5G FR1 SIGNALING TESTING SOLUTION ACCORDING TO REL.15 AND REL. 16

ROHDE&SCHWARZ

Make ideas real

AGENDA

- 3GPP Releases overview
- IIoT & URLLC
- Evolution - POSITIONING, NR-U, 2-STEP RACH , MOBILITY, POWER SAVING etc.
- NR V2X
- 5G Signaling solution CMX500

5G NR TOWARDS 6G – A CONTINUOUS JOURNEY

| April 2019

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

5G NR Release 15

5G NR Release 16

| June 2020

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

5GACIA

5GAA

5G NR Release 17

| Dec 2021

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

"5G Advanced topics identified"

5G NR Advanced Release 18

5G NR Advanced Release 18++

Fundamentals for next generation

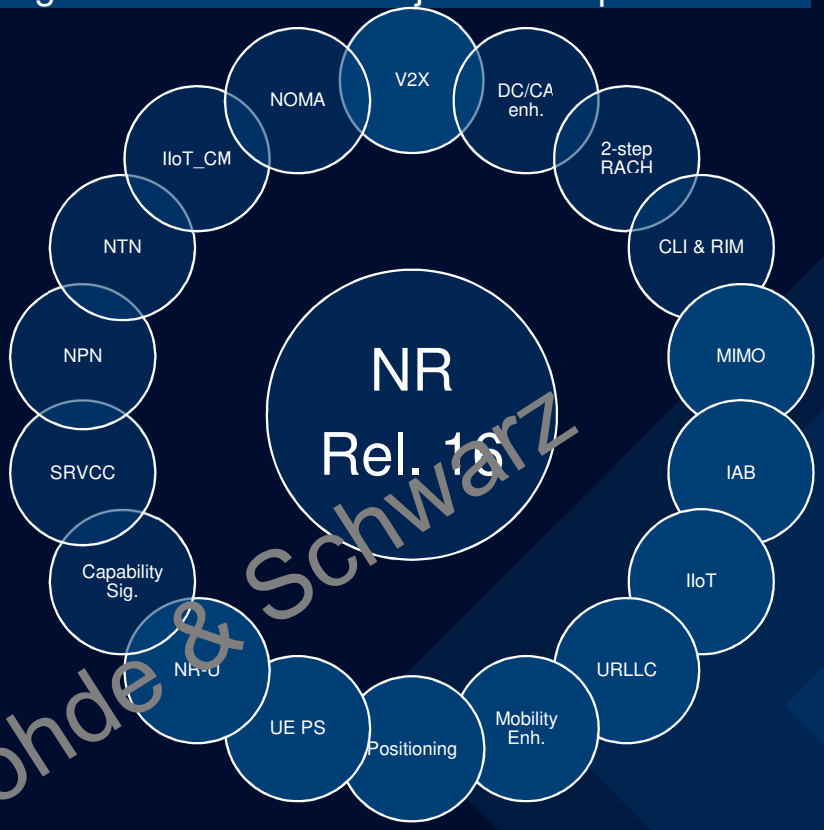
6G research kick off

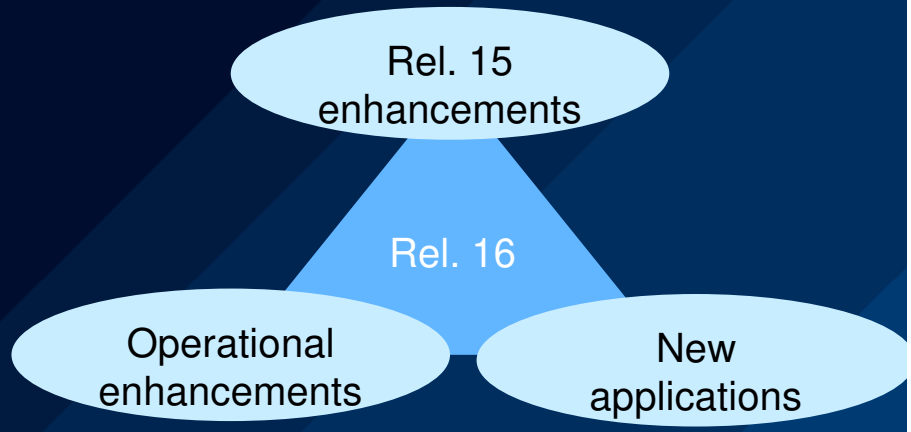
2018 2020 2022 2024 2026 2028 2030

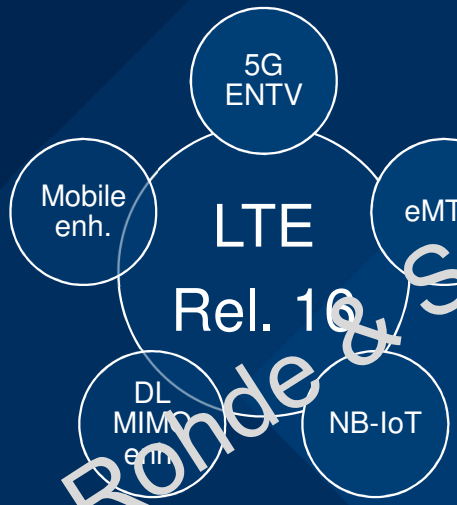
Rohde & Schwarz

3GPP REL. 16 TOPIC SUMMARY

Highlighted work items: major new aspects







3GPP FR1 frequency bands

NR operating band	Uplink	Downlink	Duplex mode
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
n14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
n18	815 MHz – 830 MHz	860 MHz – 875 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n24[16]	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n26	814 MHz – 849 MHz	859 MHz – 894 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n29	N/A	717 MHz – 728 MHz	SDL
n30[3]	2305 MHz – 2315 MHz	2350 MHz – 2360 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38[10]	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n46	5150 MHz – 5925 MHz	5150 MHz – 5925 MHz	TDD[13]
n47[11]	5855 MHz – 5925 MHz	5855 MHz – 5925 MHz	TDD
n48	3550 MHz – 3700 MHz	3550 MHz – 3700 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD[1]
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n53	2483.5 MHz – 2495 MHz	2483.5 MHz – 2495 MHz	TDD
n65	1920 MHz – 2010 MHz	2110 MHz – 2200 MHz	FDD[4]
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD

NR operating band	Uplink	Downlink	Duplex mode
n67	N/A	738 MHz – 758 MHz	SDL
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77[12]	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79[17]	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL
n85	698 MHz – 716 MHz	728 MHz – 746 MHz	FDD
n86	1710 MHz – 1780 MHz	N/A	SUL
n89	824 MHz – 849 MHz	N/A	SUL
n90	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD[5]
n91	832 MHz – 862 MHz	1427 MHz – 1432 MHz	FDD[9]
n92	832 MHz – 862 MHz	1432 MHz – 1517 MHz	FDD[9]
n93	880 MHz – 915 MHz	1427 MHz – 1432 MHz	FDD[9]
n94	880 MHz – 915 MHz	1432 MHz – 1517 MHz	FDD[9]
n95[8]	2010 MHz – 2025 MHz	N/A	SUL
n96[14]	5925 MHz – 7125 MHz	5925 MHz – 7125 MHz	TDD[13]
n97[15]	2300 MHz – 2400 MHz	N/A	SUL
n98[15]	1880 MHz – 1920 MHz	N/A	SUL
n99[16]	1626.5 MHz – 1660.5 MHz	N/A	SUL
n101	1900 MHz – 1910 MHz	1900 MHz – 1910 MHz	TDD
n102[14]	5925 MHz – 6425 MHz	5925 MHz – 6425 MHz	TDD[13]

3GPP FR2 frequency bands

NR operating band	Uplink	Downlink	Duplex mode
n257	26500 MHz – 29500 MHz	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	24250 MHz – 27500 MHz	TDD
n259	39500 MHz – 43500 MHz	39500 MHz – 43500 MHz	TDD
n260	37000 MHz – 40000 MHz	37000 MHz – 40000 MHz	TDD
n261	27500 MHz – 28350 MHz	27500 MHz – 28350 MHz	TDD
n262	47200 MHz – 48200 MHz	47200 MHz – 48200 MHz	TDD

3GPP RELEASE 16

- Enhancement of Ultra-Reliable and Low Latency Communications (URLLC)
- Support of LAN-type services
- Cellular Internet of Things (IoT)
- Advanced V2X support
- Northbound APIs related items
- Coexistence with Non-3GPP systems
- Railways and Maritime
- Mission Critical, Public Warning
- Conversational services, Streaming and TV
- 5G Location and Positioning Services
- Slicing
- Other system-wide Features
- Radio Features

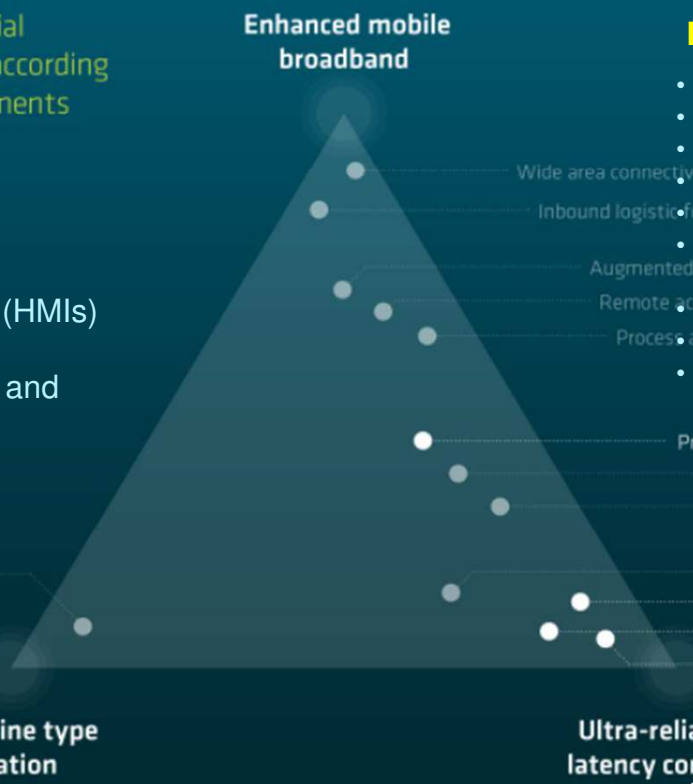
5G evolution, Releases 16

INDUSTRIAL IoT

5GACIA

Overview of selected industrial use cases and arrangement according to their basic service requirements

1. Factory automation,
2. Process automation,
3. Human-machine interfaces (HMIs) and production IT,
4. Logistics and warehousing, and
5. Monitoring and predictive maintenance



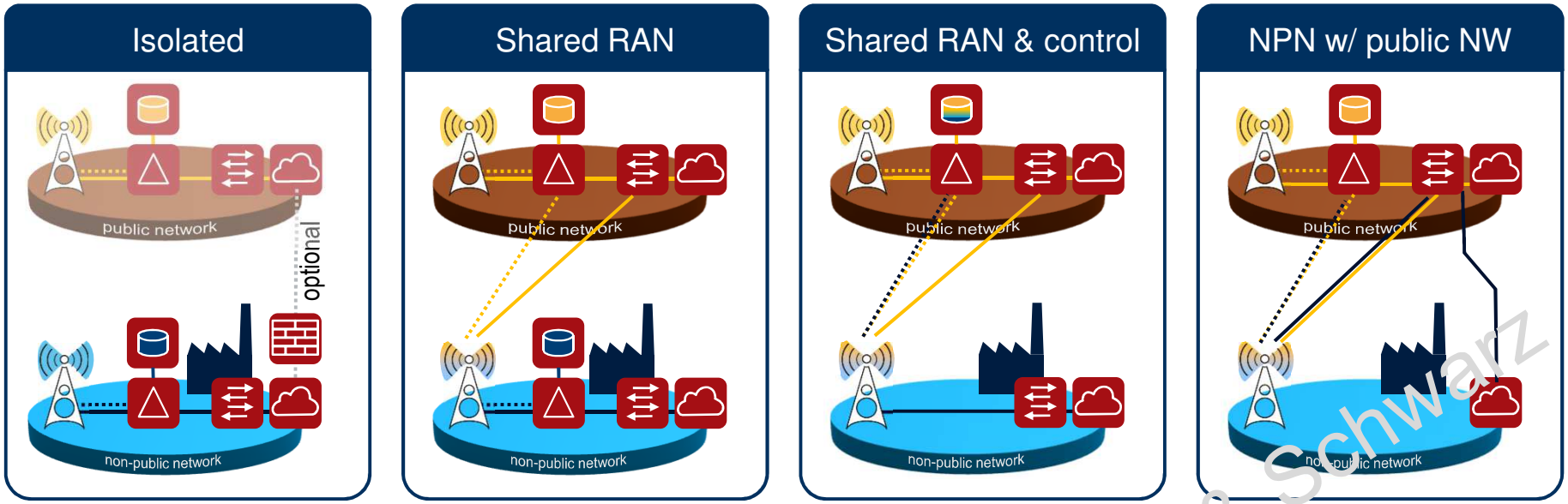
Key performance indicators

- High data rates
- Low latency
- Long battery lifetime
- Ultra-reliable
- Security-by-design
- High positioning accuracy
- High availability
- TSN support
- High synchronicity
- Deterministic communication
- Real-time support
- High connection density
- Dependable communication
- Non-public networks
- Network slicing

Surce:5GACIA, https://5g-acia.org/

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

How can we reduce network delays? 5G URLLC approach

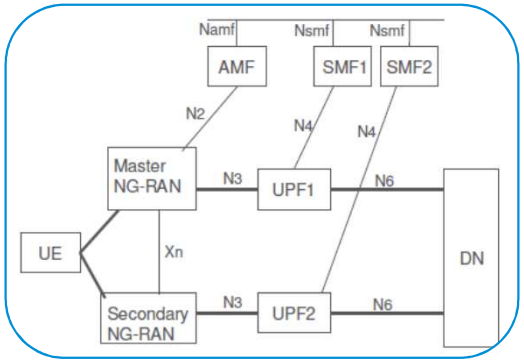
Traffic prioritization by QoS and network virtualization

Short symbol times, min-slots, semi-persistent scheduling

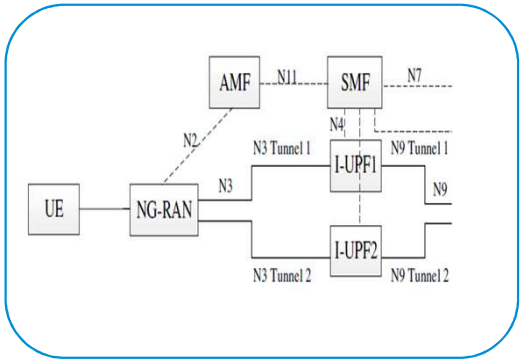
High speed data connection leveraging more bandwidth

Local processing, by edge/fog computing, non-public networks

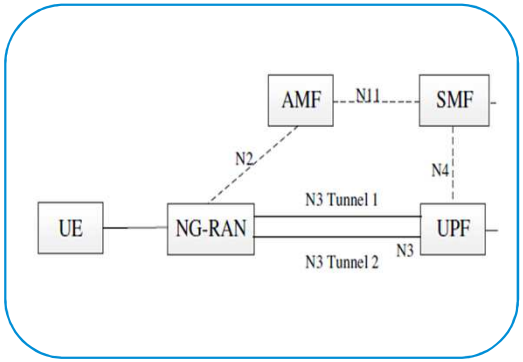
ENHANCEMENT OF URLLC SUPPORT IN THE 5G CORE NETWORK



Redundant User Plane paths using Dual Connectivity



Redundant transmission using two N3 and N9 tunnels between NG-RAN and PSA UPF



Redundant transmission using two N3 tunnels between the PSA UPF and the NG-RAN node

- QoS Monitoring: defined in R16 for the measurement of packet delay between UE and PSA UPF.
- Dynamic division of Packet Delay Budget: To obtain a more accurate delay budget for NG-RAN, SA WG2 decided to allow a dynamic value for the core network PDB (CN PDB), so that the SMF or NG-RAN can dynamically calculate delay budget of NG-RAN based on the CN PDB.

Physical Layer Enhancements for NR URLLC

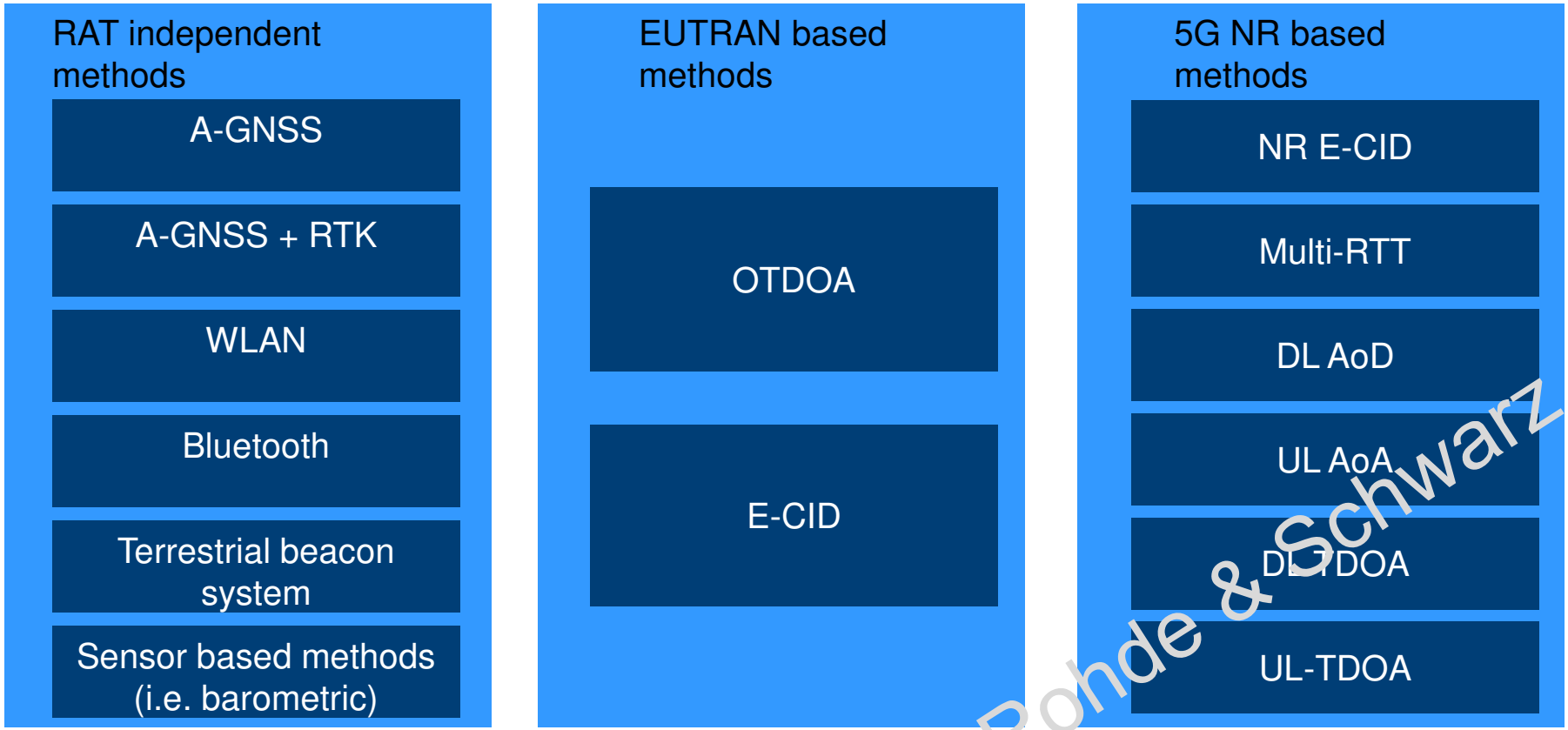
- High reliability
  - DCI format 0_2 and DCI format 1_2 (Compact DCI using smaller payload and reducing code rate)
  - Multiple active configured grant configurations for a BWP (RRC)
  - Two HARQ-ACK codebooks constructed simultaneously
- Low latency
  - Enhanced PDCCH monitoring capability
  - Sub-slot based HARQ-ACK feedback
  - PUSCH enhancements – repetition type A and B
  - Enhanced inter UE Tx prioritization/multiplexi

5G evolution, Releases 16

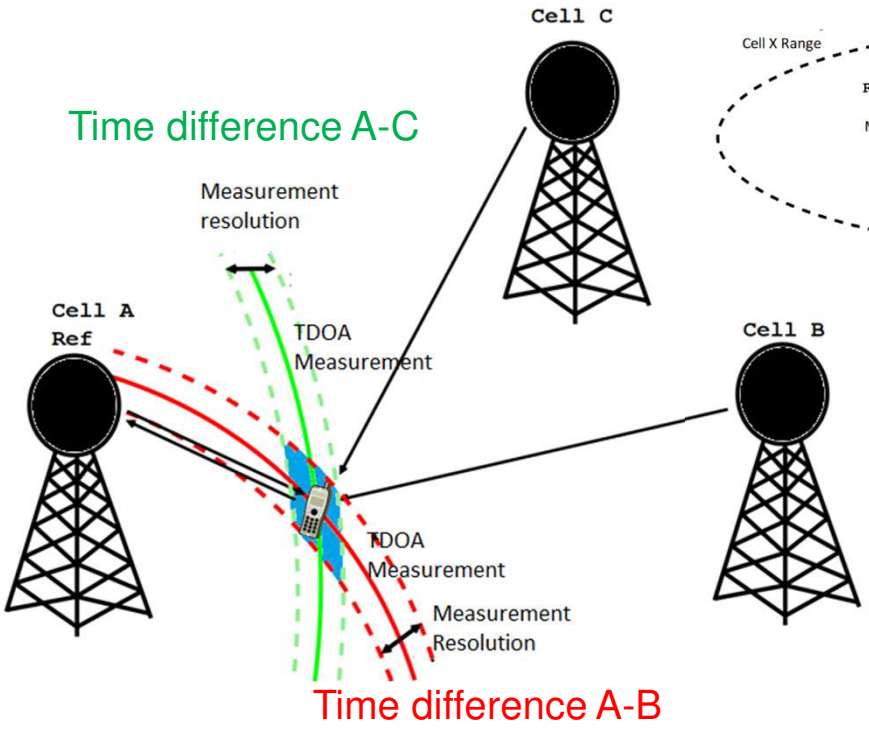
5G EVOLUTION – POSITIONING, NR-U, 2-STEP RACH , MOBILITY, POWER SAVING etc.

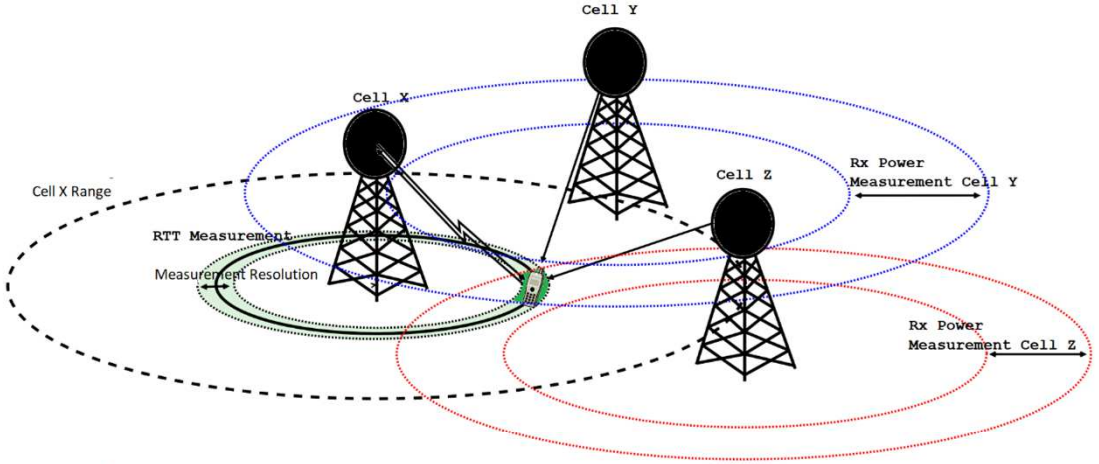
Rohde & Schwarz

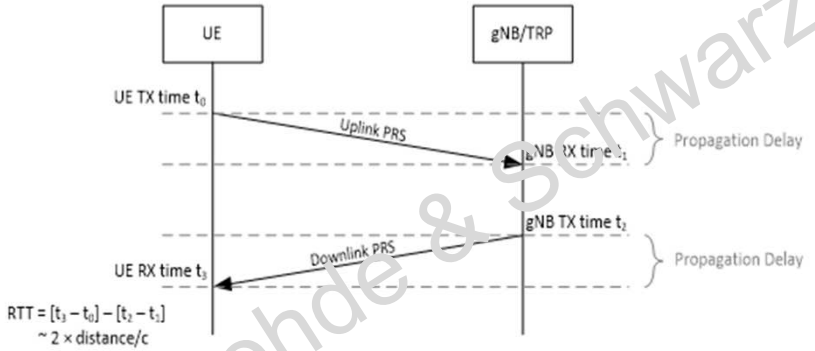
REL. 16: NR POSITIONING



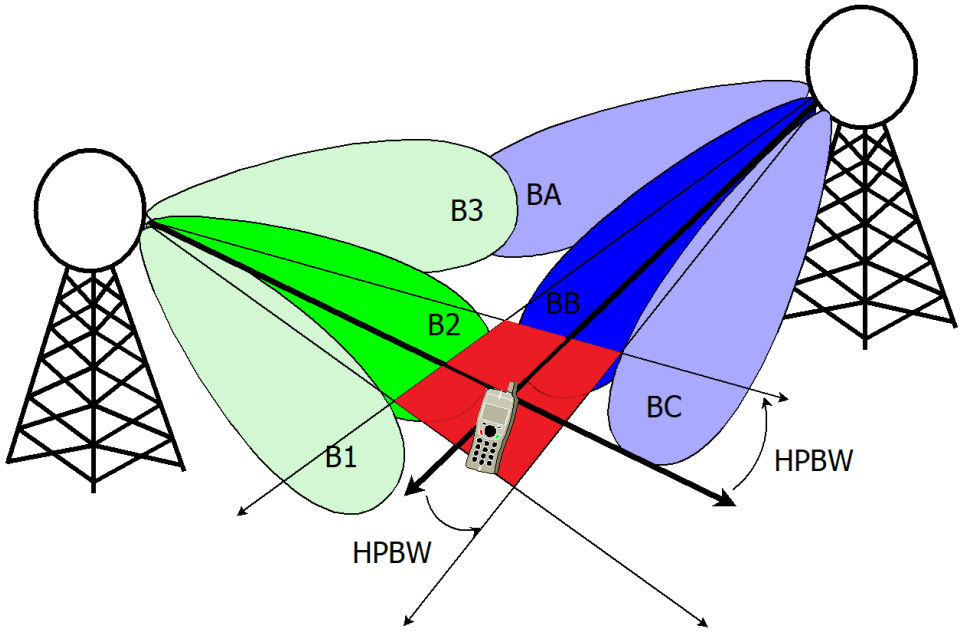
TDOA, RTT AND POWER BASED LBS TECHNOLOGIES



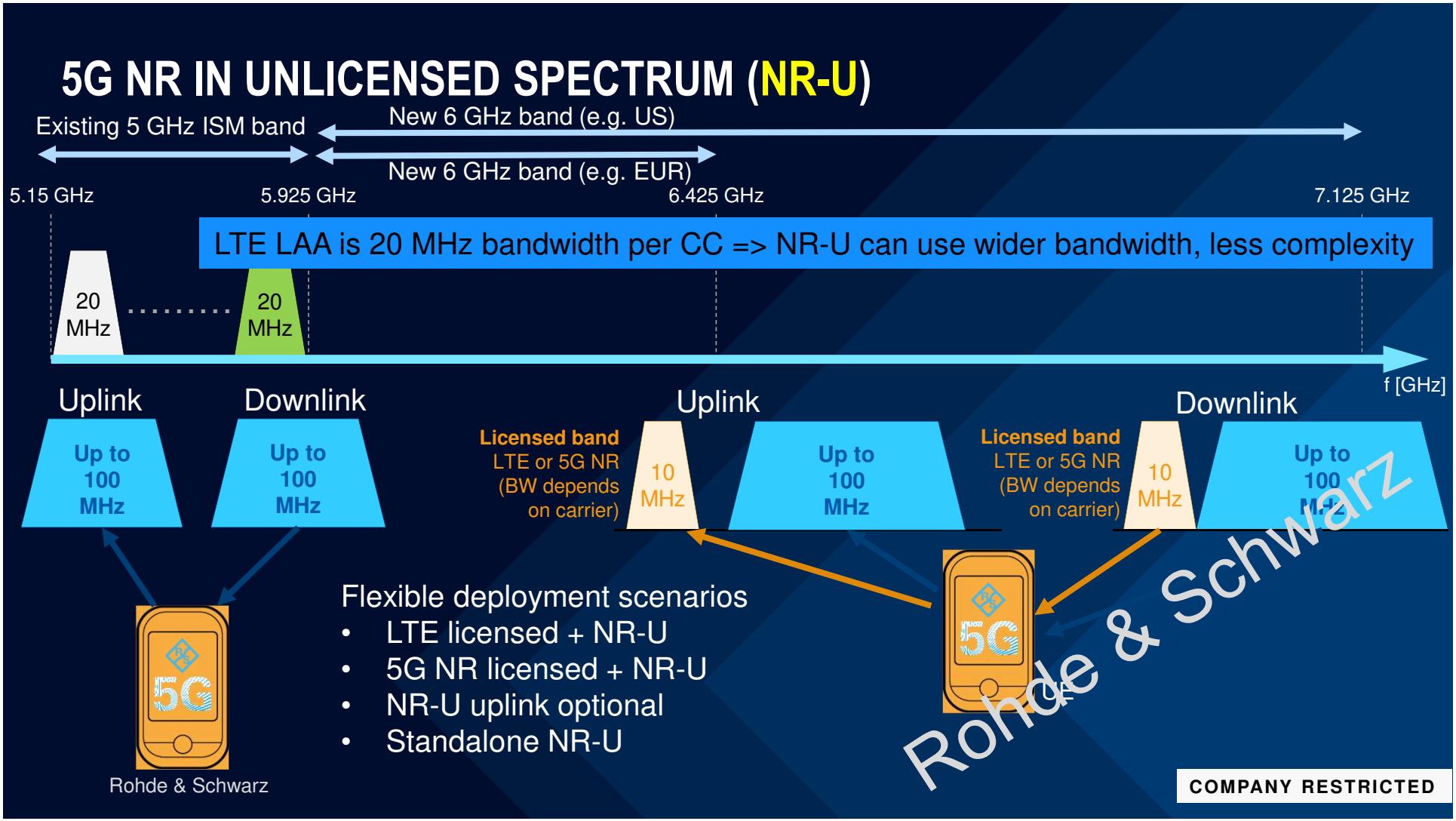




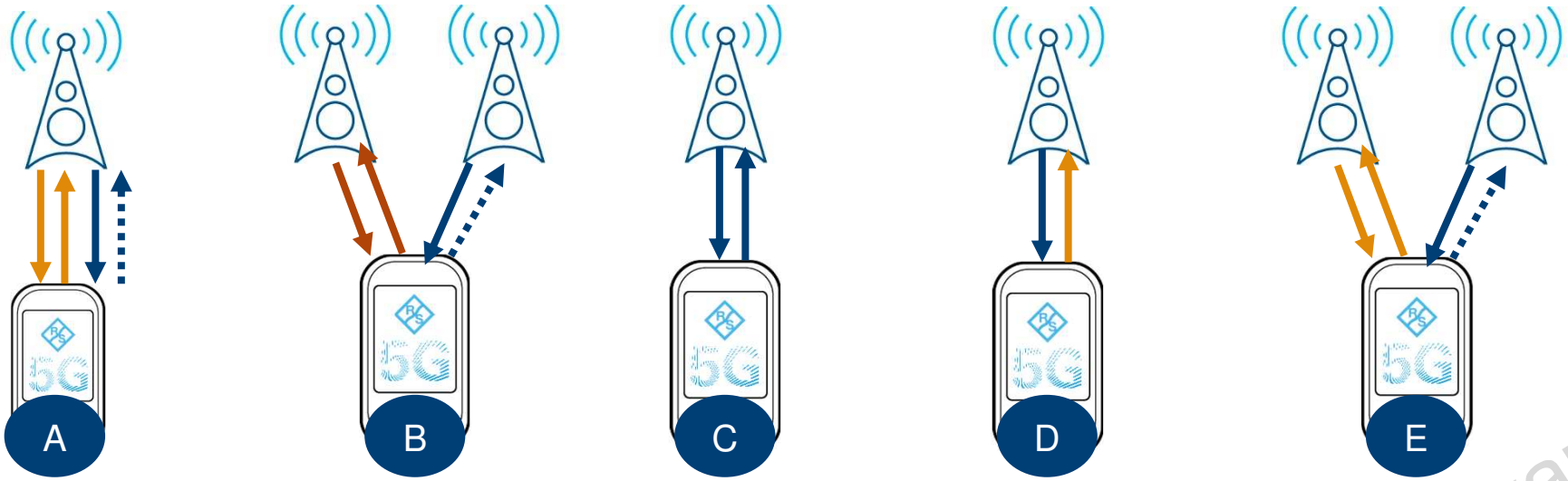
ANGLE-BASED TECHNOLOGIES



- Angle-based technologies measure the AoA or AoD of the signal
- The accuracy of the positioning is determined primarily by the Half Power Beam Width (HPBW)
- In the example, the UE can be located anywhere in the red square
- For FR2, angle-based technologies can be interesting
- They can be combined with other measurements such as RTT or OTDOA

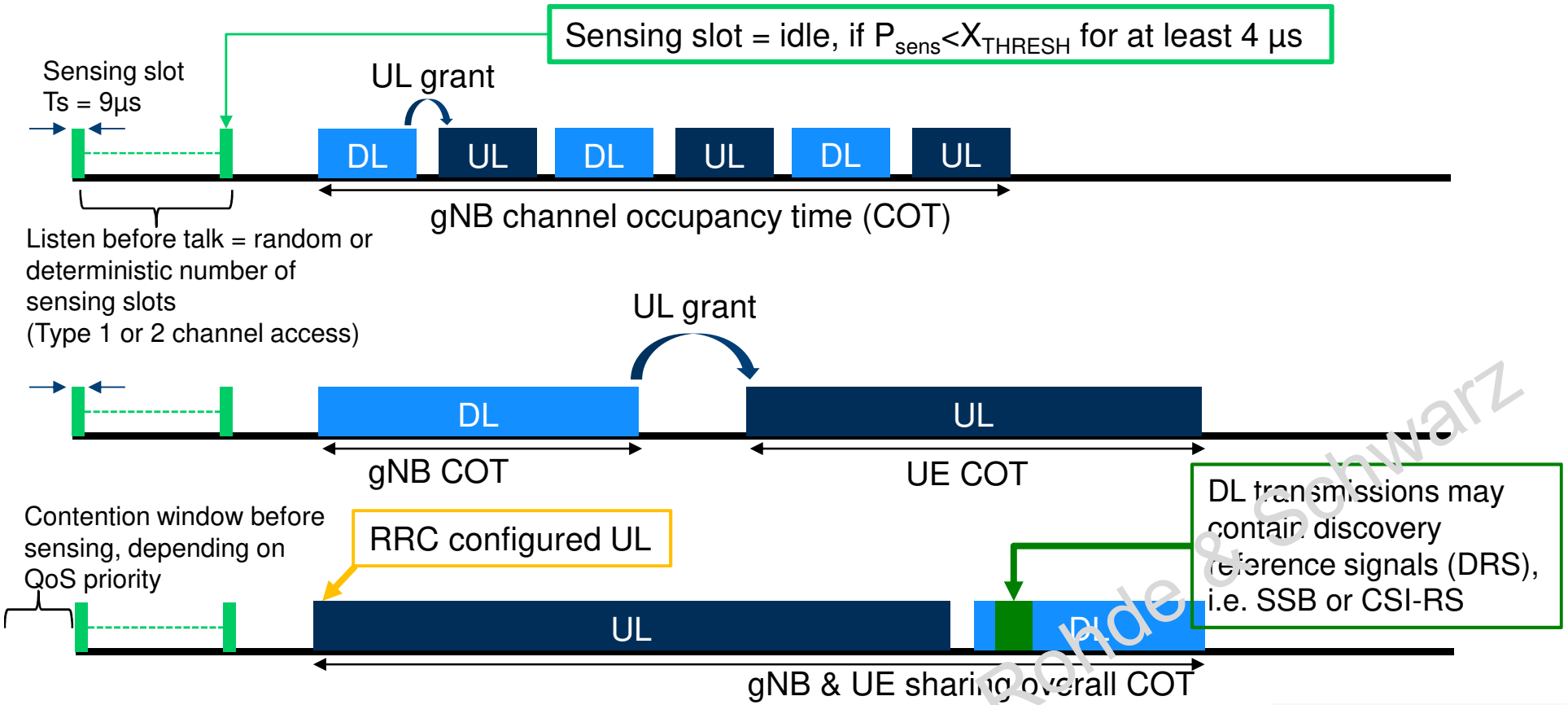

5G NR IN UNLICENSED SPECTRUM (NR-U)
Existing 5 GHz ISM band
New 6 GHz band (e.g. US)
New 6 GHz band (e.g. EUR)
5.15 GHz
5.925 GHz
6.425 GHz
7.125 GHz
LTE LAA is 20 MHz bandwidth per CC => NR-U can use wider bandwidth, less complexity
20 MHz
20 MHz
f [GHz]
Uplink
Downlink
Up to 100 MHz
Up to 100 MHz
Licensed band
LTE or 5G NR
(BW depends on carrier)
10 MHz
Uplink
Up to 100 MHz
Licensed band
LTE or 5G NR
(BW depends on carrier)
10 MHz
Downlink
Up to 100 MHz
Flexible deployment scenarios
• LTE licensed + NR-U
• 5G NR licensed + NR-U
• NR-U uplink optional
• Standalone NR-U
Rohde & Schwarz
Rohde & Schwarz
COMPANY RESTRICTED

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

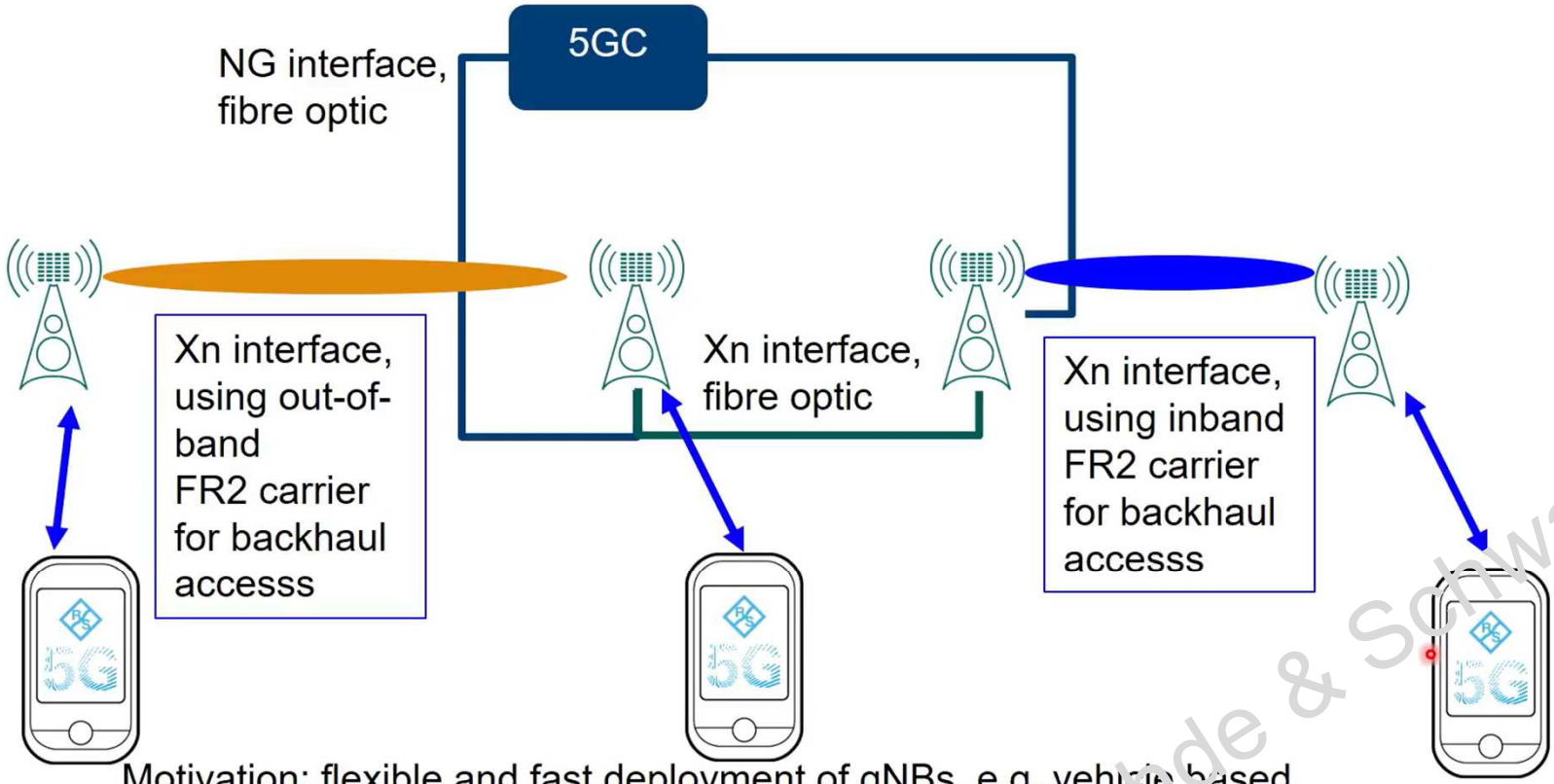


- Scenario A: Carrier aggregation between licensed band NR (PCell) and NR-U (SCell)
  - NR-U SCell may have both DL and UL, or DL-only
- Scenario B: Dual connectivity between licensed band LTE (PCell) and NR-U (PSCell)
- Scenario C: Stand-alone NR-U
- Scenario D: A stand-alone NR cell in unlicensed band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

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



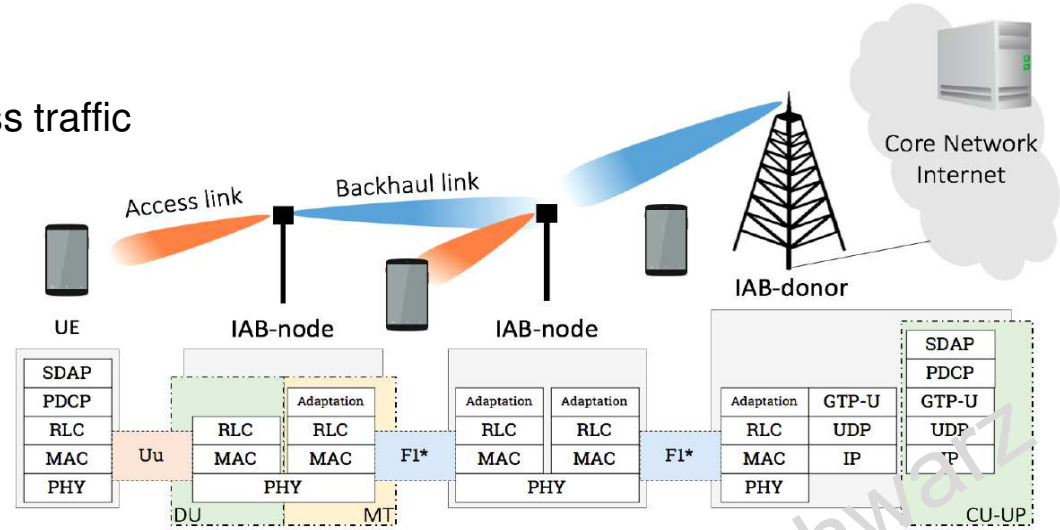
5G NR INTEGRATED ACCESS BACKHAUL (IAB)



Motivation: flexible and fast deployment of gNBs, e.g. vehicle based

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

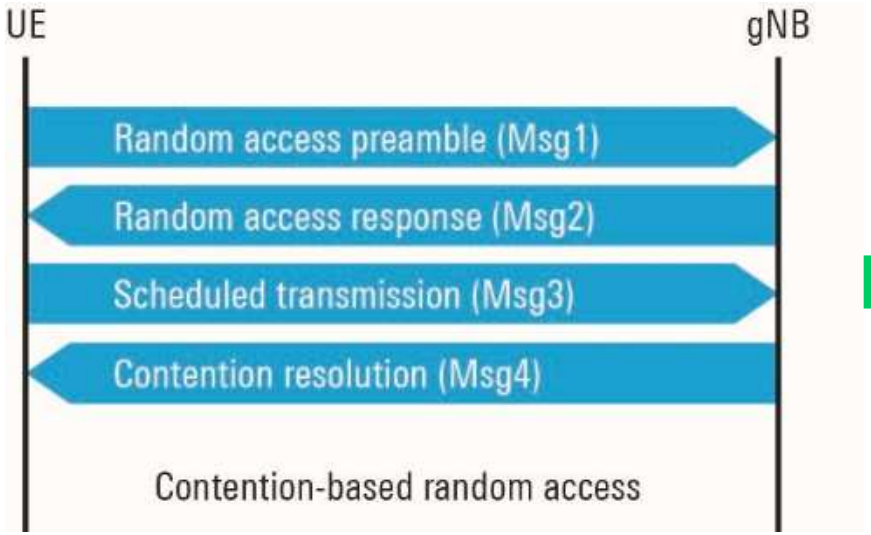
- Wireless backhaul links to relay the access traffic
- Enabling flexible and ultra-dense cell deployments at lower cost, leverages coverage (not capacity)
- Multi-hops for the short range in mmWave

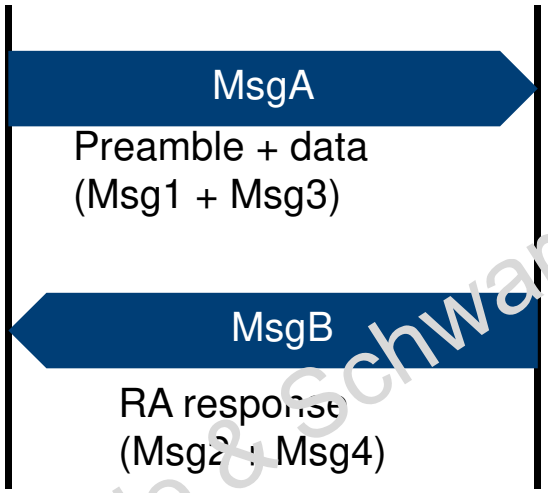


- Replaces the proprietary solutions in current (extensively used) wireless backhaul links (P2P, LOS)
- Motivated by larger bandwidths and native beamforming in NR (as opposed to LTE Rel-10 relays)
- Very beneficial for NR rollout and during the early phases of the initial growth

REL. 16: NR 2-STEP RACH

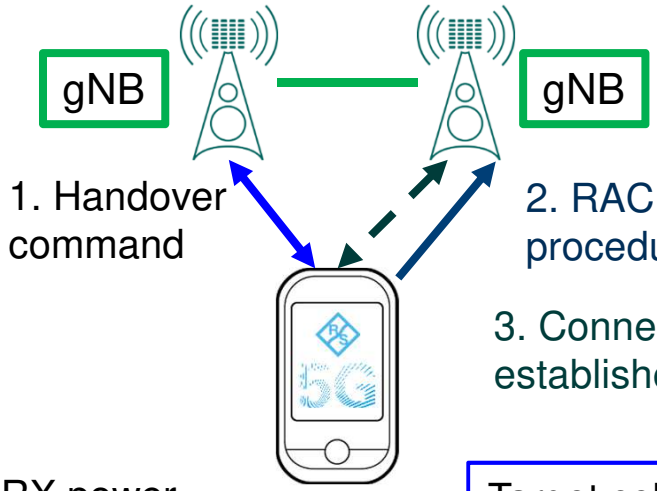
Idea: change legacy 4-step RACH into 2-step RACH
Motivation: reduce latency and control signaling overhead

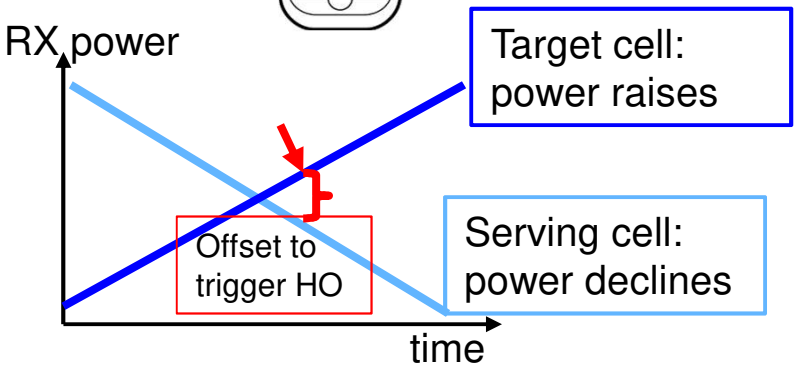




5G NR MOBILITY ENHANCEMENTS

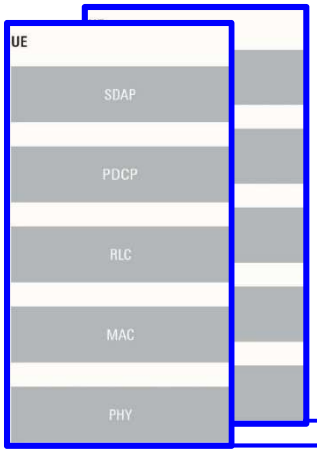
Rel. 15 mobility

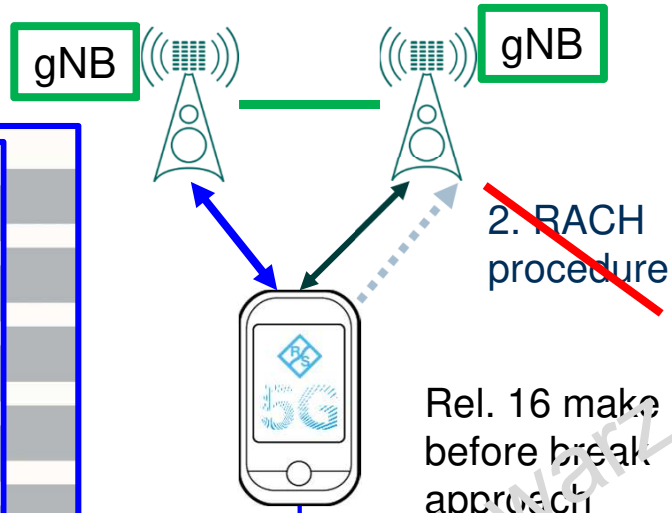




Rel. 16 mobility

Dual active protocol stacks (DAPS)





Rel. 16 make before break approach

+

RACH less handover procedure

Idea: send HO command earlier, with some configuration info to trigger HO autonomously

UE Power Saving in NR

- **Power Saving Techniques in CONNECTED state**
  - WUS(DRX adaptation)
  - Cross slot scheduling (PDCCH→DCI → PDSCH)
  - Maximum MIMO Layer Adaptation
  - Fast transition out of CONNECTED state
- **Power Saving Techniques in idle/inactive state**
  - Reduced RRM measurements in idle/inactive state
- **UE assistance information**

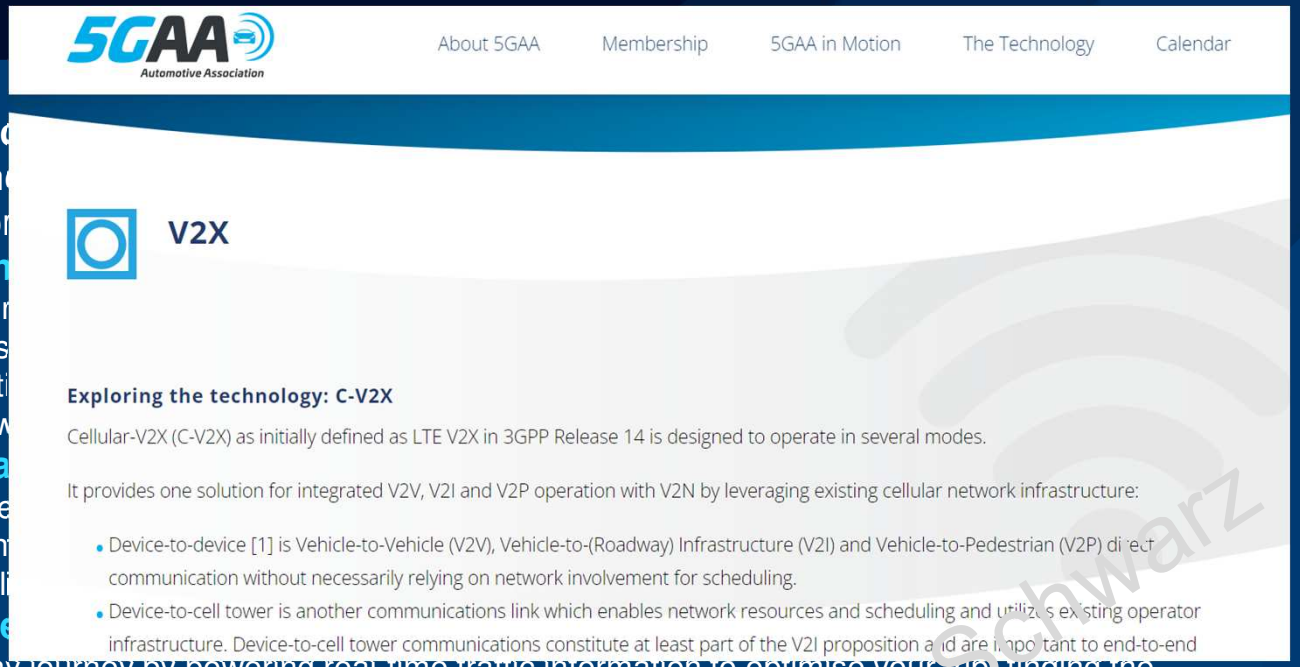
5G evolution, Releases 16

NR-V2X

COMPANY RESTRICTED

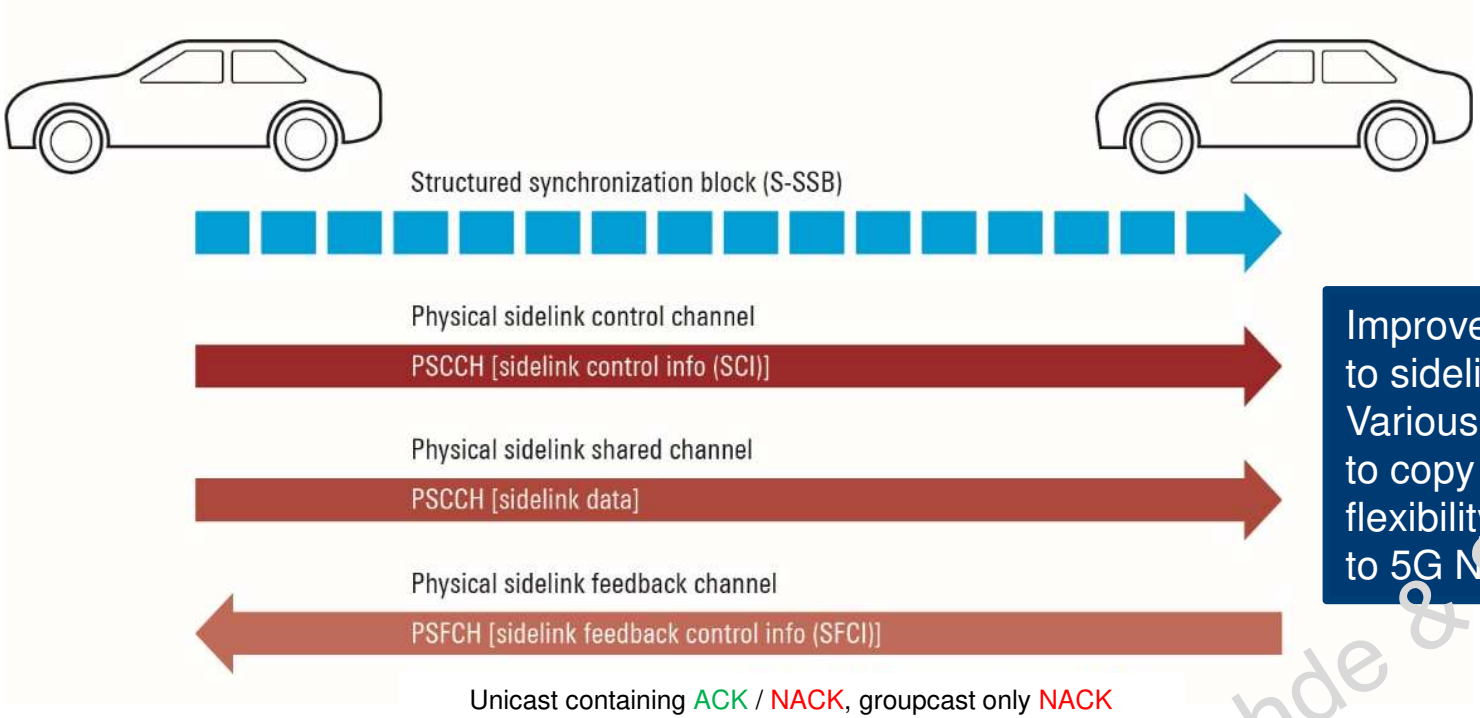
The **5G Automotive Assoc**
from the automotive, techn
develop end-to-end solutio

- **Making vehicles sm**
  Communication and co
  technologies will be ess
  everything communicati
  pedestrians (V2P), netw
- **Making vehicles sa**
  C-V2X will improve safe
  pedestrians and road in
  situations, reducing colli
- **Improving driving e**
  C-V2X will enlighten any journey by powering real-time traffic information to optimise your trip, finding the closest free parking space or enabling predictive maintenance to save drivers both time and money. And it's not just drivers who will benefit from it, passengers will too with the next-generation of infotainment services. Whether you want to watch a movie during the ride or participate in an important conference call, all of this and more is possible.



Surce:5GAA, https://5gaa.org/

5G NR SIDELINK – CHANNEL STRUCTURE

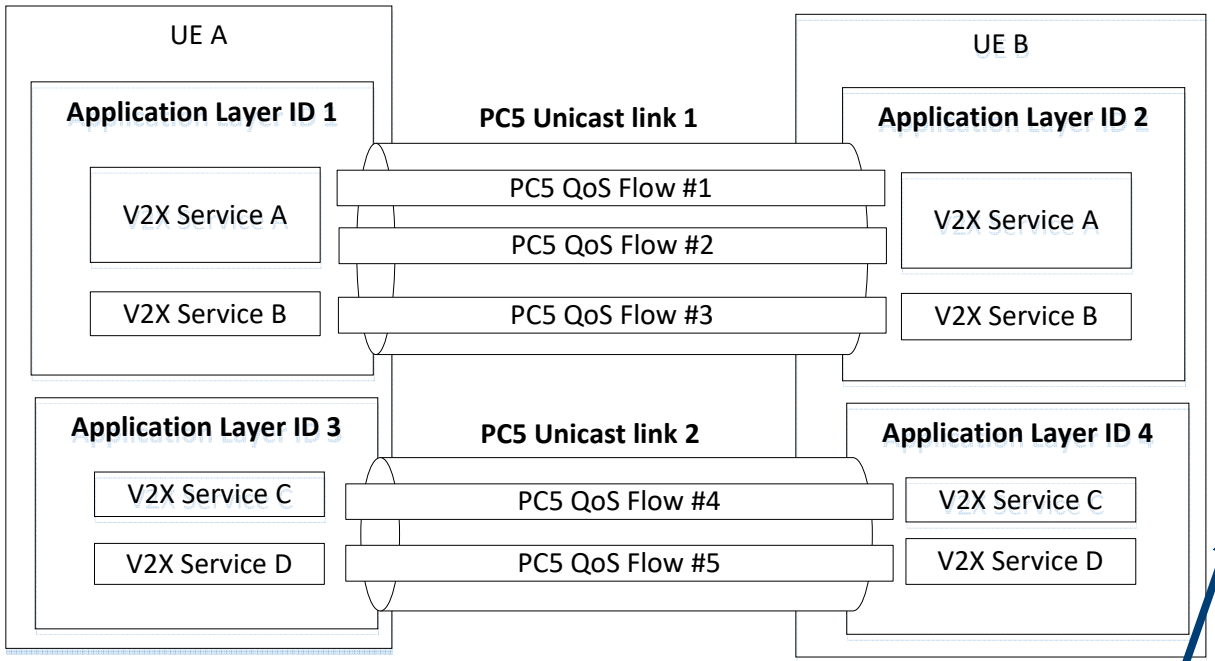


Improved flexibility due to sidelink control info. Various numerologies to copy the tremendous flexibility of 5G NR, also to 5G NR V2X

Unicast containing ACK / NACK, groupcast only NACK

Technology of PC5 direct communications (5G)

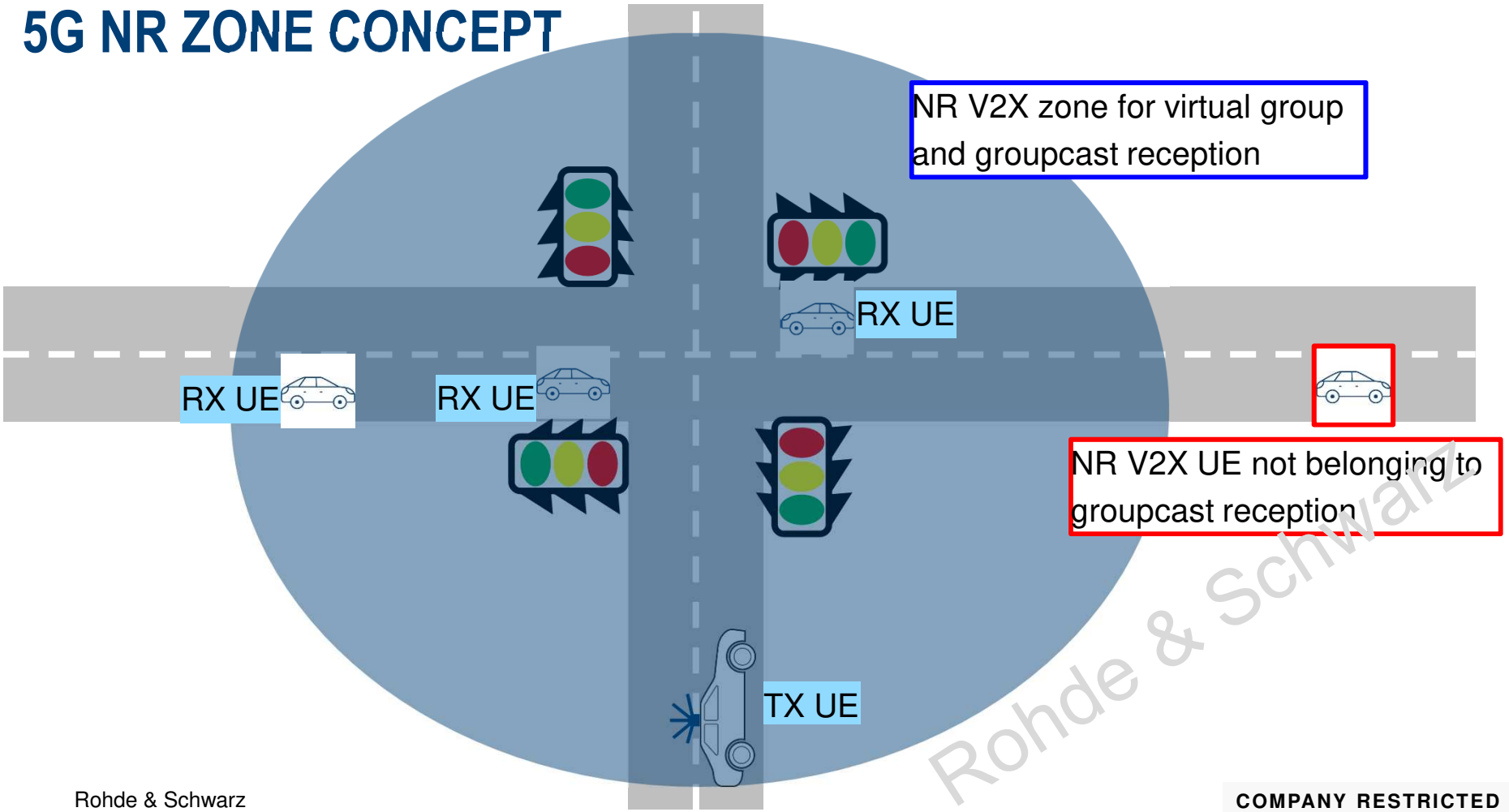
NR V2X SIDELINK SUPPORTING QoS



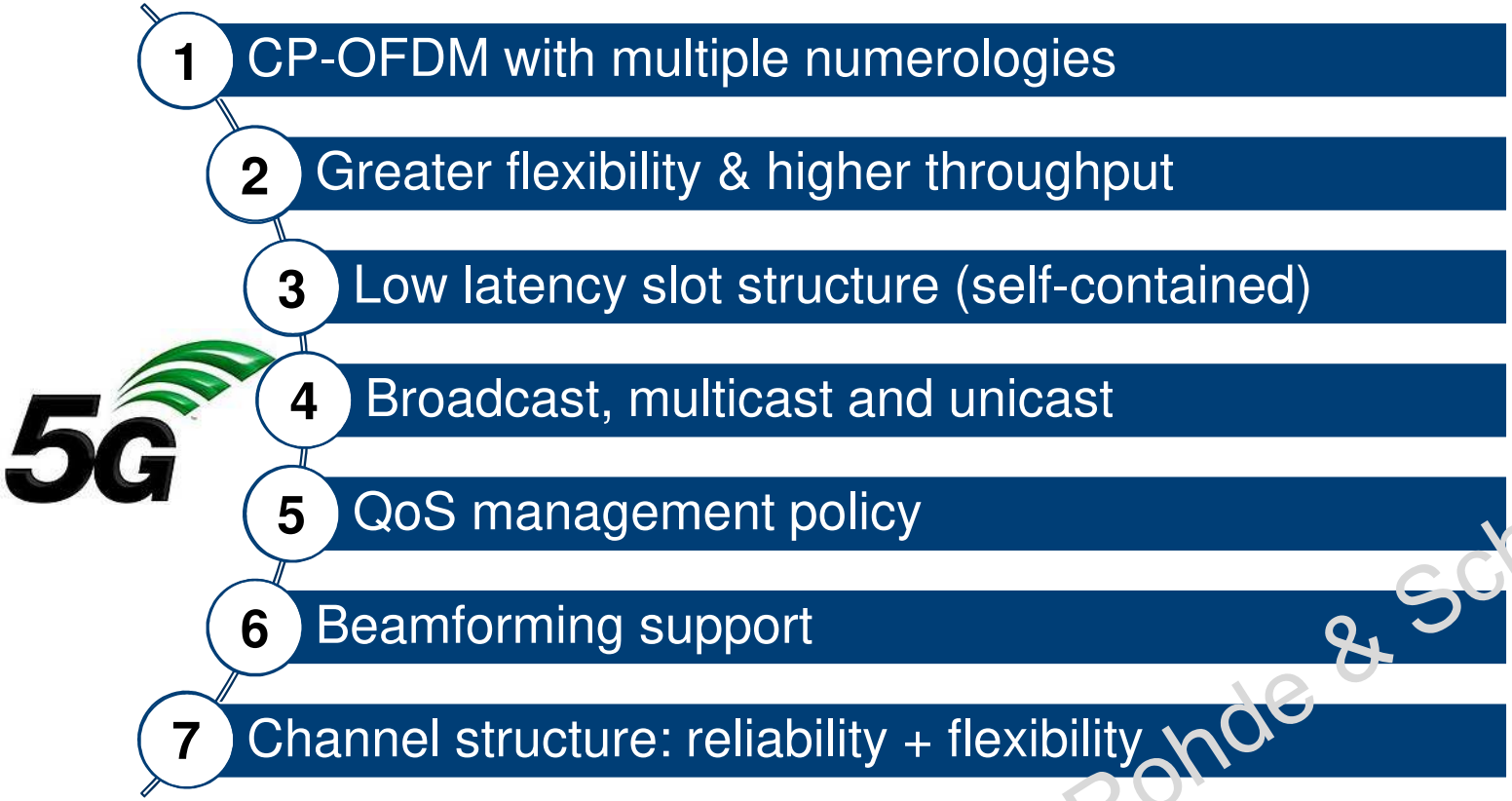
	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Service
21	GBR	3	20 ms	10^{-4}	1. N/A	2. 2000 ms	3. Platooning between UEs – Higher degree of automation; 4. Platooning between UE and RS – Higher degree of automation
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 la 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 la chan e – lower degree of automati
58		4	100 ms	10^{-2}	21. N/A	22. N/A	23. Sensor info n sharing low degree of automation
59		6	500 ms	10^{-1}	24. N/A	25. N/A	26. Platooning – reporting to an RS
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	(NOT 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 test ☺ but an example of the flexibility:
3GPP defines ~10 different QoS flow profiles for the NR V2X sidelink

5G NR ZONE CONCEPT



THE 7 PILLARS OF 5G NR-C-V2X



5G SIGNALING SOLUTION CMX500

- Up to 32 NR Layers
- Up to 32 LTE Layers
- 48 layers on air simultaneously

- Sub8: 400 MHz - 8 GHz
- mmW: 24 … 50 GHz

OLD WORLD V.S. NEW WORLD

CMX500 OBT
One Box Tester

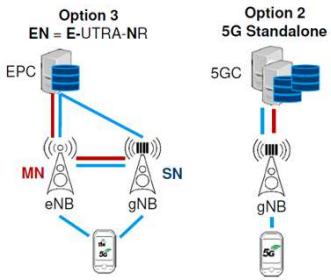
Flex Setup

OBT Setup

OLD WORLD V.S. NEW WORLD

FR1

FR2



FR1 & FR2 & LTE in a single Box

CMX500 UPDATE

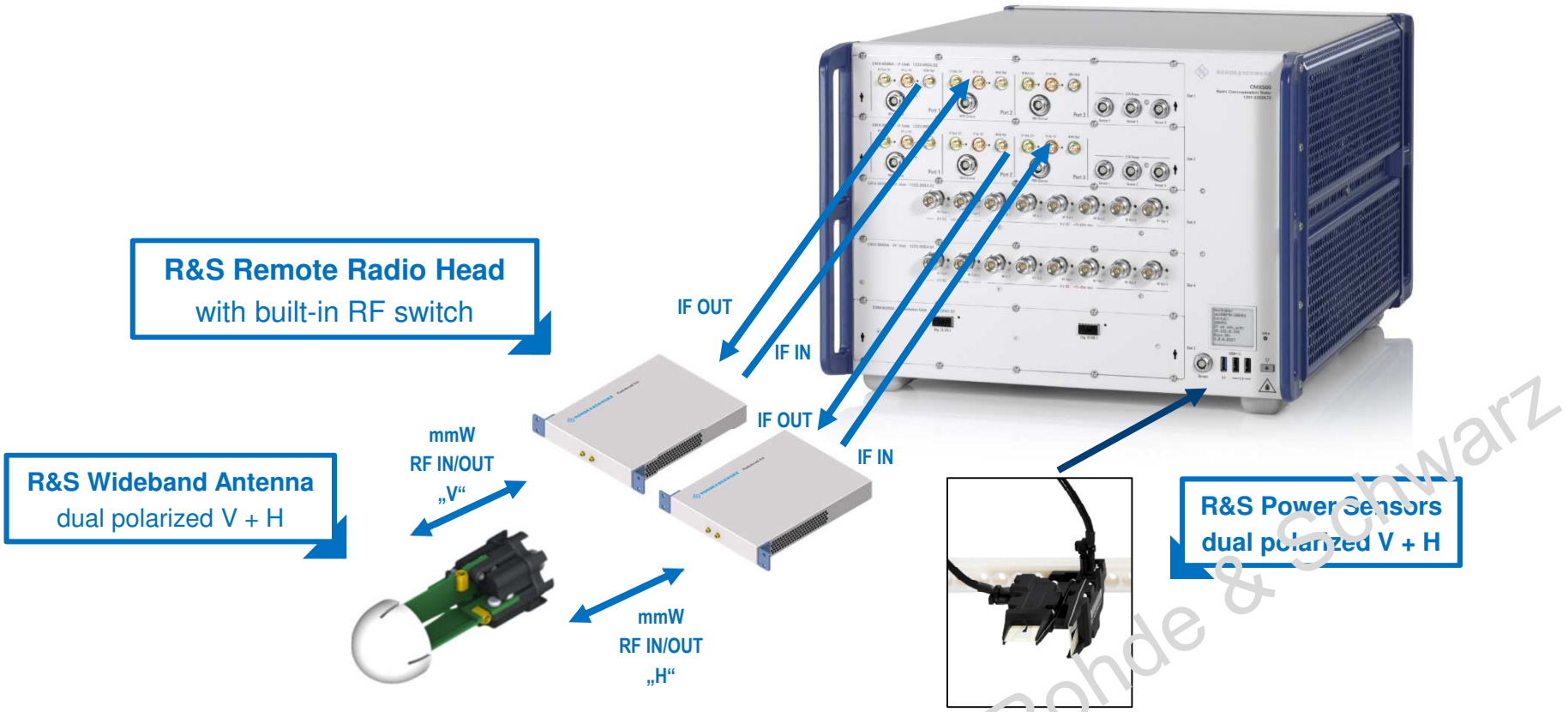
Rohde & Schwarz validates 10 Gbps end-to-end (E2E) peak downlink IP data throughput

Rohde & Schwarz announced today the next breakthrough in 5G data performance: With support of Qualcomm Technologies, Inc., Rohde & Schwarz has validated 10 Gbps end-to-end (E2E) IP data performance using its R&S CMX500 5G radio communication tester platform. The setup was powered by Snapdragon® X65 5G Modem-RF System, the world's first 3GPP Release 16 modem-RF system with Qualcomm® QTM545 mmWave Antenna Module.

Rohde & Schwarz achieved the milestone results based on a 3GPP Release 16 5G New Radio Dual Connectivity (NR-DC) network simulation, provided by its R&S CMX500 5G radio communication tester. In the simulation, two cell groups were simultaneously connected, one using spectrum in frequency range 1 (FR1) and the other in frequency range 2 (FR2; mmWave). The FR1 carrier spans over full 100 MHz bandwidth using an antenna configuration of MIMO 4x4 and 256QAM modulation. Eight additional component carriers are combined in FR2, using MIMO 2x2 and 256QAM modulation.

The demonstration covered several test cases that verified high data throughput in downlink over IP layer, using different configuration modes of the 5G protocol stack's lower layers such as Radio Link Control (RLC) in Unacknowledged Mode (UM) and Acknowledged Mode (AM). These configuration modes made it possible to push real IP data over the wireless communication link, making this the first time ever that real IP end-2-end data was used in a performance of this kind. Previously, throughput had simply been verified on the modem's lower layer 5G protocol stack. This opens up a new era of 5G data performance, which eventually will enable eMBB use cases like 4K and 8K video streaming or augmented reality applications.

MMW RF INTERFACE: V- AND H- LAYERS USING ONE DUAL-POL ANTENNA



PRIORITIES 3GPP RELEASE 16 FEATURE

- NR-DC FR1+FR2 End-to-End (E2E) data link > 10Gbps
- UE power saving
- NR in Unlicensed spectrum
- NR Positioning

Prepared for Rel-16

CMX500 5G APPLICATION TEST

- Application Test Introduction
- Feature highlights
  - Throughput testing
  - VoLTE/VoNR audio test

R&S CMX500 ONE-BOX TEST SETUP FOR APPLICATION TESTING

Unique integrated solution – Simplify your test setup!

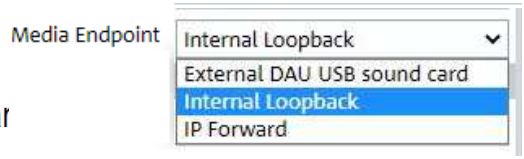
IMS SERVER – VOLTE/VONR CALLS -LOOPBACK

Use Case: Loopback Mode

Procedure:

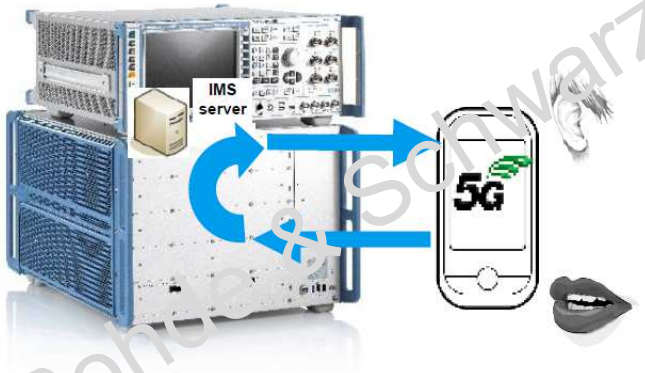
- UE registers to the internal CMX500 IMS Server
- Establishes a VoLTE/VoNR call with the virtual CMX500 phone to an arbitrar
- The user can speak into the microphone of the DUT and listen to the echo at the loudspeaker of the DUT

- IMS Media Endpoint Configuration



Test Focus:

- Functional test of the microphone and speaker
- Verification of IMS SIP registration and call setup procedure
  - Functional test of IMS client implementation
- Functional verification of uplink and downlink communication



ACOUSTIC VS. CONDUCTED TEST

Acoustics tests **based on 3GPP TS 26.132**

- Audio acoustic tests in a chamber

Use Case:

- High end audio quality test
- New hardware or mobile device introduction

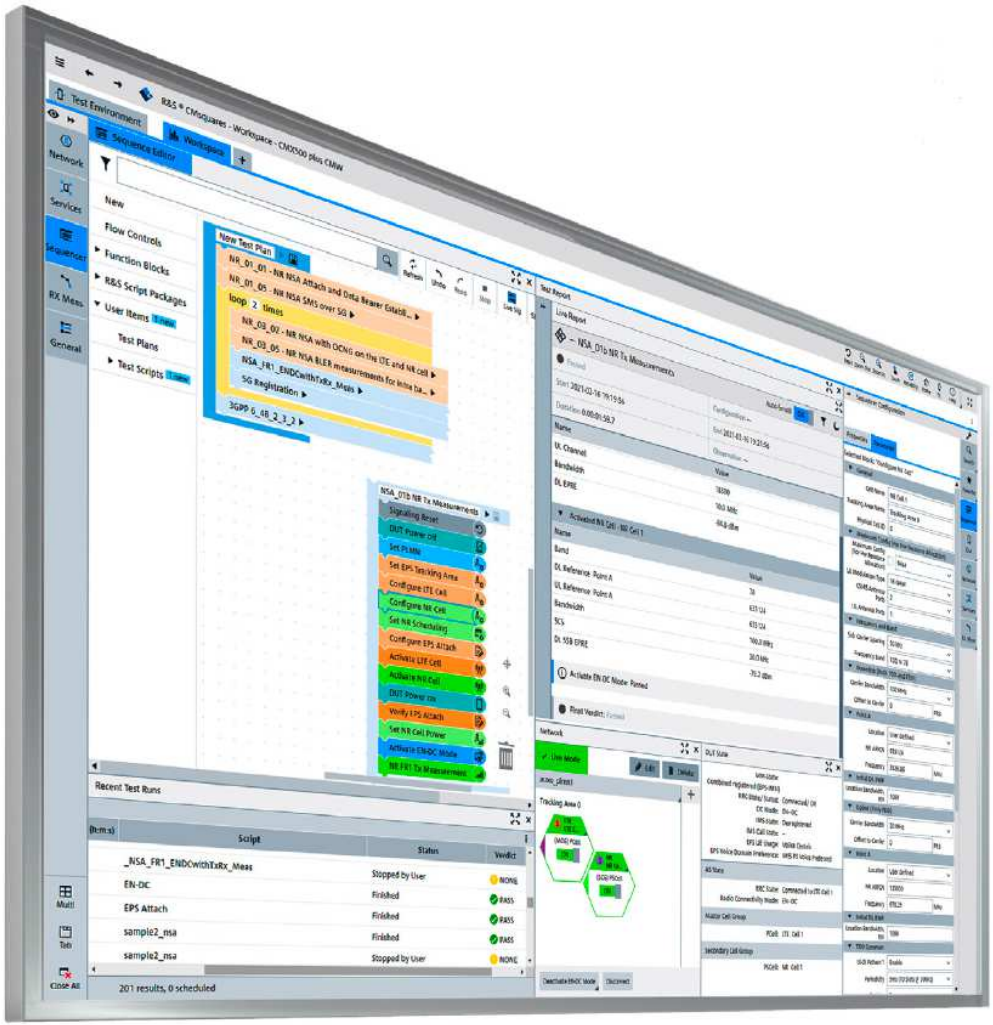
Conducted tests **3GPP TR 26.954 Tests**

- Performance and robustness test for VoNR using (Impairments / Fading)

Use Case:

- Operator performance test
- Test of software changes on mobile devices
- Test of new codec versions e.g EVS codec updates

Easy to handle and clean setup!



CMsequencer

STATE OF THE ART, FUTURE PROOF SOFTWARE

COMPLETE COVERAGE OF TESTS IN ONE GRAPHICAL APPLICATION

BUILT-IN AUTOMATED CAMPAIGN MANAGEMENT

AUTOMATIC DUT SUPPORTED BAND COMBINATION TESTS

ALL TYPES OF R&D TESTS IN ONE GRAPHICAL TOOL

3GPP Pre-conformance tests

- 38.521 in-band Tx/Rx tests
- Easy to configure & speed optimized
- Flexi mode for extended testing

Protocol & Failure tests

- 5G features like ESFB, CA, CMAS/ETWS, Multi-numerology, …
- Failures like Attach Reject, TAU Reject, Conn Reject, RLF, IMS Failures, …
- SCPI and Python code extensions

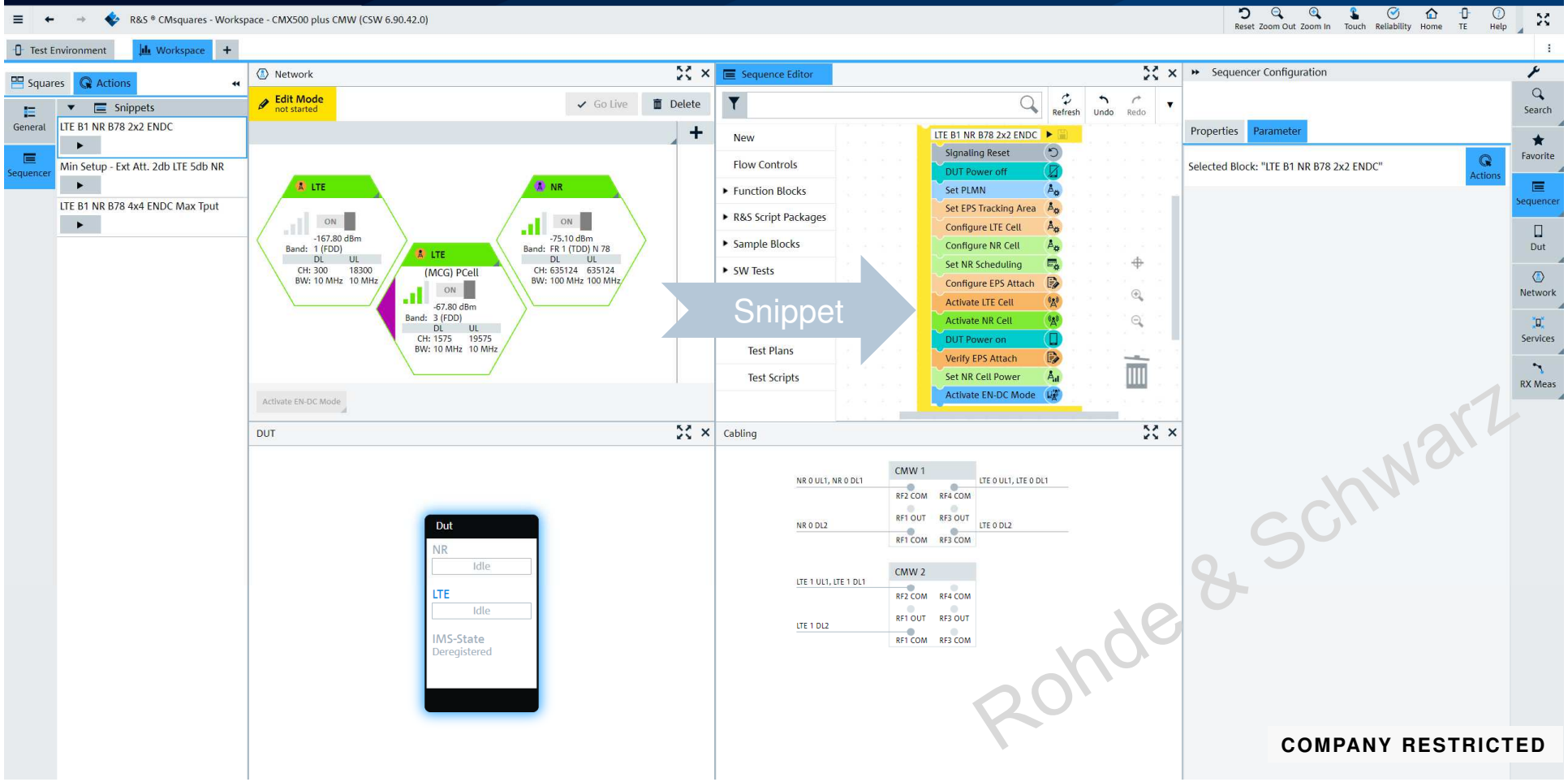
RF & Functional tests

- Multi-Eval, BLER, Rx Sensitivity with live meas results incl. graphs
- Max Throughput E2E tests
- VoLTE / VoNR with Audio analysis
- Battery life tests

Automation Support

- Re-use of CMsquares automation framework
- Easy integration into external automation frameworks
- Shuffle through ue band combination

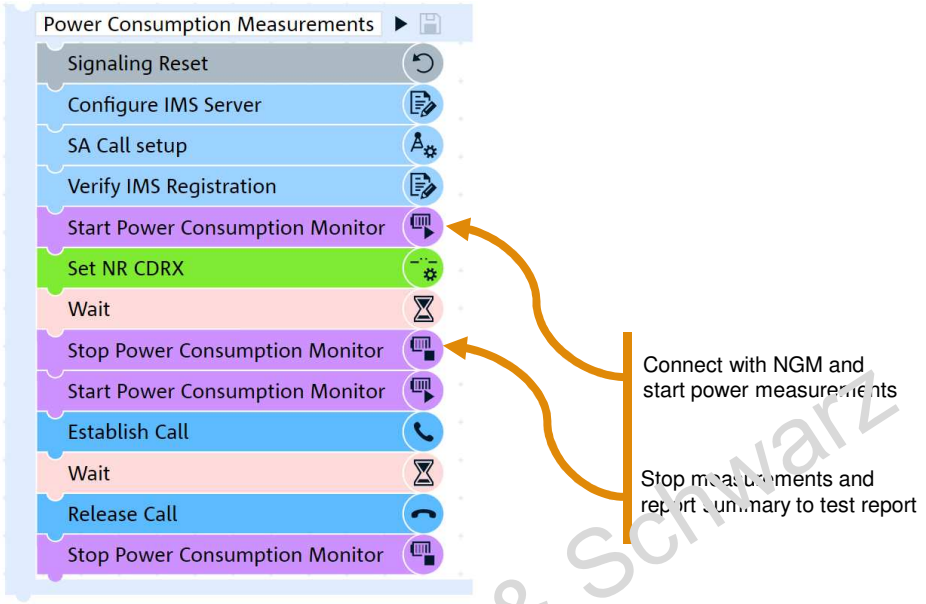
BRDIGE WEBGUI & SEQUENCER WITH SNIPPETS



BATTERY DRAIN - TESTING WITH CMX500

CMX500
5G NR Network simulator

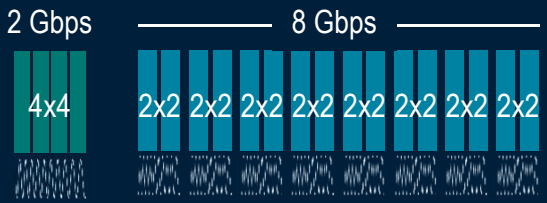
NGM200
Power Supply



Rethink 5G testing

The synergy of best performance and ease of use in one box.

All-in-one high performance 5G testing solution packed in a single box



- 10 Gbps and more end-to-end IP throughput
- All possible 5G NR (SA/NSA) FR1/FR2 deployments
- All frequency ranges and technologies (4G, 3G, 2G)
- 48 layers
- Future proof by design

Leading-edge RF performance and ease of use for all 5G NR use cases

- CMsquares – our novel, cross platform, and highly intuitive Web UI
- Designed to cover all 5G NR use cases: VoNR, IP, messaging, Video, LBS, and more
- One box solution allows simplified test set-up and reduces re-cabling and footprint
- Offering a whole portfolio of 5G NR test equipment based on one platform

THANK YOU

ROHDE&SCHWARZ

Make ideas real