Mobile Network Testing

5G IN THE WILD

WHAT IS KEY IN TESTING 5G USE CASES?

Dr. Jens Berger
September 2020

ROHDE&SCHWARZ

Make ideas real

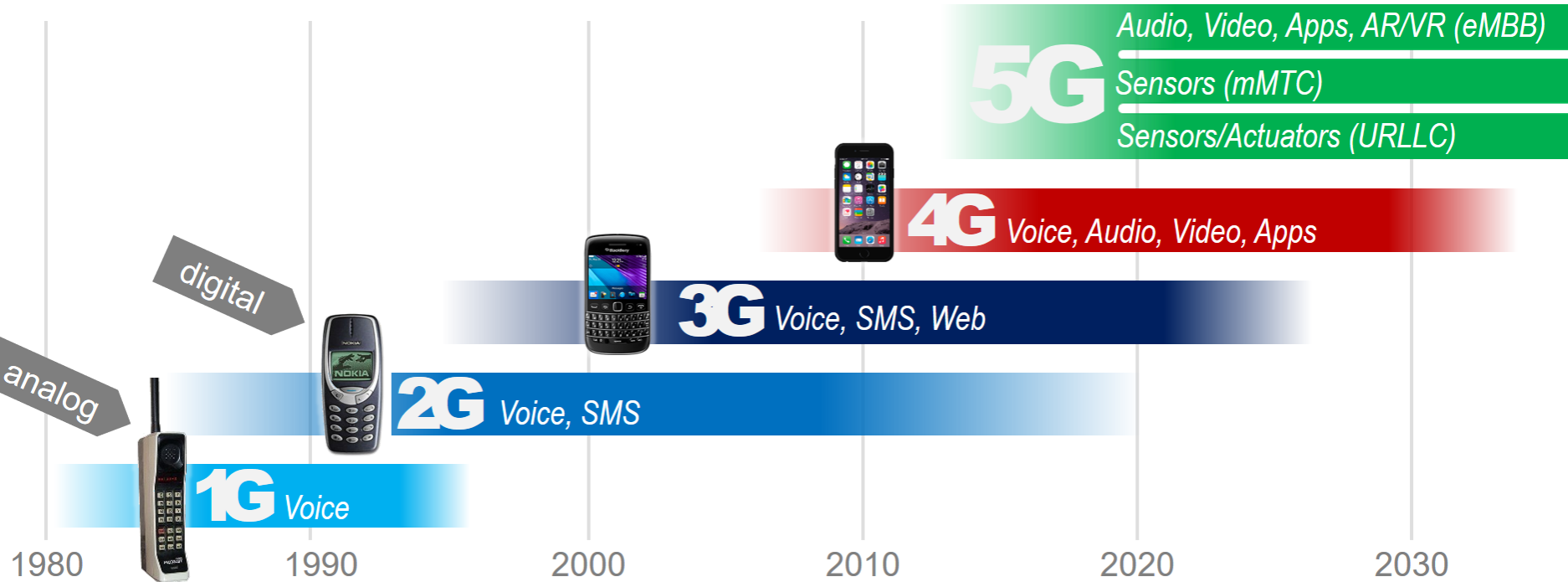# 5G IN THE WILD
WHAT IS KEY IN TESTING 5G USE CASES

► The 5G evolution and its promises

► Where we are today? 5G EN-DC and 5G SA

► More players than smartphones in public networks

► How to serve the measurement and test demands in 5G?

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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

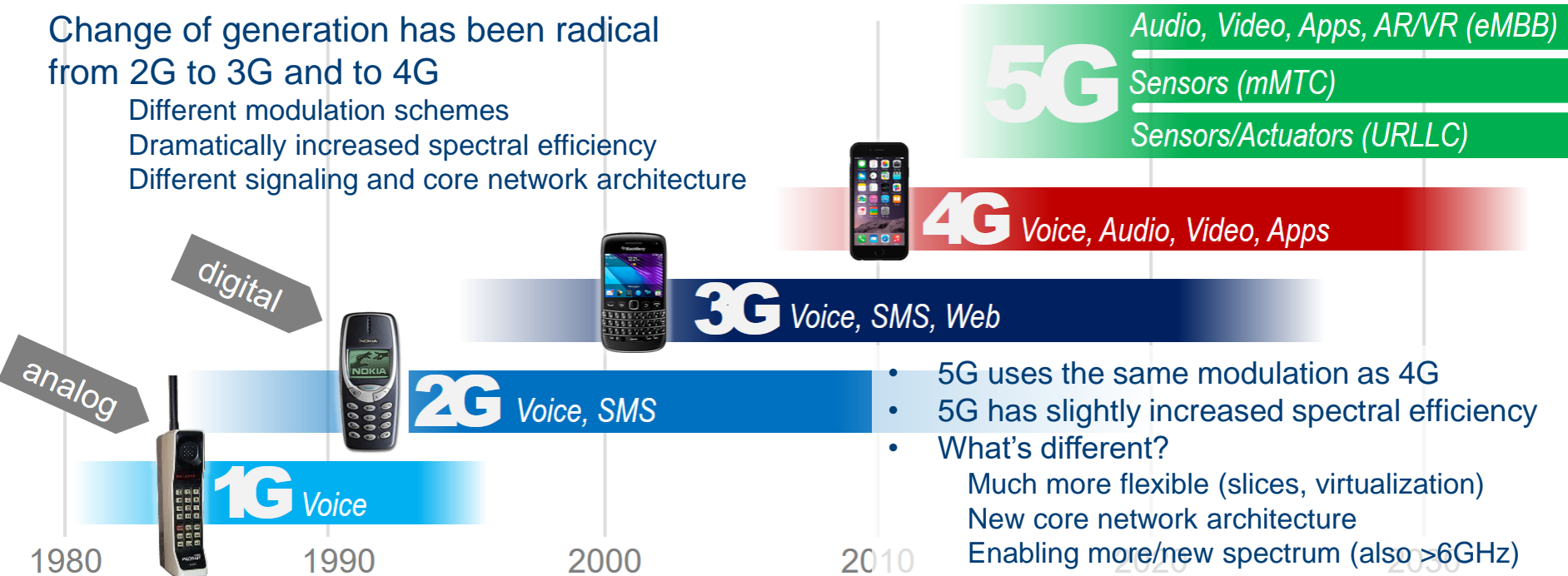1980   1990   2000   2010   2020   2030

5G is not a 'switch-on' technology, it's a multi-step transition process.

WHAT IS 5G? – IT'S A PARADIGM SHIFT
5G IS A TRUE USE-CASE DRIVEN CELLULAR TECHNOLOGY

Change of generation has been radical
from 2G to 3G and to 4G
- Different modulation schemes
- Dramatically increased spectral efficiency
- Different signaling and core network architecture

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

- 5G uses the same modulation as 4G
- 5G has slightly increased spectral efficiency
- What's different?
  - Much more flexible (slices, virtualization)
  - New core network architecture
  - Enabling more/new spectrum (also >6GHz)

5G is not a 'switch-on' technology,
it's a multi-step transition process.
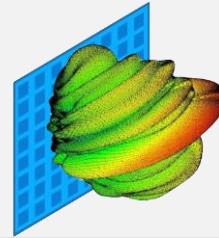
5G KEY TECHNOLOGY COMPONENTS
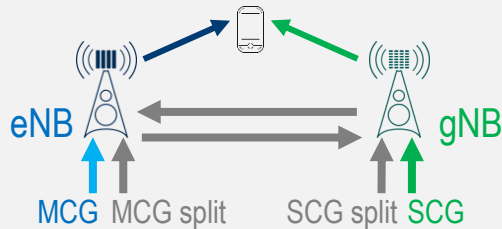## NEW RADIO BUILDS ON FOUR MAIN PILLARS

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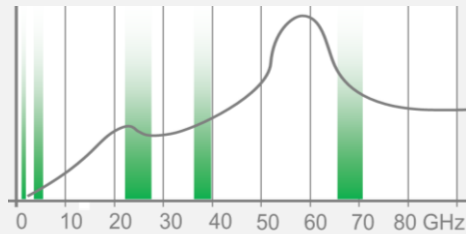
- < 1GHz
- ~ 3.5 GHz
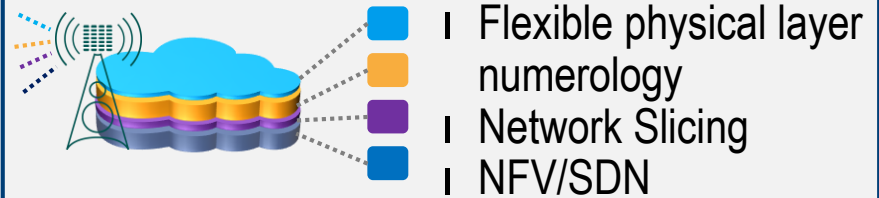- ~ 26/28/39 GHz

Massive MIMO & Beamforming

- Hybrid beamforming
- > 6GHz also UE is expected to apply beam steering

Multi-Connectivity

Initially based on Dual Connectivity with E-UTRA as master

Network flexibility - virtualization

- Flexible physical layer numerology
- Network Slicing
- NFV/SDN

5G is not a 'switch-on' technology, it's a multi-step transition process.

THE PROMISES OF 5G TO THE PUBLIC

► **Extremely high bitrates
(in fact: more transport capacity per cell, eMMB)**
  – It is still physics: more transport by more spectrum
  – Aggregation of carriers
  – Wider bands, especially in high frequencies

Higher network transport capacity
(Serving more customers with higher bitrates than today, not made for a single user >>1Gbit/s)

► **Ultra-reliable low latency communications (URLLC)**
  – URLLC is not 'switch-on' rather a process
  – Ultra-reliable means redundancy: many visible cells
  – Latency is continuously improved from release to release
  – Huge improvement expected by coming 3GPP Rel. 16 repl. LTE core architecture

These are the pre-requisites for interactive apps, automotive and real-time industrial process control

5G IN THE WILD – WHERE WE ARE TODAY
5G EN-DC AND 5G SA

► 5G EN-DC 'non-standalone'

- DC stands for Dual Connectivity (4G + 5G)
- 4G is the master, 5G as additional spectrum
- More spectrum - more transport capacity
- Core network is still 'LTE'
→ *3GPP Rel.15*

*Low investment:
Core remains,
'just new radio'*

► 5G SA 'standalone'

- No 4G connectivity needed
- Stand-alone based on new core architecture
- Enables very short latencies
→ *3GPP Rel.16+*

*Big investment:
Replacing core network*

This is '5G in the wild' today!

- In practice
  - New 5G carriers used for Downlink
  - Usually uplink transport by 4G*
  → Improving down-speed

*depends on device

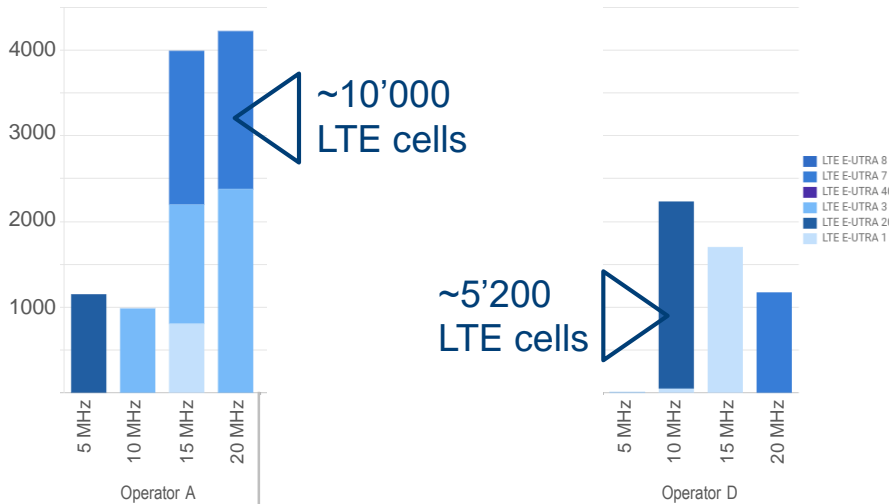5G devices today are 5G EN-DC

Like in the cinema:
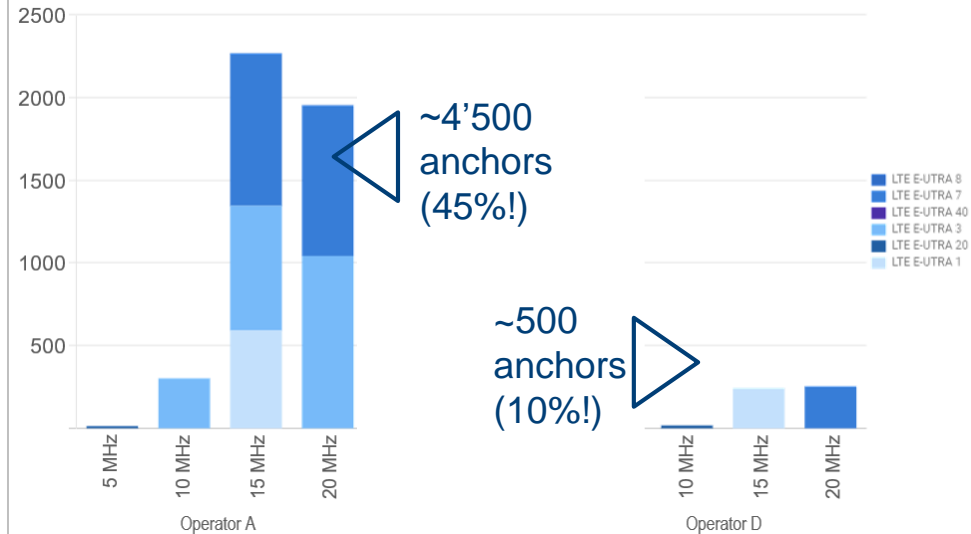
Coming soon!

5G EN-DC REQUIRES LTE ANCHOR CELLS

No 5G service without an LTE anchor cell! This is the shortest definition of 5G EN-DC.

Number of LTE cells by operator, band, bandwidth

~10'000 LTE cells

~5'200 LTE cells

Number of **defined anchor** LTE cells by operator, band, bandwidth

~4'500 anchors (45%!)

~500 anchors (10%!)

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5G IN THE WILD – 5G SPECTRUM USED TODAY
OBSERVATIONS AND TRENDS IN THE FIELD

This is 5G real field today

▶ New ~3500 MHz

Bandwidth typically ~100MHz
→ This enables transport capacity ('bitrate')

'Common' band for
5G devices today!

▶ Re-allocation 2100 MHz

Narrow bandwidths (5-20MHz)
Coming: Dynamic spectrum sharing (DSS)
→ Increases 5G coverage

Few devices today
DSS is supported
massively by new UE's

▶ New 600-850MHz

Narrow bandwidths (5-20MHz)
→ Long reach coverage

Supported by latest
U.S. devices

Wider bandwidth, much more spectrum
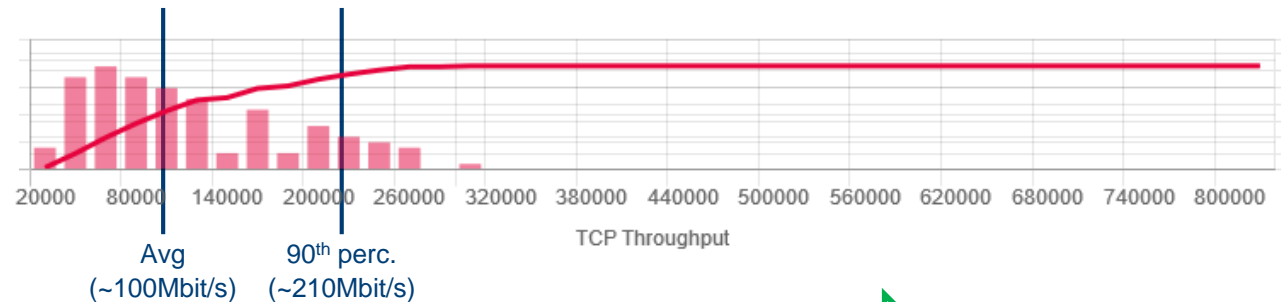Crucial (quasi-optical) propagation
→ Short distances, limited mobility

Deployed mainly in U.S.

▶ New >6GHz (mmWave)

Note: 5G corresponds to 5G EN-DC, whereas LTE 4CA corresponds to 'best' 4G technology in the test
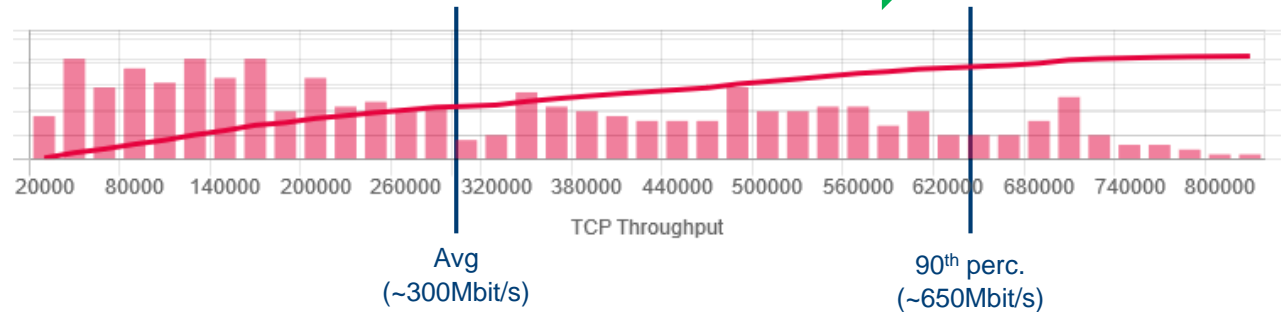
HUNTING FOR MAXIMUM BITRATES
<u>REAL-FIELD</u> DRIVE TEST SWITZERLAND 2020

► 5G carriers are added wherever possible → More spectrum → higher transport capacity

► Significant increase in bitrate (please note: there is no load in 5G cells in the field)

► LTE 4CA

► 5G EN-DC

Avg
(~100Mbit/s)

90th perc.
(~210Mbit/s)

Avg
(~300Mbit/s)

90th perc.
(~650Mbit/s)

TCP Throughput

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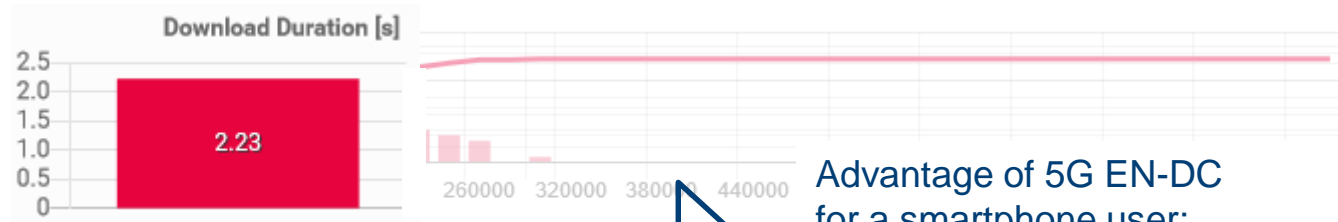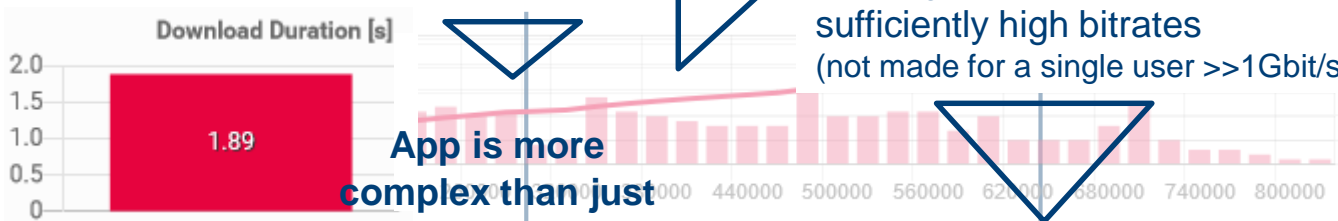
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► LTE 4CA

► avg. Webpage download

► 5G EN-DC

► avg. Webpage download

Download Duration [s]

2.23

Avg (~100Mbit/s)   90th perc (~210Mbit/s)

Download Duration [s]

1.89

Avg (~300Mbit/s)

260000 320000 38000 440000
TCP Throughput

440000 500000 560000 620000 680000 740000 800000
TCP Throughput

Improvement by 'just' 250ms

App is more complex than just download

Advantage of 5G EN-DC for a smartphone user:

Serving <u>more customers</u> with sufficiently high bitrates (not made for a single user >>1Gbit/s)

Receiving extreme bitrates does not improve QoE for a single smartphone user

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5G IS MORE THAN HIGH BITRATES!
LATENCY AND CONTINUITY OF TRANSPORT ARE KEY

► 5G use cases become interactive and real-time

► There will be tons of new interactive applications

► 'Non-human, non-smartphone use cases' arising and dominating

→ **There are many demands apart from 'just bitrate'**
    …as short latencies, no discontinuities, security,…

→ **URLLC is key!**

► Upcoming use cases and networks

► How to define measurements and QoE?

► Do we have efficient and accurate methods for Capacity, Latency and Continuity?

Bitrate

- Augm. reality
- Telephony
- 4k video
- Power metering
- Data download

5G

Continuity

Latency
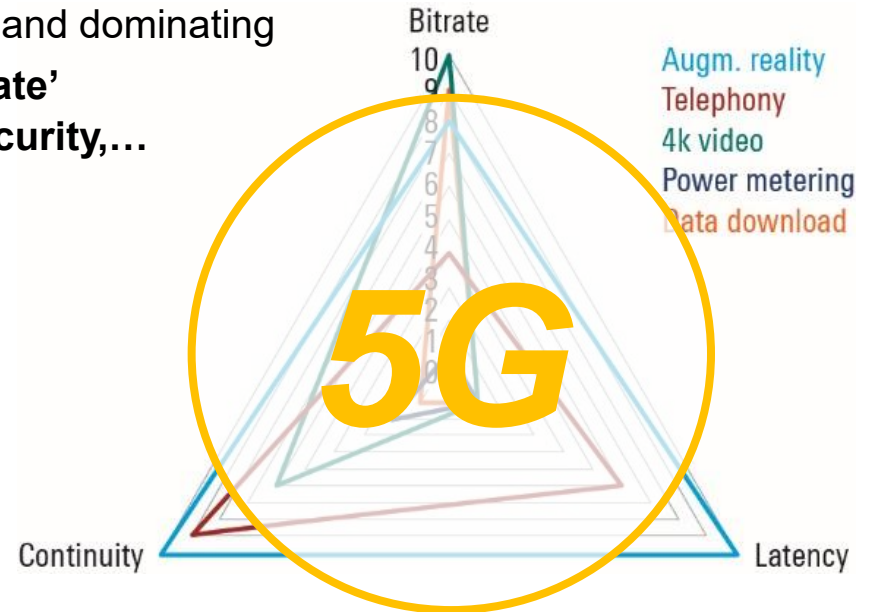
USE CASES AND NETWORKS UNDER 5G
...MORE THAN HUMAN USERS WITH SMARTPHONES

▶ Human smartphone users
- Popular apps as of today
  - Browsing, social media, video, location services,…
- New apps ('visual')
  - 4K/8K video, VR/AR/XR, real-time gaming, HD video-chat, interactive remote meeting,…

Well defined tests today for QoS and QoE
'QoE ~ bitrate' → saturation

'Just a linear extrapolation'
Latency and continuity gets some importance but not crucial

This changes the game!
Continuity/reliability and latency are essential

▶ Machine type communication
- Automotive / infrastructure
- Industrial use / process control

$$

▶ Machine type communication
- Automotive / infrastructure
- Industrial use / process control

$$$

Public networks

Private networks

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USE CASES UNDER 5G
TONS OF APPLICATIONS

► Human smartphone users

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- New apps ('visual')
  - 4K/8K video, VR/AR/XR, real-time gaming, HD video-chat, interactive remote meeting,…

► Machine type communication

- Automotive / infrastructure
- Industrial use / process control

Everyone thinks about:

VR goggles in a hi-speed train

Tons of applications are in between, from virtual remote, healthcare, entertainment to banking terminals, warehouse management to automotive…

All with different demands on connectivity

Bitrate

Augm. reality
Telephony
4k video
Power metering
Data download

5G

Continuity   Latency
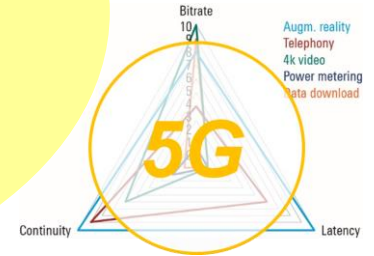
Real-time remote control of an entire production process

USE CASES UNDER 5G
DIFFERENT ECO-SYSTEMS AND NEW PLAYERS

► Human smartphone users

- Popular apps as of today
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- New apps ('visual')
  - 4K/8K video, VR/AR/XR, real-time gaming, HD video-chat, interactive remote meeting,…

► Machine type communication
- Automotive / infrastructure
- Industrial use / process control

► Smartphone clients
- Established eco-system
  operators, manufacturers, certification of devices
- Well defined QoS and QoE tests

- Tons of new apps
- Expectation and experience depends on use case

► Modem-like clients
- Enhanced and diverse eco-system
  operators, manufacturers, private networks, verticals
- Certification and QoS tests not existing (yet)
- QoS is more than pass/fail

USE CASES UNDER 5G MEASUREMENT PROBES

► Human smartphone users

- Popular apps as of today
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- New apps ('visual')
  - 4K/8K video, VR/AR/XR, real-time gaming, HD video-chat, interactive remote meeting,…

► Machine type communication

- Automotive / infrastructure
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Smartphone-based measurement probe

QoE tests and measurements

- Is app-testing an option for thousands of apps?
- What's about accessibility to interfaces on commercial smartphones?

- Focus on QoS tests
- No 'apps'

QoS network performance

- Can we measure max. capacity by a single UE? (CPU, temp,…)
- Is today's HTTP/TCP based measurement the right approach?

- Capacity, Latency, Reliability as accurate performance measures

Modem-like measurement probe
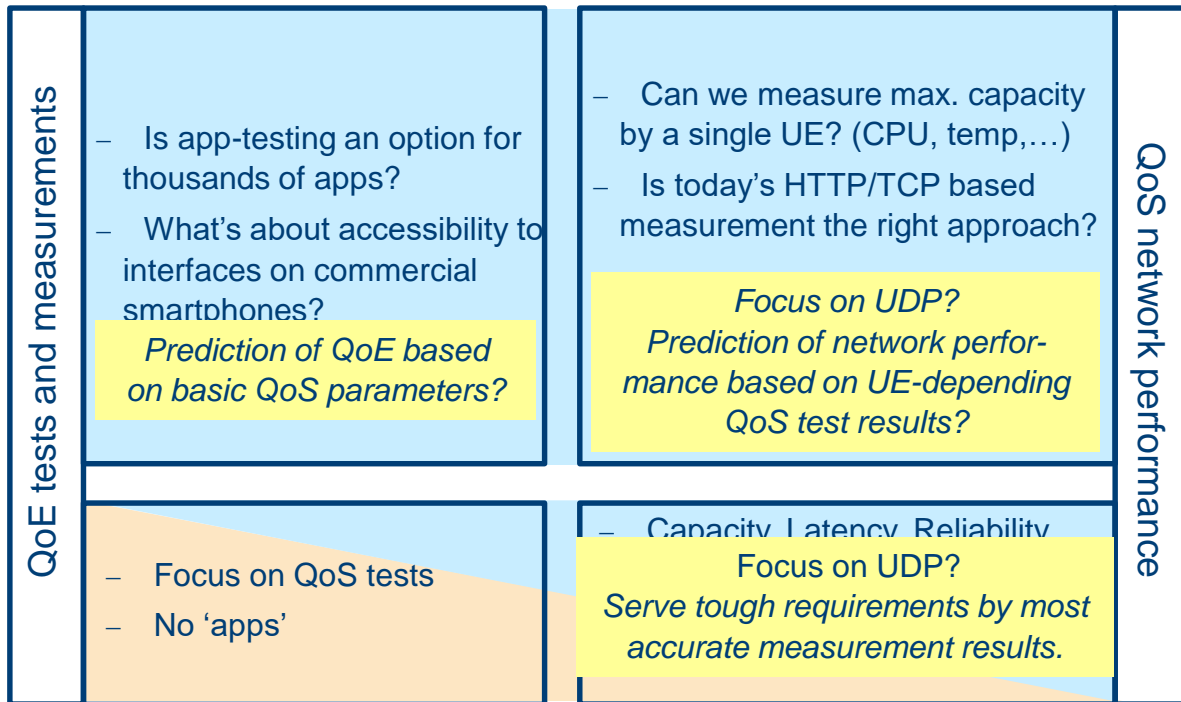
USE CASES UNDER 5G
PREDICTION OF PERFORMANCE?

▶ Human smartphone users

- Popular apps as of today
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▶ Machine type communication

- Automotive / infrastructure
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Smartphone-based measurement probe

QoE tests and measurements

- Is app-testing an option for thousands of apps?
- What's about accessibility to interfaces on commercial smartphones?

Prediction of QoE based on basic QoS parameters?

- Can we measure max. capacity by a single UE? (CPU, temp,…)
- Is today's HTTP/TCP based measurement the right approach?

Focus on UDP? Prediction of network performance based on UE-depending QoS test results?

- Focus on QoS tests
- No 'apps'

- Capacity, Latency, Reliability

Focus on UDP? Serve tough requirements by most accurate measurement results.

QoS network performance

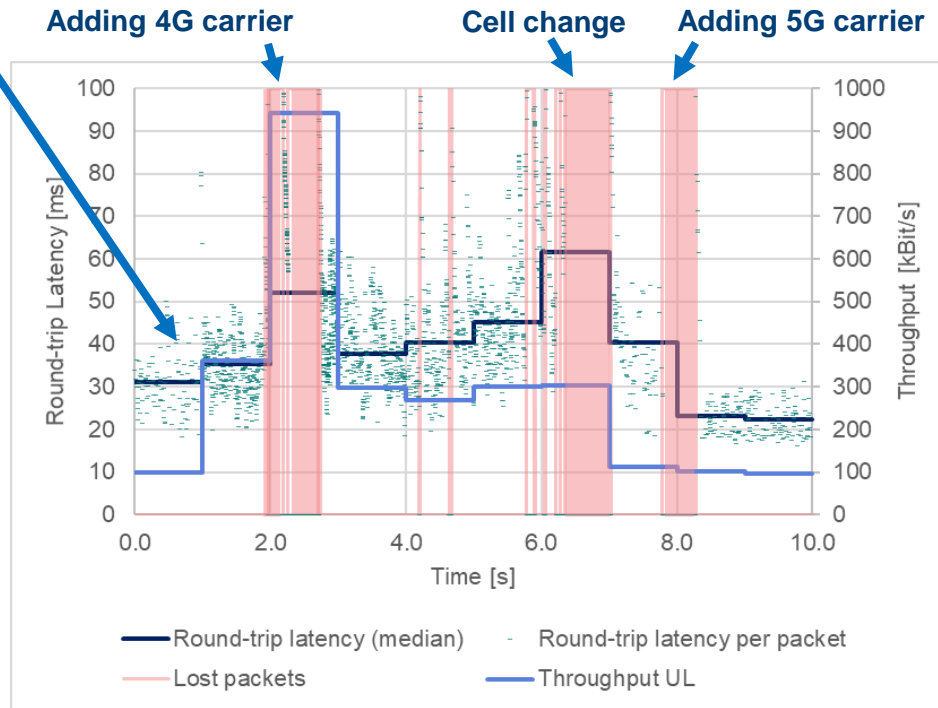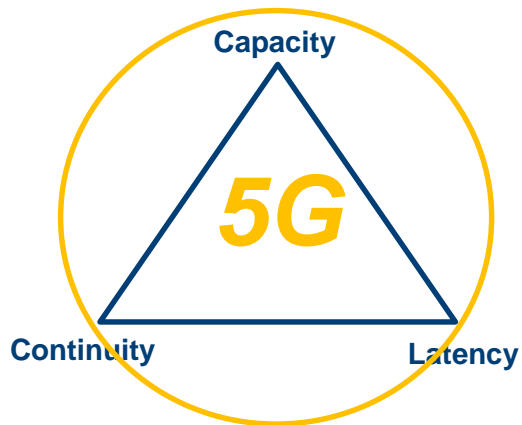*Modem-like measurement probe*

QUO VADIS? TEST CASES AND PROBES

Testing an application (e.g. 'VR retail shopping') on a smartphone results in a performance of the app (-implementation) on this UE and its implemented chipset under the given network conditions.

► Smartphones remain as measurement probes for 'human use cases', but…
- – 'App-Testing' moves to 'testing the app' and not 'testing the network'
- → QoE <u>prediction</u> on QoS parameters, how a class of use cases will perform

- – Increasing dependency on phone brand and chipset
- → <u>Prediction</u> of network performance based on measurement results (UE agnostic, Machine Learning)

► Smartphones are not the optimal probes for industrial use cases
- – 'Modem-like' measurement probes, focus on native, IP layer measurements
- – Measuring to the edge (extreme high bitrates, latencies <<1ms, detection of shortest discontinuities)
- – Many 'users' will not move → Testing under stationary conditions

…THERE IS STILL A WAY TO GO!
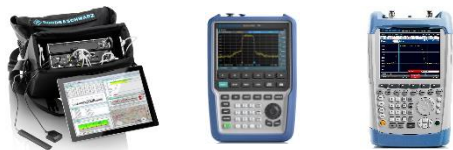## FREQUENT CARRIER AGGREGATION – A DISASTER FOR LATENCIES

► Frequent carrier aggregation/release and aggressive cell changes maximize data rates but on cost of latency (and continuity)!

Each dot is the RTT latency of **one** packet

Capacity

5G

Continuity   **Latency**

Adding 4G carrier   Cell change   Adding 5G carrier

All happens within 10s!

R&S SOLUTIONS TO DEPLOY AND TEST 5G NETWORKS

Spectrum clearance
Interference hunting

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

R&S®MNT100&PR200   R&S®MobileLocator

Site Troubleshooting and Acceptance

R&S®5G STS   R&S®FPH   QualiPoc Android

5G New Radio network measurement solution

Passive measurements

R&S®TSME6   R&S®TSMA6

Shoulder bag   Freerider4 Backpack
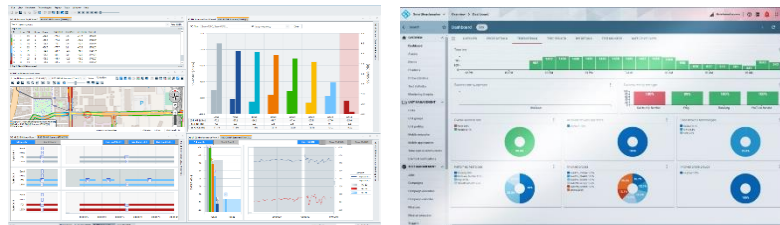for FR1 and FR2
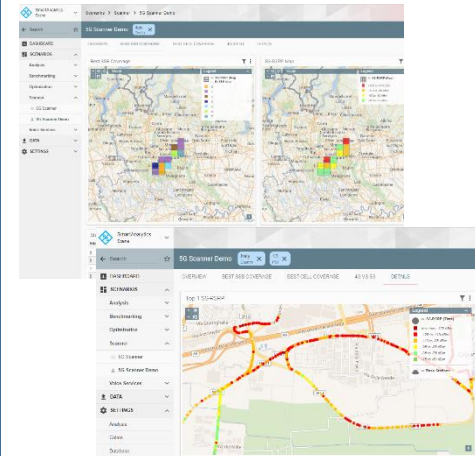
Active measurements

5G Router   5G smartphones
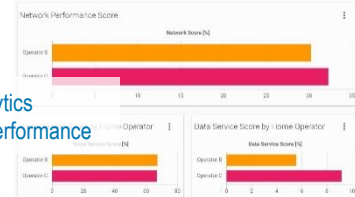
QualiPoc Android

R&S®SmartONE (expert and standard mode): 5G NR ONE tool for
optimization, network benchmarking and engineering

Data analytics
Network performance

SmartAnalytics Scene

SmartAnalytics
Network Performance

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THANK YOU!

…AND STAY CONNECTED AND REAL-TIME IN 5TH GENERATION

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Make ideas real