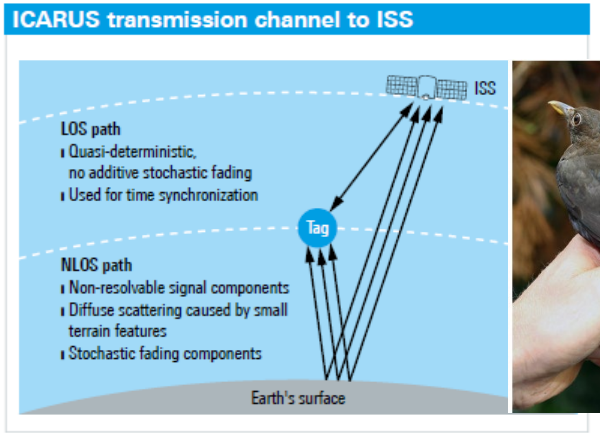
3GPP: NR over NTN
5G NR air interface adopted to NTN
GEO, LEO, HAPS -> air to ground
Fixed or moving terrestrial cells
UE support GNSS + NTN
Business case: „human“: eMBB

3GPP: IoT over NTN
NB-IoT & LTE-M adopted to NTN
GEO, LEO, HAPS -> air to ground
Business case: „IoT“
e.g. ICARUS: Internet of animals @400MHz

Remote areas

Public safety

Temporary hotspots



NON TERRESTRIAL NETWORK IN ONE SLIDE

Non-terrestrial networks refer to networks, or segments of networks, using an airborne or spaceborne vehicle for transmission (part of Rel. 17):

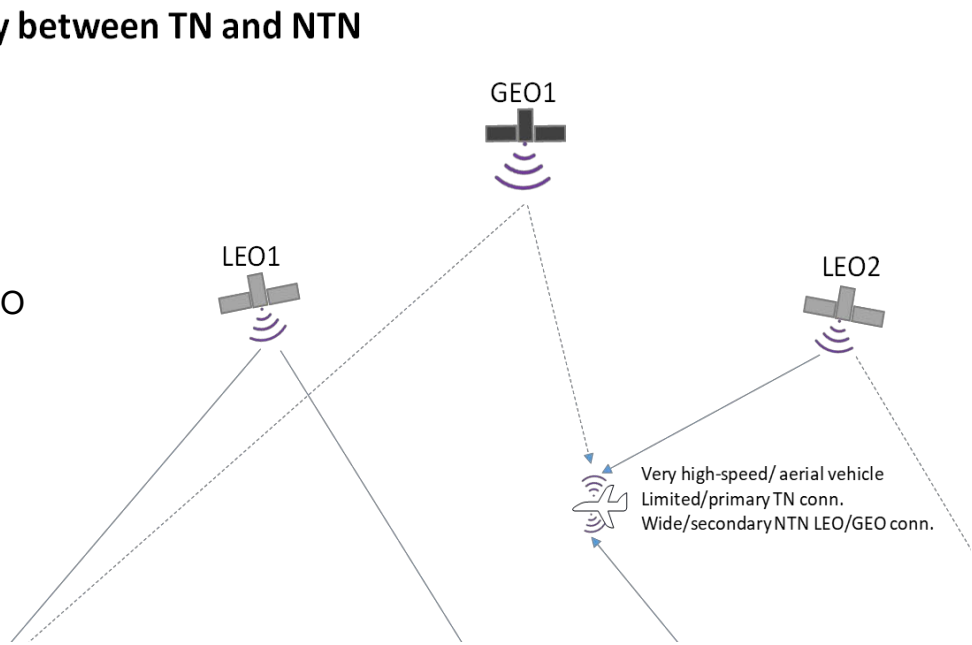
Scenario:

- Device :
  - Low speed, pedestrian/ship, VSAT
  - Medium/high speed vehicle/train
  - Very high speed aerial
  - Unmanned aerial system UAS

- Base station
  - Spaceborne: satellite systems like GEO, MEO or LEO
  - Airborne: aerial vehicles (8 to 50 km)
  - Air 2 ground (A2G) system
  - High altitude platform station (HAPS)
  - Terrestrial

Deployment:

- Rural, suburban, isolated areas
- Internet access rural areas (MBB), MTC/IoT
- Cataclysm/disaster relief, public safety
- **Discussion to operate in S and Ka-band**

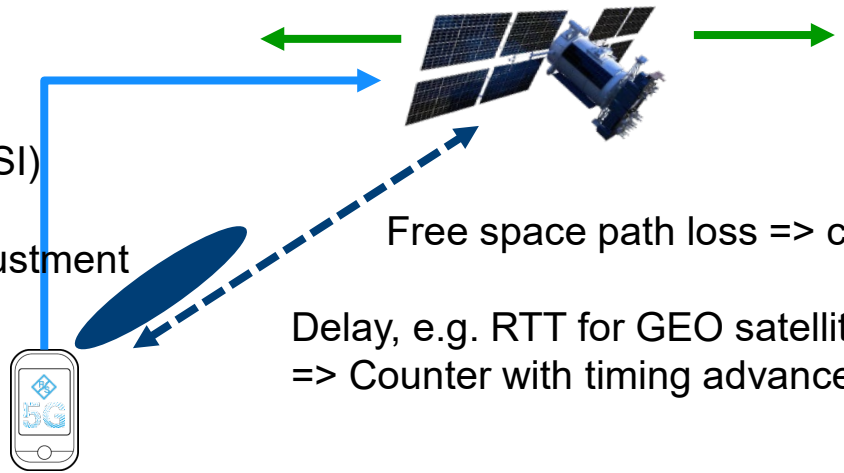


5G NR SATELLITE CONSTELLATION ASPECTS

Doppler shift due to UE and/or gNB mobility => use location/orbit info to compensate Doppler

Long delay:
no perfect
channel info (CSI)

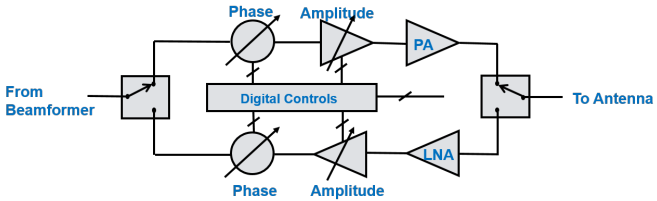
UL&DL beam adjustment



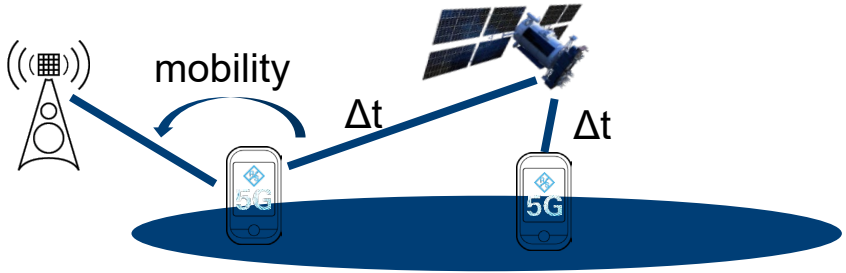
Free space path loss => compensation: beamforming + TX power

Delay, e.g. RTT for GEO satellites ~544ms (note: NR max RTT = 2ms)
=> Counter with timing advance strategies

Carrier frequency offset



Rohde & Schwarz



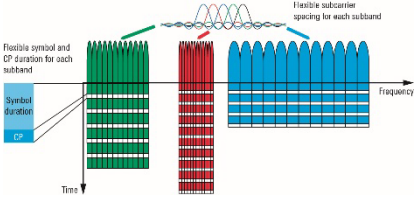
Large cell sizes: RTT delay spread

5G evolution, Releases 16 and 17

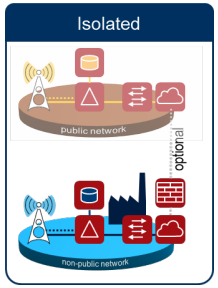
INDUSTRIAL INTERNET OF THINGS (IIOT)

IIOT & URLLC : USECASES

Goal : **extend the NR applicability in various verticals for URLLC**



e.g. flexible numerologies



e.g. NPN

Rel.15 NR

Baseline use cases for URLLC, e.g. AR/VR – entertainment industry

Rel.16 URLLC & IIoT

- Factory automation
- Transport Industry
- Electrical Power Distribution

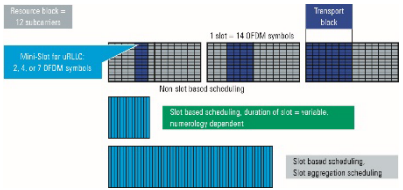
Rel-17 XR

XR / entertainment improvement needs

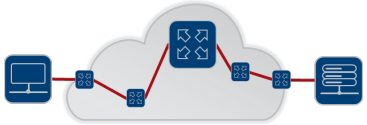
Rel-17 IIoT / URLLC enh.

Rel.16 industries identified additional improvement needs

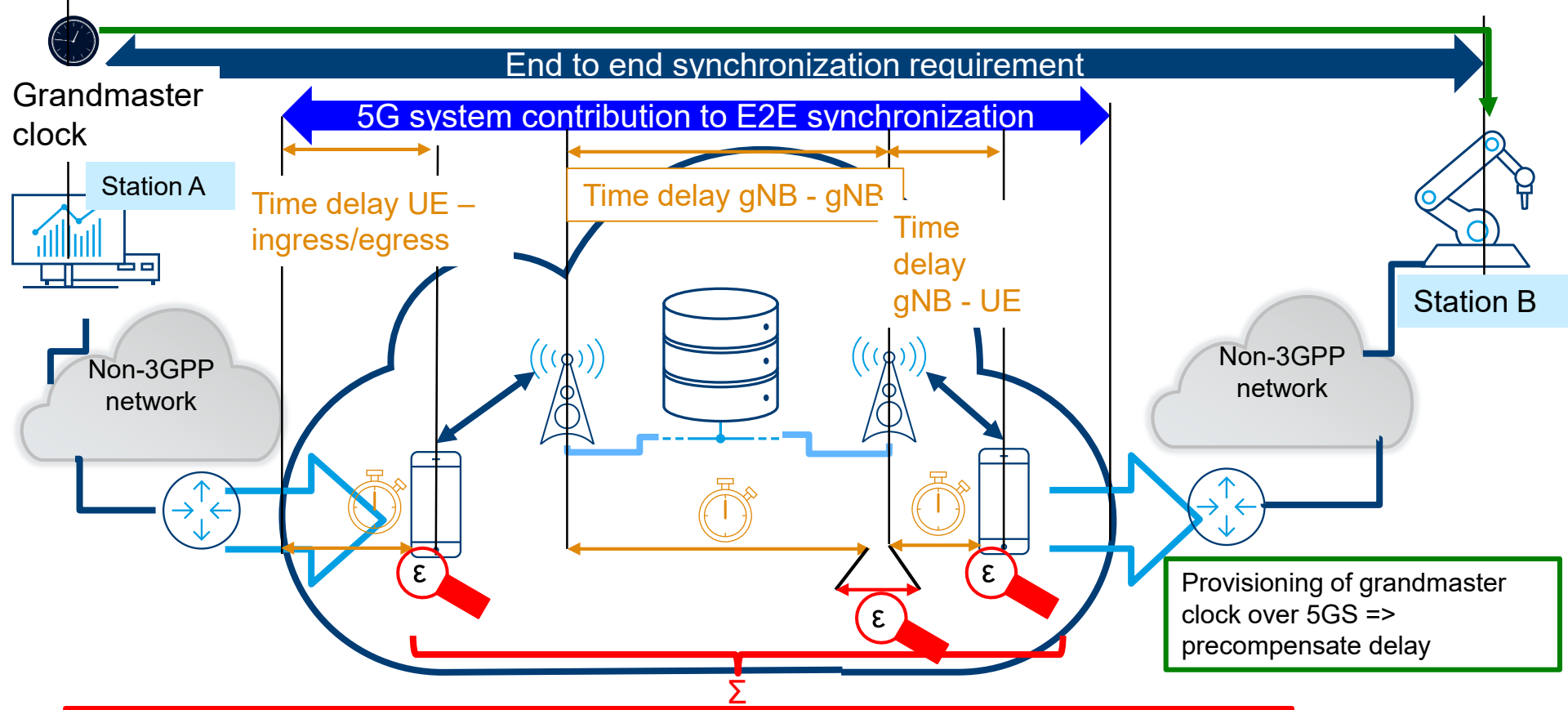
e.g. mini-slot



e.g. TSN



RELEASE 17 – IIOT ENHANCEMENTS ON TIME SYNCHRONIZATION



5GS provides info about maximum sync error budget as the maximum uncertainty

REL-17 IIOT: QoS EXTENSION: SURVIVAL TIME

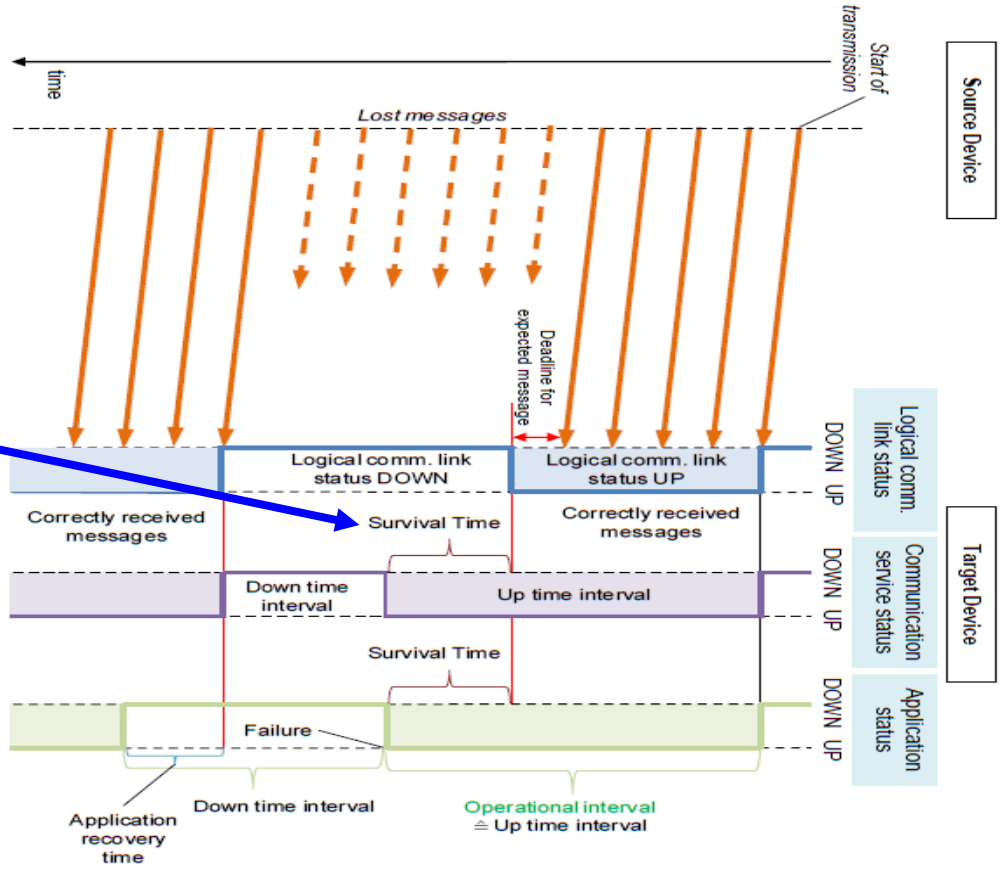
Assessment of periodic deterministic communication services:

Successful = correct and in time
Unsuccessful = incorrect or untimely

⇒New QoS parameter
"Survival time"

Once the application / target device senses the absence of expected messages it will wait a pre-set period before it considers the communication "down".

=> Faster resume connection after absence and make it more robust with respect to time delays

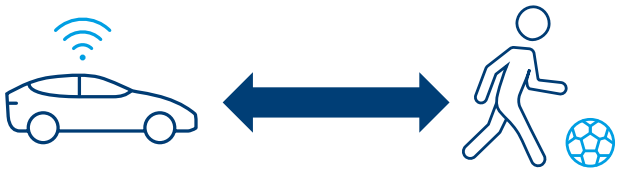


5G evolution, Releases 16 and 17

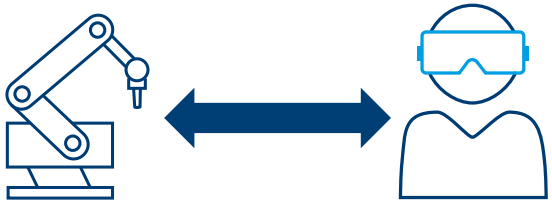
SIDELINK ENHANCEMENTS + RELAY

REL.17 NR SIDELINK ENHANCEMENTS

Release 16 sidelink with focus on automotive!



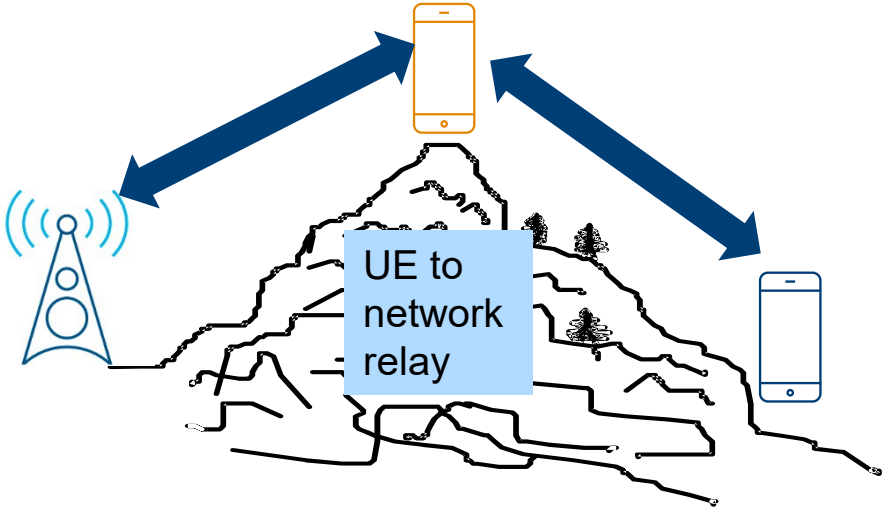
Release 17 sidelink with focus on battery consumption! (default resource pool allocation. TX side DTX & RX side DRX alignment, SL sensing)



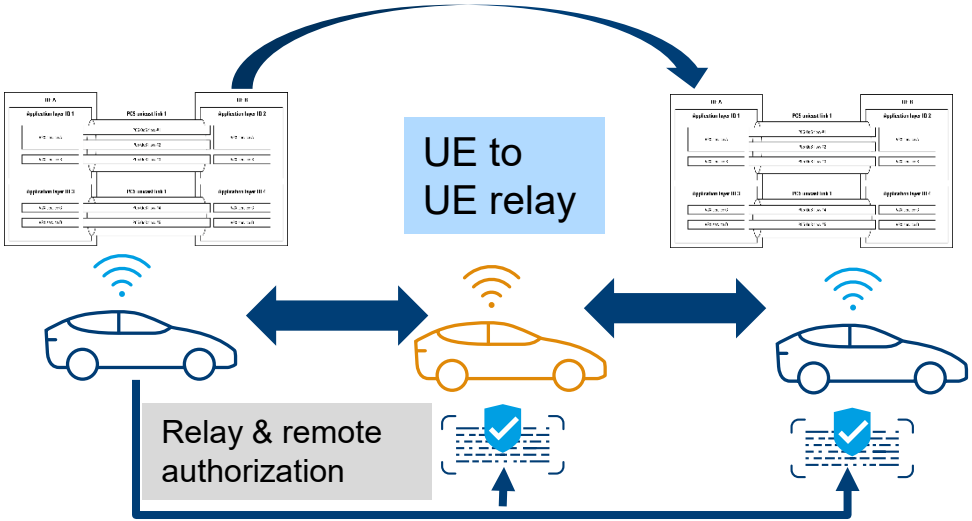
Release 17 sidelink with focus on uRLLC! (reliability & reduced latency, Inter-Ue coordination, new frequency bands: Uu and SL interface in licensed spectrum, SL operation geofencing)

Release 17 sidelink with focus on ProSe! (network controlled interactive services, enhanced relay & coverage)

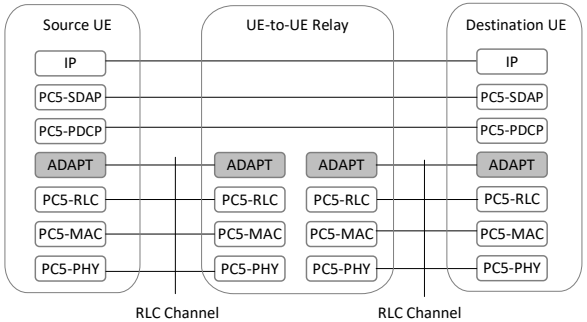
REL.17 NR RELAY

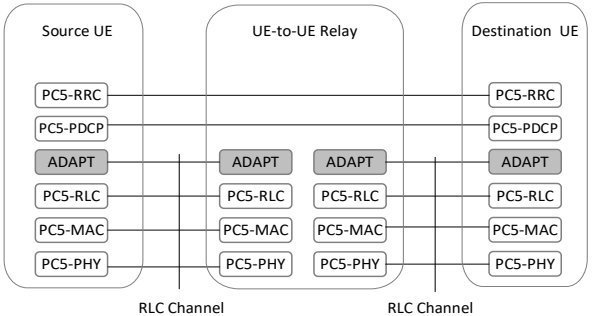


QoS mapping, e.g. new sidelink adaptation layer protocol



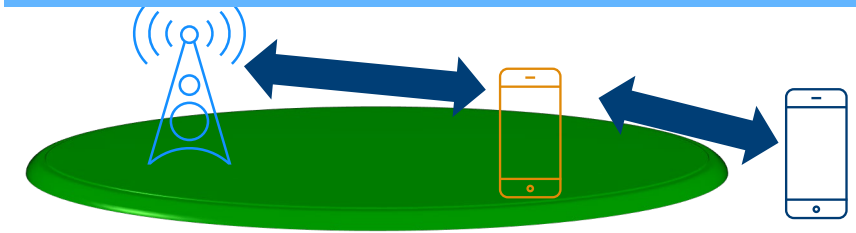
Procedures needed for: Discovery, QoS maintenance, C- and U-plane, authorization and service continuity



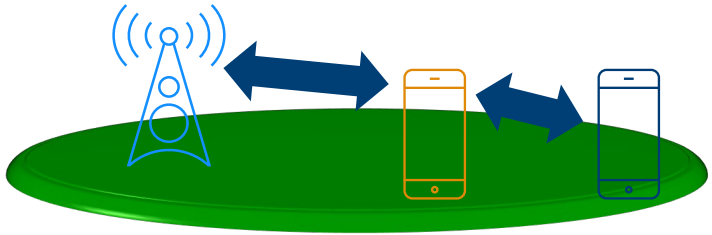


REL.17 NR RELAY – VARIOUS SCENARIOS

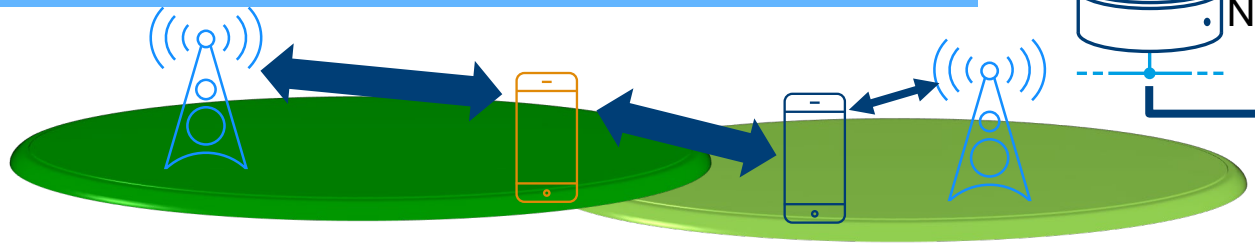
Network relay UE in coverage, remote UE out of coverage



Network relay UE in coverage, remote UE in coverage

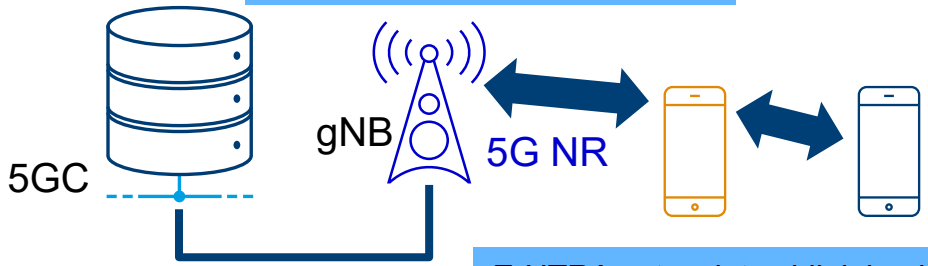


Network relay UE in coverage, remote UE in different cell coverage

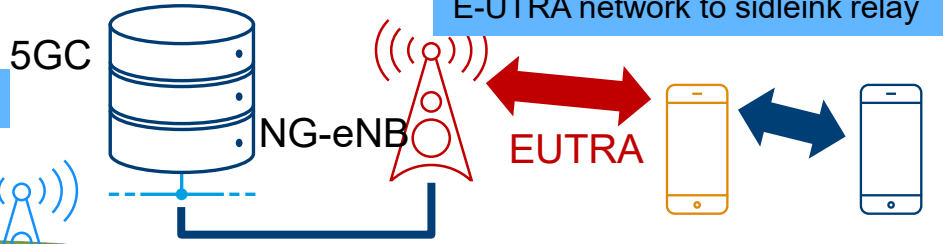


UE to UE sidelink relay

5G NR network to sidelink relay



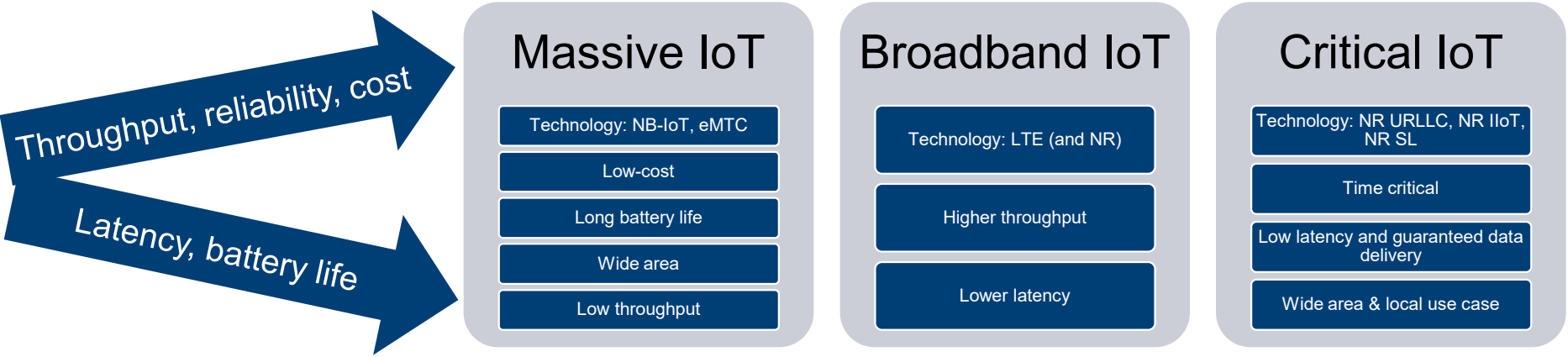
E-UTRA network to sidleink relay



5G evolution, Releases 16 and 17

REDUCED CAPABILITY (REDCAP) + POWER SAVING

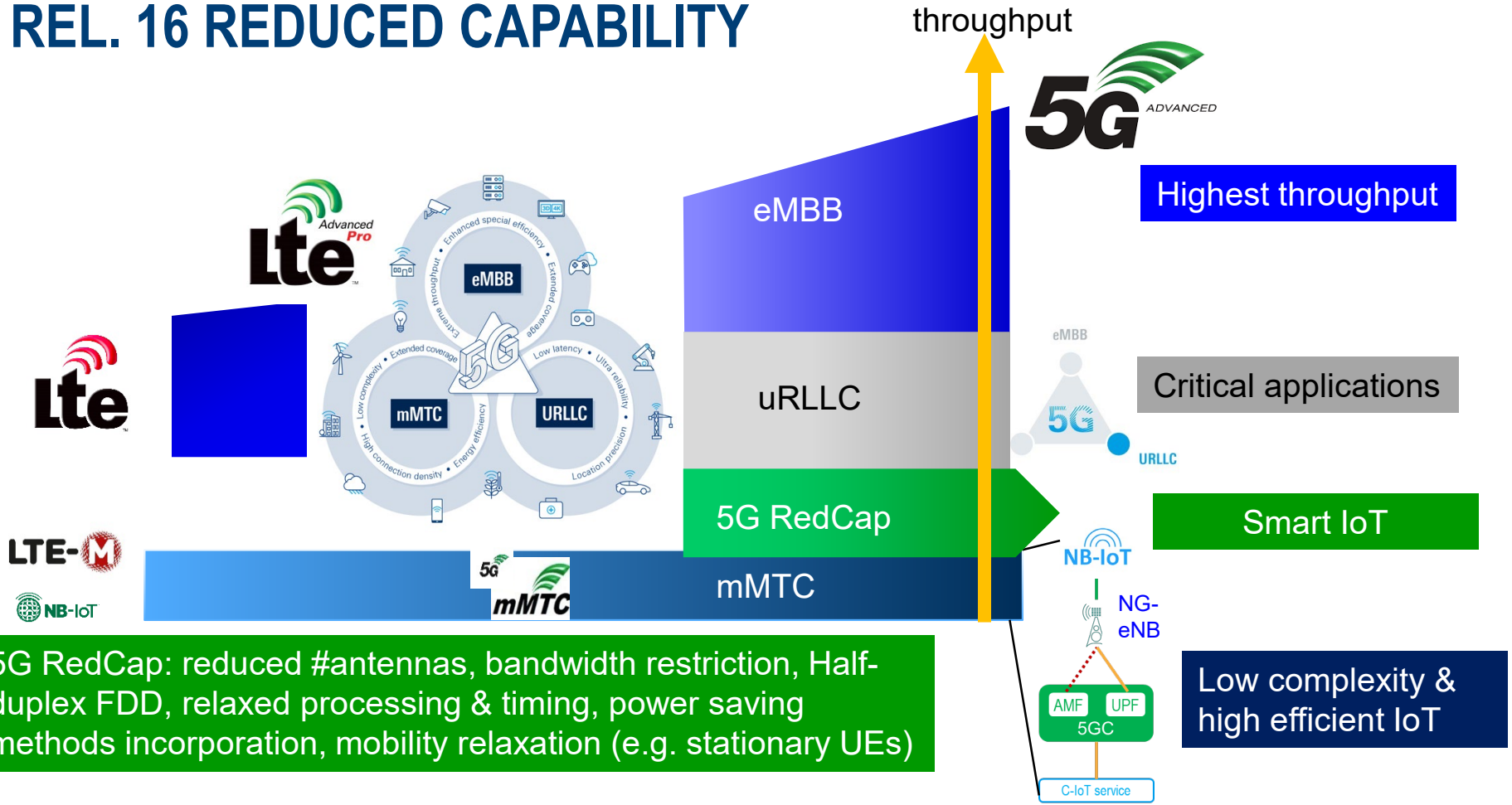
IOT – DEFINITION OF DIFFERENT DEVICES



- **Massive IoT** primarily consists of wide-area use cases, connecting large numbers of low-complexity, low-cost devices that have long battery life and relatively low throughput. NB-IoT and Cat-M technologies complement each other; out of the 123 service providers identified as having launched at least one of these, 25 percent have launched both. At the end of 2025, NB-IoT and Cat-M are projected to account for 52 percent of all cellular IoT connections. Cat-M and NB-IoT follow a smooth evolution path into 5G networks, and can continue to be deployed in the same bands as today, even when 5G is introduced. Commercial devices for Massive IoT include various types of meters, sensors, trackers and wearables.
- **Broadband IoT** mainly includes wide-area use cases that require higher throughput, lower latency and larger data volumes than Massive IoT technologies can support. LTE is already supporting many use cases in this segment. By the end of 2025, 34 percent of cellular IoT connections will be broadband IoT, with 4G connecting the majority. With the introduction of 5G New Radio (NR) in old and new spectrum, throughput data rates will increase substantially for this segment.
- **Critical IoT** is used for time-critical communications in both wide- and local-area use cases that require guaranteed data delivery with specified latency targets. **Critical IoT will be introduced in 5G networks** with the advanced time-critical communication capabilities of 5G NR. Deployment of the first modules supporting Critical IoT use cases is expected in 2021. Typical use cases include cloud-based AR/VR, cloud robotics, autonomous vehicles, advanced cloud gaming, and real-time coordination and control of machines and processes.

Source: Ericsson mobility report

REL. 16 REDUCED CAPABILITY



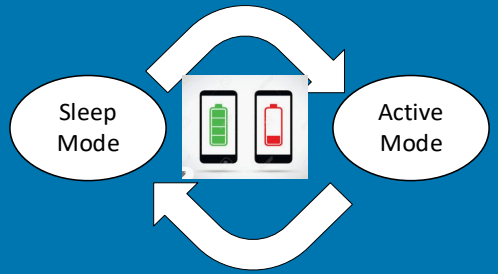
5G RedCap: reduced #antennas, bandwidth restriction, Half-duplex FDD, relaxed processing & timing, power saving methods incorporation, mobility relaxation (e.g. stationary UEs)

REL-17 POWER SAVING

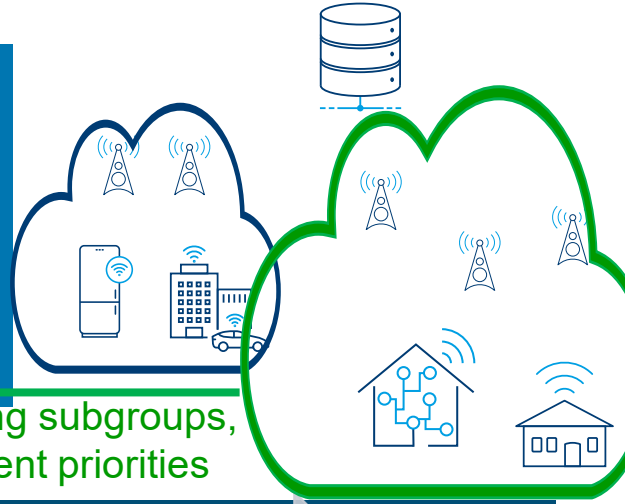
Rel-16

Rel.16 Power Saving Techniques

Wake Up Signals
Efficient Transition to Idle
Dynamic Cross Slot Scheduling



Relaxed Measurement
Adaptive MIMO Layers
UE-Assisted adaptive DRX parameters, CA and Max BW



Paging subgroups, different priorities

Rel-17

Idle
Inactive for SA

paging enhancement(s) to reduce unnecessary UE paging receptions

provide potential TRS/CSI-RS occasion(s) available in connected mode to idle/inactive-mode UEs

Connected Mode

PDCCH monitoring reduction when C-DRX is configured

Relaxing UE measurements for RLM and/or BFD particularly for low mobility UE with short DRX periodicity/cycle

Provide TRS/CSI-RS info via SIB

5G evolution, Releases 16 and 17

POSITIONING ENHANCEMENTS

LOCATION-BASED SERVICES IN RELEASE 17 - OUTLOOK

Ambitious targets for Rel-17 target positioning requirements

Commercial use cases:

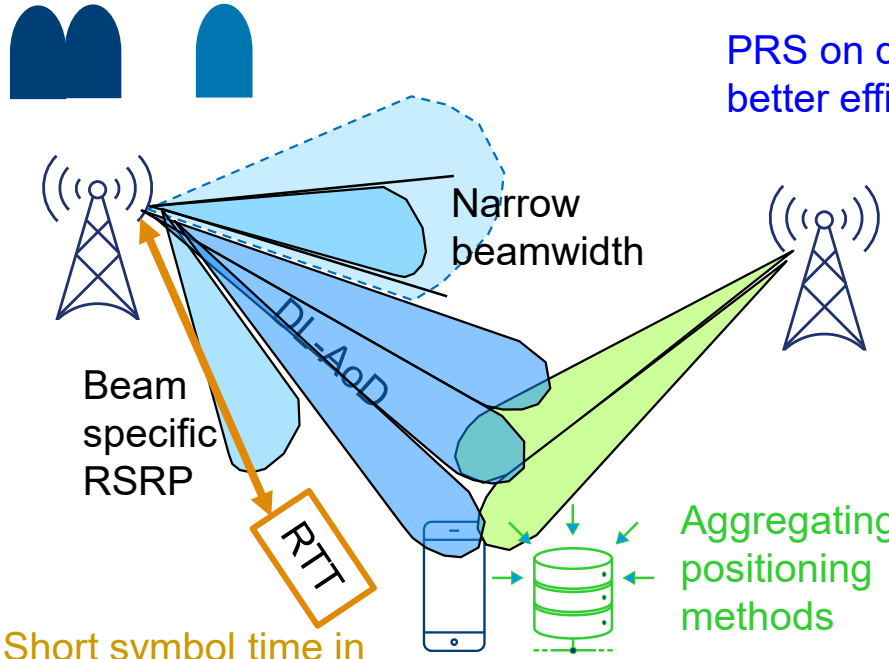
- Horizontal position accuracy (< 1 m) for 90% of UEs
- Vertical position accuracy (< 3 m) for 90% of UEs
- End-to-end latency for position estimation of UE (< 100 ms)
- Physical layer latency for position estimation of UE (< 10 ms)

IIoT use cases:

- Horizontal position accuracy (< 0.2 m) for 90% of UEs
- Vertical position accuracy (< 1 m) for 90% of UEs
- End-to-end latency for position estimation of UE (< 100ms, in the order of 10 ms is desired)
- Physical layer latency for position estimation of UE (<10ms)

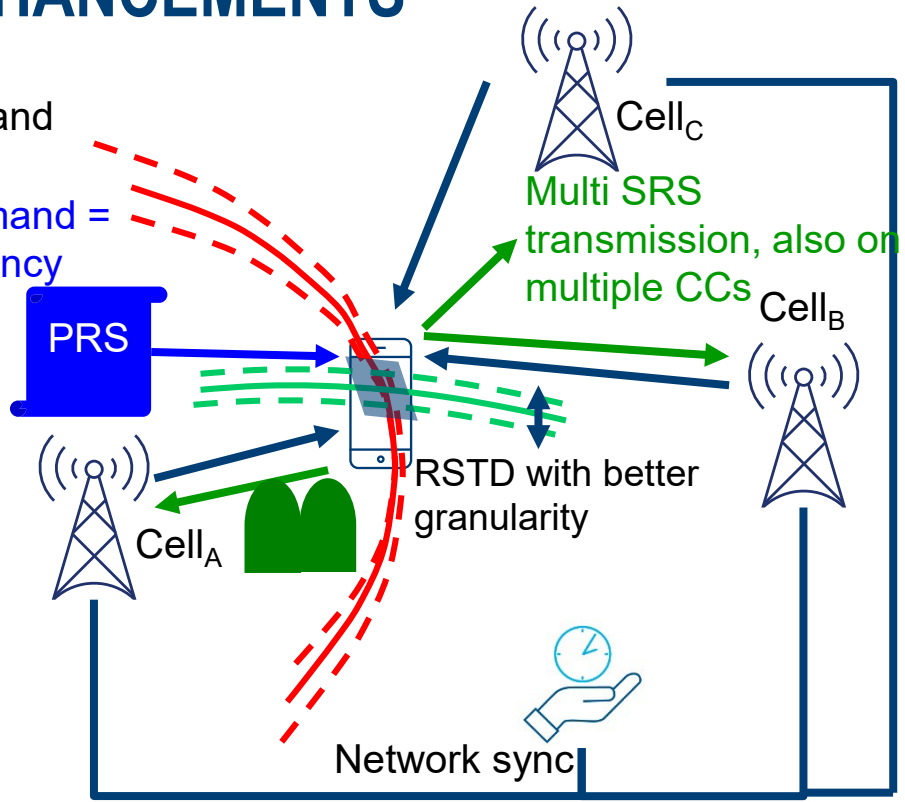
RELEASE 17 – POSITIONING ENHANCEMENTS

PRS TX and positioning on multiple CCs and multi-band



Short symbol time in FR2 = better RTT granularity

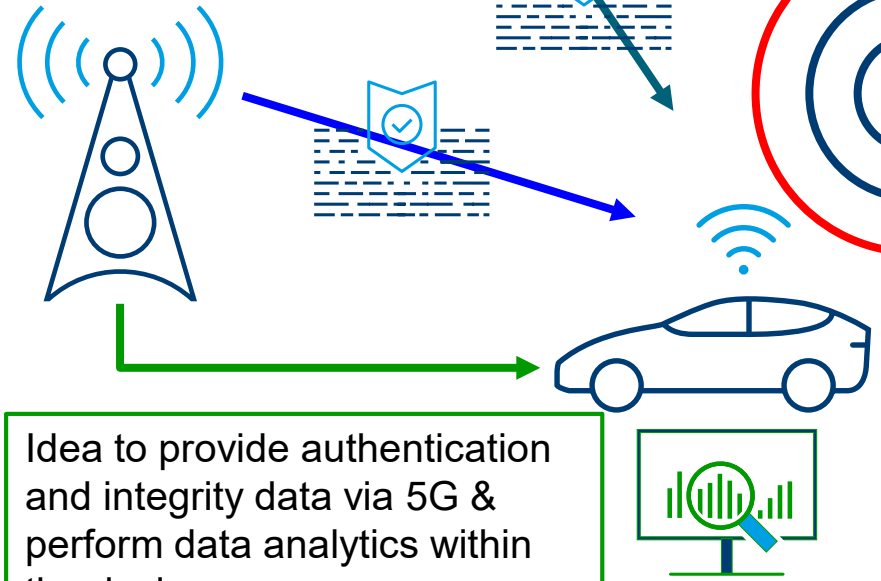
PRS on demand = better efficiency



NR positioning in RRC_INACTIVE / IDLE state

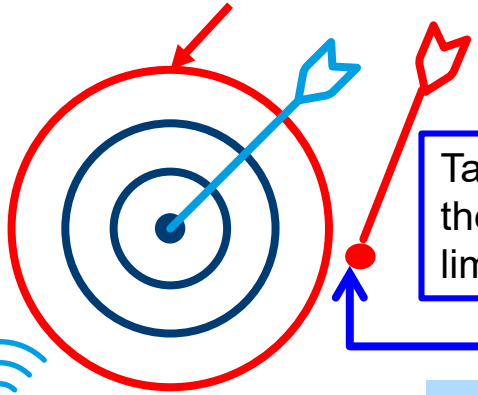
LOCATION-BASED SERVICES IN RELEASE 17 - OUTLOOK

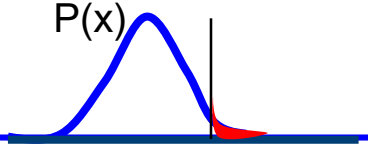
GNSS assistance data integrity



Idea to provide authentication and integrity data via 5G & perform data analytics within the device

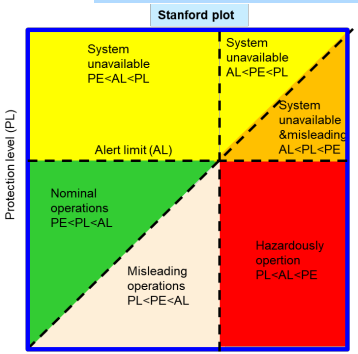
Alert limit = maximum allowable positioning error

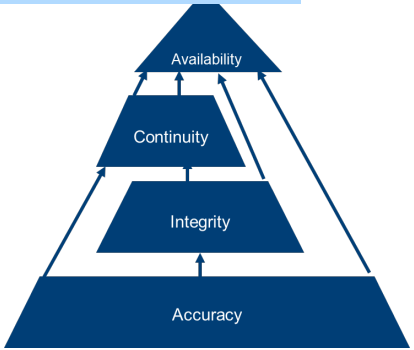




Target integrity risk = probability that the positioning error exceeds the alert limit without warning

Integrity model (Stanford plot)





3GPP RELEASE 18 KICK-OFF

Reduce UE measurements, almost zero power wake-up receiver, energy harvesting

Power saving

Continued NB-IoT support, usage of spectrum chunks, e.g. CA with CC and no SSB sync there, narrowband cell operation

Narrowband operation

Base station downtime, breathing cell + SON

NW energy saving

AI framework for UE, use cases, evaluation, link and positioning prediction, Ref. Signal reduction, beam management

AI/ML

5 MHz UE bandwidth, power saving enhancements, wake-up signals

RedCap evo

LTE & 5G broadcast, NR MBS and multicast

5G broadcast

New KPI / QoS, application awareness, power consumption coverage, capacity and mobility

XR

SL positioning, high accuracy, RedCap positioning, positioning integrity

Expanded positioning

SL enh. (unlicensed, power saving, efficiency), SL relay, coexistence LTE-NR V2X

Sidelink enh.

Flexible duplex, eg. DL only deployments, interference management, cross division duplex XDD

Duplex operation enh.

L1/L2 inter cell HO, DAPS improvements, FR2 HO

Mobility enhancements

> 4 TX, freq. Selective precoding, coverage enh.

UL enhancements

CSI reporting + multi-TRP / multi-beam

Evolution DL MIMO

Indoor 5G + WLAN operation, dual connectivity with > 2 DC

Multi radio – multi connectivity

Mobile IAB, smart repeater

Topology improvement

Short interruption time, including sidelink into NPN,

IIoT uRLLC

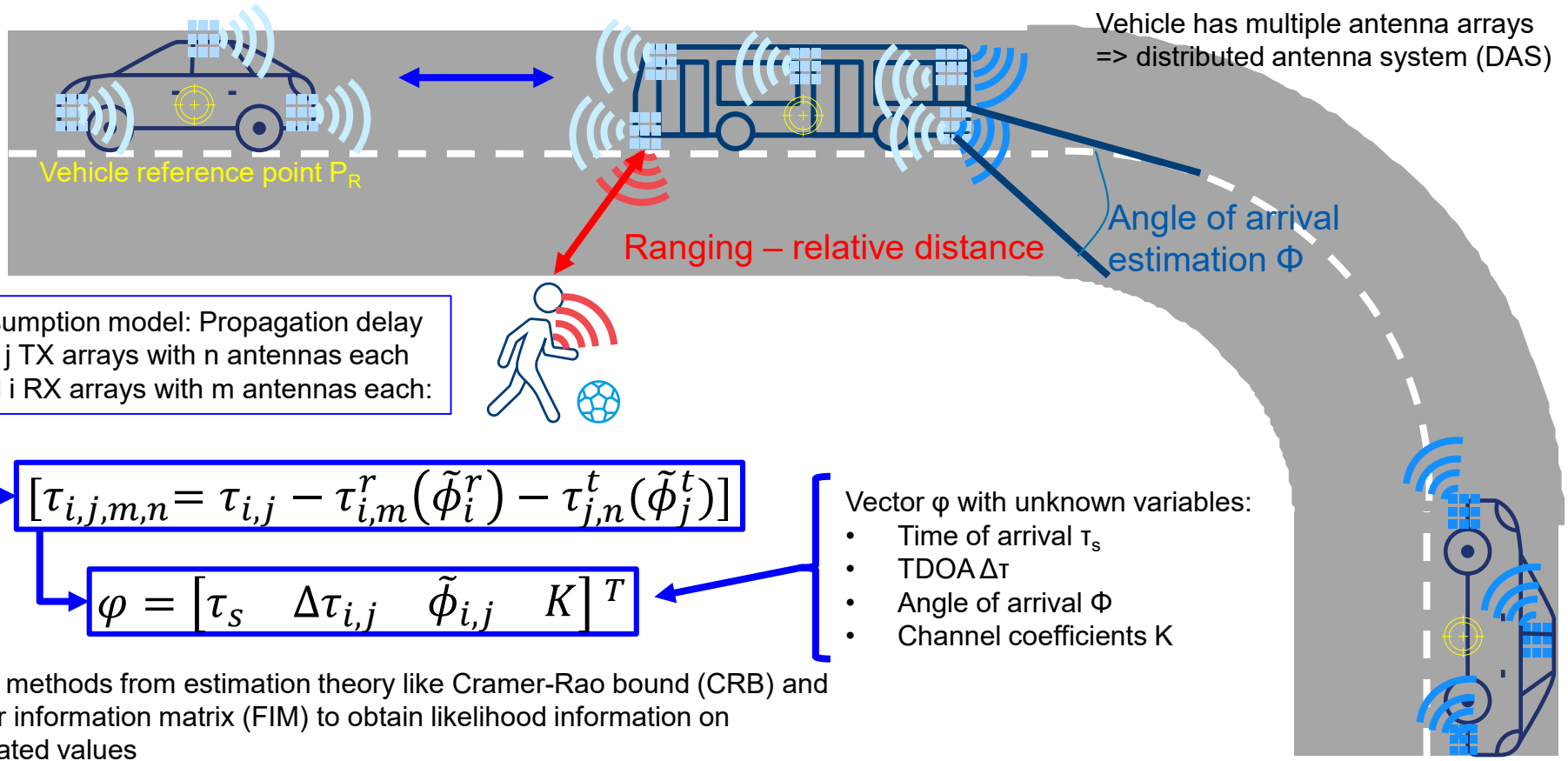
HAPS + UAV, network slicing NTN, IoT optimizing (no GNSS), NTN emergency calls

NTN evo

V2X in 60 GHz, unlicensed bands, extension up to 114.25 GHz

> 52.6 GHz

LBS IN RELEASE 18 – DIFFERENTIAL POSITIONING USING DAS



Assumption model: Propagation delay τ of j TX arrays with n antennas each and i RX arrays with m antennas each:

$$[\tau_{i,j,m,n} = \tau_{i,j} - \tau^{r}_{i,m}(\tilde{\phi}^{r}_{i}) - \tau^{t}_{j,n}(\tilde{\phi}^{t}_{j})]$$

$$\varphi = \left[\tau_s \quad \Delta\tau_{i,j} \quad \tilde{\phi}_{i,j} \quad K\right]^T$$

Vector φ with unknown variables:

- Time of arrival τ_s
- TDOA Δτ
- Angle of arrival Φ
- Channel coefficients K

Apply methods from estimation theory like Cramer-Rao bound (CRB) and Fisher information matrix (FIM) to obtain likelihood information on estimated values

5G evolution, Releases 16 and 17

BEYOND 5G

FROM 5G NR PHASE 2 AND 2+ TOWARDS BEYOND 5G & 6G

LTE LTE ADVANCED LTE ADVANCED PRO

5G

eMBB

mMTC

URLLC

5G NR Phase 1

| March 2019

5G NR Phase 2

5G NR Phase 2+

6G research kicks off…

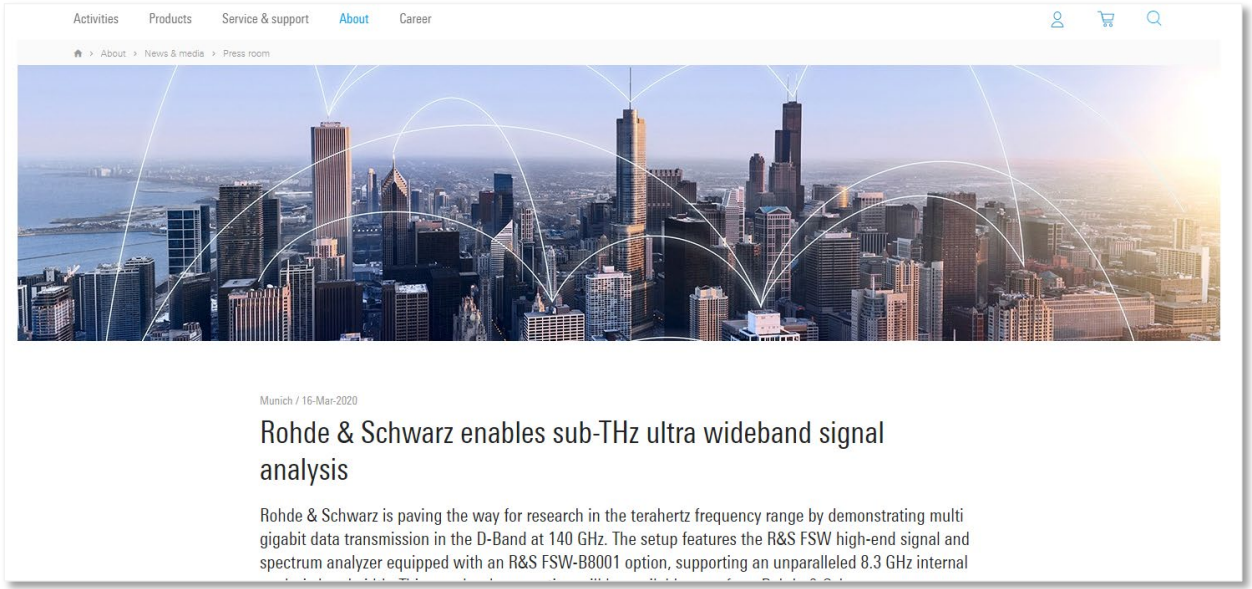
Beyond 5G/6G related workshops, organized by research community

2018 2020 2022 2024 2030

eMBB: enhanced Mobile Broadband
URLLC: Ultra-Reliable Low Latency Communication
mMTC: massive Machine Type Communication

TRENDS TO HIGHER FREQUENCIES AND WIDER BANDWIDTHS WILL CONTINUE

Bandwidth extension for FSW signal and spectrum analyzer up to 8.3 GHz



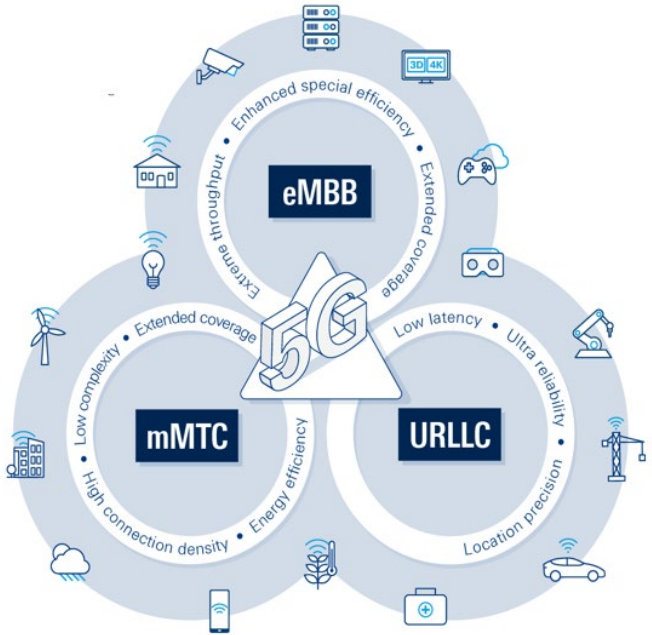
Source: https://www.rohde-schwarz.com/us/about/news-press/all-news/rohde-schwarz-enables-sub-thz-ultra-wideband-signal-analysis-press-release-detailpage_229356-793512.html

Technology management (GF-M1)

SUMMARY AND CONCLUSION

5G IS A MARATHON, NOT A 100M SPRINT

- First 5G NR network are being deployment based on Non-standalone (NSA) mode (Option 3X) using FR1 and FR2 frequencies
  - Not yet mature, optimization ongoing
  - Standalone (SA) rollout started
- Initial 5G deployments focus on enhanced mobile broadband (eMBB), upcoming releases of the standard will focus on URLLC use cases to address the two market verticals Industrial IoT (IIoT) and automotive
- Rohde & Schwarz helps the industry to pave the way with innovative test solutions for 5G



5G NR technology aspects

5G NEW RADIO

BEYOND RELEASE 15

Thank you for listening.

And now it’s time for your questions

ROHDE&SCHWARZ

Make ideas real