# 5G New Radio Mobile Network Testing

## MNT Seminar, Lisbon, 7th June 2019

**Jerry Carpenter**
Marketing Manager
Rohde & Schwarz Mobile Network Testing
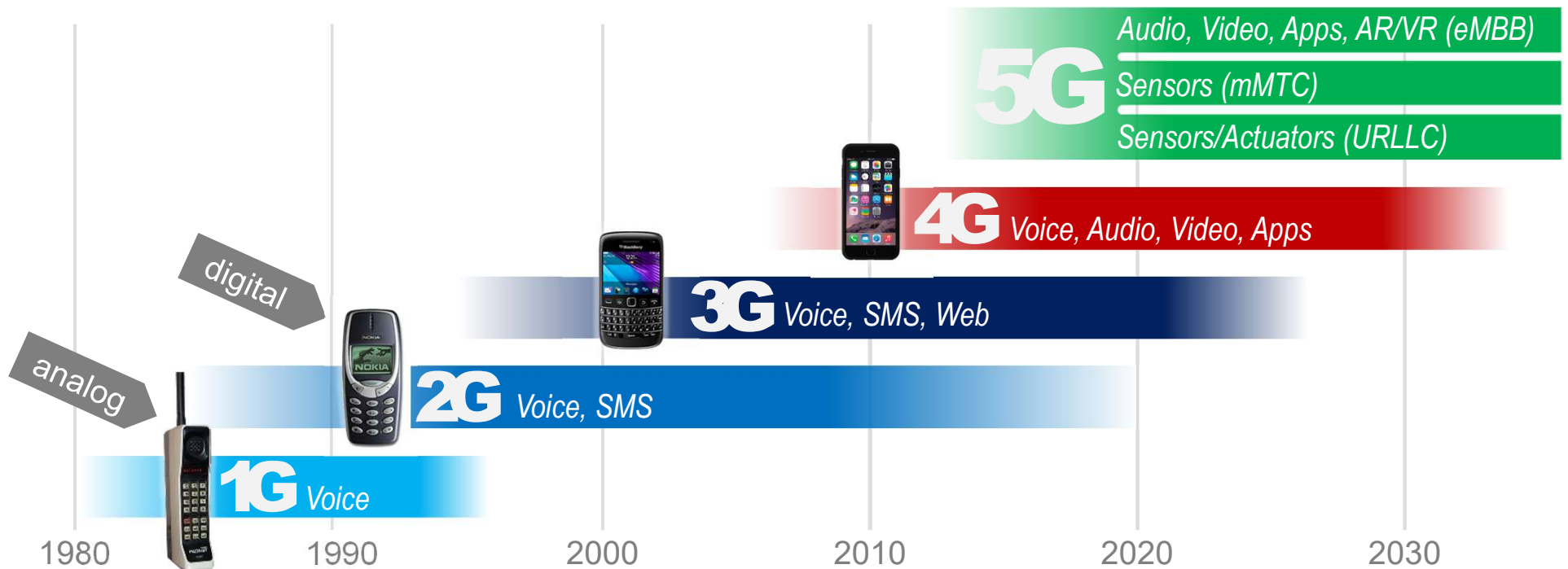
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# Contents

# What is 5G? – It's a paradigm shift

## 5G is a true use-case driven cellular technology

**5G** — Audio, Video, Apps, AR/VR (eMBB)
Sensors (mMTC)
Sensors/Actuators (URLLC)

**4G** — Voice, Audio, Video, Apps

**3G** — Voice, SMS, Web

**2G** — Voice, SMS

**1G** — Voice

digital

analog

1980    1990    2000    2010    2020    2030

# 4G today and 5G technology forecast

- **GSA Reports (January '19):**
  - **712** commercially launched LTE / LTE-Advanced networks in **213** countries (6 networks with cat. 18 speeds (> 1Gbps))
  - **201** operators in **83** countries that have launched (limited availability or non-3GPP networks), demonstrated, tested or trialed 5G-enabling and candidate technologies.
  - **74** telecom operators in **43** countries have announced intentions of making **5G** available to their customers between 2018 and 2022

**Legend:**
- 5G
- LTE
- WCDMA/HSPA
- GSM/EDGE-only
- CDMA-only

Mobile subscriptions by region and technology (percent)



India — 2018: 56% / 2024: 81%
Middle East and Africa — 2018: 44% / 2024: 42%
South East Asia and Oceania — 2018: 48% / 2024: 63%
Central and Eastern Europe — 2018: 43% / 2024: 86%
Latin America — 2018: 42% / 2024: 74%
North East Asia — 2018: 82% / 2024: 43%
Western Europe — 2018: 57% / 2024: 29%
North America — 2018: 87% / 2024: 55%

Source: GSA Evolution from LTE to 5G report, January 2019

Source: Ericsson Mobility Report November 2018

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# Frequency trends for 5G
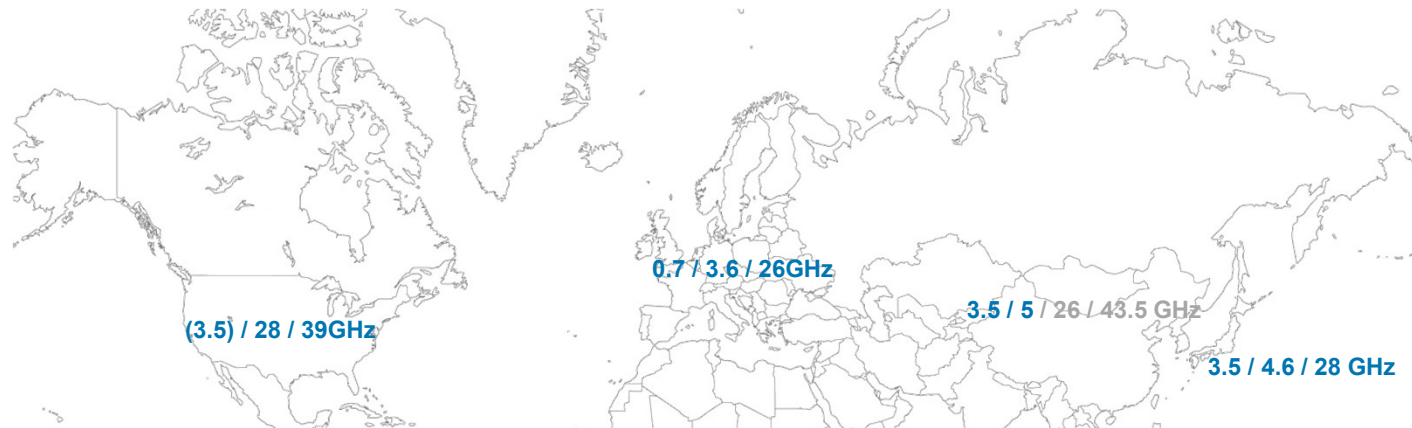
Europe
700 MHz
3.4 - 3.8 GHz
24.25 - 27.5 GHz

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

US
[CBRS band (3.5GHz)]
27.5 - 28.35 GHz
37.0 - 40 GHz
64 - 71 GHz (unlicensed)

Australia
3.6 GHz
26 GHz

Korea
3.5 GHz
28 GHz

Japan
4.4 - 4.9 GHz
28 GHz

(3.5) / 28 / 39GHz

0.7 / 3.6 / 26GHz

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 |

# 3GPP RAN NR Standardization Overview
## Status after 3GPP RAN #83 (March 2019)

| 2017 | 2018 | 2019 | 2020 | 2021 |
|------|------|------|------|------|

**Now**

**Rel-15**

RAN #80
June 2018

RAN #84
June 2019

RAN #86
Dec 2019

Rel-15 NSA Option 3,
SA Option 2, 5

Late-Drop for
Option 4, 7

**Rel-15 completed
(RAN1, 2, 3, 4 (core))**

Rel-15 completed
(RAN 4 (perf), RAN5)

**Rel-16**

RAN #83
March 2019

RAN #88
June 2020

**Rel-16 completed**

Rel-16 Study-Item Phase

Rel-16 Work-Item Phase

**Tentative Rel-17 Schedule**

June 2019

Dec 2019

Sep 2020

June 2021

**Rel-17
completed**

Rel-17 Kick-Off
Workshop

E-mail
discussion of
work areas

Approval of
Rel-17 Study-Items
/ Work-Items

Study-Item
Phase

Work-Item
Phase

**Source:** RP-190563

# The status of commercial 5G NR deployments



Status: May 29th, 2019

DEPLOYMENT TYPES
- Commercial Availability  239
- Limited Availability  50
- Pre-Release  62

5G News & Updates

Source: Ookla 5G map
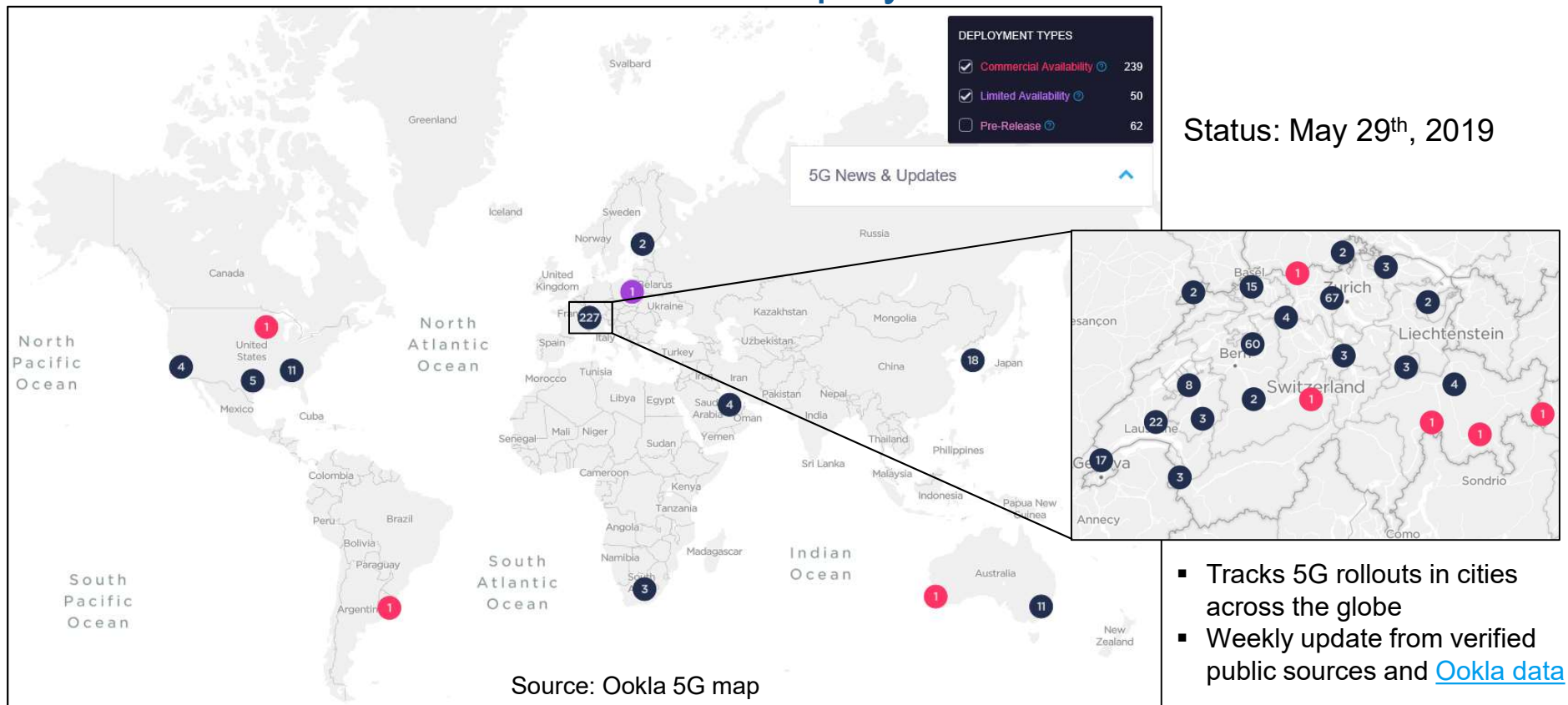
- Tracks 5G rollouts in cities across the globe
- Weekly update from verified public sources and Ookla data

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# Managing the key RF challenges related to 5G NR RAN

## New spectrum

▪ Even 3.5 GHz is different from today's frequencies
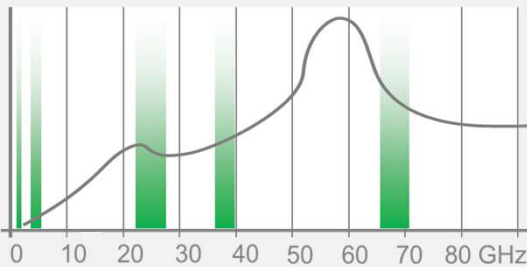


▪ What about coverage?
▪ Spectrum clearance?

## Beamforming and massive MIMO

▪ How does beamforming work?
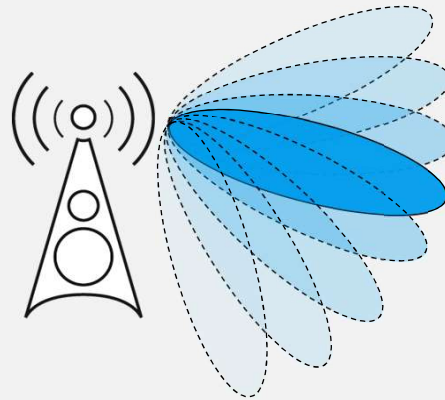


## Flexibility of air interface and gNB configuration

▪ 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 onto antenna ports: single beam / multi beam sweeping

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

# 5G New Radio (NR) offers a flexible air interface
## Summary of key parameters

**Changed to 7.125 GHz**

| Parameter | FR1 (450 MHz – 6 GHz) | FR2 (24.25 – 52.6 GHz) |
|---|---|---|
| Carrier aggregation | Up to 16 carriers | |
| Bandwidth per carrier | 5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 90, 100MHz | 50, 100, 200, 400 MHz |
| Subcarrier spacing | 15, 30, 60 kHz | 60, 120, 240 (not for data) kHz |
| Max. number of subcarriers | 3300 (FFT4096 mandatory) | |
| Modulation scheme | QPSK, 16QAM, 64QAM, 256QAM; uplink also supports π/2-BPSK (only DFT-s-OFDM) | |
| Radio frame length | 10ms | |
| Subframe duration | 1 ms (alignment at symbol boundaries every 1 ms) | |
| MIMO scheme | Max. 2 codewords mapped to max 8 layers in downlink and to max 4 layers in uplink | |
| Duplex mode | TDD, FDD | TDD |
| Access scheme | DL: CP-OFDM; UL: CP-OFDM, DFT-s-OFDM | |

# 5G Use Cases
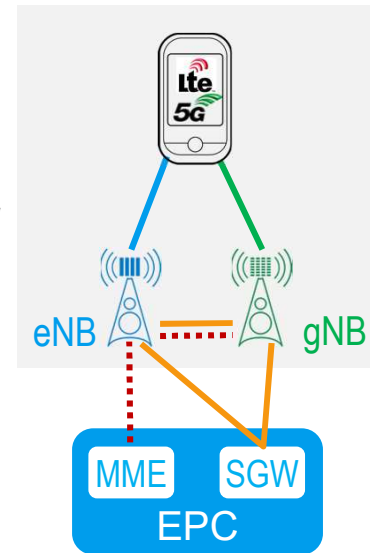## eMBB remains priority 1 but …

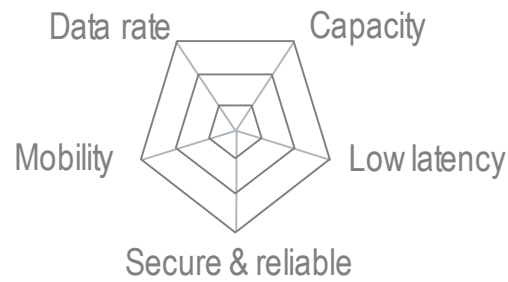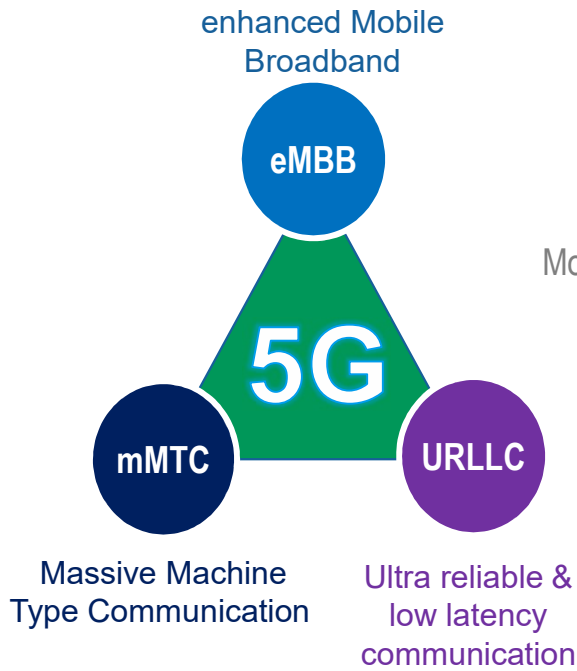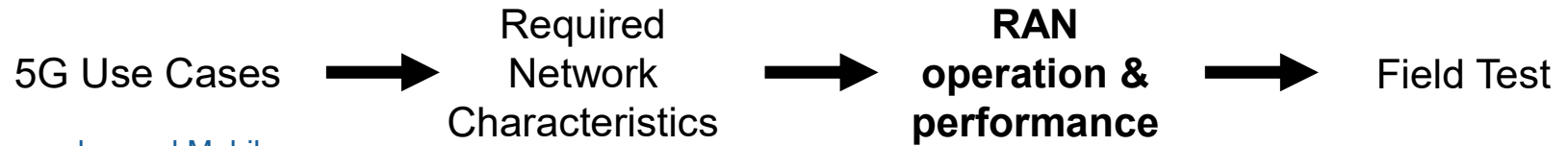### eMBB – the known playground
- Established ecosystem (operators, manufacturers, certification of devices)
- Evolution from existing technologies and revolutionary additions (cm- / mm-wave)
- It's all about data (speed and capacity)
- Realizing and facing the challenges of cm-wave spectrum and OTA testing; 3.5GHz is important!

### Massive IoT
- A diverse ecosystem (operators, manufacturers, local authorities, certification only for some technologies)
- Mix of technologies (GSM, Lora, ZigBee, WLAN, Bluetooth, Cat M, NB-IoT,…)
- It's all about cost efficiency and massive connectivity
- 3GPP: No NR based solution; will be addressed by evolving LTE-M (eMTC) and NB-IoT

enhanced Mobile Broadband

**eMBB**

**5G**

**mMTC**

**URLLC**

Massive Machine Type Communication

Ultra reliable & low latency communication

### URLLC
- A significantly enhanced and diverse ecosystem (operators (?), manufacturers, verticals, certification not existing (yet))
- Principal support with high SCS and self-contained slots
- It's all about reliability and security

# 5G Use Cases drive the need to test
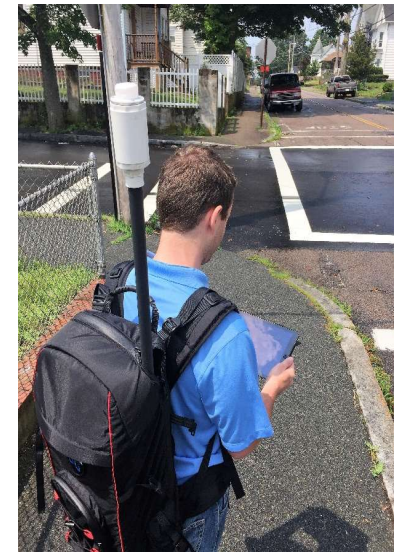
5G Use Cases → Required Network Characteristics → **RAN operation & performance** → Field Test

enhanced Mobile Broadband

eMBB

**5G**

mMTC

URLLC

Massive Machine Type Communication

Ultra reliable & low latency communication

Data rate

Capacity

Mobility

Low latency

Secure & reliable

lte 5G

eNB

gNB

MME

SGW

EPC

# Contents

- Market drivers and key challenges of 5G NR networks
- **5G NR technology**
- 5G NR field measurements
- 5G NR field test solutions
- Learnings and conclusion

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# 5G Key Technology Components
## NR builds on four main pillars

### New Spectrum
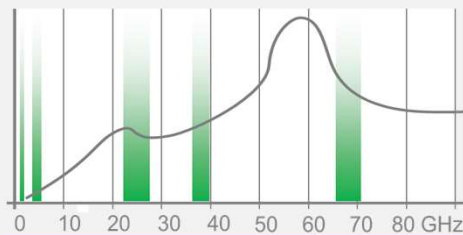


- < 1GHz
- ~ 3.5 GHz
- ~ 26/28/39 GHz

### Massive MIMO & Beamforming
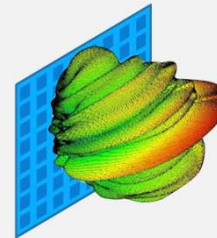
- Hybrid beamforming
- > 6GHz also UE is expected to apply beam steering

### Multi-Connectivity

eNB · gNB · MCG · MCG split · SCG split · SCG
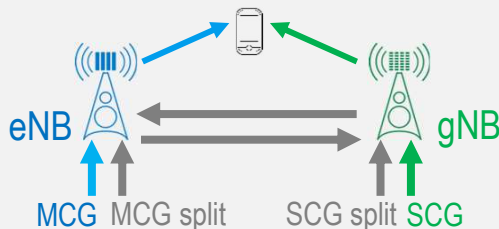
Initially based on Dual Connectivity with E-UTRA as master

### Network flexibility - virtualization
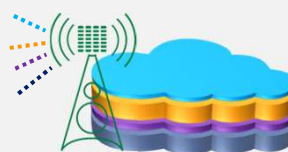
- Flexible physical layer numerology
- Network Slicing
- NFV/SDN

# 5G Network Architecture Vocabulary

LTE Core = EPC

**MME** **SGW**
**EPC**

5G Core = NGC

**AMF** **UPF**
**NGC**

────── Data
········ Control

MME = Mobility Management Entity
S-GW = Serving Gateway

AMF = Access and Mobility Management Function
UPF = User Plane Function

LTE BS = eNB
(connected to EPC)

LTE BS = NG-eNB
(connected to NGC)

5G BS = gNB

A base station in a DC (= Dual Connectivity) connection with the UE may have different roles:
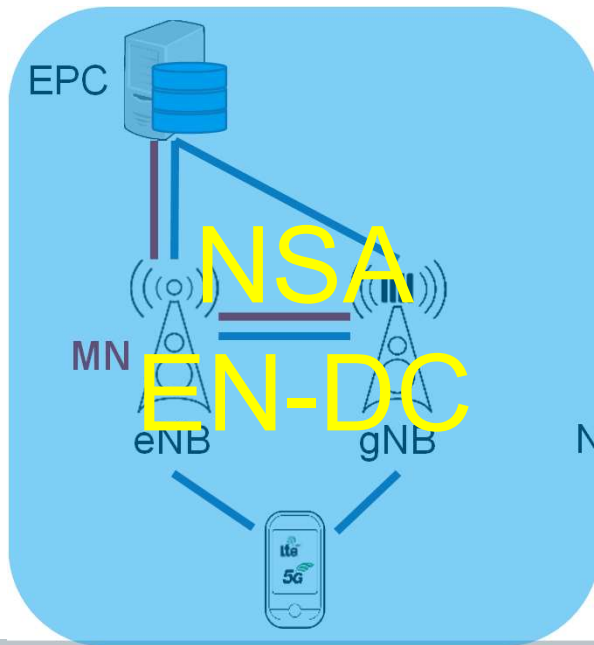MN = Master Node
or
SN = Secondary Node

# Architecture Evolution – DC Options
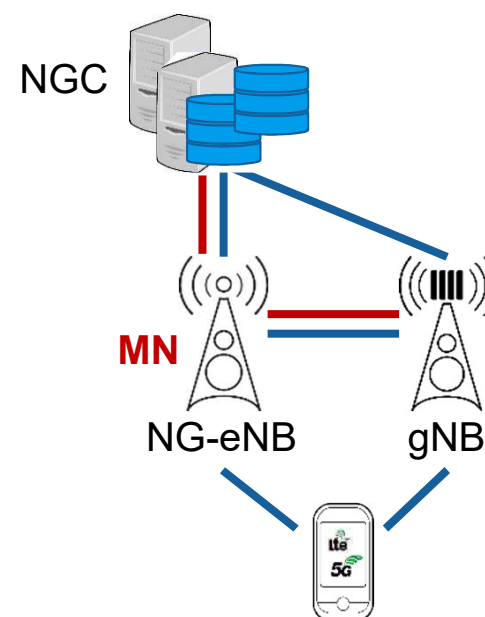## Option 3 is priority 1 in 3GPP, followed by Option 2

Data
Control



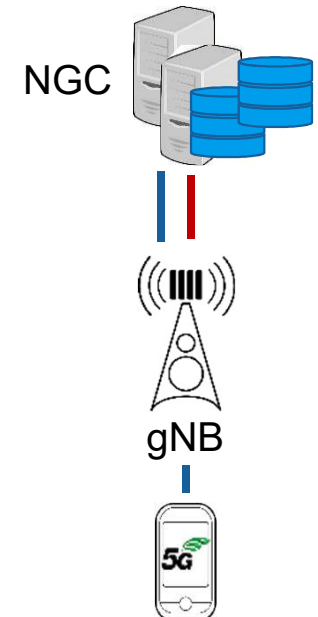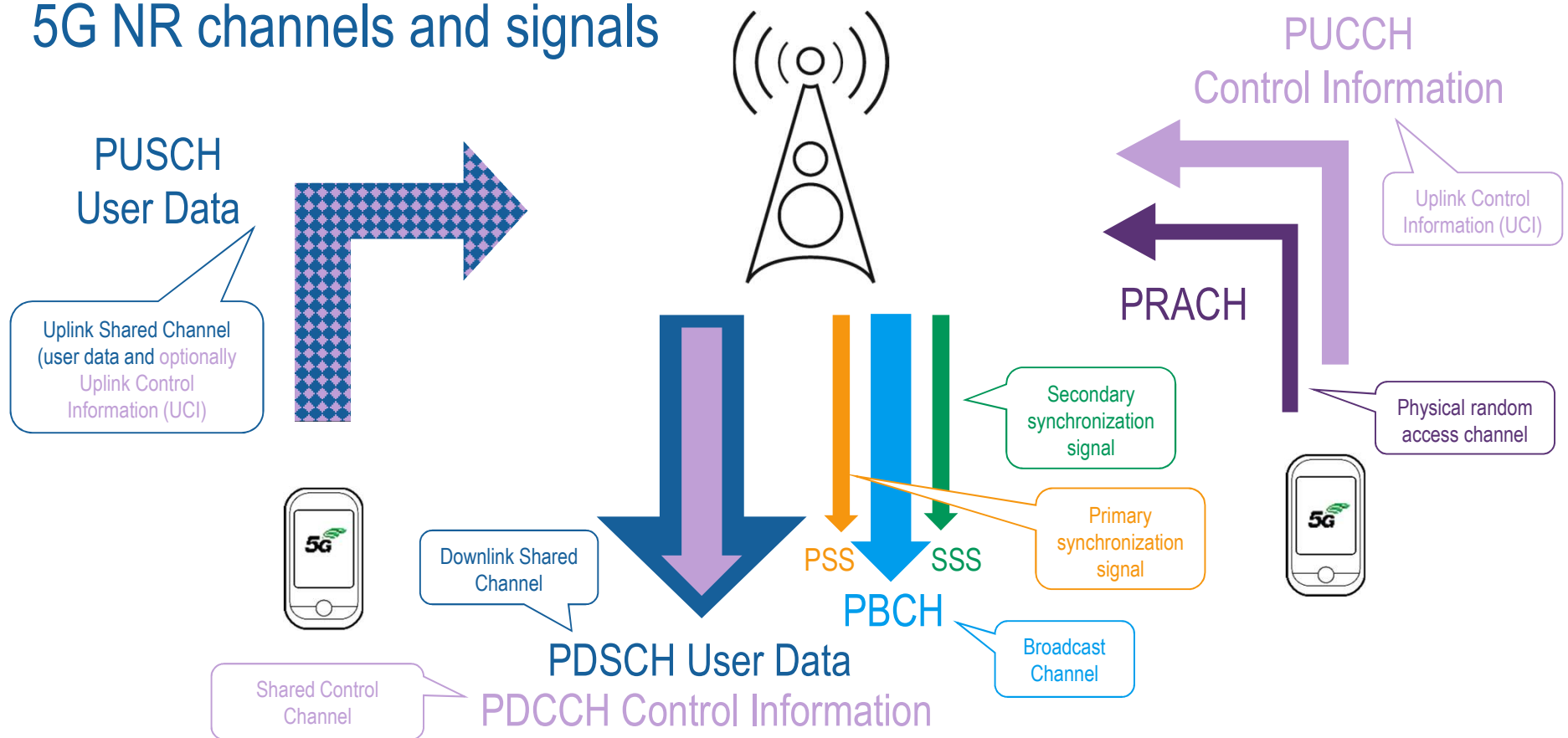| Option 3 EN = E-UTRA-NR | Option 4 NGEN = NG-RAN E-UTRA-NR | Option 7 NE = NR-E-UTRA | Option 2 Standalone |
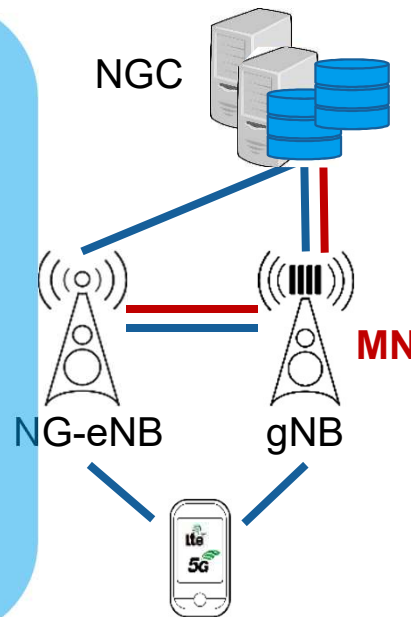
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# 5G NR channels and signals



**PUSCH User Data**

Uplink Shared Channel (user data and optionally Uplink Control Information (UCI))

**PUCCH Control Information**

Uplink Control Information (UCI)

**PRACH**

Physical random access channel

**PDSCH User Data**

Downlink Shared Channel

**PDCCH Control Information**

Shared Control Channel

**PSS** — Primary synchronization signal

**SSS** — Secondary synchronization signal

**PBCH** — Broadcast Channel

# How can a UE identify a 5G carrier?

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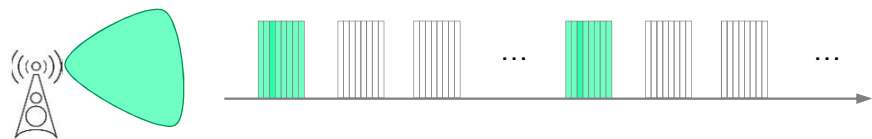


SSB = SS/PBCH block
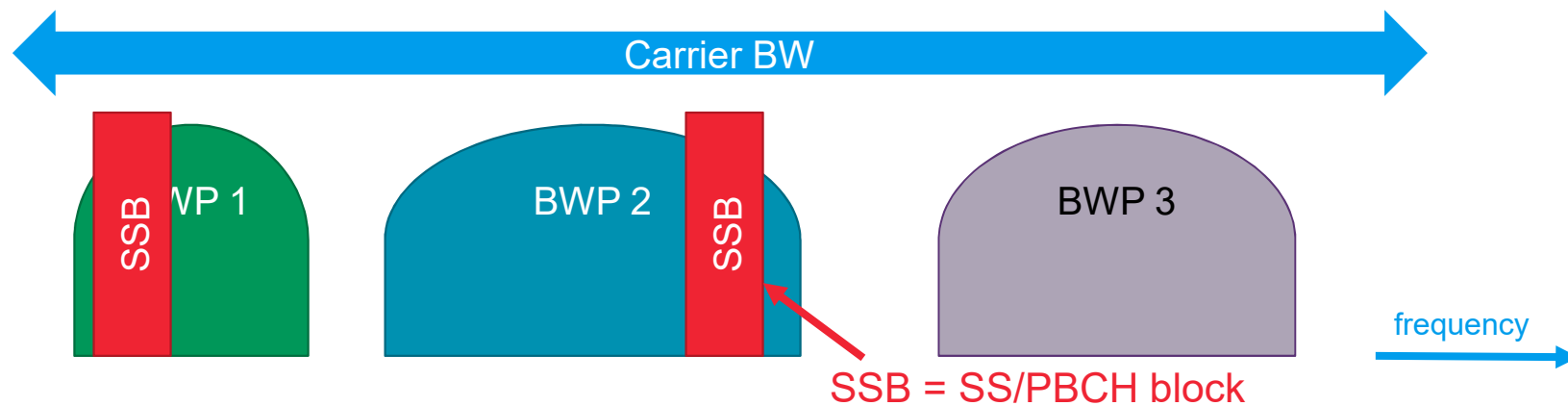
- One SSB is always transmitted → the **only Always-On signal** in 5G NR!
- The 5G NR UE uses the SSB for
  - Synchronization
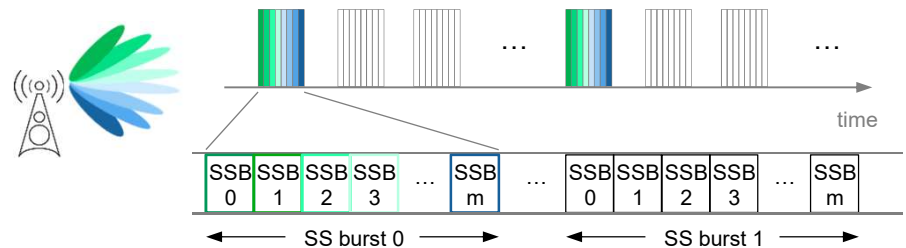  - System information (MIB/SIB)
  - Cell and Beam quality measurements

# SSB – in single beam or multi beam configuration

- SSB index is used to separate SSB transmission on different beams (encoded in the MIB)

- Mapping of antenna ports and physical beams to the SSB index can differ between infrastructure suppliers

- SS Bursts can also be repeated (periodicity is given in MIB)

Single Beam

Multi Beam sweeping

time

| SSB 0 | SSB 1 | SSB 2 | SSB 3 | ... | SSB m | ... | SSB 0 | SSB 1 | SSB 2 | SSB 3 | ... | SSB m |

SS burst 0          SS burst 1

> **5G NR network measurements need to cope with high flexibility and configurability**
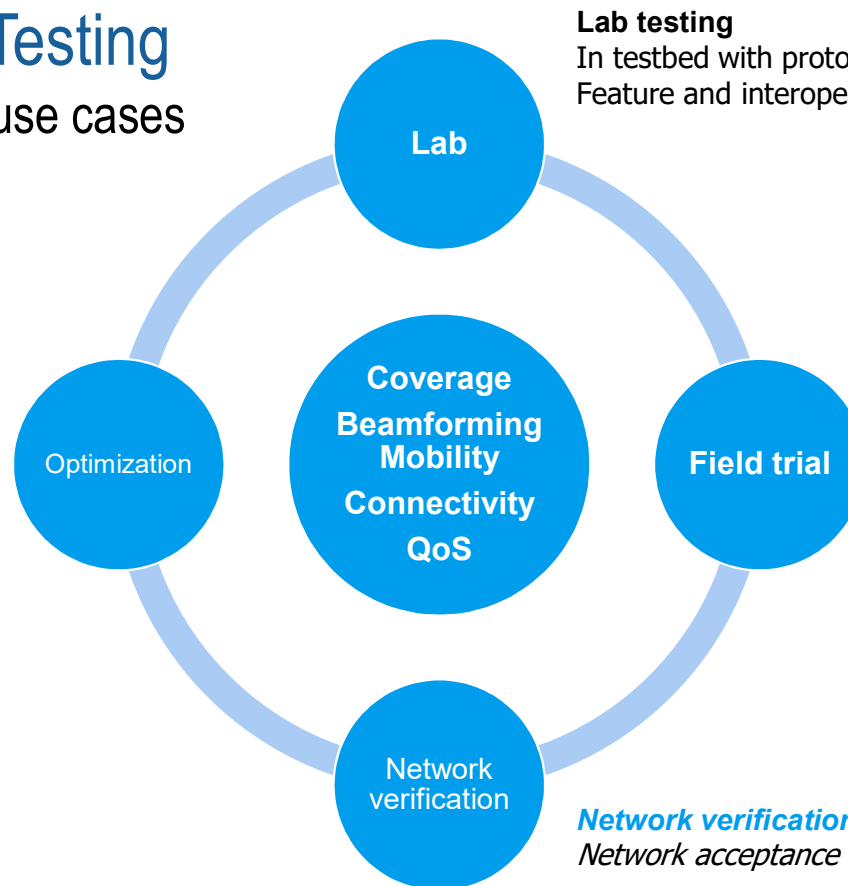
# Contents



- Market drivers and key challenges of 5G NR networks

- 5G NR technology

- **5G NR field measurements**

- 5G NR field test solutions

- Learnings and conclusion

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# 5G Network Testing
## Scanner and UE use cases

**Lab testing**
In testbed with prototype UEs (MTPs)
Feature and interoperability testing

**Lab**

**Coverage**
**Beamforming**
**Mobility**
**Connectivity**
**QoS**

**Optimization**

**Field trial**

**Network verification**

*Operational network*
e.g.
*Regression*
**Tuning**
**Troubleshooting**

***Field testing with Trial sites***
**Propagation modelling**
**Site type and antenna evaluation**
**Spectral clearance**
**Link budget evaluation**
**Coverage verification**
Beam management performance
Dual Connectivity and Mobility KPIs
SCS/BWP allocation
eMBB & URLLC QoS differentiations

**Data acquisition via scanner and/or UE**

*Network verification*
Network acceptance

# The 5G NR RF measurement needs



Coverage and Beamforming

Beam and Cell Quality Ranking

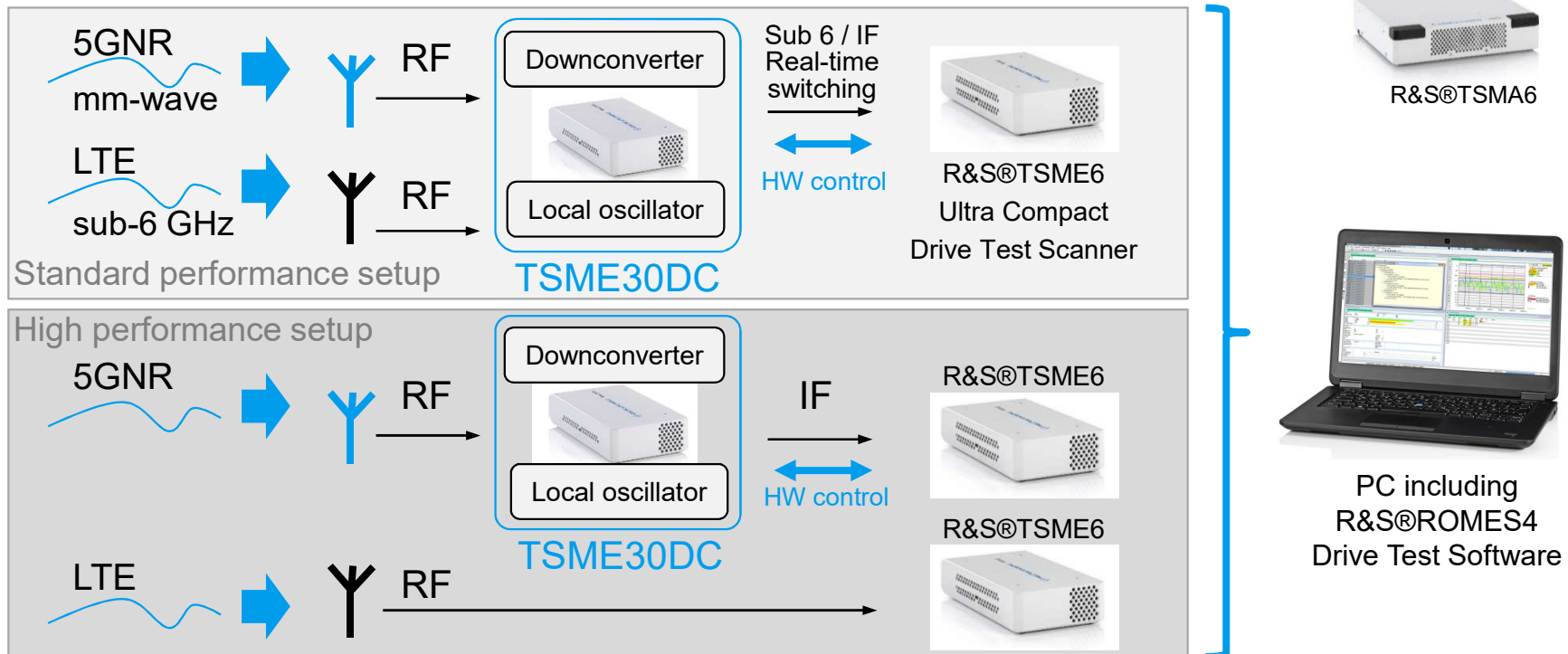Channel characteristics and propagation

Spectral measurements

R&S®TSME6

# Block diagram for mm-wave and sub 6 GHz measurement setup
## including TSME6 / TSMA6, simultaneous measurements



**Standard performance setup**

5GNR mm-wave → RF
LTE sub-6 GHz → RF

TSME30DC
Downconverter
Local oscillator

Sub 6 / IF Real-time switching
HW control

R&S®TSME6 Ultra Compact Drive Test Scanner

**High performance setup**

5GNR → RF
LTE → RF

TSME30DC
Downconverter
Local oscillator

IF
HW control

R&S®TSME6
R&S®TSME6

R&S®TSMA6

PC including R&S®ROMES4 Drive Test Software

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# Why are SSB measurements essential?

BWP

SSB

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

- One SSB is always transmitted
  - The **only Always-On signal** in 5G NR

- Therefore SSB should be used for :
  - Coverage measurement
  - CIR measurement
  - Interference measurement
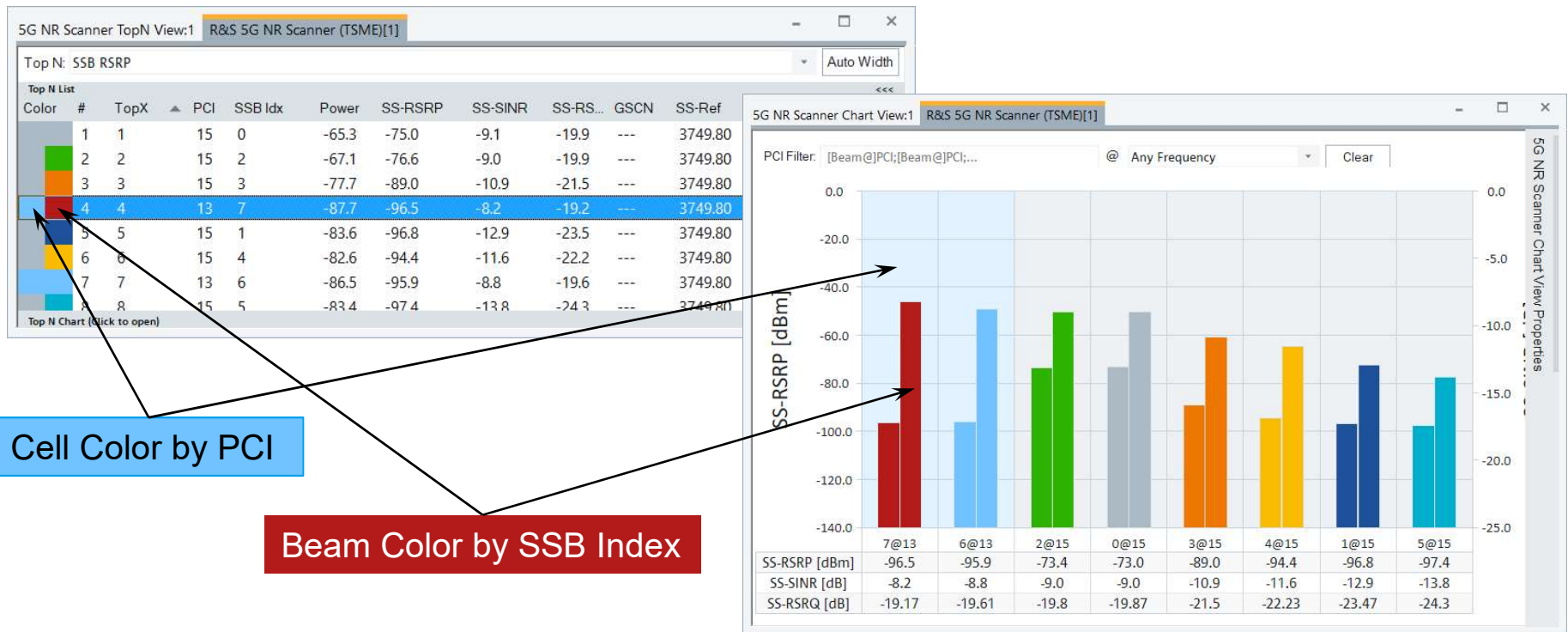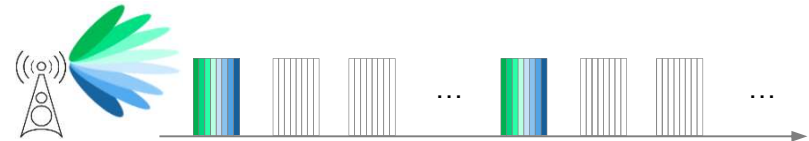  - Beamforming evaluation

R&S®TSME6

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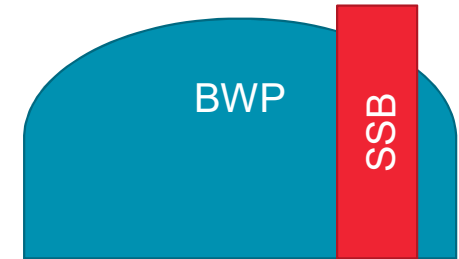
# Finding the SSB is now very easy!

## 5G NR Automatic Channel Detection

- 5G NR ACD uses fast spectrum sweep
  - Visualized with Grey lines

- Detected SSBs are visualized with blue marker

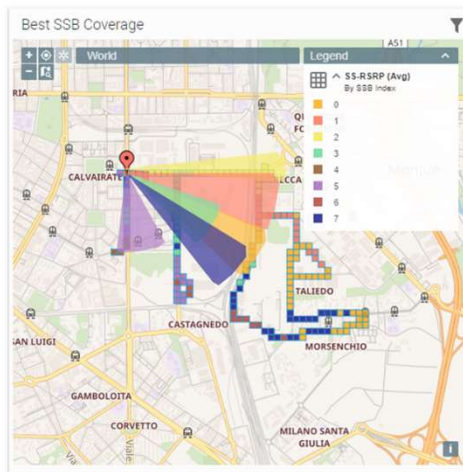- 5G NR Scanner configuration updates automatically

BWP

SSB

ACD Status View:1

Shortcuts

Output

Signal Tree

1427 MHz                                                                5G: n76

5G
3551.520 MHz
(7882)

Devices

3300 MHz                                                                5G: n77

User Gri

R&S®TSME6

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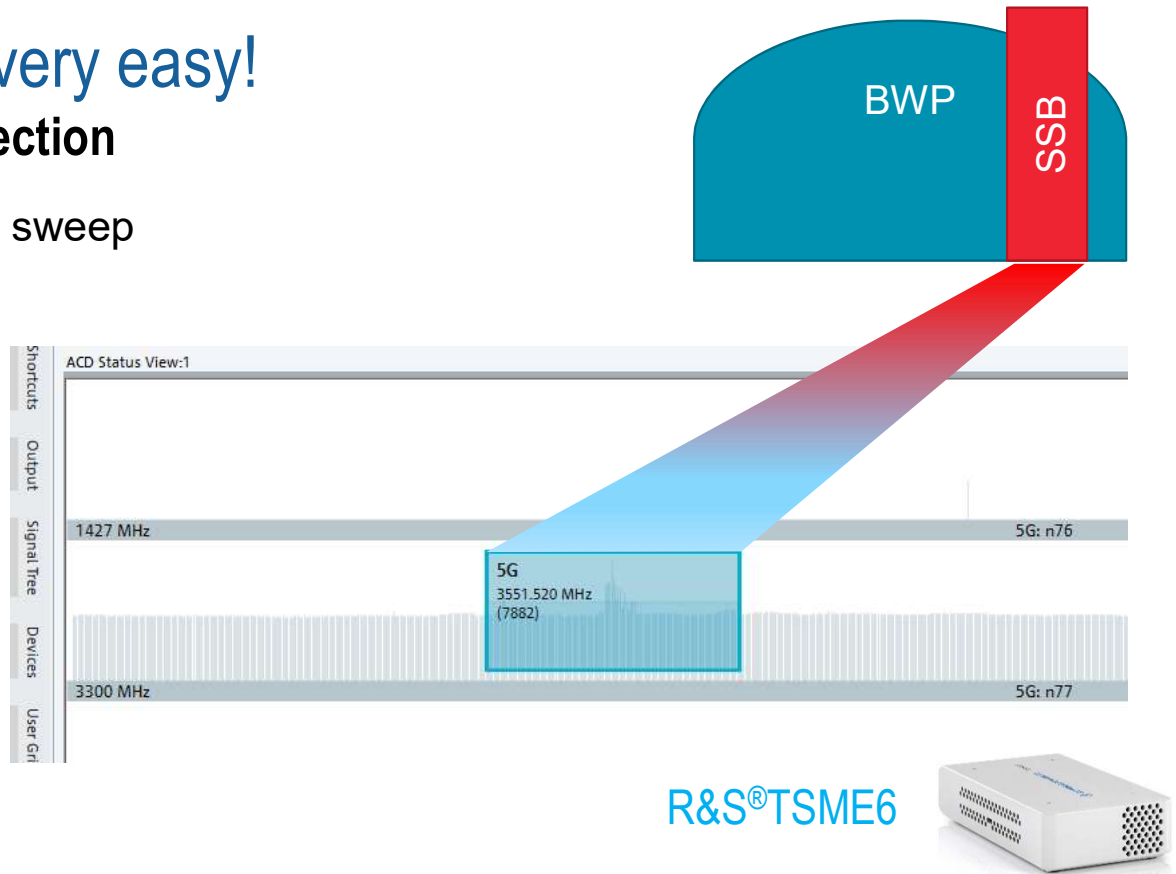
# Scanner-based 5G NR measurements: Multi Beam Example in ROMES



**Cell Color by PCI**

**Beam Color by SSB Index**

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# 5G Scanner Beam coverage analysis



5G NR Scanner Analysis in R&S®SmartAnalytics
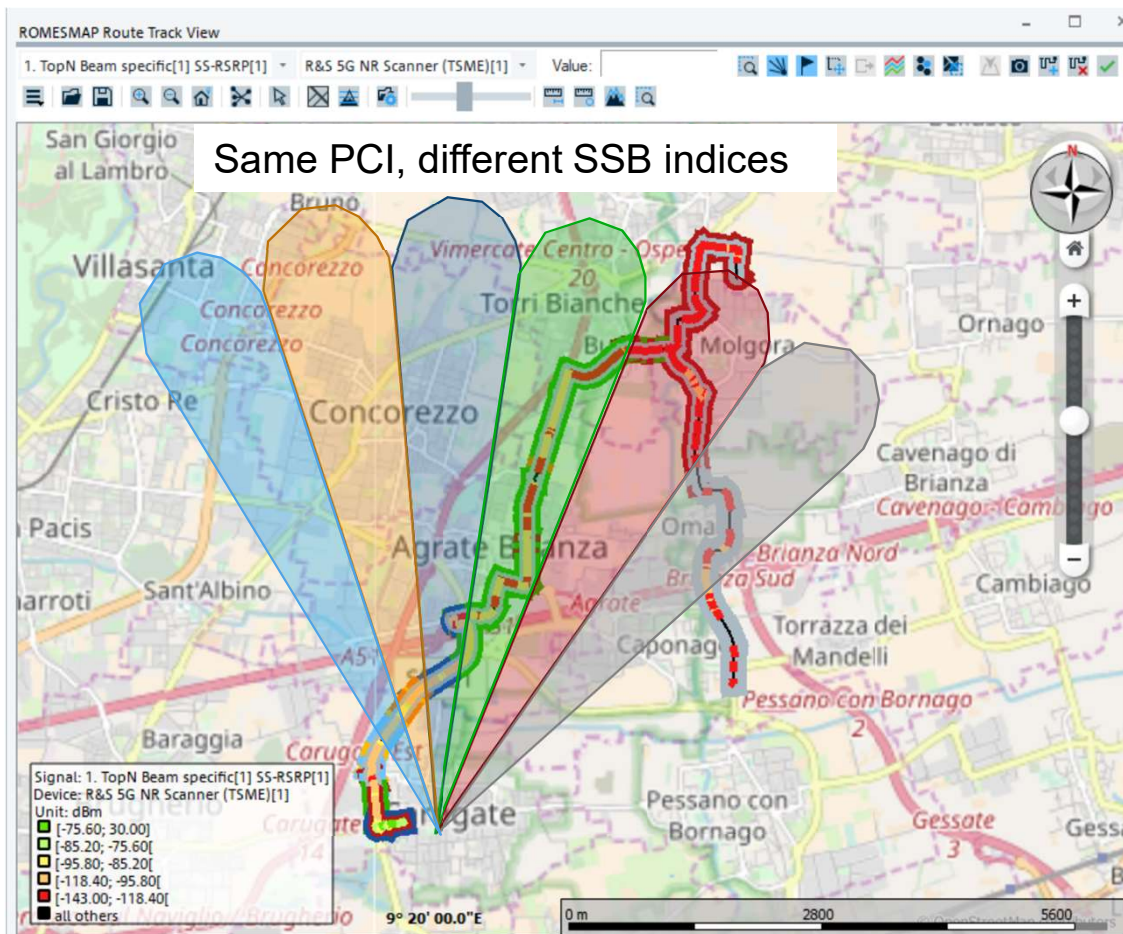
Cell SSB Coverage per SSB index
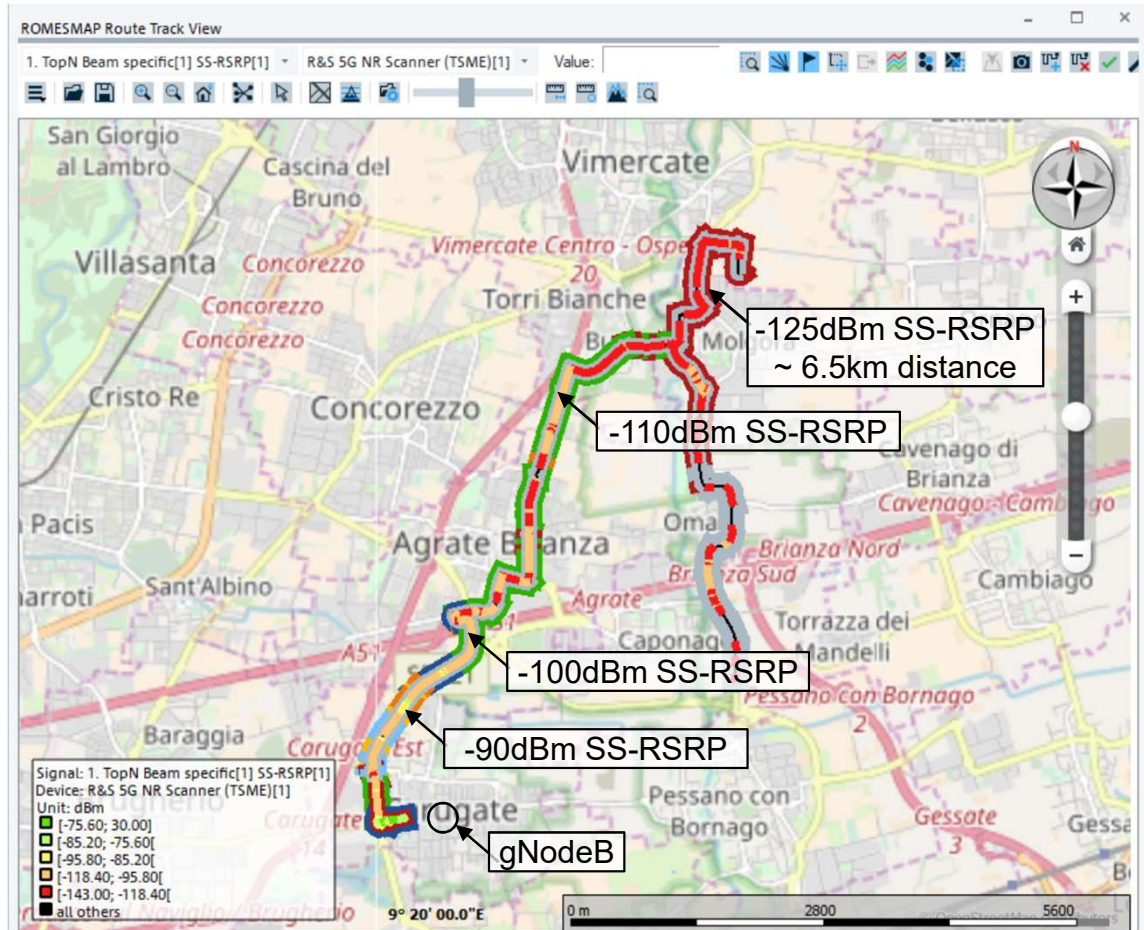
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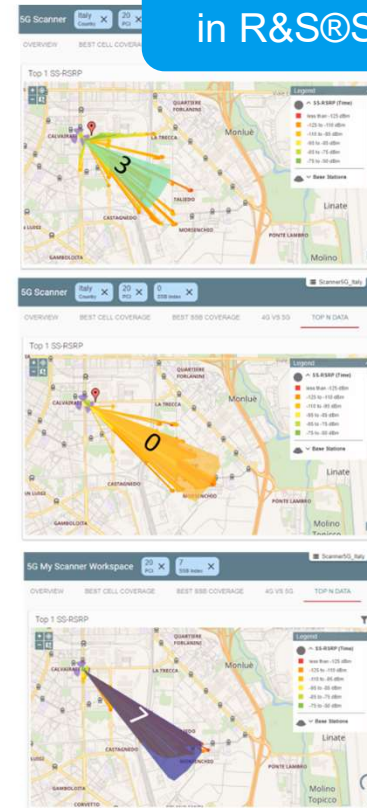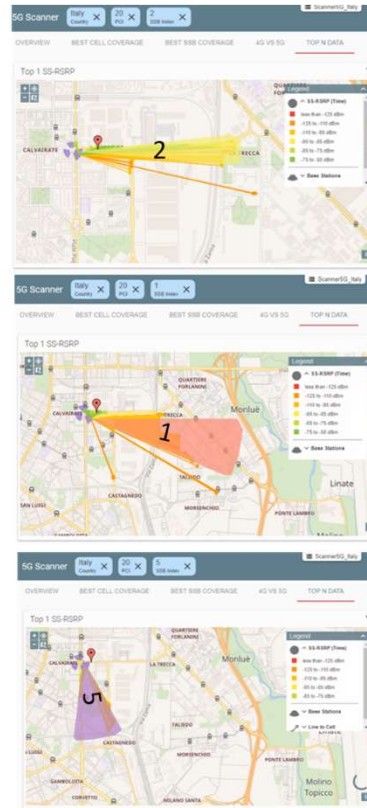
# Field measurement result SSB / beam ranking

- **SSB / beam index visualized over time (history) and on the map**

- **Surprisingly good match with horizontal "micro sectors" (SSB beam indices)**

✓



ROMESMAP Route Track View

1. TopN Beam specific[1] SS-RSRP[1]    R&S 5G NR Scanner (TSME)[1]    Value:

Same PCI, different SSB indices

Signal: 1. TopN Beam specific[1] SS-RSRP[1]
Device: R&S 5G NR Scanner (TSME)[1]
Unit: dBm
■ [-75.60; 30.00]
□ [-85.20; -75.60[
□ [-95.80; -85.20[
□ [-118.40; -95.80[
■ [-143.00; -118.40[
■ all others

9° 20' 00.0"E

0 m     2800     5600

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# Field measurement result Coverage

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

- **Surprisingly good SSB coverage in suburban area**

- **Analog SSB beamforming allows for long radio range**

✓



ROMESMAP Route Track View

1. TopN Beam specific[1] SS-RSRP[1]     R&S 5G NR Scanner (TSME)[1]     Value:

-125dBm SS-RSRP ~ 6.5km distance

-110dBm SS-RSRP

-100dBm SS-RSRP

-90dBm SS-RSRP

gNodeB

Signal: 1. TopN Beam specific[1] SS-RSRP[1]
Device: R&S 5G NR Scanner (TSME)[1]
Unit: dBm
[-75.60; 30.00]
[-85.20; -75.60[
[-95.80; -85.20[
[-118.40; -95.80[
[-143.00; -118.40[
all others

9° 20' 00.0"E

0 m        2800        5600

# Main take-aways from first drive tests in 5G NR networks

Surprisingly good
coverage @ 3.75 GHz
due to beamforming

**-125 dBm (SS-RSRP)**
**Distance: ~ 6.5 km !!**
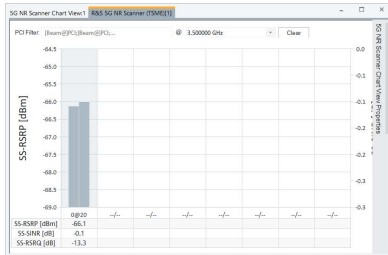**In suburban environment**
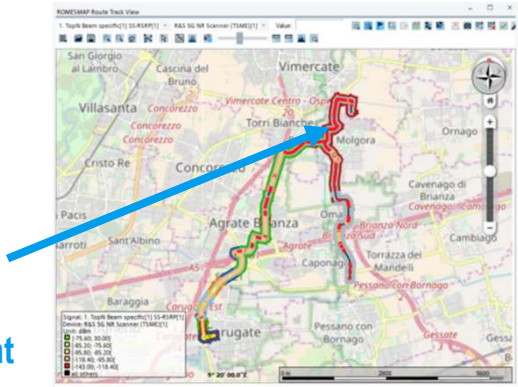


SSB Beamforming
can be verified in
field measurements

**Mapping beams on**
**SSBs is possible**
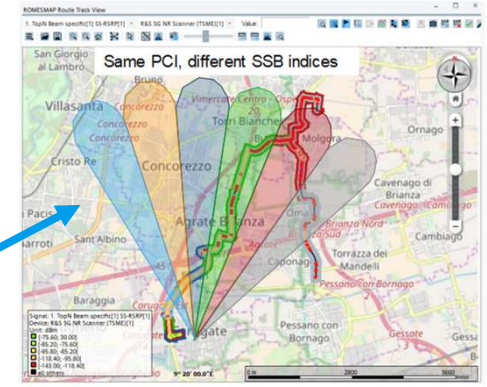


5G NR SSB / beam configurations are very flexible and
can be verified by field measurements



Number of received SSBs / beams depends on
LOS / NLOS scenario
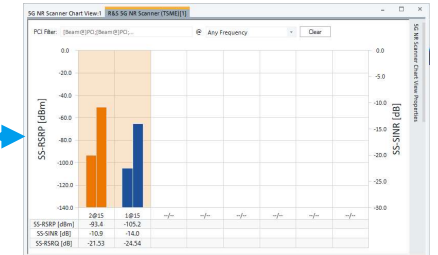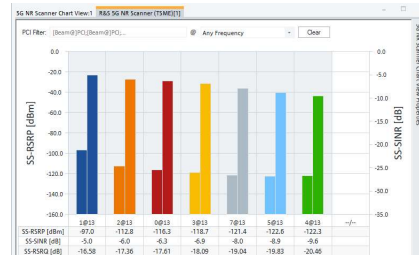
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- Market drivers and key challenges of 5G NR networks

- 5G NR technology

- 5G NR field measurements

- **5G NR field test solutions**

- Learnings and conclusion

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Mobile Network Testing

# R&S test solutions for 5G NR mobile network testing

## Field Services, Interference 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
                   (ready for 5G)

## 5G NR network measurement solution

### Passive measurements



R&S®TSME6      R&S®TSMA6



Shoulder bag      Backpack for mmwave
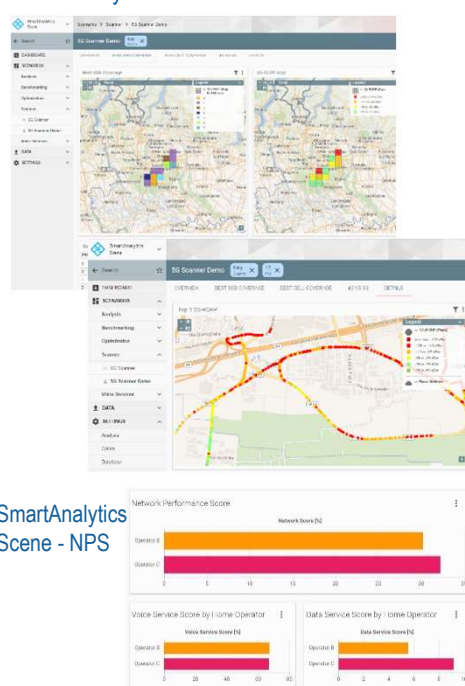
### Active measurements



Smartphones    Mobile Test
               Platform

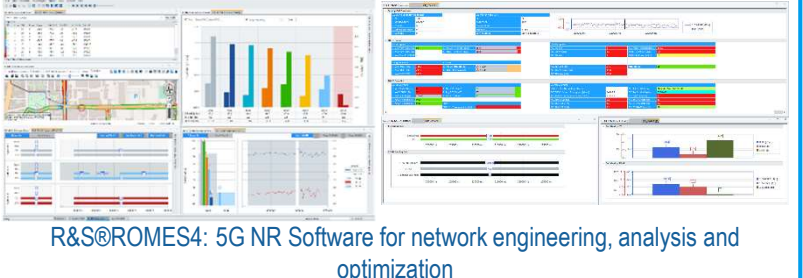QualiPoc Android ready for 5G



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

## Data Analytics

SmartAnalytics Scene



SmartAnalytics
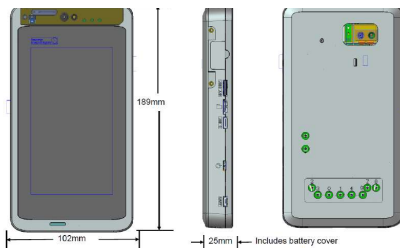Scene - NPS

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# First UE-based 5G NR measurements

ROMES4 measuring on 5G mobile device

WNC Qualcomm based 5G Router

MTP8150 5GTest Device Now S10 5G



5G NR Serving Cell

5G NR Uplink

5G NR Downlink

5G NR Cell History

5G NR Cell Quality

RSRP, RSRQ

Tx Power

DL Thp

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# 5G UE measurements using ROMES



EN-DC Overview

LTE - 5G NR RSRP

5G NR Secondary Node

LTE Master Node
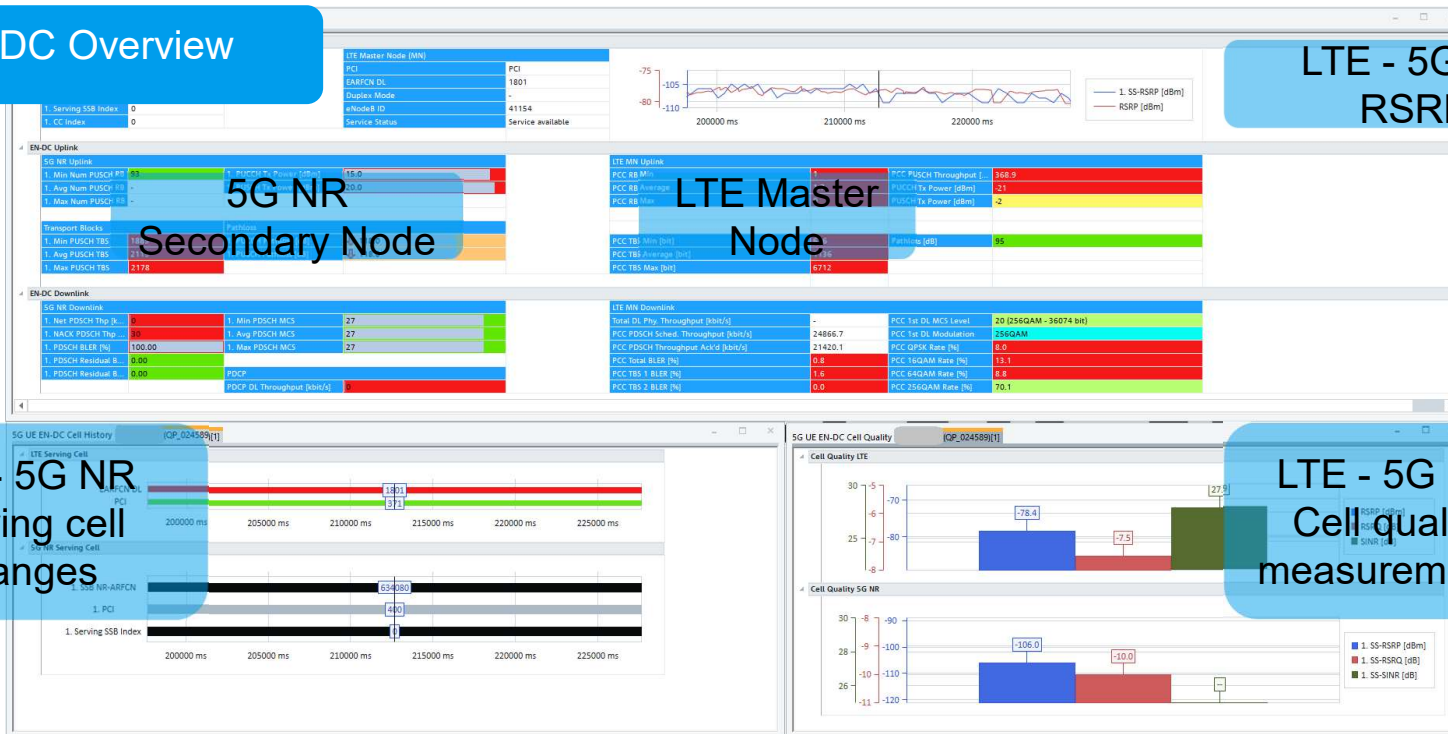
LTE - 5G NR Serving cell changes

LTE - 5G NR Cell quality measurements

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# First UE-based 5G NR measurements direcly on a Smartphone

- NR Serving cell information:
  - NR DL ARFCN
  - PCI
  - SSB Index
- L1 RSRP / RSRQ
- L2 PDSCH, PDCP, PUSCH information
- LTE-NR EN-DC L3 signaling
- Application layer info

**LTE – 5G NR EN-DC Dual Connectivity**
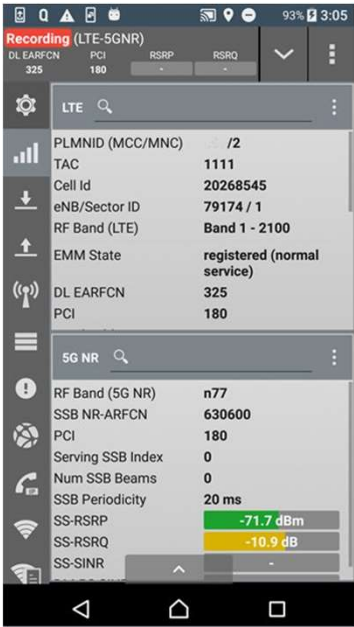
**5G NR measurement in QualiPoc Android**

**5G NR RRC Layer 3 signaling**

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# 5G UE measurements – QualiPoc Android

5G Smartphone measurements in QualiPoc

5G NR Cell

LTE Cell
EN-DC Master Node

5G NR Cell
EN-DC Secondary Node

LTE & 5G NR DL Data

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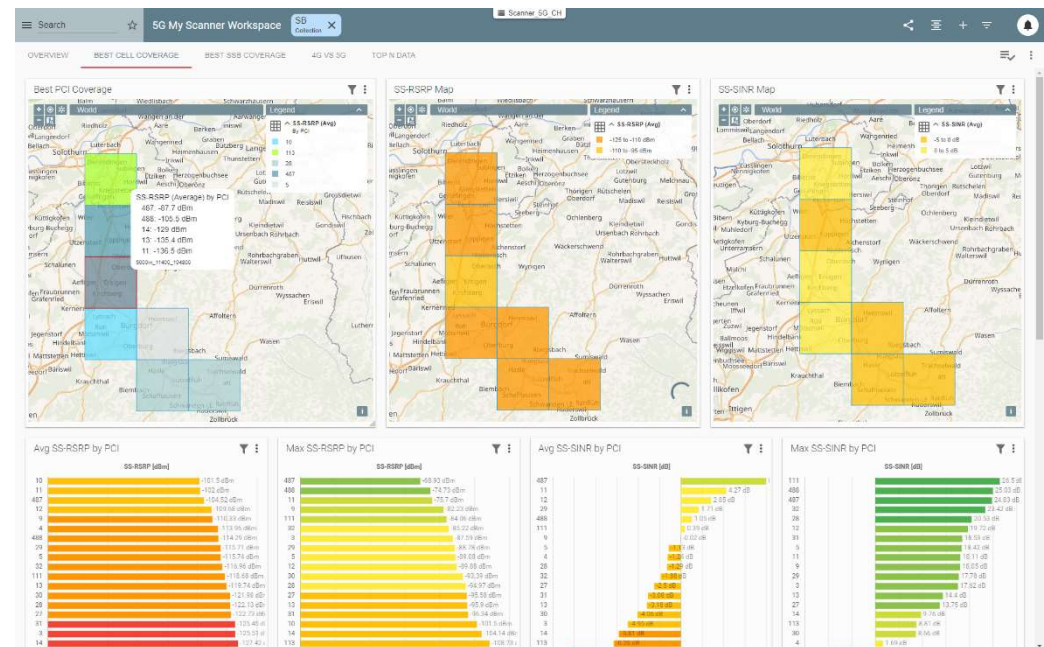
# 5G NR Post Processing in the Cloud

**5G NR Scanner Analysis in R&S®SmartAnalytics**

- Use-case driven analytics
- Cloud based or locally installed
- Aggregated data layers +
  High resolution file data
- Intuitive filtering
- 5G NR Scanner Workspace
  - Best Cell Coverage
  - Best SSB Coverage
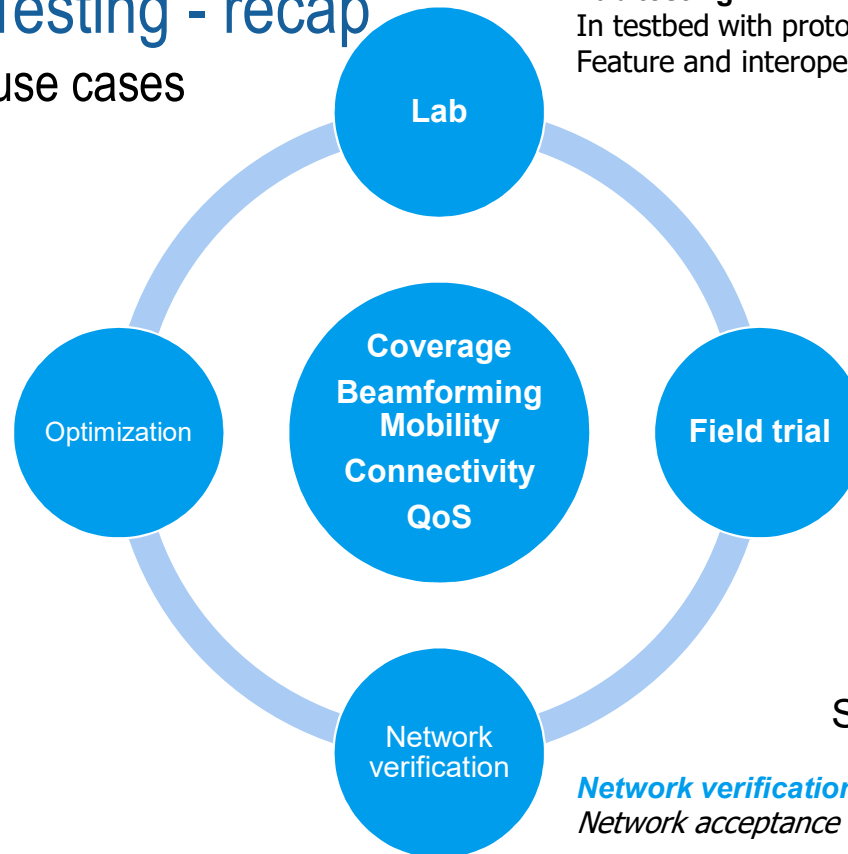  - NR vs 4G Coverage Comparison
  - TopN Details

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# 5G Network Testing - recap
## Scanner and UE use cases

**Lab testing**
In testbed with prototype UEs (MTPs)
Feature and interoperability testing

**Lab**

*Field testing with Trial sites*
**Propagation modelling**
**Site type and antenna evaluation**
**Link budget evaluation**
**Coverage verification**
Beam management performance
Dual Connectivity and Mobility KPIs
SCS/BWP allocation
eMBB & URLLC QoS differentiations

**Coverage**
**Beamforming**
**Mobility**
**Connectivity**
**QoS**

*Operational network*
*e.g.*
*Regression*
**Tuning**
**Troubleshooting**

Optimization

**Field trial**

Network
verification

Scanner and/or UE data acquisition

*Network verification*
*Network acceptance*

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# Conclusion

5G NR commercial rollout running now – many pre-commercial trials!
Commercial 5G NR smartphones available on the market

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

5G NR network measurements need to cope with high flexibility and configurability

Commercial 5G NR network measurement solutions are now available
Compatible with commercial 5G NR UEs

Pre-commercial trial measurements reveal surprisingly good SSB coverage due to
analog SSB beamforming

➢ **Rohde & Schwarz MNT is committed to support the industry with network test solutions from early trial to commercial deployment phases**

# 5G NR Mobile Network Testing

MNT Seminar, Lisbon, 7th June 2019

## Questions and where to find more information

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Marketing Manager
Rohde & Schwarz Mobile Network Testing

http://www.rohde-schwarz.com/MNT
http://blog.mobile-network-testing.com/

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