THE KEY NEWS IN 5G TESTING AND OPTIMIZATION

Rohde & Schwarz Mobile Network Testing

ROHDE & SCHWARZ

Make ideas real

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# FREQUENCY TRENDS FOR 5G

Europe
700 MHz
3.4 - 3.8 GHz
24.25 - 27.5 GHz

China
2.5 – 2.6 GHz
3.3 - 3.6 GHz
4.8 - 5.0 GHz
24.75 - 27.5GHz (study)
37 - 43.5 GHz (study)

US
600 MHz
2.5 GHz
[CBRS band (3.5GHz)]
24 / 28 GHz
37 / 39 / 47 GHz

Australia
3.6 GHz
26 GHz

Korea
3.42 - 3.7 GHz
26.5 – 28.9 GHz

Japan
3.6 – 4.1 GHz
4.5 - 4.6 GHz
27 – 28.2 / 29.1 – 29.5GHz

600 MHz; 2.5, (3.5) / 24 / 28 / 37 / 39 / 47 GHz

700 MHz / 3.6 / 26 GHz

3.5 / 5 26 / 43.5 GHz

3.5 / 4.6 / 28 GHz

3.6 / 26 GHz

NR frequency range 1 reserved numbers 65-256	Downlink	Uplink
…	…	…
n77	3.3 – 4.2 GHz	3.3 – 4.2 GHz
n78	3.3 – 3.8 GHz	3.3 – 3.8 GHz
n79	4.4 – 5.0 GHz	4.4 – 5.0 GHz
…	…	…

NR frequency range 2 Reserved numbers 257-512	Downlink	Uplink
n257	26.5 – 29.5 GHz	26.5 – 29.5 GHz
n258	24.25 – 27.5 GHz	24.25 – 27.5 GHz
n259	n/a	n/a
n260	37 – 40 GHz	37 – 40 GHz

NEW FREQUENCIES

Attenuation

► Is the new spectrum really free?

| Criteria	600/700 MHz	3.5 GHz	26/28 GHz
Signal propagation	Very good	Limited	Very difficult
Mobile communication	Known	Theory known, but practice?	Unknown

> **Be aware of TDD as dominant duplex mode in 5G (DL covers UL)!**
> **Signal propagation = Interference propagation! Impact?**

WHAT IS THE IMPACT OF INTERFERENCE ON CAPACITY?

Example MCS vs. SINR

Rule of thumb:
10 dB less SINR
→ 50% less
data throughput

256QAM (MCS 20...27)

64QAM (MCS 11...19)

16QAM (MCS 5...10)

QPSK (MCS 0...4)

Relative throughput / %

SINR / dB
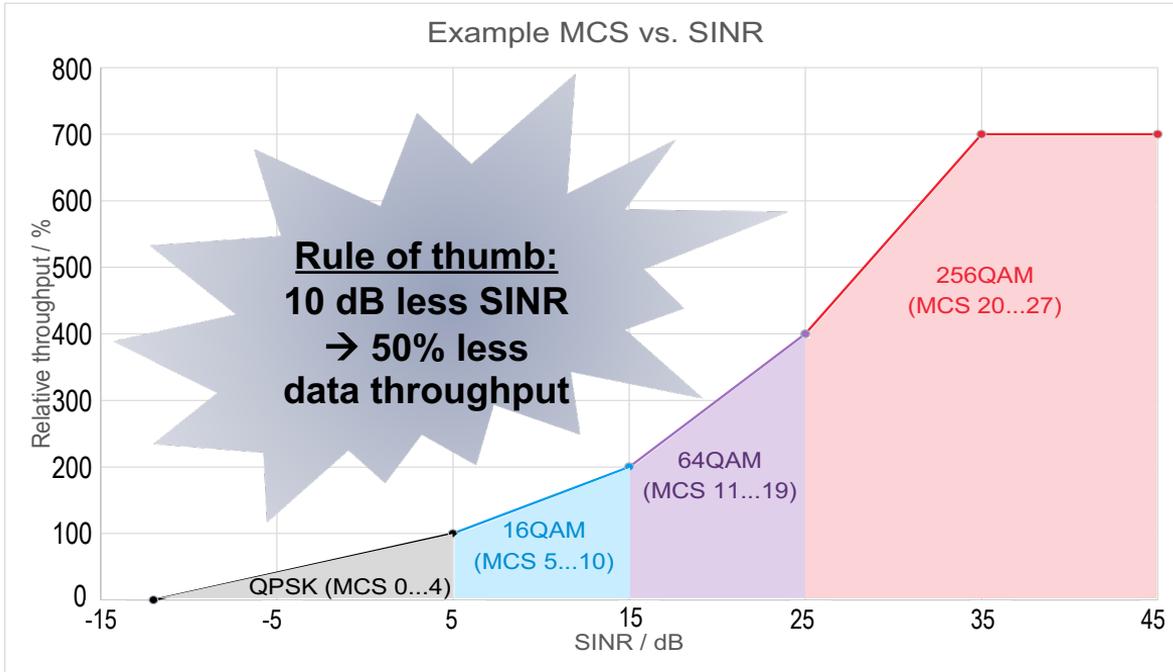
► Not easy to quantify

► Depending on many parameters and implementation

The graph is a simplified real-world example for EPA5, 2x2MIMO and HARQ.
The MCS-SINR relation depends on the specific Base Station vendors' algorithms, performance and scheduler implementation, as well as on the channel fading profile etc.

MCS: Modulation and Coding scheme
SINR: Signal to Interference and Noise Ratio

TAKEAWAY: Interference dramatically impacts network performance
→ Spectrum clearance in new spectrum becomes essential

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MANAGING KEY RF CHALLENGES RELATED TO 5G NR RAN

New Spectrum

Different frequencies
Even 3.5GHz is different
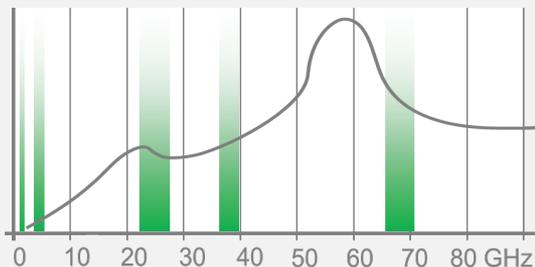
Coverage and Spectrum Clearance

Beamforming and Massive MIMO

Flexibility of air interface and gNB configuration

Bandwidth:
5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 100 MHz (FR1)
50, 100, 200, 400 MHz (FR2)

Subcarrier Spacing:
15, 30, 60 kHz (FR1)
60, 120, (240) kHz (FR2)

Mapping antenna ports:
single beam / multi beam sweeping

New technology elements drive the need for (and complexity of) 5G NR network measurements

WHAT IS 5G COVERAGE?

LTE Anchor Cell Coverage | **Result 5G Service Coverage** | 5G NR Carrier Coverage
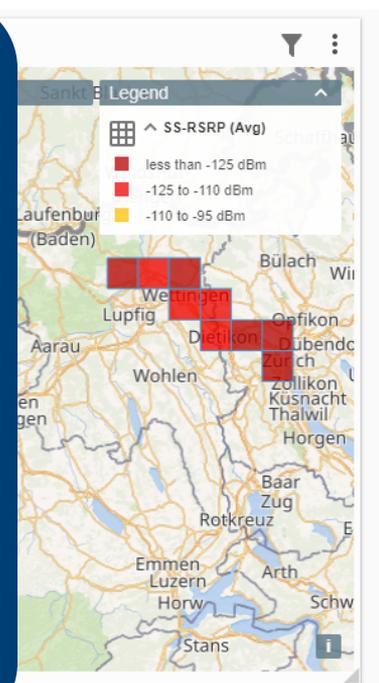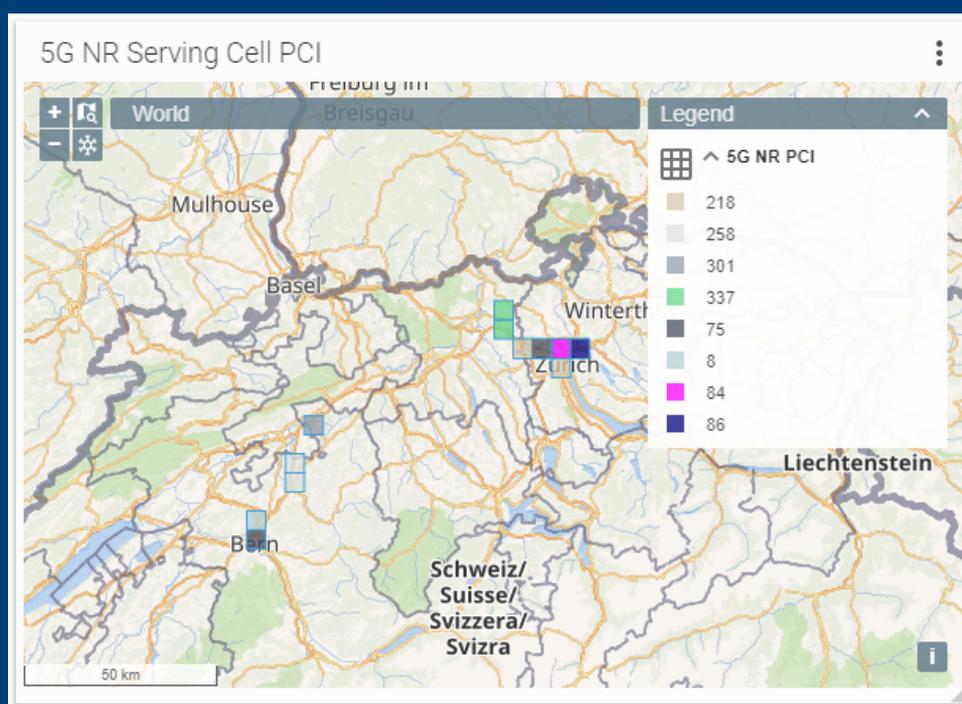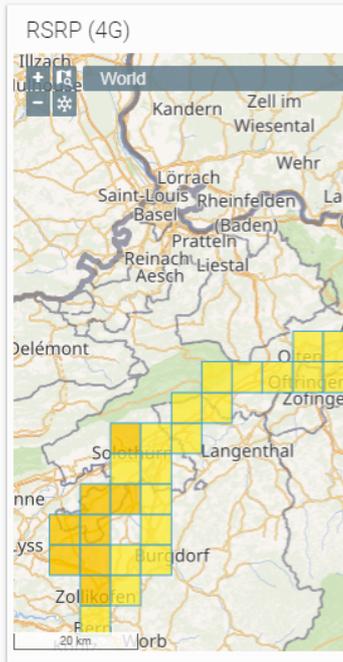
HOW CAN A UE IDENTIFY A 5G CARRIER?

First action of UE looking for 5G cell: search for Synchronization Signals

SSB = Sync Signal Block
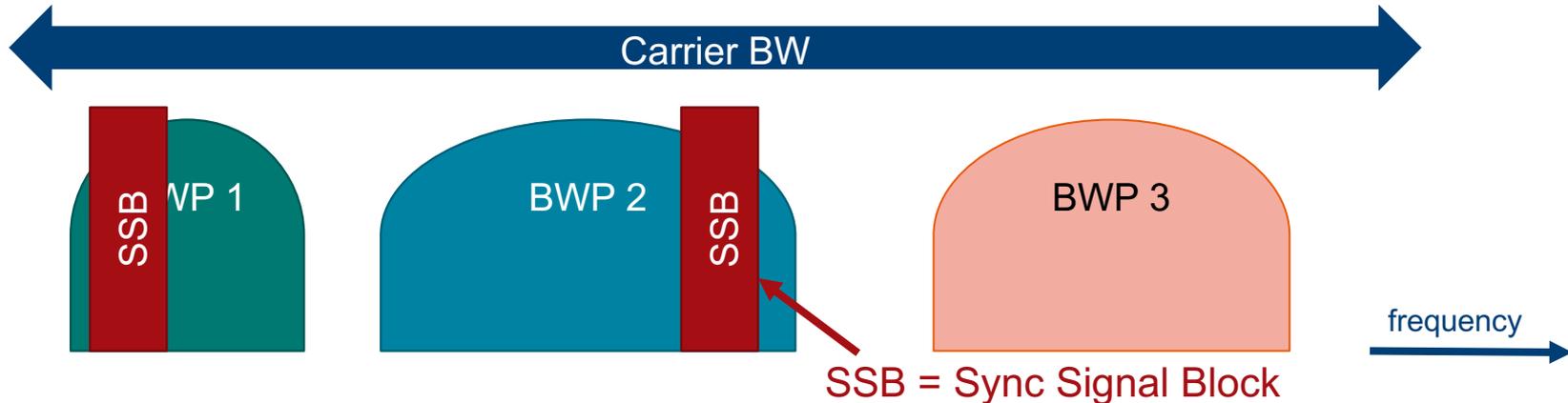
- One SSB is always transmitted → the **only Always-On signal** in 5G NR!
  BUT: it is not easy to find!

- The 5G NR UE uses the SSB for
  - Synchronization
  - System information (MIB/SIB)
  - Cell and Beam quality measurements

BWP (BandWidth Part): contiguous subset of physical resource blocks within the overall carrier bandwidth

5G NR SIMPLE BEAMFORMING

SSBs mapped on „static" beams

UE Data Channels PDSCH & PUSCH use same beam shapes

SSB #1
SSB #2
SSB #3
SSB #4
SSB #5
SSB #6

eNB

gNB
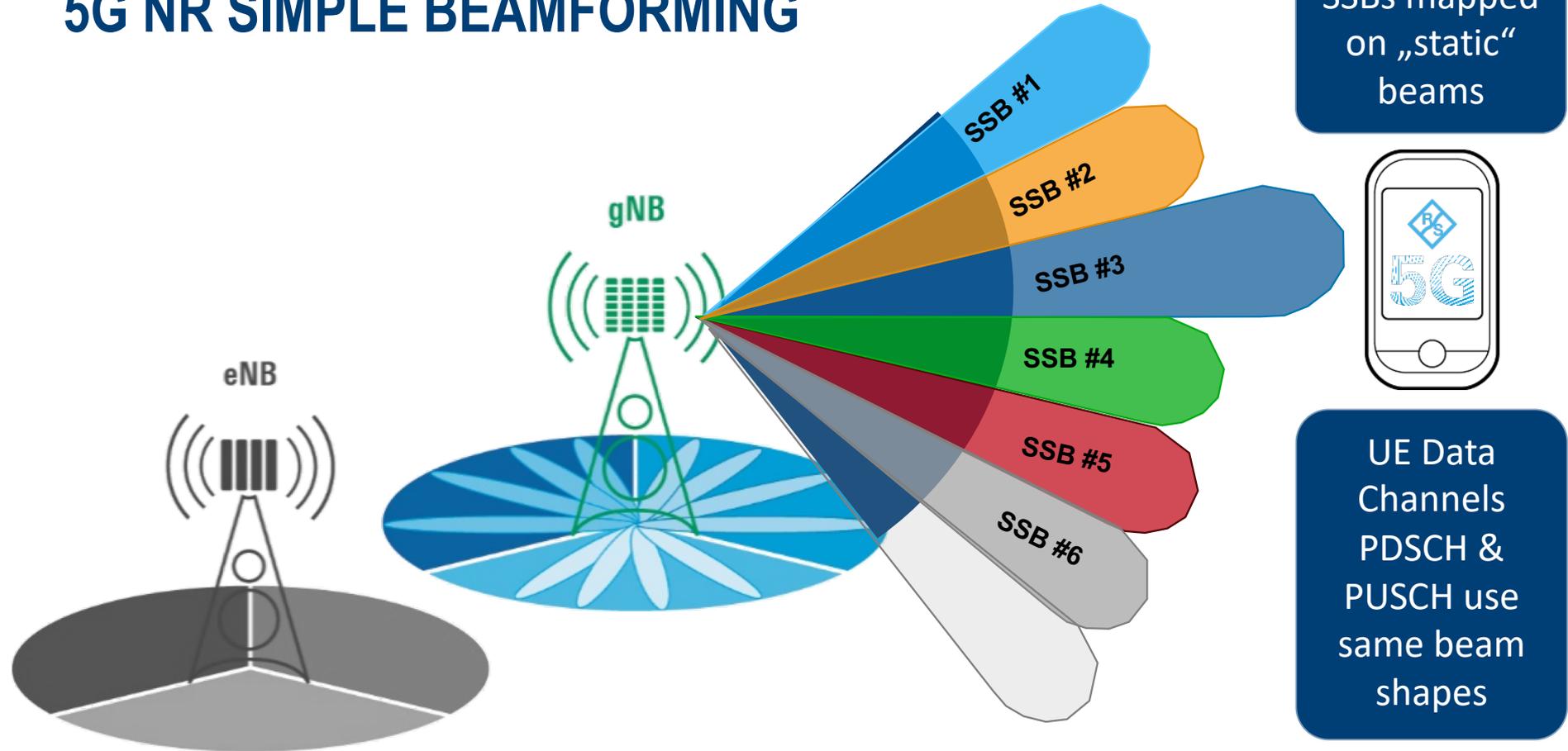
SSB BEAM COVERAGE ANALYSIS

Cell SSB Coverage per SSB index

SSB Rx Power per SSB index

Max SS-RSRP by SSB Index

SS-RSRP [dBm]

SSB Index	SS-RSRP [dBm]
5	-75.23
3	-79.97
1	-84.16
6	-85.5
0	-86.72
4	-89.69
7	-90.33
2	-93.53

Legend

SSB Index

	4
	5
	3
	6
	2
	1
	0
	7

Testing 5G Networks

5G NR BEAM SIGNALS

SSB Broadcast Reference Signals

Beamformed

Identified by SSB Index

Used by the UE
At initial access and for mobility measurements

Connected Mode Reference Signals

SSB and/or CSI-RS signals used
CSI-RS will typically be UE specific with either static or dynamic beaforming

Data channels beam selection
Rely on UE feedback to gNB of beam measurements

gNB

SSB/CSI-RS feedback

SSB/CSI-RS BEAM MEASUREMENTS

SSB Measurements

SSB Index	SSB RSRP	SSB RSRQ	SSB SINR
4	-84.3	-10.9	17.3
11	-107.1	-11.9	5.4
12	-96.9	-10.9	14.6
15	-105.1	-11.4	8.1

5G NR UE Avg CSI-RSRP:8

Parameter	[Unit]	Qualcomm [1]
PSCell Avg. CSI-RS RSRP 1	dBm	-58
PSCell Avg. CSI-RS RSRP 2	dBm	-70
PSCell Avg. CSI-RS RSRP 3	dBm	-76
PSCell Avg. CSI-RS RSRP 4	dBm	-

gNB

SSB/CSI-RS measurements
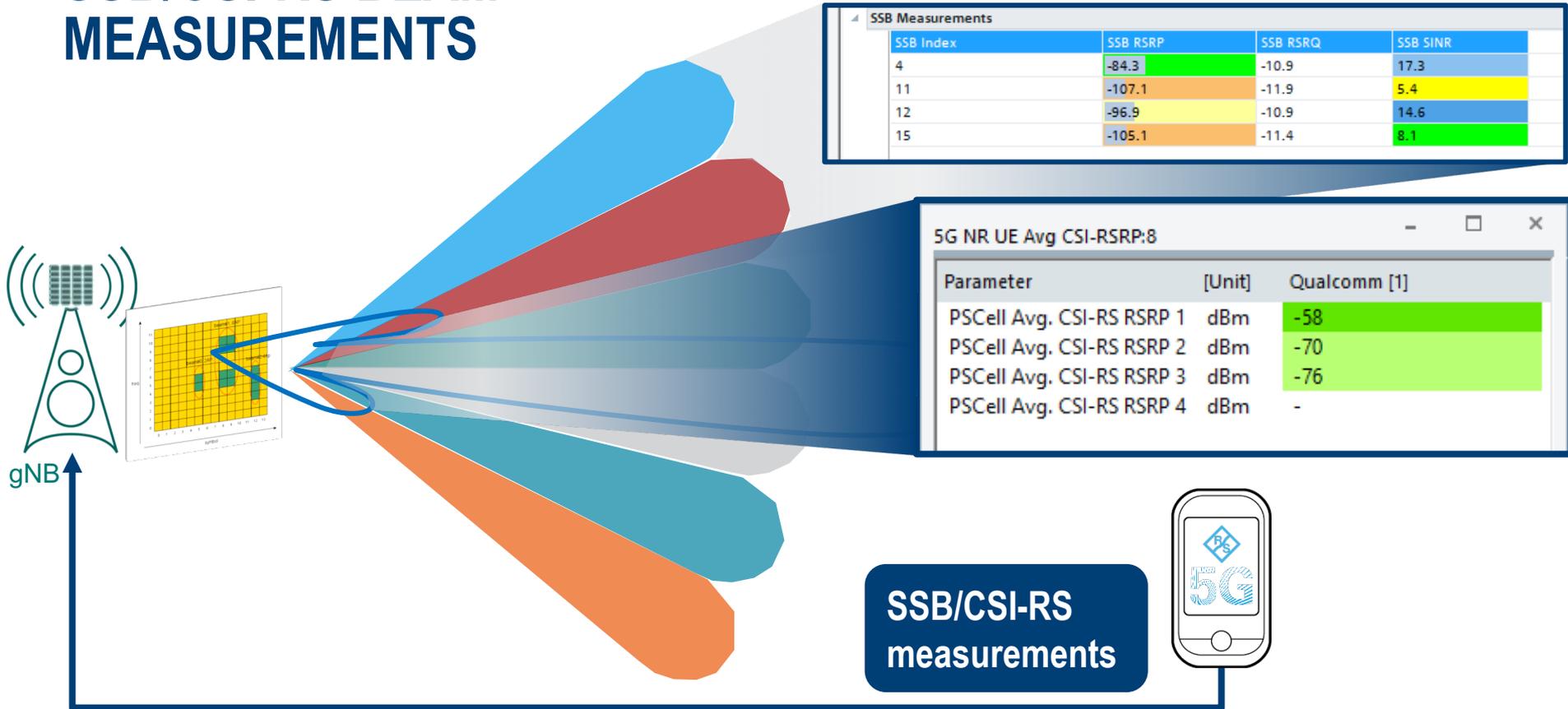
ADVANCED BEAMFORMING FOR MILLIMETER WAVES

▶ Tilt of 0 degree: <u>16 beams</u> with indices 4-7, 12-15, 20-23 and 28-31 which are spread from azimuth -60 to 60 degree

▶ Tilt -10 degree: <u>15 beams</u> with indices 36-39, 44-47, 52-55 and 60-62 which are spread from azimuth -60 to 60 degree

▶ Tilt -25 degree: 1 beam with index 63

▶ Total of 32 SSB index
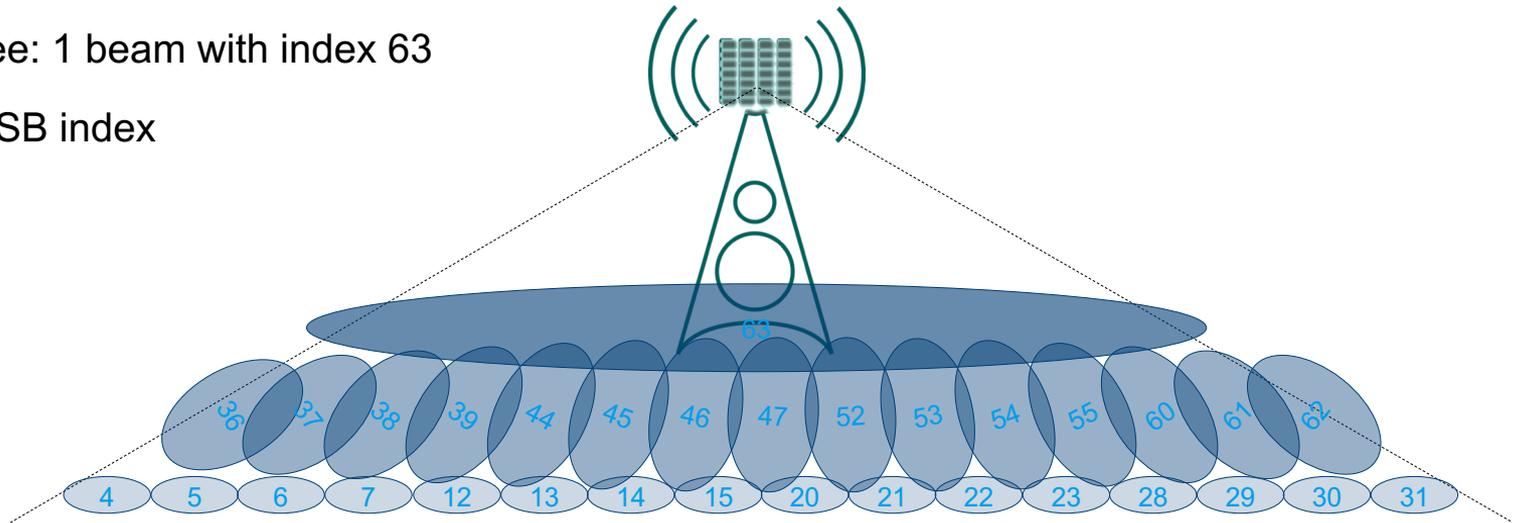
ADVANCED BEAMFORMING COVERAGE ANALYSIS

Cell SSB Coverage per SSB index

SSB Colors

Signal: 1. TopN <Auto>[1] SSB Idx[1]
Device: R&S 5G NR Scanner (TSME)[1]
Unit:
- 55
- 63
- 45
- 38
- 20
- 53;15
- 60
- 47
- 44
- 37
- 54
- 61
- 46
- 39
- 36
- 14;52
- all others

Expected beam map

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ARCHITECTURE OPTIONS
## OPTION 3 IS PRIORITY 1 IN 3GPP, FOLLOWED BY OPTION 2
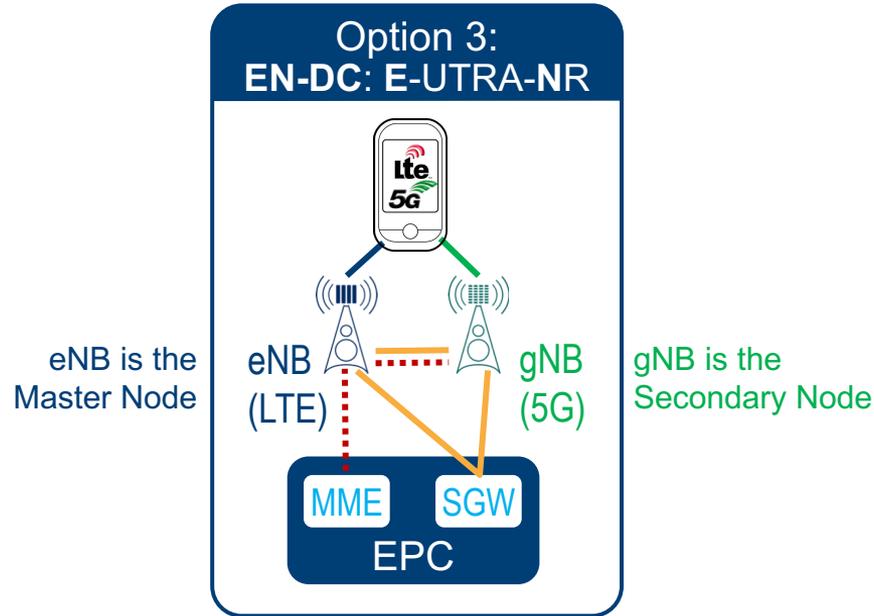
MME = Mobility Management Entity
S-GW = Serving Gateway
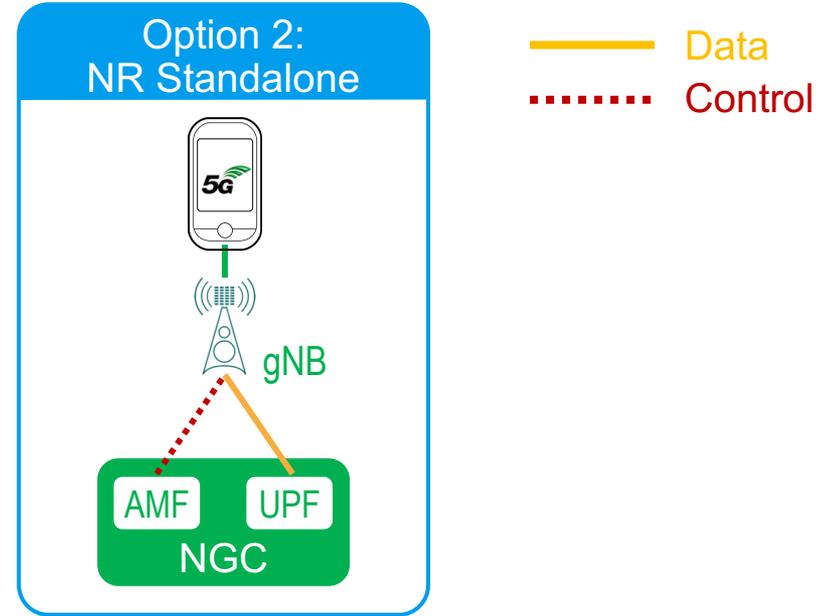
AMF = Access and Mobility Management Function
UPF = User Plane Function

LTE – 5G NR DUAL CONNECTIVITY

LTE PCell - EN-DC Master Node

5G NR PSCell – Secondary Node
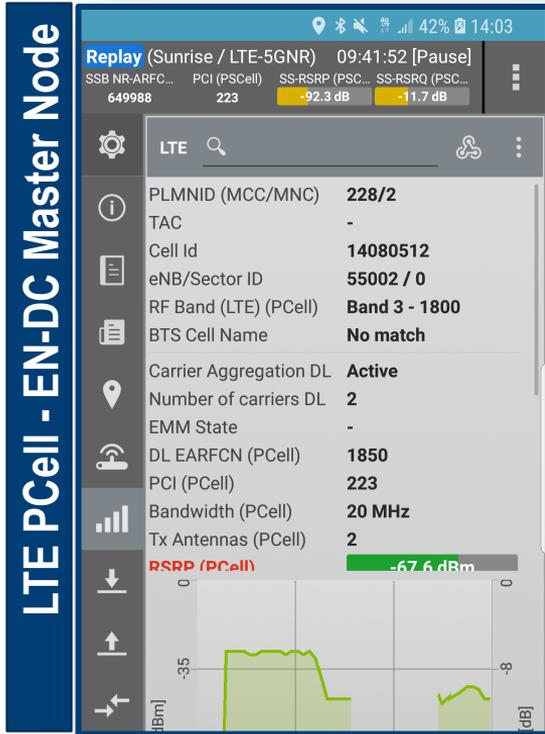
Option 3
EN-DC (Non Standalone)
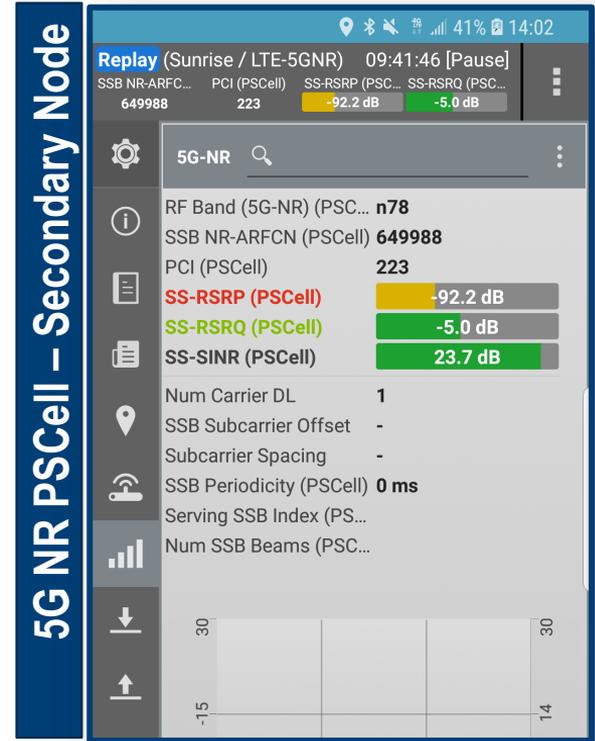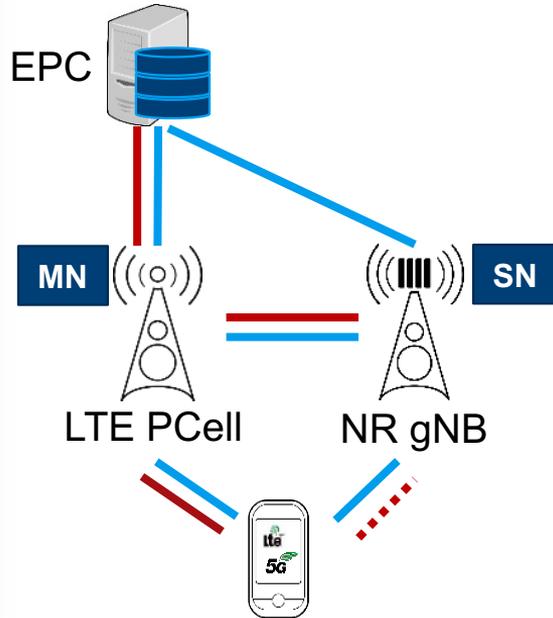
LTE and 5G NR Serving Cell information and measurements
Carrier Aggregation with Secondary Cell information

Option 3
EN-DC (Non Standalone)

EPC

SCG

SCell

SCell

PCell

PSCell

5G CARRIER AGGREGATION
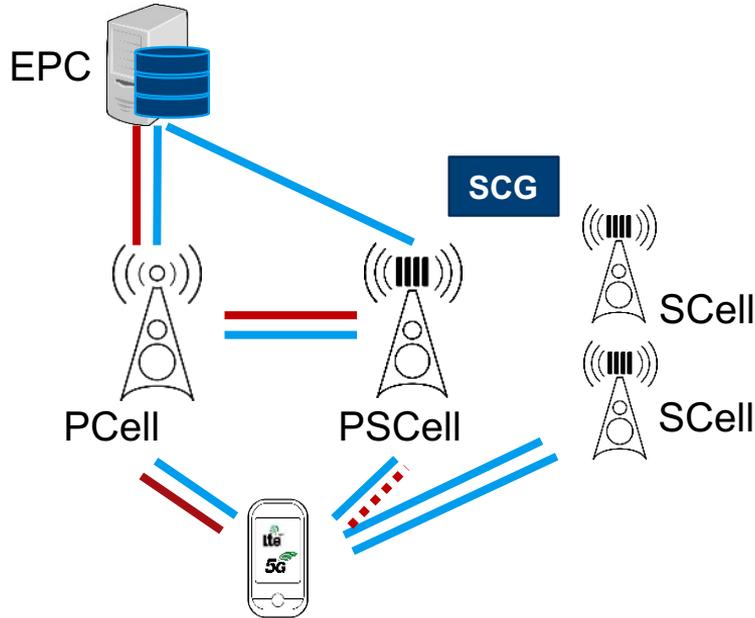
► **Secondary Cell Group (SCG)**

► **Primary 5G NR Cell (PSCell)**

► **Secondary 5G Cells (SCell)**

5G CARRIER AGGREGATION

► **5G Data Throughput**

  – **Total Aggregated Thp**

  – **Thp per 5G NR Cell**

Option 3
EN-DC (Non Standalone)

EPC

MN
LTE eNB

SN

NR gNB

MN
LTE eNB
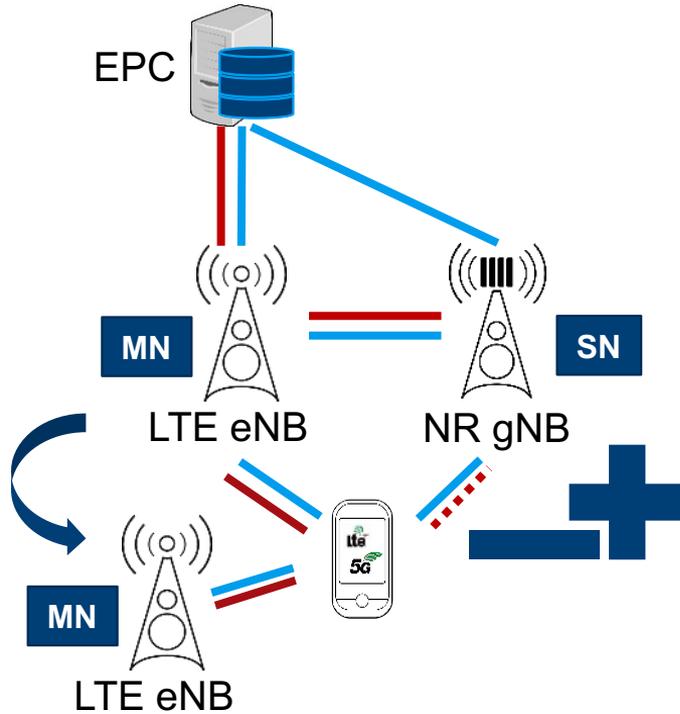
DC MOBILITY PROCEDURES

► **Handover only occurs between LTE Master Nodes**

► **NR cells are Secondary Nodes (SN) with mobility procedures**

- Secondary Node Addition
- Secondary Node Modification
- Secondary Node Release
- Secondary Node Change
- Primary Secondary Cell (PSCell) change

DUAL CONNECTIVITY MOBILITY PROCEDURES

Inter-MN Handover with SN change

SN Release
PSCell PCI 308

SN Addition
PSCell PCI 308
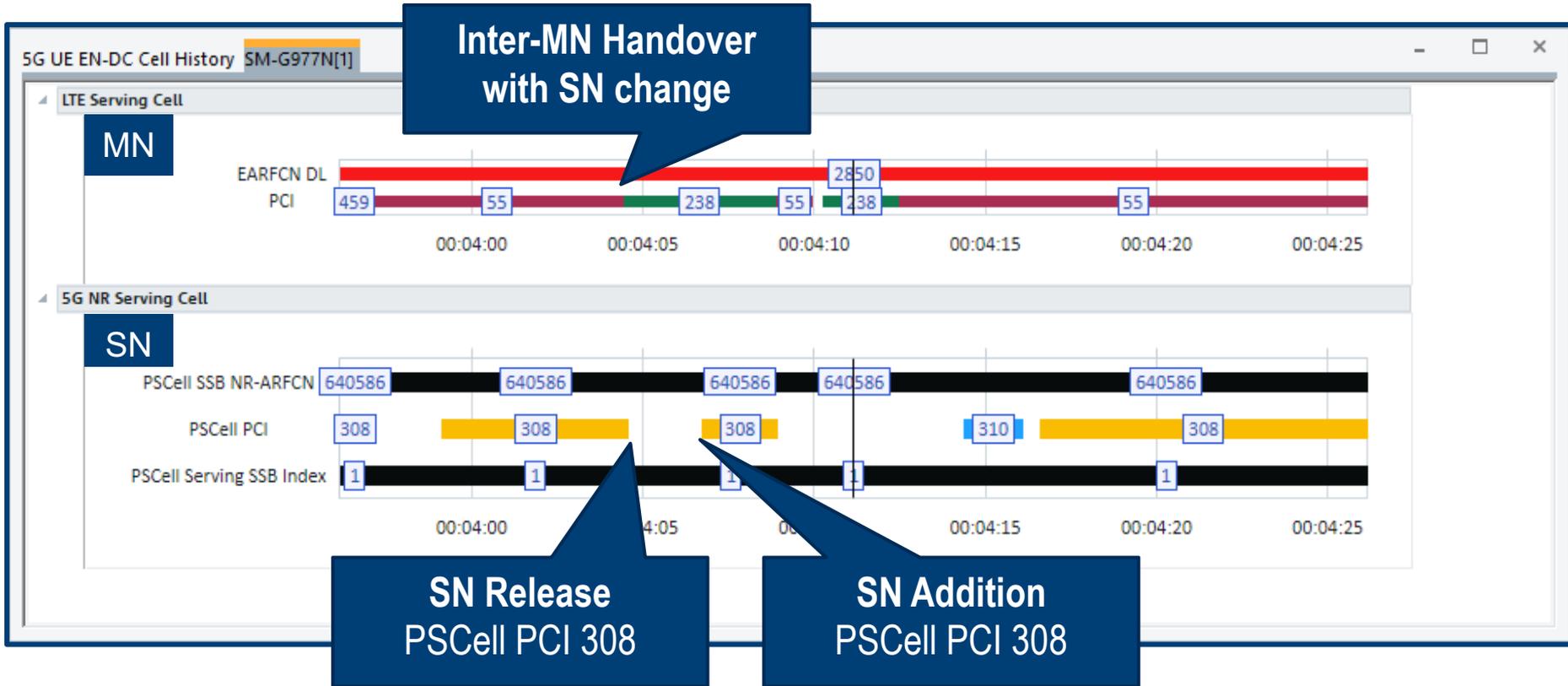
MAIN TAKE-AWAY – COVERAGE

▶ **Expected UE sensitivity: ~ -120 dBm (SS-RSRP)**

▶ **Suburban area (3.7 GHz)**

▶ **Surprisingly good SSB coverage**

▶ **Static SSB beamforming allows for long radio range**

➤ **Operators can try to reuse site grid ?**
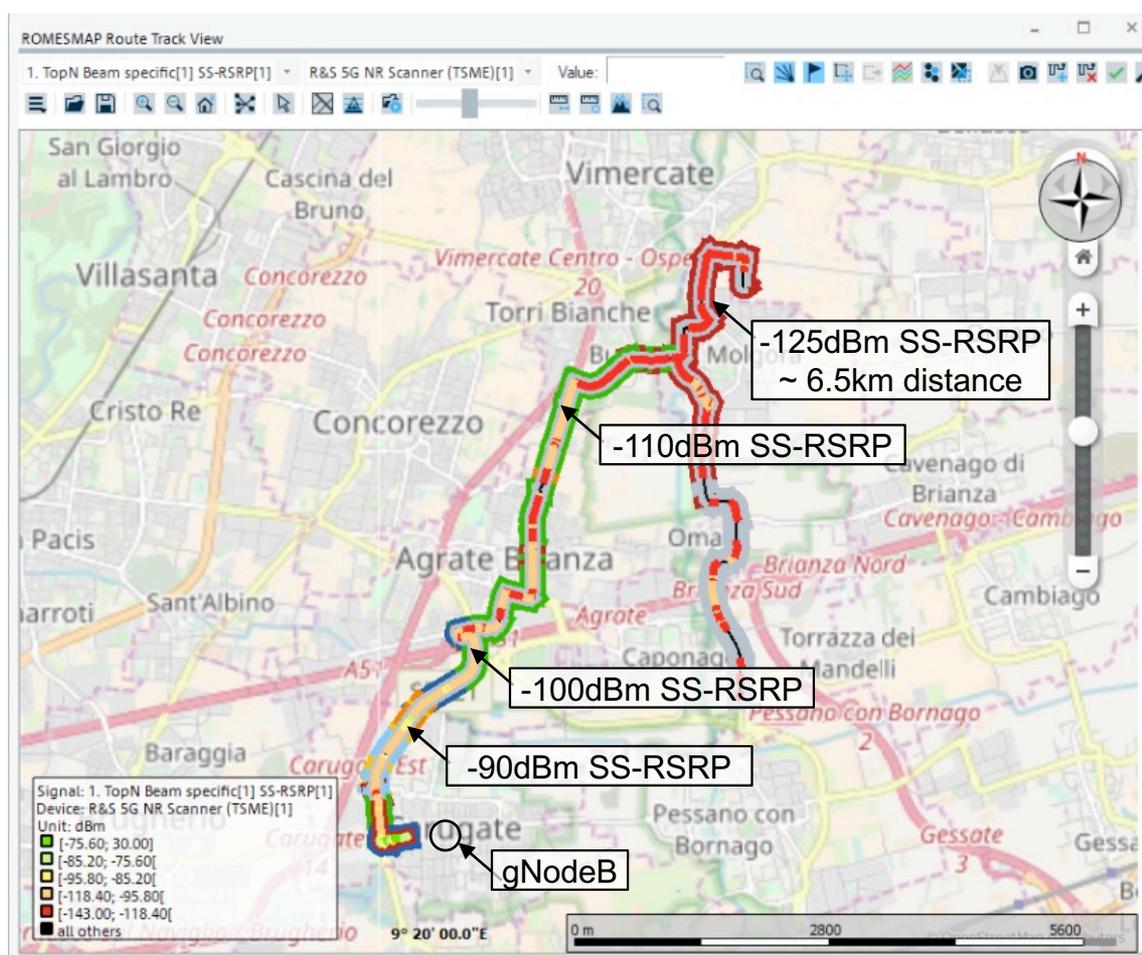
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WHO USES 5G AND HOW?

► Todays networks are optimized for humans using smartphones (LTE and 5G non-standalone)
→ User perceived QoE is the KPI today

► In 5G new **classes** of users will take advantage of the 5G infrastructure

– **Humans** (smartphone use case)

– **Automotive** (connected, autonomous driving, Vehicle-to-X)

– **Industry** 4.0 (Smart Manufacturing, private 5G networks)

**URLLC,
5G standalone**

– **IoT, mMTC** (Smart City, Connected Energy, ...)

► Each class causes <u>individual traffic patterns</u> and has <u>individual requirements</u> to the network!

➢ A network optimized for human users may not deliver best performance for cars or industry
➢ Different Network Slices for different user classes and applications!

MEASURING QOS AND QOE OF 5G APPLICATIONS

5G

| GBs in a second | 3D Video UHD | Cloud Work & Play | AR/VR | Industry Automation | Mission Critical | Self-Driving Vehicles | Smart City |

The number of application and use cases will increase by folds in 5G.

Good Performance and QOE

> *Minimum amount of data rate* > **CAPACITY** >

> *Minimum response time* > **LATENCY** >

> *Maximum length of interruptions* > **CONTINUITY** >

Interactivity

- Augm. Reality
- Telephony
- 4k video
- Power Metering
- Data Download

bitrate

latency

continuity
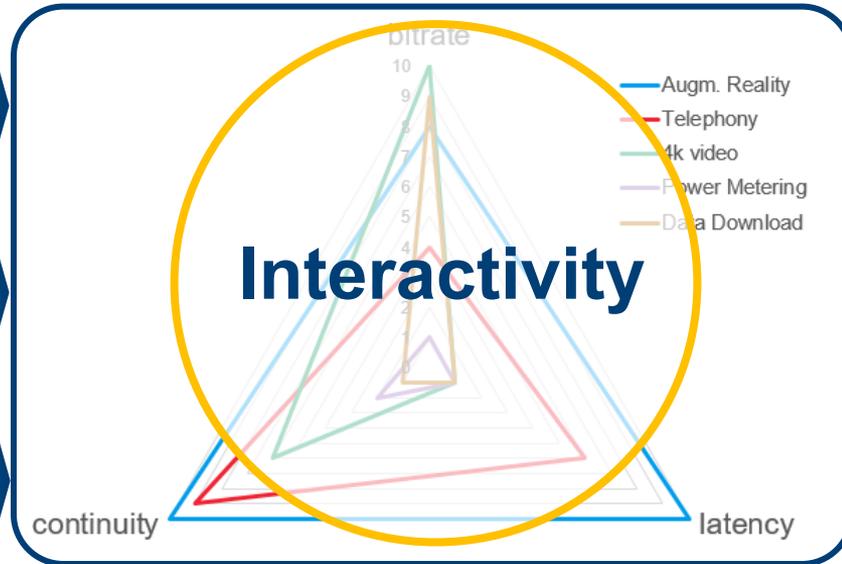
CLOUD GAMING

Platform Independent

Quasi Continuous Update Information

Update information
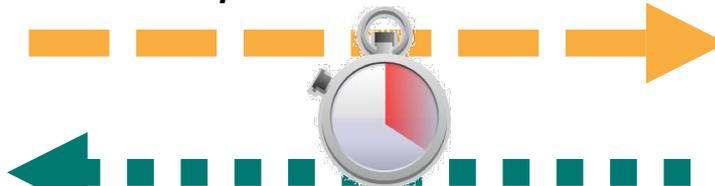
Encoded video 'stream', VR or AR 'stream'

GPU

High DL Traffic

Very Low Latency

INTERACTIVITY TEST

Frequency and size of packets controlled

Device sends unique packets to server

Measured
Latency (RTT)
Jitter
Packet Loss
Corruption
Ratio

Server sends back packets as responses

Continuous Packet Flow
Packet Rates of 100 to 1500 per second
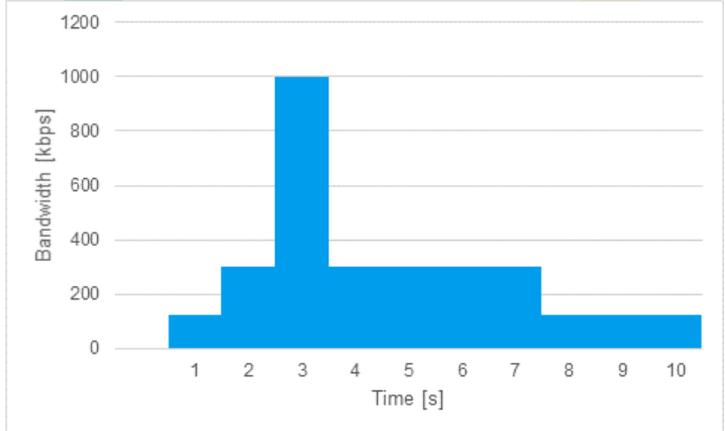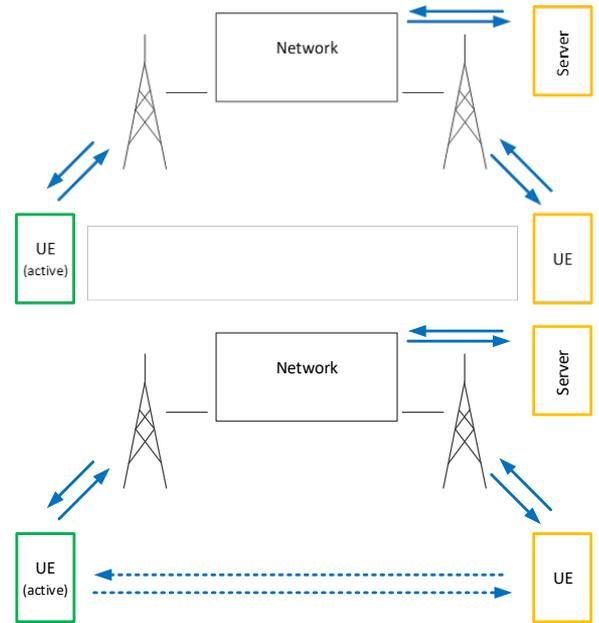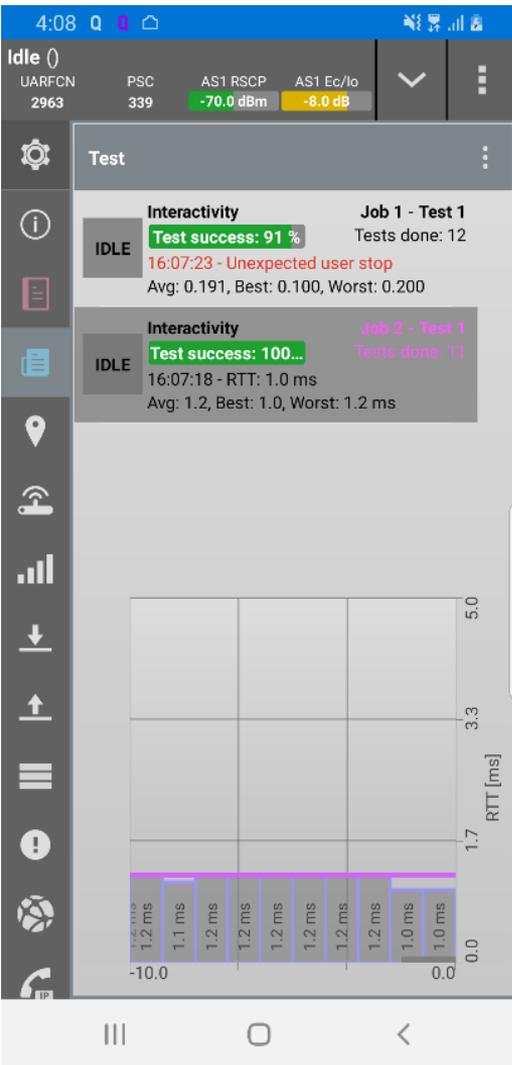
CONTINUOUS EVOLUTION

► **INTERACTIVITY TEST**

► **Traffic Pattern to emulate applications**
  – Constant rate
  – eGaming real-time

► **Technical Results**
  – Latency
  – Packet Delay Variation
  – Packet Error Rate
  – Connectivity

CONTENTS

1. New frequencies

2. Beamforming and coverage verification

3. Dual connectivity

4. Reconsider QoE in 5G?

5. **Optimization in 5G**

# NETWORK OPTIMIZATION

Our MNT mission in short:
We provide solutions to **maximize network quality and performance**

What is Network Optimization?

► Higher user data rates

► Higher network capacity

► Seamless coverage (no serious degradation during mobility)

➢ **Higher network quality and performance!**

HOW TO REALIZE „HIGHER USER DATA RATES"

Dominant best server	Low interference	Low/no PIM (UL)

⬇

Higher SINR (Signal to Interference and Noise Ratio)

⬇

Higher MCS (Modulation and Coding Scheme)

⬇

Higher user data rates (same amount of resources!)

HOW TO REALIZE „HIGHER NETWORK CAPACITY"

Clean spectrum: low noise level, less interference

Higher user data rates (same resources; see above)

New spectrum (additional resources)

Higher network capacity

HOW TO REALIZE „SEAMLESS COVERAGE"

Low frequency coverage layer (5G: sub 6 GHz)

Proper network planning   Multi-technology LTE / 5G

Correct deployment (site upgrades or new sites)

Seamless coverage (no serious degradation during mobility)

KEY NEWS SUMMARY

Spectrum clearance in new spectrum is essential for network performance

Beamforming and coverage can be evaluated in the field (in FR1 and FR2)

Dual connectivity and carrier aggregation are essential ingredients

Over-The-Air (OTA) testing becomes crucial

QoE in 5G needs reconsideration: generic computational approach (technical KPIs)

Optimization principles are still valid, with new aspects on beamforming and dual connectivity

➢ 5G provides huge amount of data → data analytics and machine learning essential !

R&S TEST SOLUTIONS TO DEPLOY 5G NR NETWORKS

Spectr. Clearance / Interfer. Hunting

R&S®TSMA6   R&S®FPH 31GHz   R&S®FSH
TDD gated trigger

R&S®MNT100/PR100   R&S®MobileLocator

Site Acceptance

R&S®TSMA6   QualiPoc Android

5G NR network measurement solution

Passive measurements

R&S®TSME6   R&S®TSMA6

Shoulder bag   Backpack for mmwave

Active measurements

5G Router   Mobile Test Platform

QualiPoc Android
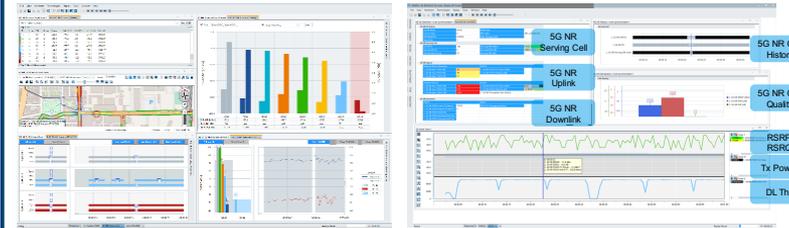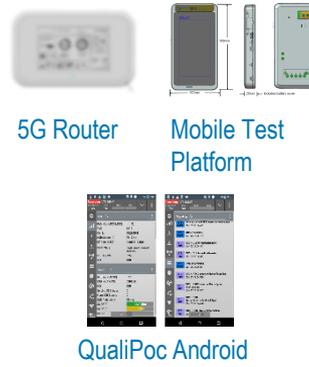
R&S®ROMES4: 5G NR Software for network engineering, analysis and optimization

Data Analytics

SmartAnalytics Scene
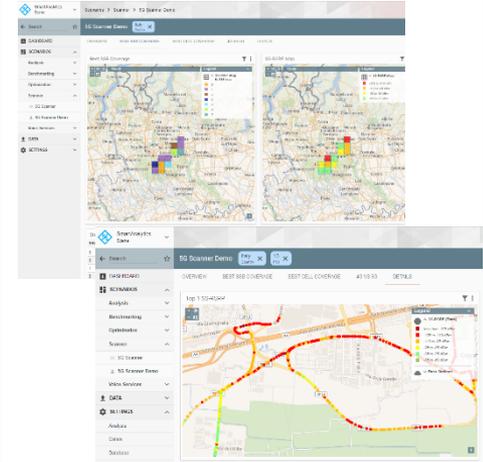
SmartAnalytics Scene - NPS

THANK YOU!

ROHDE & SCHWARZ

Make ideas real