

SIMPLIFYING 5G MOBILE DEVICE TESTING

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ROHDE & SCHWARZ

Make ideas real



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IN THIS WEBINAR, WE OUTLINE...

- ▶ The trends and the industry priorities of a wide range of features which the next generation 5G devices are set to cover.
- ▶ The typical test requirements and challenges in ensuring performance of a 5G device across different layers.
- ▶ Rounding it up with a demonstration of the R&S®CMX500 5G tester using R&S®CMsquares, a web based GUI which seamlessly integrates the different test approaches, from interactive UI to a Python based interface to create test scenarios programmatically.

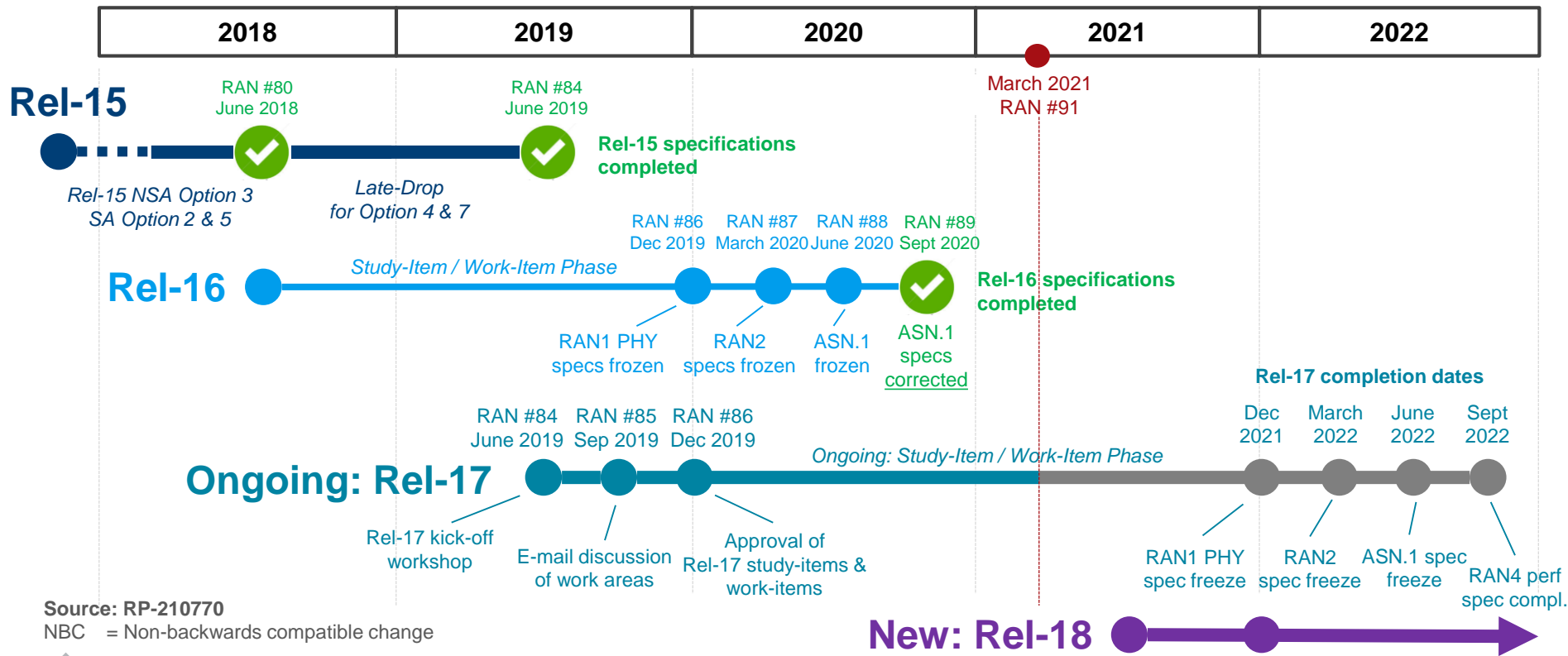
TODAY'S WEBINAR

- ▶ 3GPP standardization timelines
- ▶ Device ecosystem in a nutshell
- ▶ Current 5G technology milestones and its testing challenges
- ▶ 5G device testing made easy with R&S[®]CMX500 and R&S[®]CMsquares
- ▶ Demo time



3GPP RAN STANDARDIZATION TIMELINE

MARCH 2021 (RAN #91)



Source: RP-210770

NBC = Non-backwards compatible change





703
announced devices

132 **22.2%** ↑
indoor/outdoor CPE's for **FWA**

50% phones

eMBB
Smartphones and CPE's

22 form factors

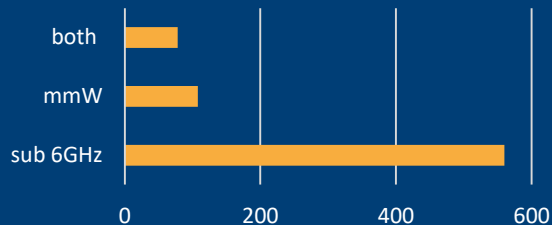
91 modules



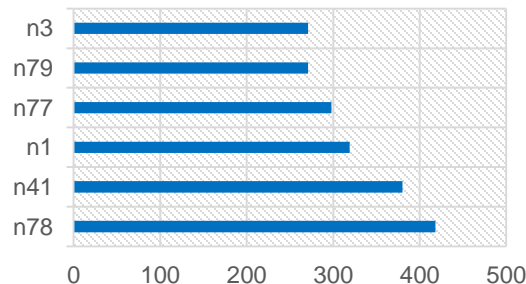
428 operators in 132 countries are investing in 5G

66 SA

Spectrum support



Most popular sub6GHz bands

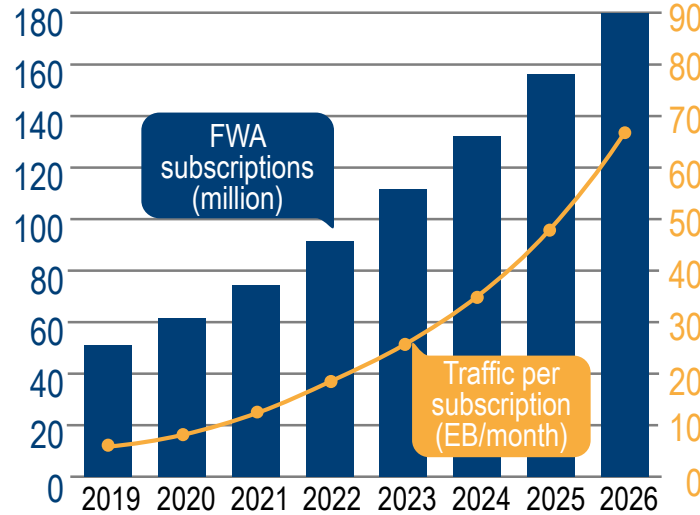


Source: GSA April 2021



The rise of FWA

- ▶ FWA among fastest growing market
- ▶ CPE's (indoor & outdoor)
- ▶ Operator's opportunity for additional revenues
 - Data plan
 - Smart home connectivity
- ▶ Testing CPE's is similar to testing smartphones. CPE's mostly support 4G, 5GNR FR1, FR2 and WLAN



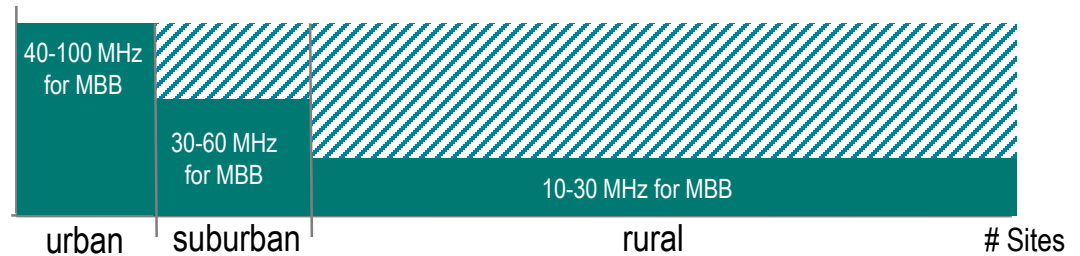
Forecasts

Massive growth in FWA subs (CAGR: 20%) and high traffic growth per FWA (CAGR: 39%)

2% of mobile subs consume 23% of mobile network traffic in 2026

Source: Ericsson Mobility Report (Nov. 2020)

Utilizing acquired but still undeployed bands in rural and suburban areas for FWA?

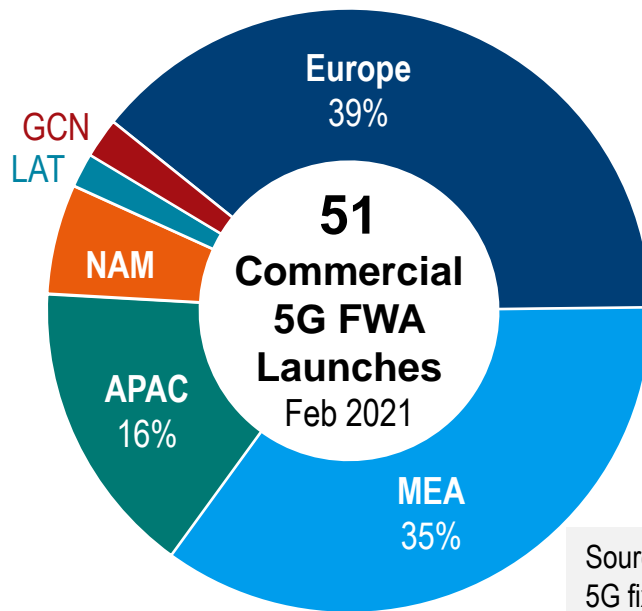


Source: Ericsson FWA handbook 2020 (3rd edition)

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The FWA opportunity

- ▶ Europe and MEA count for more than 70% of 5G FWA launches
- ▶ Consumers can expect more than 50 FWA CPE models to be available on the market in 2021.
- ▶ 5G FWA CPE market will grow at CAGR 48% over the next five years



40% of the 5G commercial launches worldwide contain an FWA offering

Source: GSMA (March 2021)
5G fixed wireless: a renewed playbook

ABI Research, forecasts that worldwide 5G FWA CPE market will ship over 4 million units in 2021, jumping to **11.7 million units in 2025.**

[ABI Research Jan 2021](#)

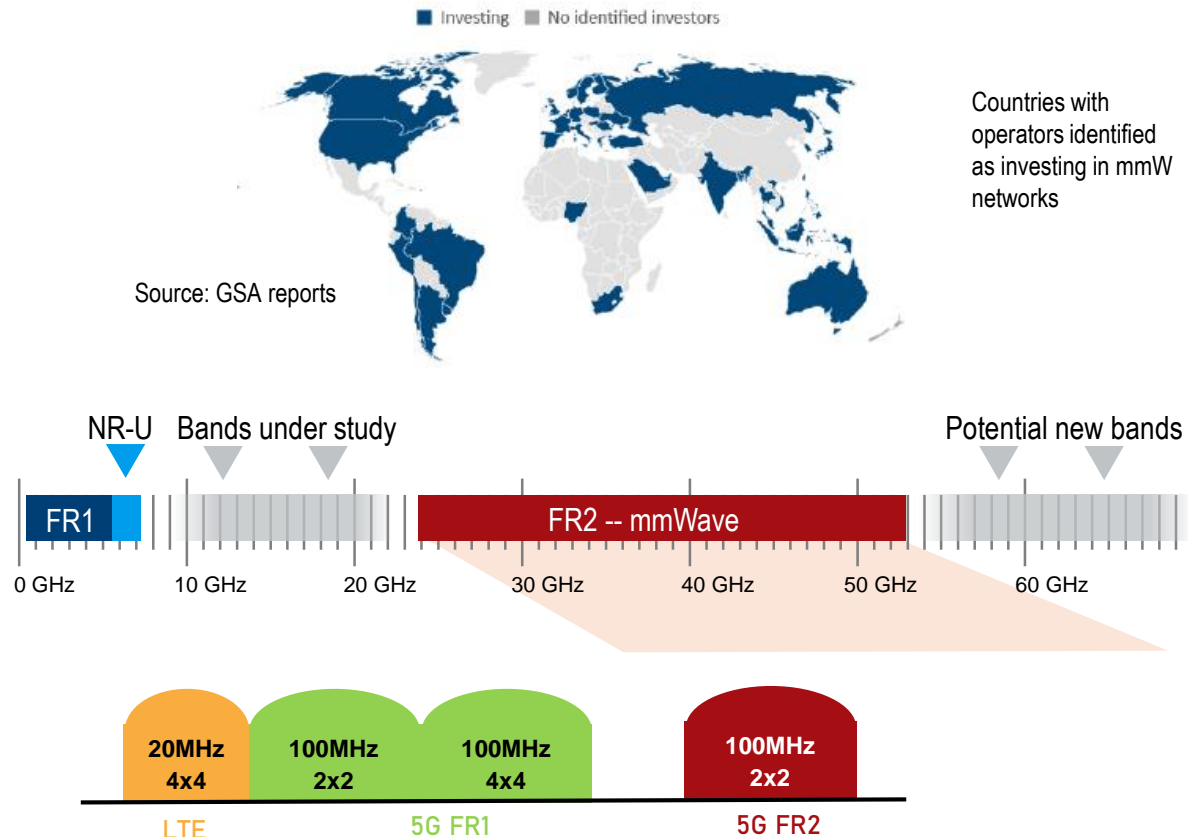
TODAY'S WEBINAR

- ▶ 3GPP standardization timelines
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MULTI GIGABIT THROUGHPUT

- ▶ Currently the industry milestone is to reach a **10Gbps+** throughput.
- ▶ To achieve this feat, exploring mmW spectrum becomes a key.
- ▶ Combined with carrier aggregation and strong LTE anchor set to represent real deployment scenarios.
- ▶ Higher bandwidth, higher number of MIMO layers and higher order modulation schemes.



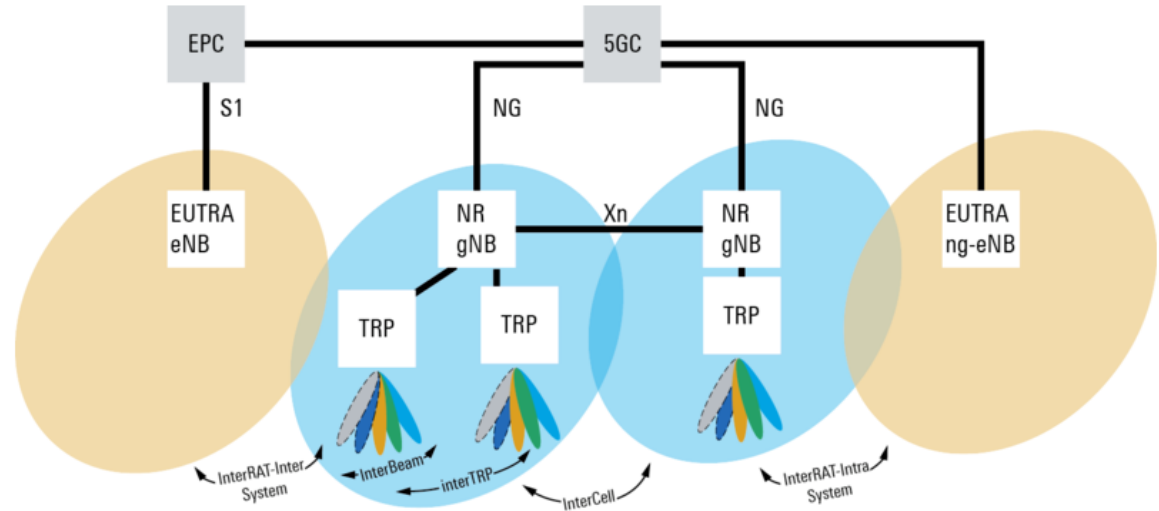
5G Device Spec. At a glance

- ▶ Different worldwide network deployments demand multi-technology and multi-band device capabilities
- ▶ Carrier aggregation in LTE and 5G NR adds another dimension of multiband capabilities

	Today's 5G device typical specs
Cellular technology	5G NR, LTE, HSPA, WCDMA, GSM/EDGE
5G Features	DSS, VoNR, mmW, sub6GHz
5G mmW specs	800 MHz Bandwidth, 8 carriers, 2x2 MIMO
5G sub6GHz	200 MHz bandwidth, 4x4 MIMO
Multi SIM feature	Global 5G multi-SIM
Peak DL speed	Upto 7.5 Gbps
Peak UL speed	Upto 3 Gbps

MOBILITY

- ▶ Heterogenous network deployment
- ▶ Scenarios involving carrier aggregation between LTE + 5G FR1 + 5G FR2 carriers and mobility – rising the complexity of test scenarios



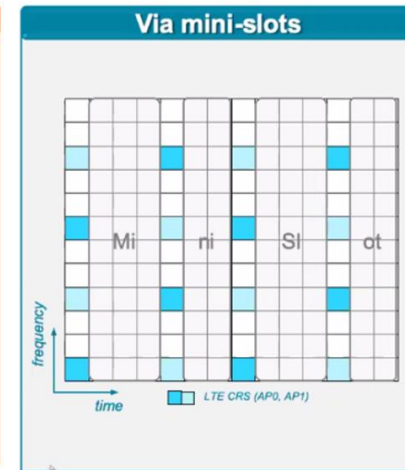
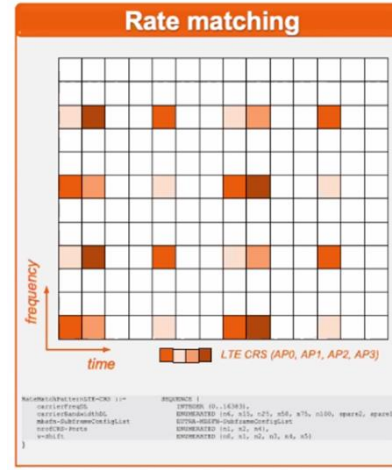
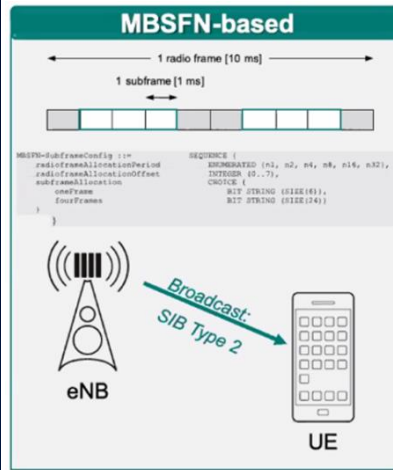
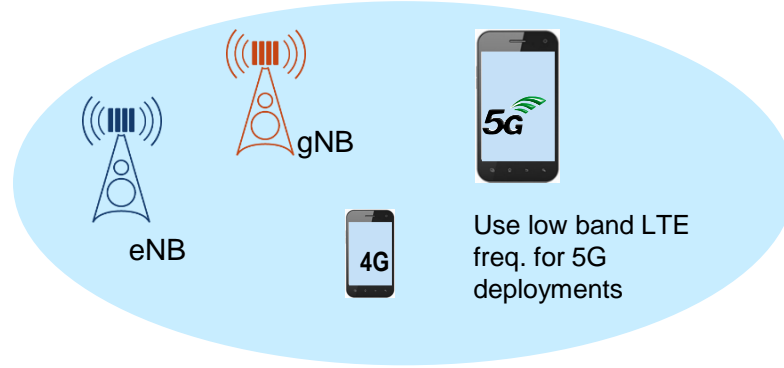
Mobility in complex heterogenous scenarios involve

- the UE capabilities and protocol message flow adding, removing and modifying cells/beams.
- And the changes on the physical layer (RF)

Ability to monitor both protocol messages and RF on a single web GUI is an advantage for any test bench.

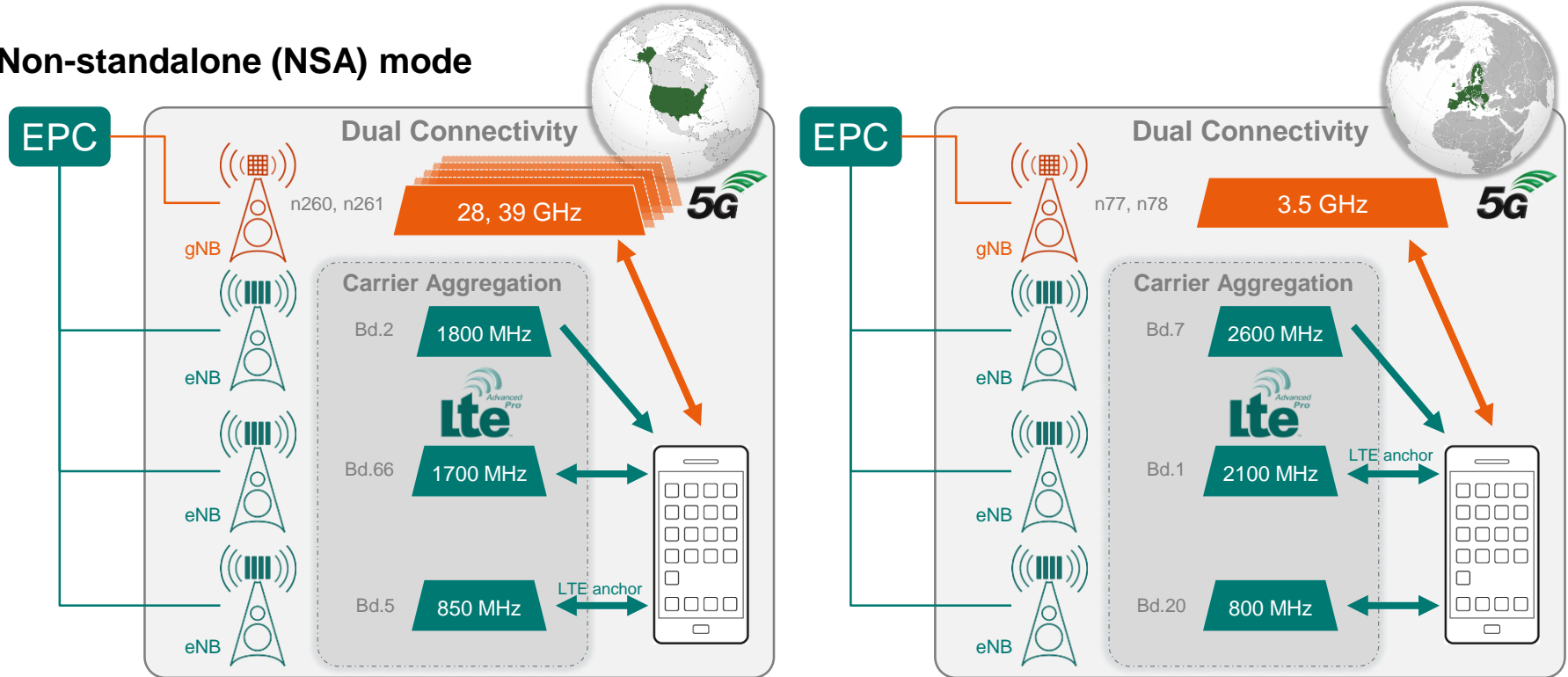
DYNAMIC SPECTRUM SHARING (DSS)

- ▶ An easier cost effective way to achieve 5G coverage using the low band LTE frequency
- ▶ Can be an intermediate step before launching a standalone 5G network
- ▶ 3 ways to achieve
 - MBSFN-based
 - Rate matching
 - Via mini-slots



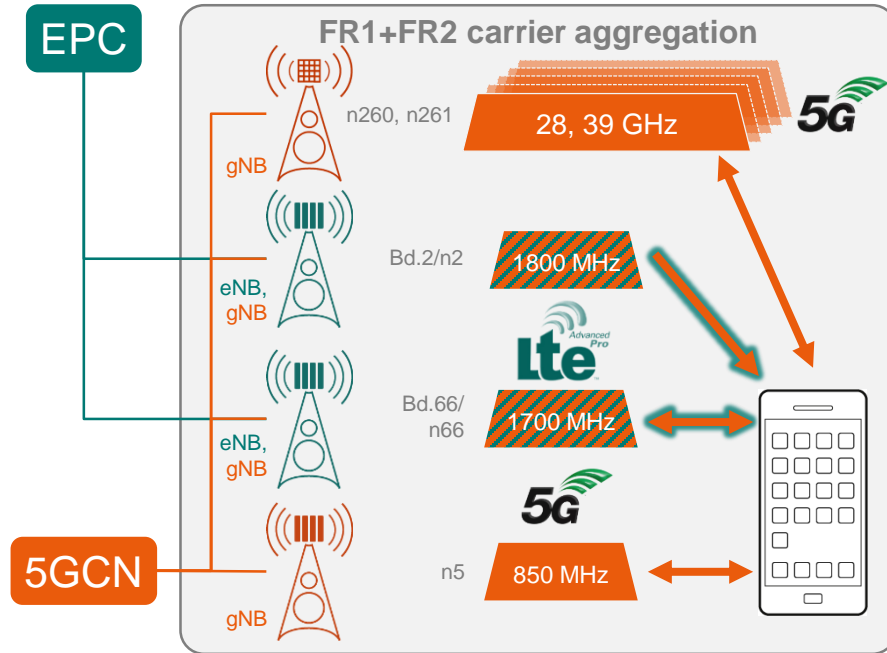
TODAY'S 5G SPECTRUM DEPLOYMENT STRATEGY

Non-standalone (NSA) mode

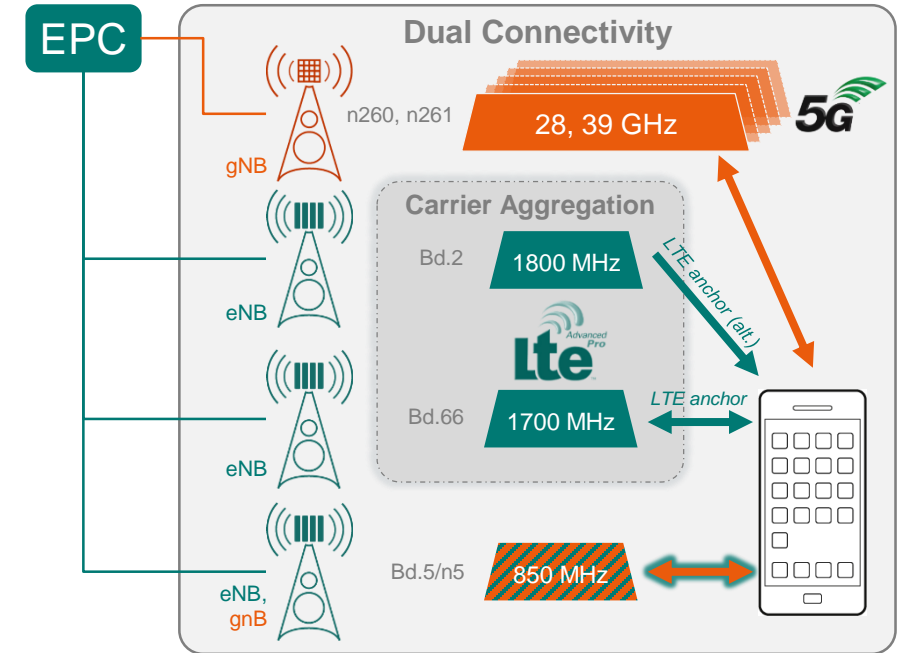


TOMORROW'S 5G SPECTRUM DEPLOYMENT STRATEGY

Standalone (SA) mode w/ DSS (~2021/22)

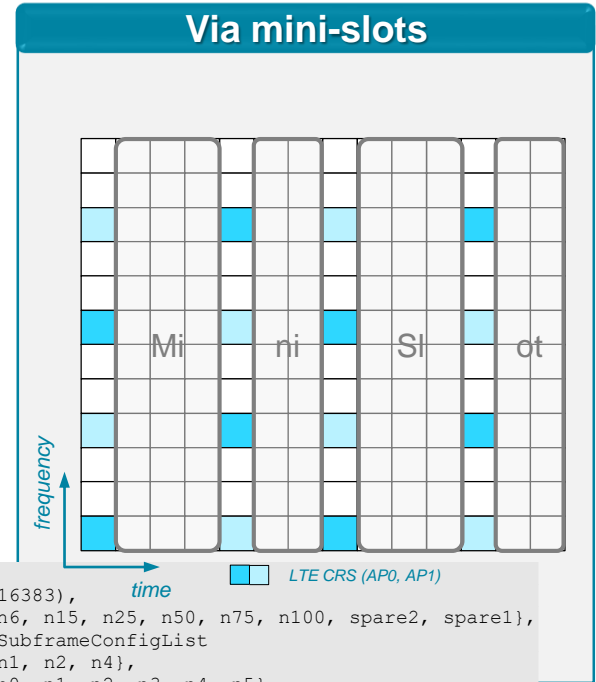
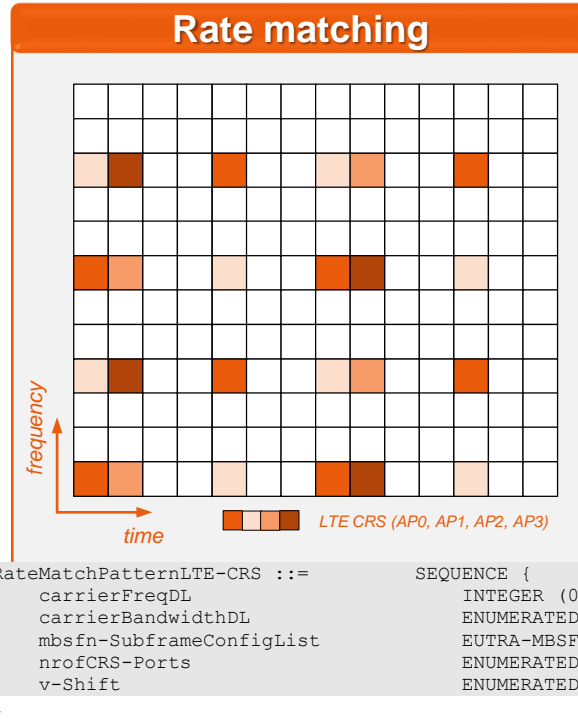
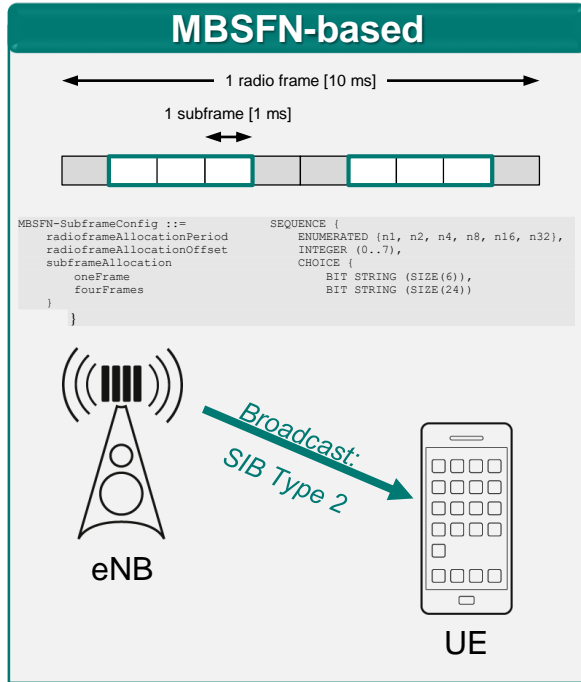


The intermediate step (today: since late 2020)



DYNAMIC SPECTRUM SHARING DEPLOYMENT OPTIONS

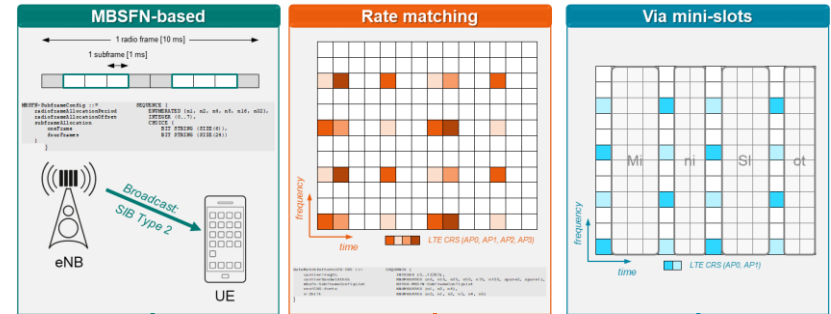
There is no one fits all!



FEATURE SET SUMMARY BASED ON DYNAMIC SPECTRUM SHARING (DSS) DEPLOYMENT OPTIONS

Feature	Layer-1 Feature List Index (TS 38.822)	Short Explanation	Example of Field Name in RRC (TS 38.331)	DSS Option		
				1	2	3
LTE MBSFN subframe	LTE feature	Shared with LTE MBSFN subframes	mbsfn-Subframe ConfigList	0		
NR SSB with 30 kHz SCS	Based on band	For the applicable bands in FR1	subcarrierSpacing	0	0	
LTE CRS rate matching	5-28	RE-level rate matching. Allows transmission of NR PDSCH in non-MBSFN subframes	rateMatchingLTE-CRS			0
General rate matching pattern	5-26	RB-level rate matching. Allows PDSCH rate matching around LTE PSS/SSS and PBCH	rateMatchingResrcSetSemi-Static			0
NR PDCCH in symbol 2	3-1	Search Space Mapping for CORESET	monitoringSymbolWithinSlot	0	0	0
PDCCH monitoring on any up to 3 consecutive symbols	3-2	NR UE capability to mitigate DSS impact on PDCCH capacity	pdcchMonitoringSingleOccasion		0	0
PDSCH Mapping Type A (< 7 OFDM symbols)	5-6	Data channel mapping	pdsch-MappingTypeA	0	0	0
PDSCH Mapping Type B	5-6a		pdsch-MappingTypeB		0	
Alternative additional NR DMRS location	2-6b	For co-existence with LTE CRS	additionalMRS-DL-Alt			0
NR TRS in symbol 6 and 10	Mandatory for NR	Used to avoid collision with LTE CRS	Refer to table 11 in this paper	0	0	0
Flexible NR CSI-RS	Mandatory for NR			0	0	0
7.5 kHz UL shift	Mandatory for some NR bands	Enable the NR UL transmission with a 7.5 kHz shift to the LTE raster	frequencyShift7p5khz	0	0	0

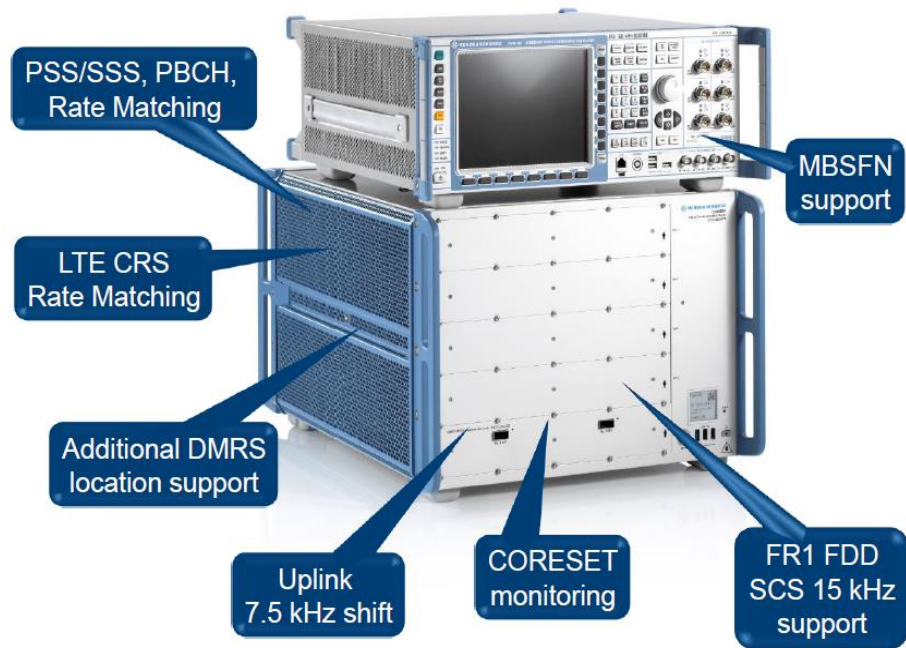
- Today's commercial 5G NR deployments that take advantage of dynamic spectrum sharing (DSS) using a combination of MBSFN-based and rate matching



Source: [MediaTek DSS White Paper](#) (March 2020)

DSS - From a testing perspective

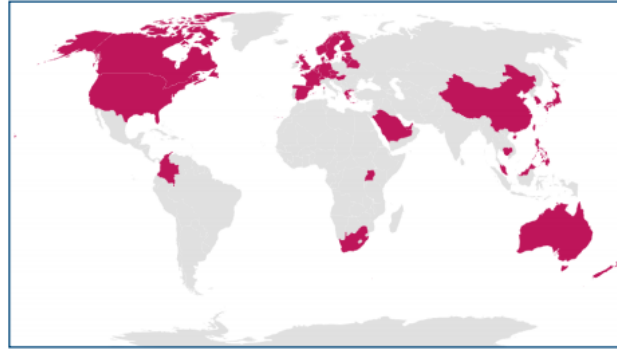
- ▶ With numerous possibilities for parameterization and a number of test scenarios possible around DSS
- ▶ An easy API to create test scenarios in a programmatic way helps device vendors validate their DSS implementation for various scenarios
- ▶ Testcase package available on CMX500



MIGRATION FROM NSA TO SA

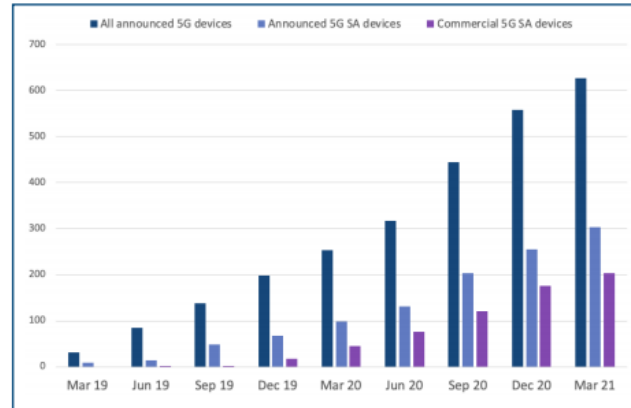
- ▶ Over time most NSA deployments will migrate or will be augmented with 5G SA deployments to realize the full potential of 5G
- ▶ The number of 5G devices supporting SA is growing
- ▶ As operators migrate to SA mode, **VoNR & EPS** fallback implementation becomes important.

Countries with operators identified as investing in public 5G SA networks



66 operators are investing in 5G SA deployments

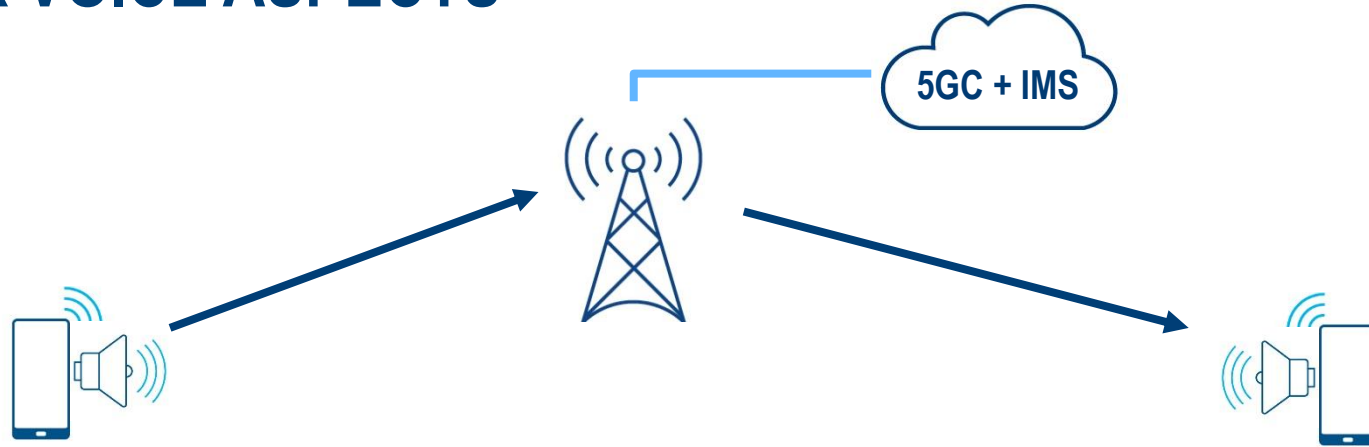
Announced and commercially available 5G devices with stated 5G SA support



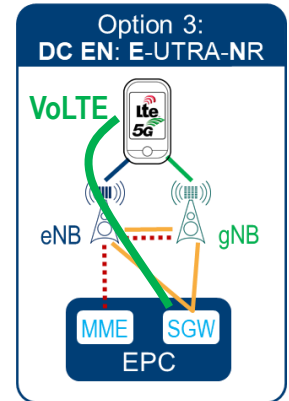
~200 5G SA devices are commercially available today

VoNR is an important feature as migration from NSA to SA picks up pace

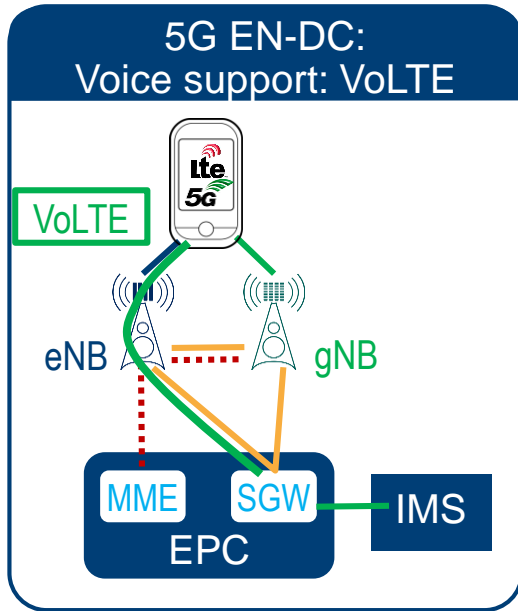
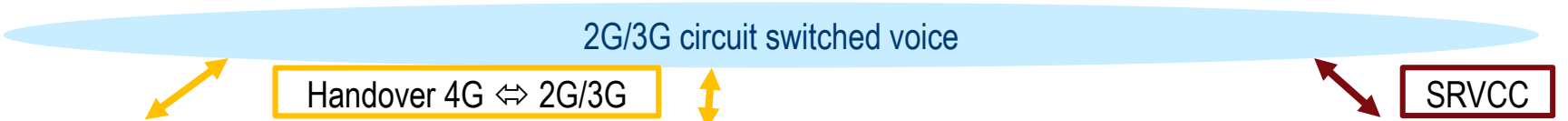
5G NR VOICE ASPECTS



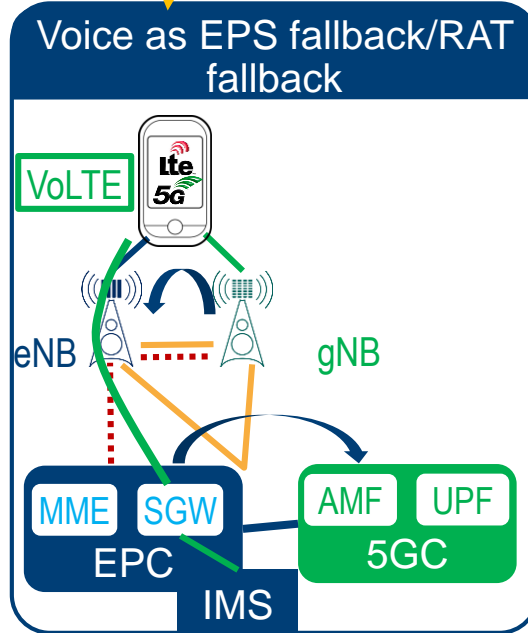
- 5G NR as VoNR considered for standalone (SA) mode.
- In NSA mode = VoLTE
- Various UE deployments for NSA VoLTE/5G voice
- No circuit switched fallback from 5G to 3G/2G in Rel. 15
- 5G voice uses evolved voice system (EVS) speech codecs
- EVS = higher data rate + bandwidth, but also compatible to legacy speech codecs



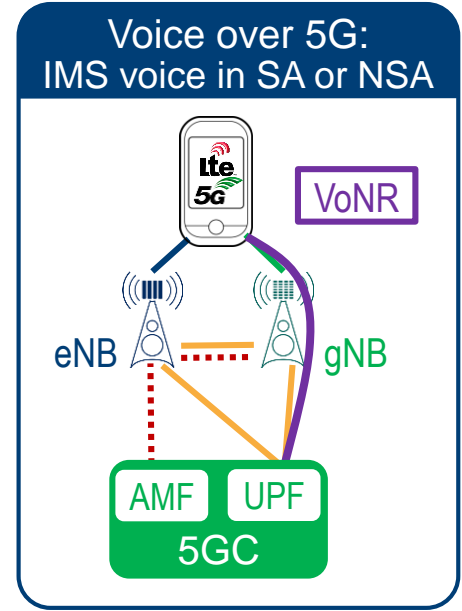
5G NR VOICE ASPECTS AND EVOLUTION



- Dual connectivity: VoLTE + 5G data**
- ⇒ UL coverage due to higher freq. 5G band
 - ⇒ Battery consumption



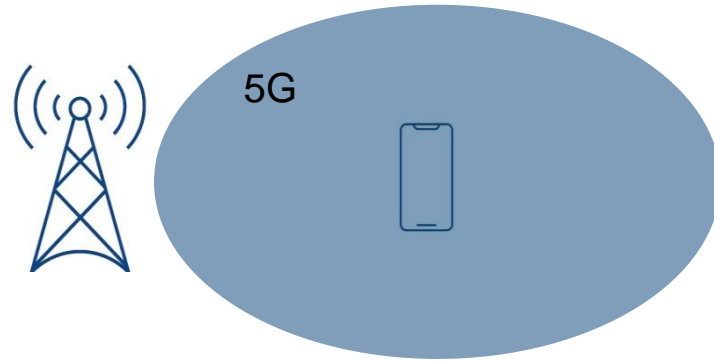
- EPS fallback: VoLTE only**
- ⇒ Handover to EPC or EUTRA during call setup



- Voice over 5G NR**
- ⇒ Voice over NR and 5GC
 - ⇒ 5G coverage needed, risk of large #handovers/call drop

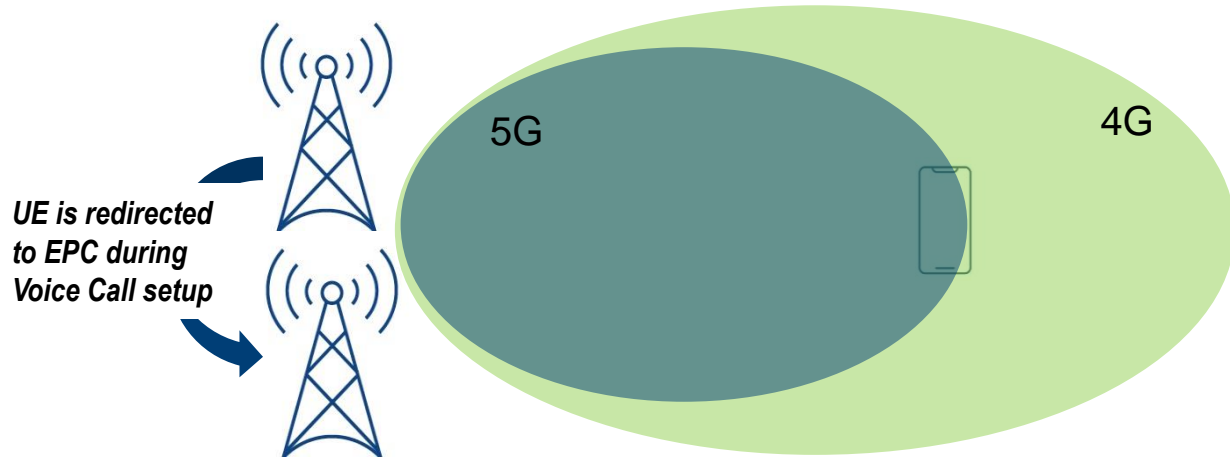
VoNR

- ▶ 5G SA Mode
- ▶ Successor of VoLTE
- ▶ Uses IMS as service enabler
- ▶ Ultra fast call setup time
- ▶ High quality voice service



EPS FALLBACK

- ▶ Weak 5G coverage
- ▶ 5G cell not configured for VoNR calls
- ▶ Mobile device doesn't support VoNR calls
- ▶ Avoid handover during a call @ the cell edge



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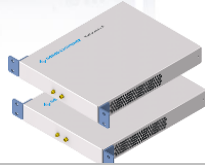
DEVICE TESTING MADE SIMPLE WITH R&S[®]CMX500

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R&S®CMW500



R&S®CMX500



R&S®CMhead30

Multi Technology Platform

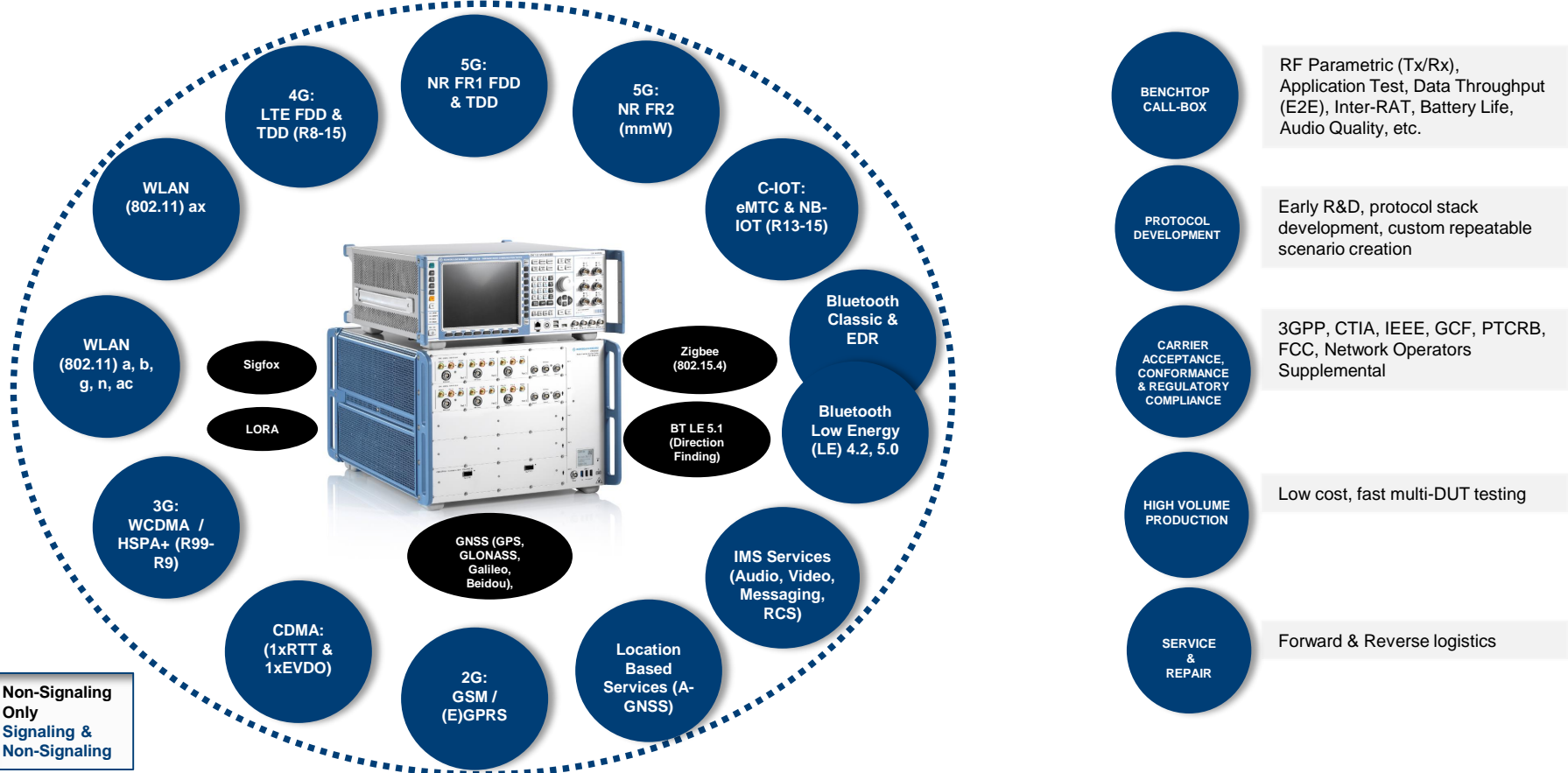
Supports signaling for most technologies from 2G through 5G NR FR1/FR2 and Wi-Fi 11ax to Bluetooth®

Future proof, modular scalable HW architecture
20 Gbps+ E2E data performance capability

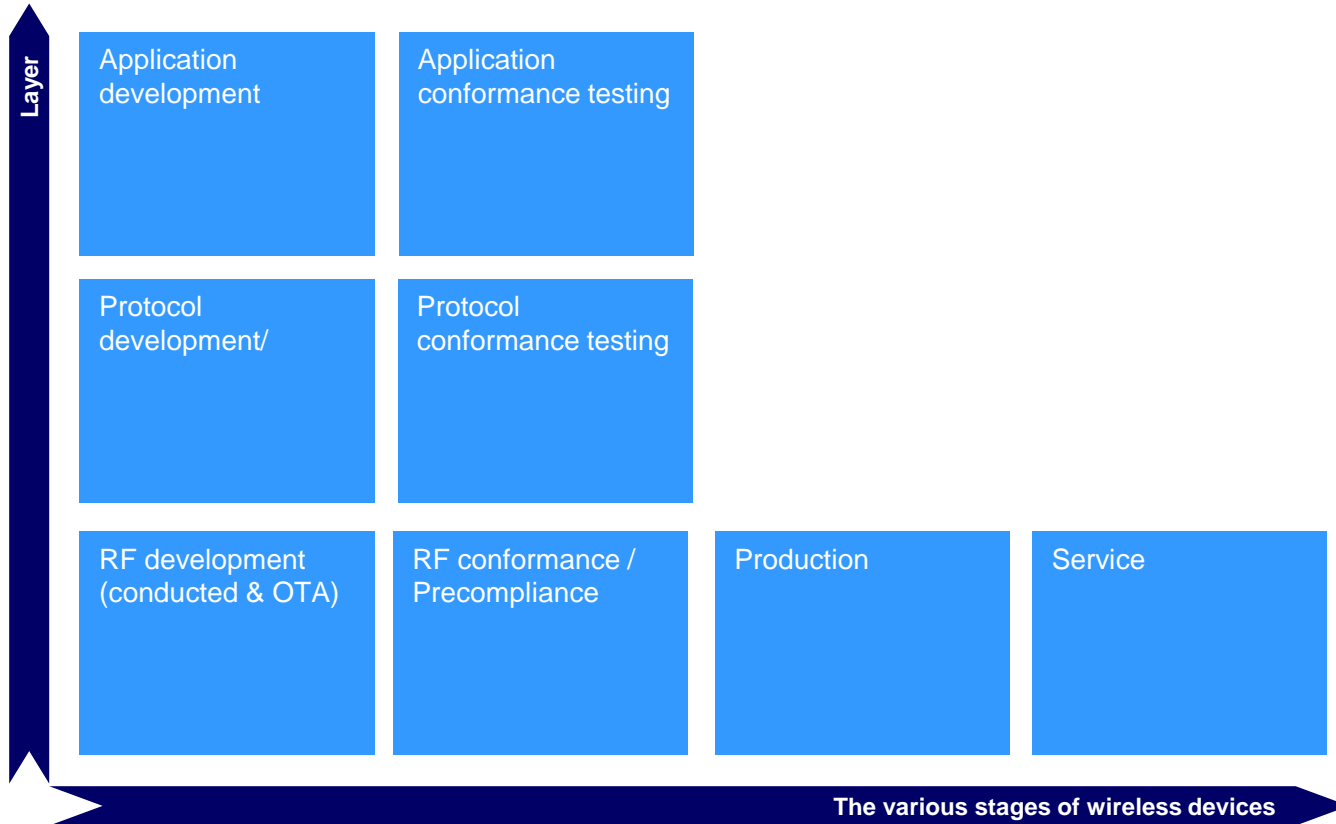
FR2 **Multiband** remote radio support (24 – 43.5 GHz)
LTE anchor supporting **8CC LTE**, 8x4 DL MIMO, 1024 QAM

Single web based GUI for **RF, Protocol and App** test

CMW500 + CMX500: All Technologies & All Applications



ALL FIELDS OF APPLICATION OF THE CMW500 + CMX500

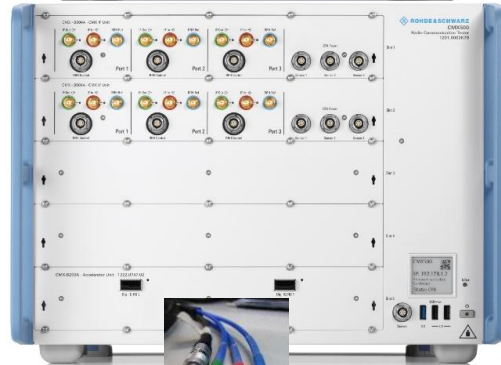


5G HW COMPONENTS

CMW500



CMX500



CM-Z30



CMXHEAD30



LTE Network Emulator – R&S®CMW500

- LTE anchor
- Sub6 RF for 5G NR
- DAU for uplane NR & LTE

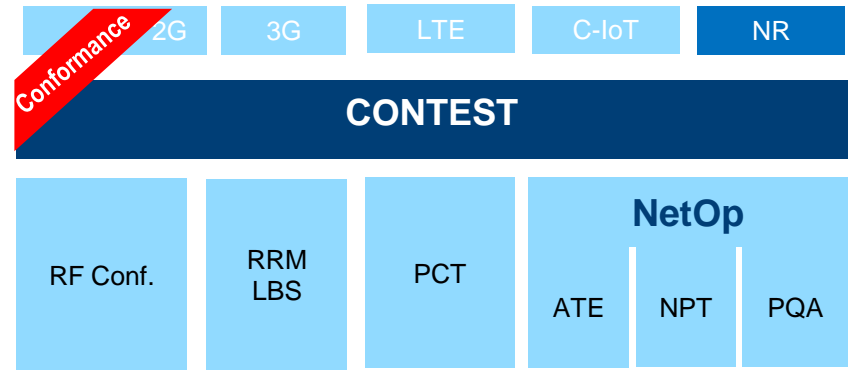
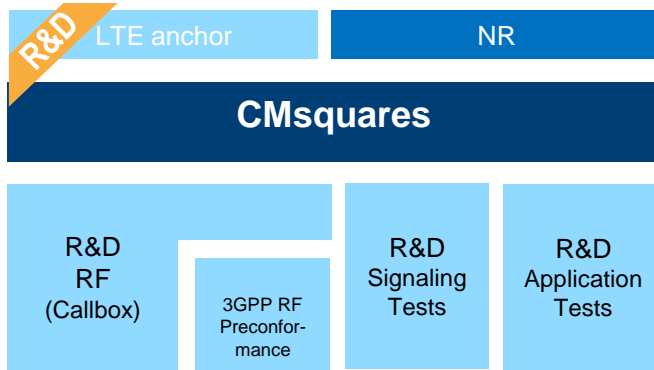
5G Network Emulator – R&S®CMX500

- 5G NR FR1 und FR2 L1 stack
- Supports IF connection in the same box
- Max. possible RF BW: 1 GHz

Remote Radio Head – R&S®CMXHEAD30

- Supports all FR2 bands up to 43.5 GHz
- Up- and down converter IF <-> FR2
- Integrated RF switch matrix for RX/TX paths
- CM-Z30A cable set bw. CMX and CMXHEAD30

R&S® CMX500 TOOLCHAIN: CMSQUARES & CONTEST

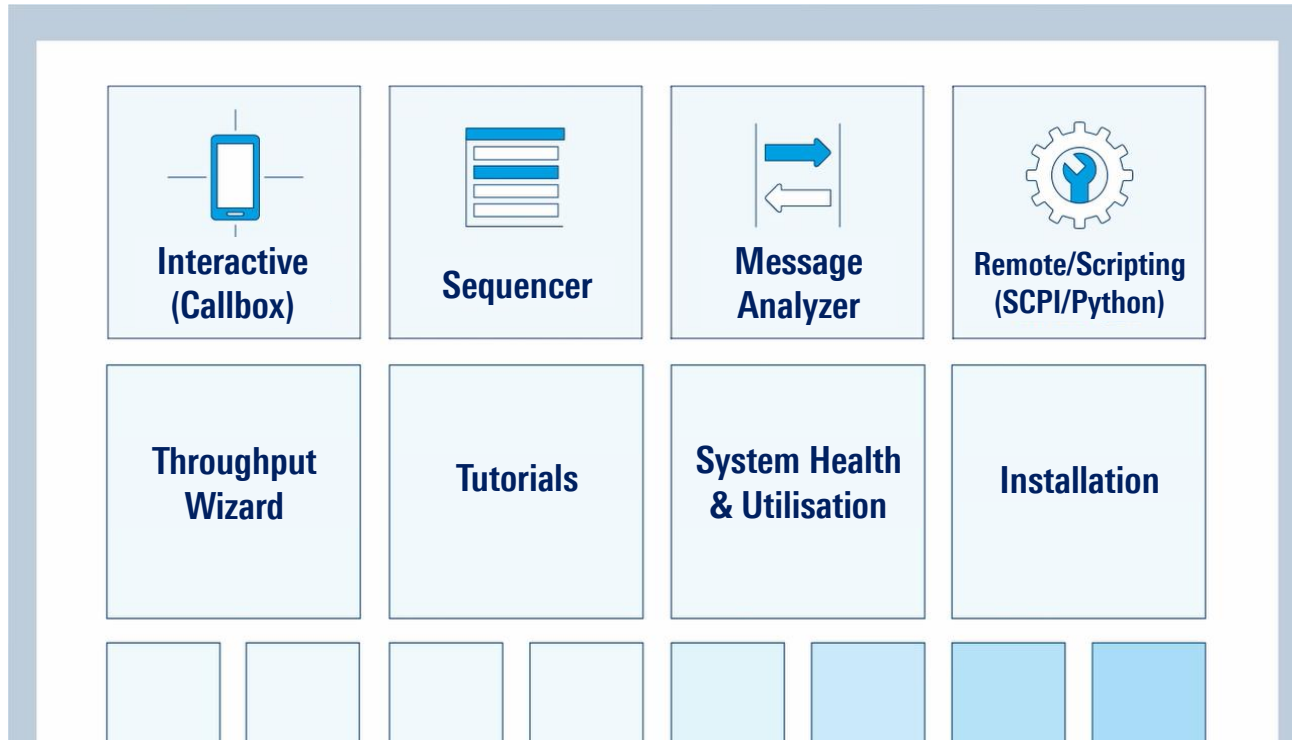




CMsquares

The place of measurements

CMSQUARES – ALL TOOLS IN ONE PLACE



INTERACTIVE

- ▶ Test environment
- ▶ Place of **setup configuration**
- ▶ Quick access to network, services (e.g. IP), measurements and cabling
- ▶ DUT centric approach
- ▶ Extensive DUT manager
 - UE capabilities
 - Cabling
 - Automation

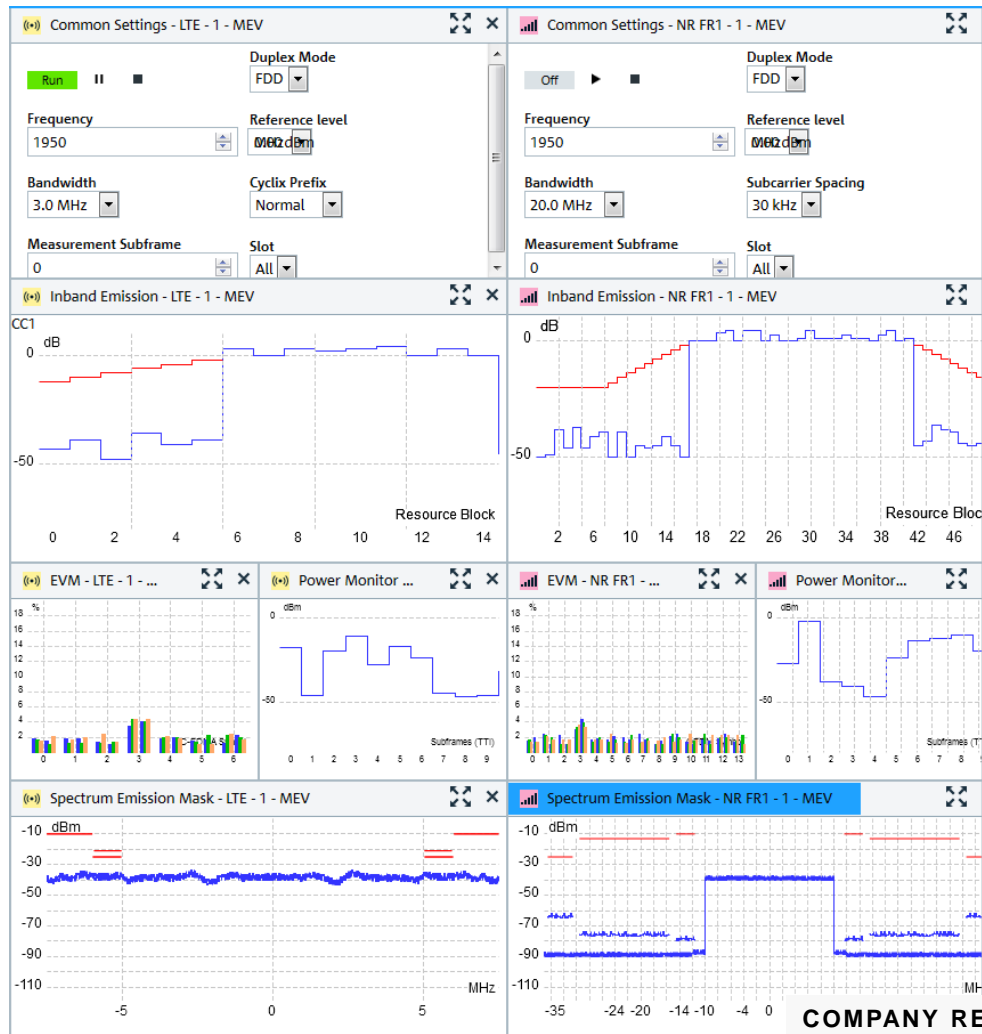
The screenshot displays a network testing software interface with several panels:

- Network square:** Shows three LTE cells (LTE 1-1, LTE 1-2, LTE 1-3) for PLMN 1, TA 1. Each cell is configured with Sub 6 GHz, On status, -57.00 dBm power, and Band: 1 (FDD). Parameters include FDD1, DL 300, UL 18300, 20 MHz bandwidth, 4x4 MIMO, and SISO.
- Services square:** Displays the status of various services:
 - Data/IP Service: On, IP Address: 10.113.12.1::232553453
 - FTP: On, No of users: 2, No of connections: 10
 - HTTP: On, No of connections: 3
 - IMP: On, No of connections: 3
 - IPerf: Off
 - Ping: Off, Packet Size: 424 B/s, IP v4: 10.121.0.15, IP v6: 21243:24:423::14
 - Voice/Video Call: Call Duration: 5.32, LTE/IMS Video Call Established
- Measurement & Generator square:** Shows MEV > LTE Tx configuration:
 - Reliability: Ready
 - Mode: CW
 - Path 1
 - Duplex Mode: FDD
 - Frequency: 1.95 GHz
 - Bandwidth: 20.0 MHz
 - Connector: Not Available
 - Ref. Level: 0.00 dBm
 - 50/100
- Cabling square:** Shows two test setups:
 - Test 5. Setup Z24-M4 (CMW-Z24 1) with AC and BC connections.
 - Test 5. Setup Z24-M4 (CMW-Z24 2) with AC and BC connections.
- Dut (Device Under Test):** A smartphone displaying:
 - MM-State: Deregistered
 - RRC-State/ Status: Idle/ OK
 - DC Mode: OFF
 - IMS-State: -

INTERACTIVE

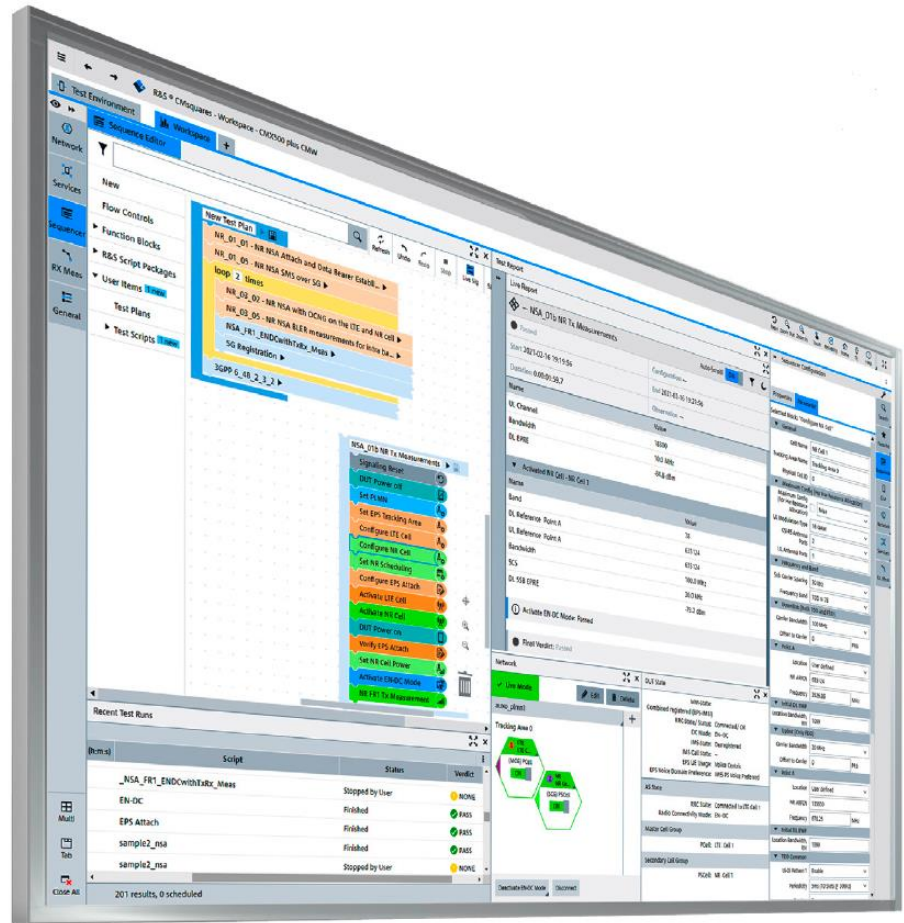
- ▶ Workspace
- ▶ Place of measurements
- ▶ Unified user experience
- ▶ Real time
- ▶ Easy mixing of all types of measurements

- ▶ Compare LTE and 5G
- ▶ ...or FR2
- ▶ ...or end-to-end (IP)



SEQUENCER

- ▶ Place of GUI scripting and automation
- ▶ Includes comprehensive campaign management
- ▶ State of the art, future proof software
- ▶ Complete coverage of 5G NR R&D tests incl. 3GPP RF in one application
- ▶ Automatic band combination tests



Signaling Reset	Set Log Level	Configure NR Cell	Configure LTE Cell
Configure DUT	Delay	Activate NR Cell	Activate LTE Cell
Set PLMN	User Prompt	Deactivate NR Cell	Deactivate LTE Cell
Set EPS Tracking Area	User Comment	Set NR Cell Power	Set LTE Cell Power
Activate EN-DC Mode	Start IP Data Service	Set NR Scheduling	LTE Registration
LTE SCG Release	Stop IP Data Service	Set Max NR Scheduling	Verify EPS Attach
LTE SCG Addition Failure	DUT Power on	Configure 5GS Registration	Set LTE Scheduling
Check DUT Event	DUT Power off	Verify 5GS Registration	Configure EPS Attach
Evaluate UE Measurement Report	Report DUT Information	5GS Deregistration	Send SMS over SG
Configure IMS Server	LTE TX Measurements	5GS PDU Session Establishment	Configure EPS Service Request
Verify IMS Registration	NR FR1 TX Measurements	Verify 5GS Registration Failure	Verify EPS Service Accept
IMS Deregistration	Cellular BLER	Configure NR UE Measurements	Verify EPS Service Reject
Establish VoLTE Call	Cellular RX Sensitivity	NR Common Channel Scheduling	Verify EPS Attach Failure
Release VoLTE Call	Configure LTE UE Measurements	NR UL Power Control	Configure EPS PDN Connectivity
Set Channel Model Matrix	Carrier Aggregation	Set 5GS Tracking Area	Verify EPS PDN Connectivity
Check Target UL Rx Power	Configure Bearer Resource Allocation	Configure NR Connection Settings	LTE Detach
LTE RRC Connection Release	Verify EPS Bearer Resource Allocation Accept	Modify NR Cell	Configure EPS T
LTE UL Power Control	Verify EPS Bearer Resource Allocation Reject	Set LTE Test Mode	Verify EP
Configure LTE UE Measurements			

SEAMLESS SWITCHING

Interactive Mode

R&S * CMX500 plus CMW

Test Environment Workspace Sequencer

Network square

Live Mode

PLMN 0

EPS TrackingArea 0

NR Cell

DC Mode OFF

IMS-State

Global Services

Data Unit State: On DNS State: Off IMS State: On

Sequence Editor

- New
- Flow Controls
- Function Blocks
- Sample Blocks
- SW Tests
- User Items

Sequencer Mode

Test Report

NR_ENDC_witthx

Configuration

Start 2020-10-19 08:27:08 End 2020-10-19 08:30:33

Duration 0.0003242

Observation

Test Item	Test Condition	Lower Limit	Upper Limit	Measured	Unit	Verdict
Reliability	---	---	---	0		
Out Of Tolerance	---	---	---	0		
EVM RMS low	---	12.5	2.0091	%	Passed	
EVM RMS high	---	12.5	2.0087	%	Passed	
EVM Peak low	---	25.0	14.3478	%	Passed	
EVM Peak high	---	25.0	14.2095	%	Passed	
Magn. Err. RMS low	---	12.5	1.4047	%	Passed	
Magn. Err. RMS high	---	12.5	1.4041	%	Passed	
Magn. Err. Peak low	---	25.0	12.7442	%	Passed	
Magn. Err. Peak high	---	25.0	12.4887	%	Passed	
Phase. Err. RMS low	---	12.5	1.1395	*	Passed	
Phase. Err. RMS high	---	12.5	1.1392	*	Passed	
Phase. Err. Peak low	---	25.0	13.4468	*	Passed	
Phase. Err. Peak high	---	25.0	13.5587	*	Passed	
IQ Offset	---	-19.2	-72.6596	dBc	Passed	
Frequency Error	---	-357.600	357.600	0.616	Hz	Passed
Timing Error	---	---	-421.8183	Ts		
Tx Power	---	---	---	---		

!! Unique in Wireless Testing Industry !!



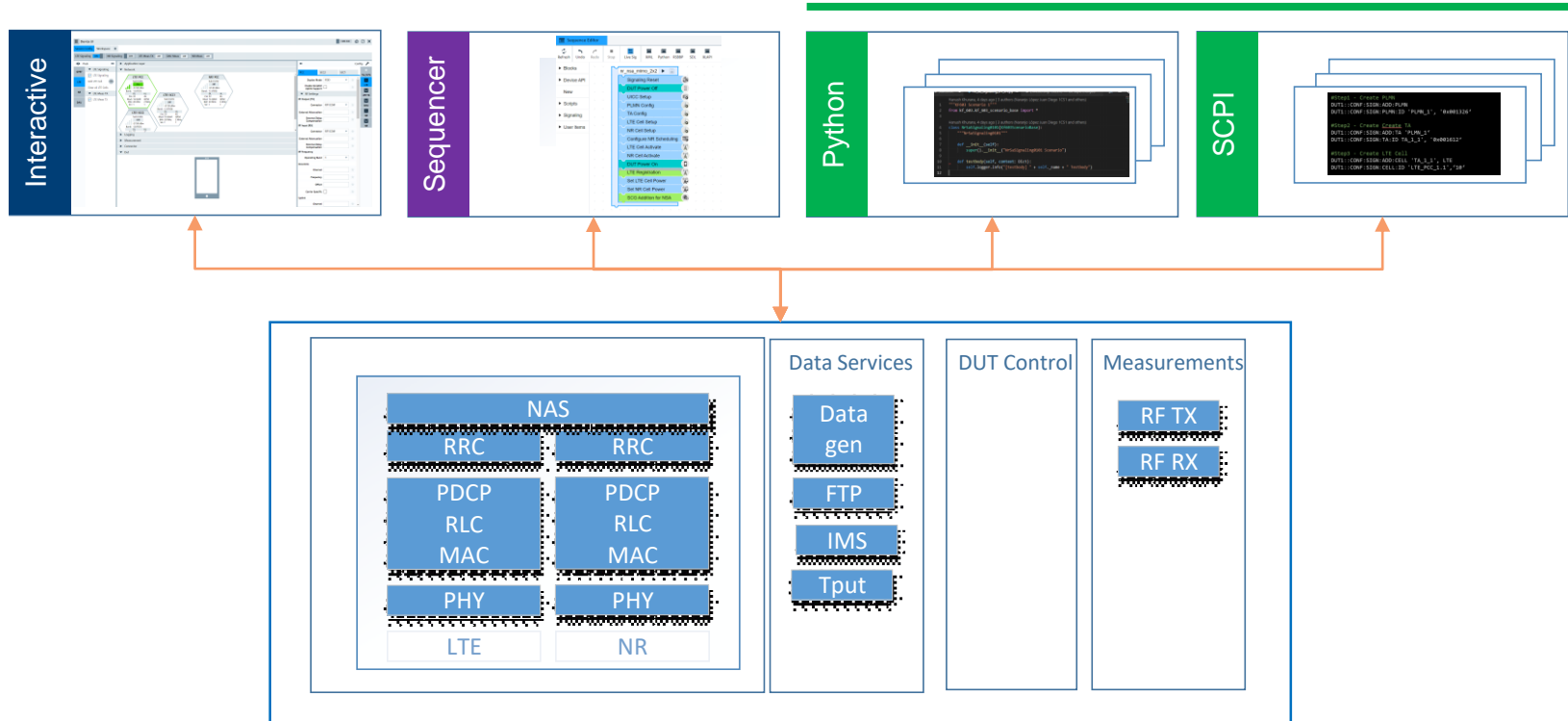
MESSAGE ANALYZER

- ▶ Place of **real time tracing** and **post processing** (online and offline)
- ▶ Evolution of well-established CMWmars
- ▶ Message tracing between network tester and UE from PHY to IP
- ▶ UE capabilities
- ▶ Message compare function

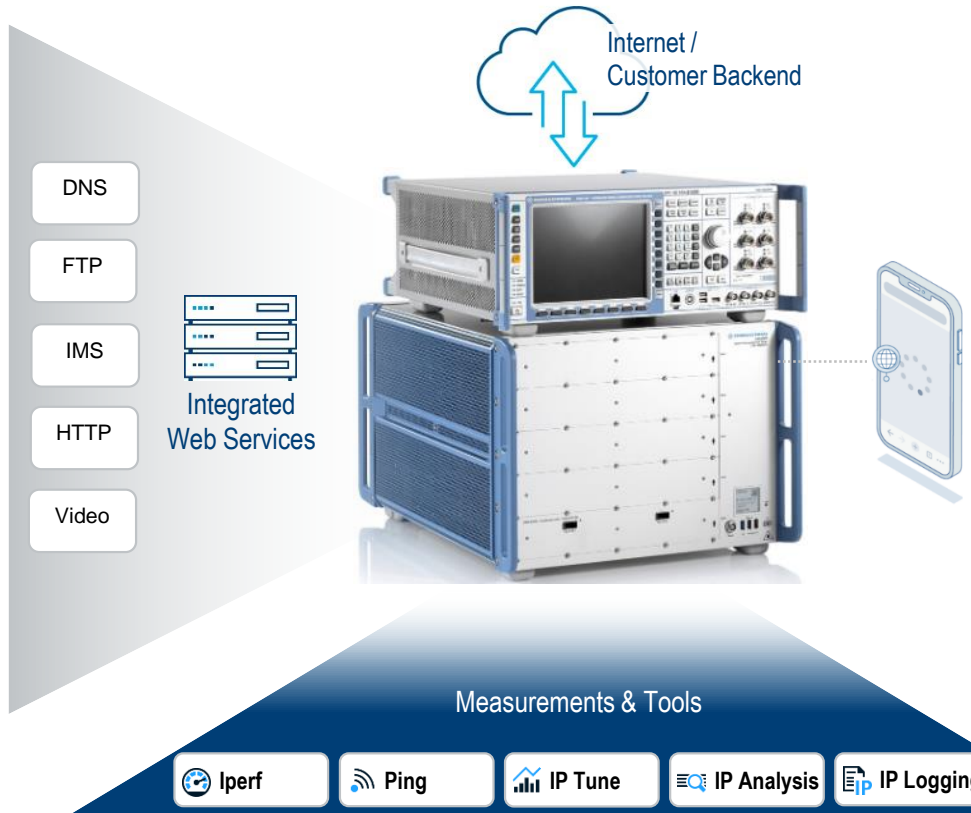
The screenshot displays the Rohde & Schwarz CMXmars interface. The top window shows a log for presentation/5G UE Capabilities.rmsmglog with a '1 mismatched MDDBs' error. Below this, a 'Message Table' window lists various protocol messages such as RRCConnectionRequest, RRCConnectionSetup, and EpsL3Message. To the right, an 'UE Capabilities' window shows a sequence diagram for LTE with messages like EpsL3Message: EMM Authentication Response and EpsL3Message: EMM Security Mode Command. At the bottom, a 'Message Tree' window shows a detailed view of an RRC_RRC_LOG_SYSTEM_INFORMATION_BLOCK_Ind message, including fields like ASPHeader, Choice, SystemInformationBlockInd, Cell Handle, SIB Type, Asn1BitLength, System Information Block ASN.1 Data, radioResourceConfigCommon, rach_ConfigCommon, and preambleInfo. A 'Bit' window on the right shows the bitstream and identifier for the selected message.

CUSTOMER INTERFACES

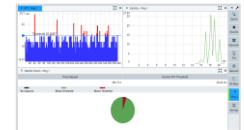
REMOTE CONTROL



IP AND DATA TESTING WITH R&S®CMX500

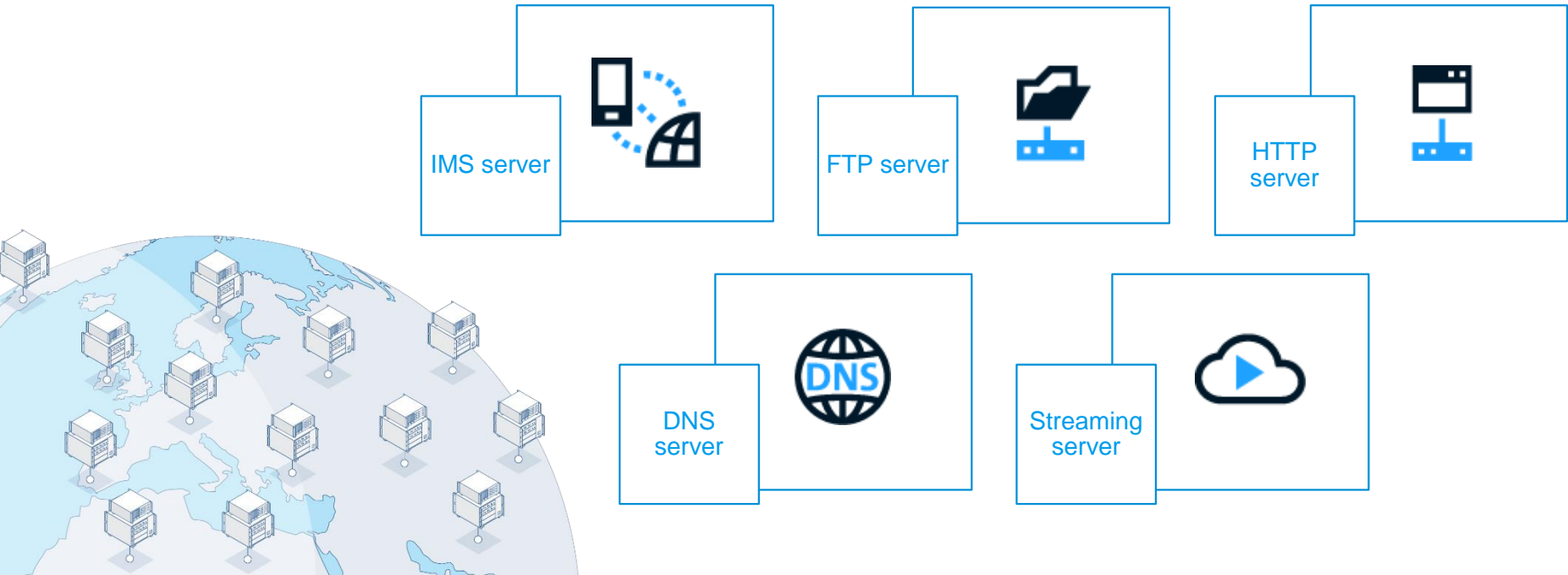


- ▶ **R&S®CMX500** offers a fully integrated setup for E2E data testing:
 - Pre-configured servers – ready for testing right away:
 - DNS-, FTP-, IMS-, HTTP-server
 - IPv4 and IPv6 support
 - IP measurements and tools to enable 5G E2E IP throughput test and latency measurements
 - Connection to the internet or user backend to test over-the-top (OTT) applications
 - Simple to use and easy to configure interface in **R&S®CMsquares** interactive mode or via remote (SCPI & XLAPI)



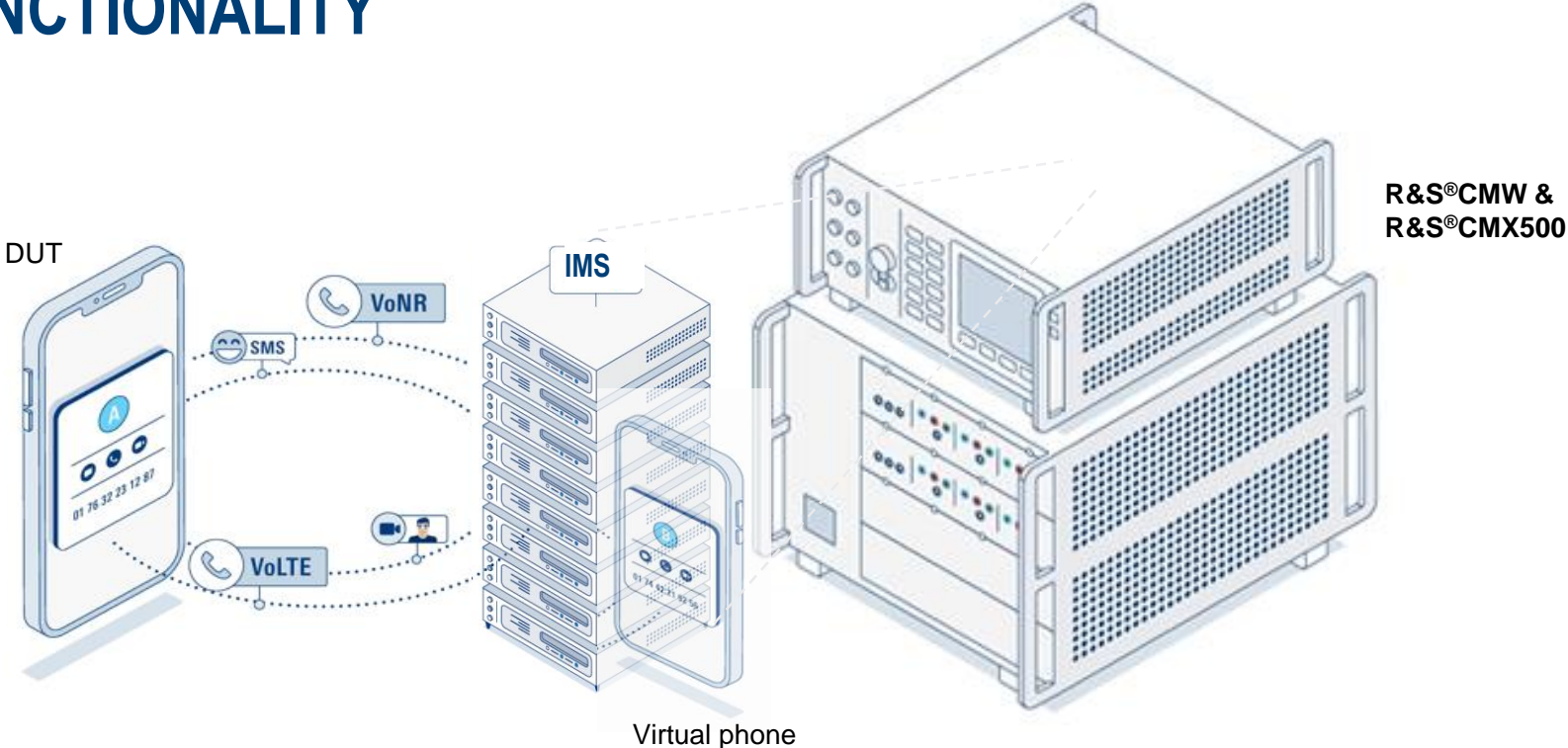
FULLY INTEGRATED SERVERS

Unique integrated solution – Simplify your test setup!



Best reproducibility and stability wherever you need it

R&S®CMX500 APPLICATION TEST IMS FUNCTIONALITY



ALL TYPES OF R&D TESTS IN ONE 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

TODAY'S WEBINAR

- ▶ 3GPP standardization timelines
- ▶ Device ecosystem in a nutshell
- ▶ Current 5G technology milestones and its testing challenges
- ▶ 5G device testing made easy with R&S[®]CMX500 and R&S[®]CMsquares

- ▶ Demo time

