Assuring QoS and QoE in 5G networks

ITU WORKSHOP ON NETWORK PERFORMANCE

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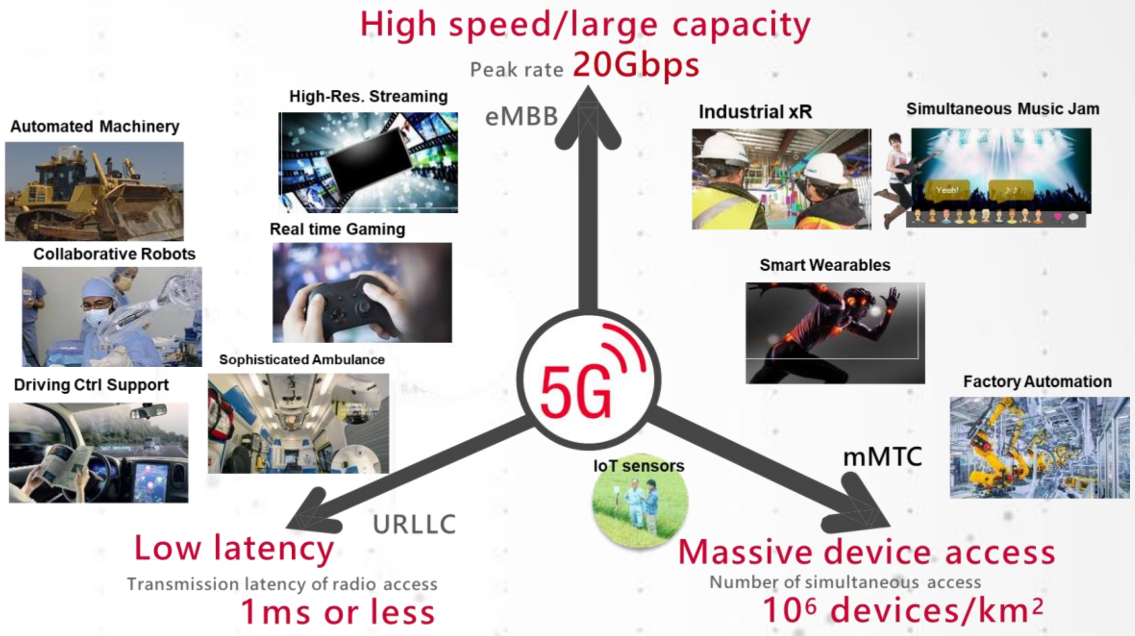
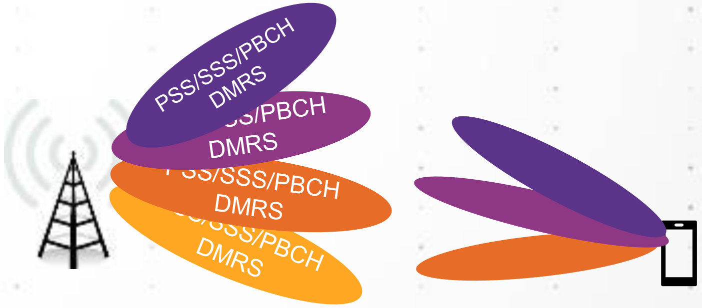
5G NR challenges

- 5G means new use cases, environments and network dimensions
  - Higher capacity and peak rates
  - Mission Critical with 1 ms latency
  - Massive Number of Devices and network load scenarios
  - Higher frequences ➔ more unreliable connection
  - Beam forming changes the network coverage concept
- QoE analysis for data connection require E2E visibility
- 5G creates more demanding test cases for QoS measurements and testing setups
- Evolving and new applications and use cases will require new QoE models and new QoE concept. Need KPIs and QoS parameters for interactivity and continuity
- Focus for test automation to enable repeatability and statistical meaningful results
- Measure 5G with phone own MIMO antennas
- Need equal RF and thermal conditions to get comparable, scientific and accurate results



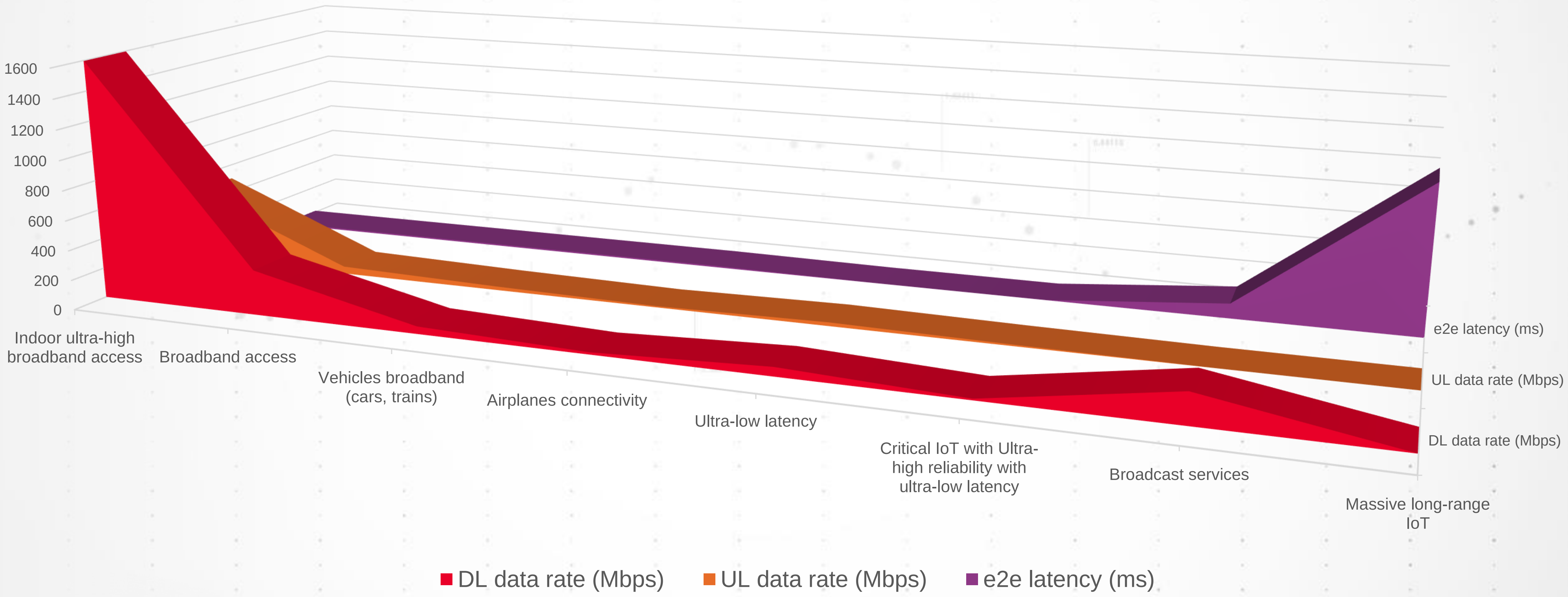


NGMN 5G NR test cases for each use case type

List of contributing, reviewing and supporting companies

Identifier	Use Case	Description
VR	Virtual Reality	Based on mobile phone-based or dedicated VR gear
GA	Gaming	Used in mobile phones or connected consolles
AR	Augmented Reality	For mobile phones or AR glasses/head gear
CS	Content Distribution Streaming Services	Typical streaming service in DL. This includes content on demand as well as live streaming.
LS	Live Streaming Services	Modern user-based streaming in UL. Examples in Facebook live, Periscope
SN	Social Networking	Content posting in online platforms
HS	High Speed Internet	Traditional browsing or files up/download
PM	Patient Monitoring	Transmission of life critical and/or low latency medical data
ES	Emergency Services	Emergency services such as «panic button», communication with emergency dispatch center
SM	Smart Metering	Deployed metering sensors, mostly IoT devices.
SG	Smart Grids	Electricity meters and actuators for grid management
CV	Connected Vehicles	Services for V2X interconnection, road safety, road traffic management and steering

Downlink and uplink data rates and e2e latencies of 5G use cases



KEYSIGHT TECHNOLOGIES

5G enabled user experience requirements

- The 5G system should be able to deliver a consistent user experience, defined by service-dependent minimum KPIs
- When considering latency requirements, the following metrics are considered:
  - E2E Latency: Measures the duration between the transmission of a small data packet from the application layer at the source node and the successful reception at the application layer at the destination node plus the equivalent time needed to carry the response back
  - User Plane Latency: Measures the time it takes to transfer a small data packet from user terminal to the Layer 2 / Layer 3 interface of the 5G system destination node, plus the equivalent time needed to carry the response back

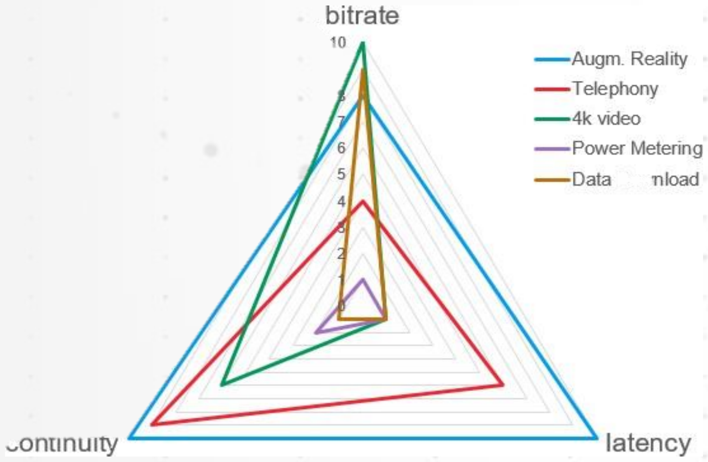
Use case category	User Experienced Data Rate	E2E Latency	Mobility
Broadband access in dense areas	DL: 300 Mbps UL: 50 Mbps	10 ms	On demand, 0-100 km/h
Indoor ultra-high broadband access	DL: 1 Gbps, UL: 500 Mbps	10 ms	Pedestrian
Broadband access in a crowd	DL: 25 Mbps UL: 50 Mbps	10 ms	Pedestrian
50+ Mbps everywhere	DL: 50 Mbps UL: 25 Mbps	10 ms	0-120 km/h
Ultra-low cost broadband access for low ARPU areas	DL: 10 Mbps UL: 10 Mbps	50 ms	on demand: 0-50 km/h
Mobile broadband in vehicles (cars, trains)	DL: 50 Mbps UL: 25 Mbps	10 ms	On demand, up to 500 km/h
Airplanes connectivity	DL: 15 Mbps per user UL: 7.5 Mbps per user	10 ms	Up to 1000 km/h
Massive low-cost/long-range/low-power MTC	Low (typically 1-100 kbps)	Seconds to hours	on demand: 0-500 km/h
Broadband MTC	See the requirements for the Broadband access in dense areas and 50+Mbps everywhere categories		
Ultra-low latency	DL: 50 Mbps UL: 25 Mbps	<1 ms	Pedestrian
Resilience and traffic surge	DL: 0.1-1 Mbps UL: 0.1-1 Mbps	Regular communication: not critical	0-120 km/h
Ultra-high reliability & Ultra-low latency	DL: From 50 kbps to 10 Mbps; UL: From a few bps to 10 Mbps	1 ms	on demand: 0-500 km/h
Ultra-high availability & reliability	DL: 10 Mbps UL: 10 Mbps	10 ms	On demand, 0-500 km/h
Broadcast like services	DL: Up to 200 Mbps UL: Modest (e.g. 500 kbps)	<100 ms	on demand: 0-500 km/h

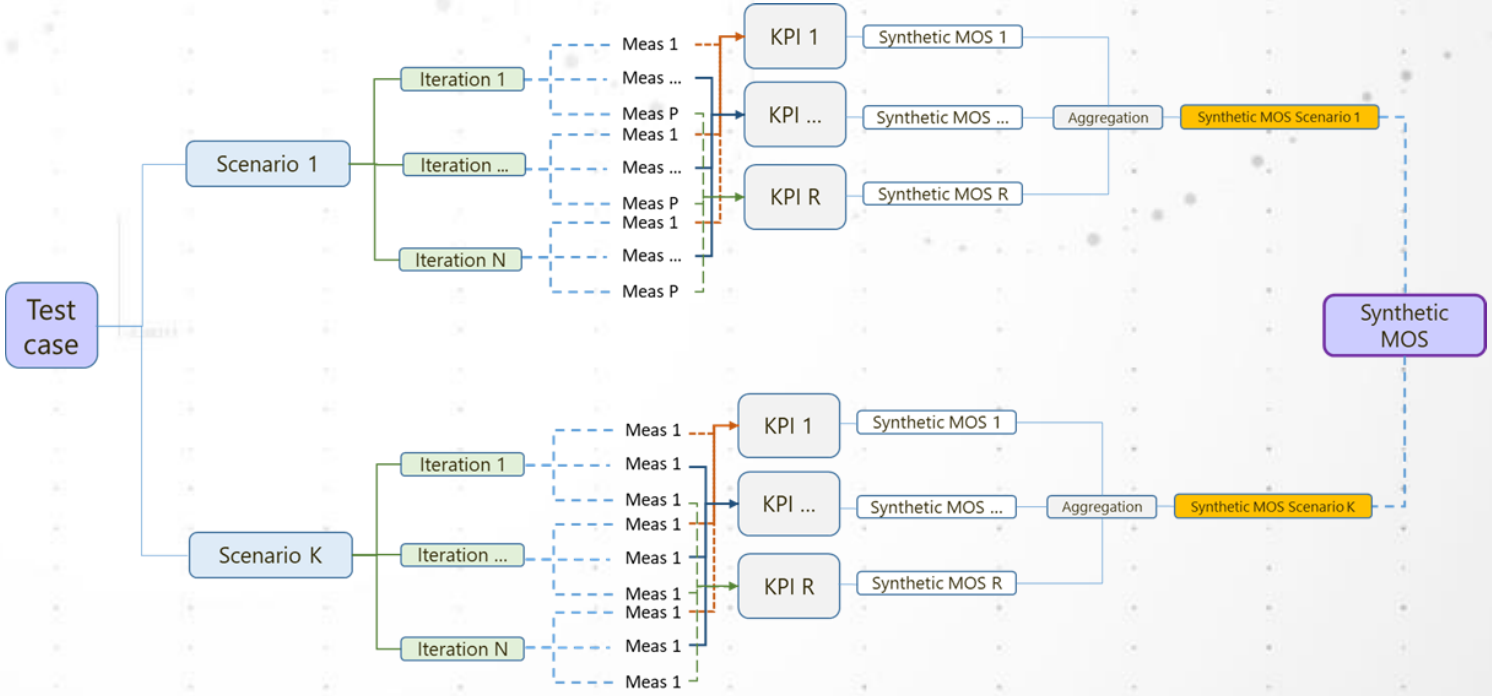
Source: NMGN 5G White paper

Estimating QoE MOS for 5G use cases

The 5G system should be able to deliver a consistent user experience, defined by service-dependent minimum KPIs

- Each 5G use case would require individual "QoE MOS”
- MOS per each new 5G use case calculated based on the same underlying measurement techniques
- **Use repeatable** and **automated** technical measurements (RF, IP, Application level)
- Based on measured KPI’s, solution can predict a separate MOS value for each new 5G use case

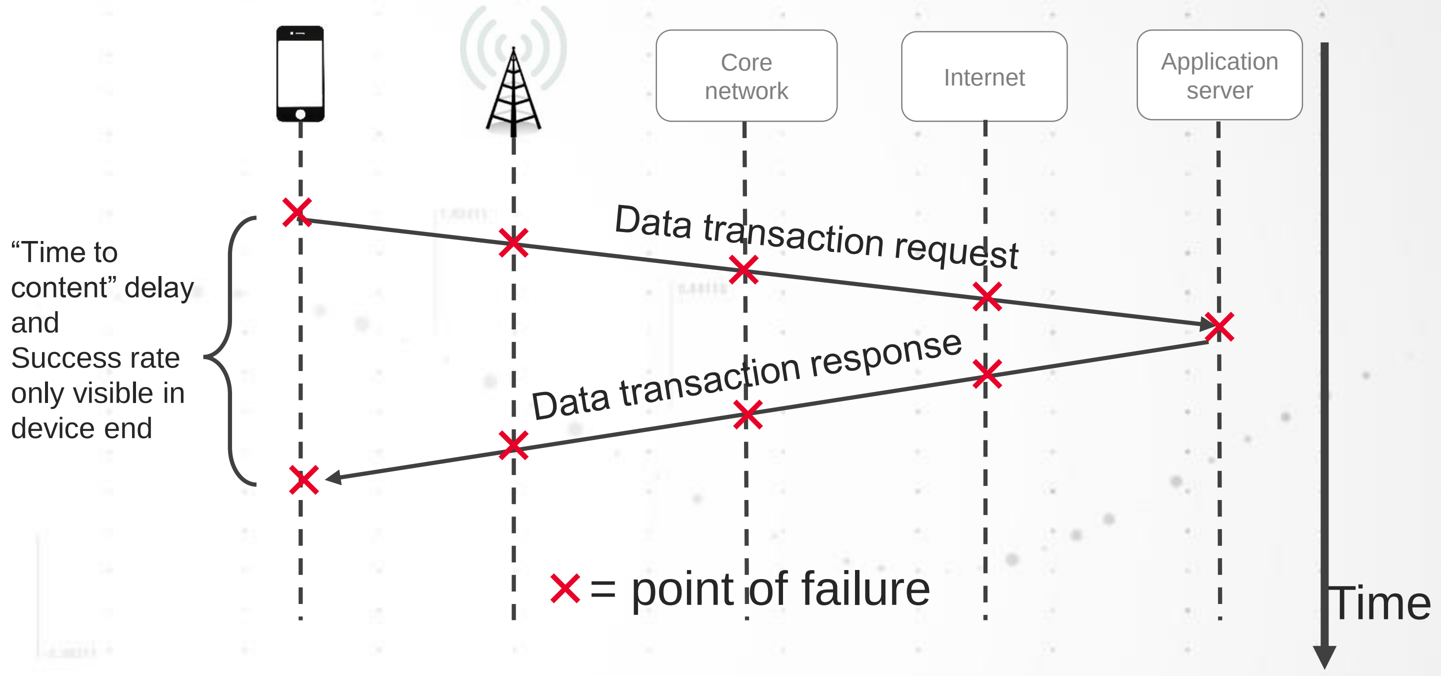


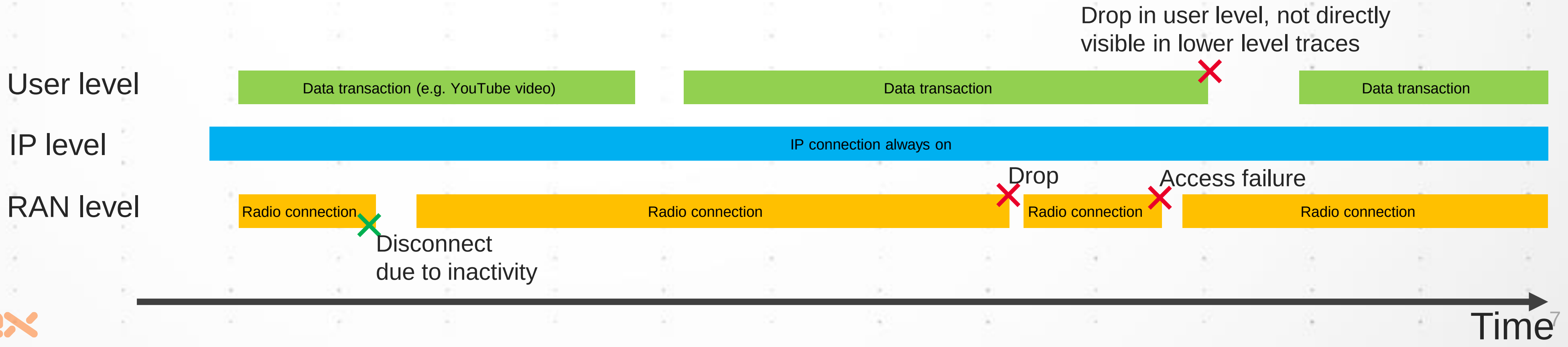


Mobile Network QoE Assessment Challenges

LACK OF VISIBILITY

- No visibility to end to end QoS in current mobile networks
- Currently available network datafeeds and tools provide technical KPIs that do not translate to the QoE
- Passive device agents and network side passive monitoring provide more user behavior related data than quantifiable QoE KPIs
- Active, controlled device end testing is the only way to get accurate picture of the QoE





5G network slicing introduce challenges for QoE verification

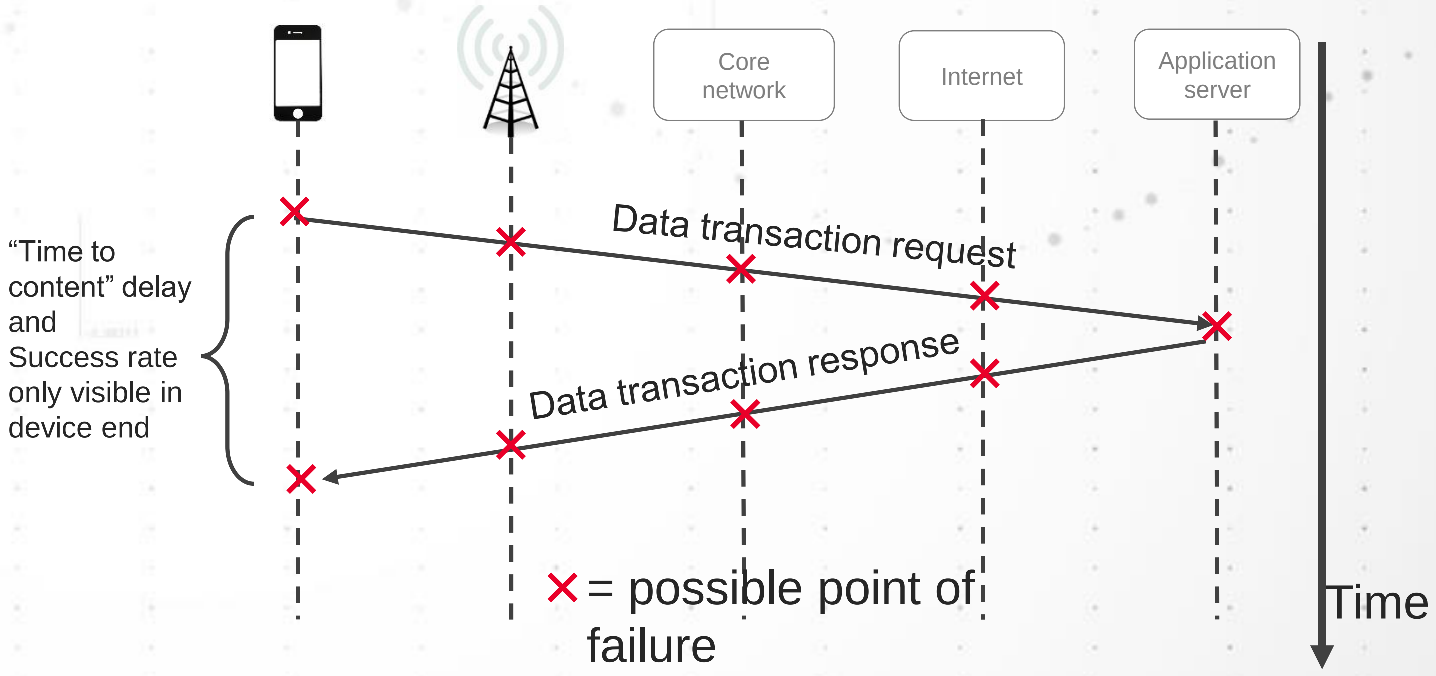
Dedicated slices for authorities use

A slice for mission critical IoT with ms level latency

Slices for ultra reliable connections

- Network slicing replaces the QoS profiles used in LTE
- Network can adopt relevant QoS settings for each app
- lower level traces won't directly indicate user level drops

➔ Need to **perform on-device measurements to assess the QoE of sliced 5G network**



Drop in user level, not directly visible in lower level traces

MOS score for 5G slices based on real UE measurements

PERFORM MEASUREMENTS FROM REAL END-USER PERSPECTIVE

- Measure QoE of 5G NR network slices by performing measurements in the UE
- Require a solution which performs on-device measurements where all services and data protocols are **running in a smartphone**
- Measure with commercial 5G non-rooted phones

Benefits

- Performs QoE measurements from real end-user perspective
- Provide insights to the real QoE
- Uses the real IMS/VoLTE protocols, settings and OTT applications of the UE in the very same way as the real consumer would use those

Success %
DL & UL speed
Delay, Drop rate, throughput
- and tens more

Service Accessibility

Service Retainability

Service Integrity

KEYSIGHT TECHNOLOGIES

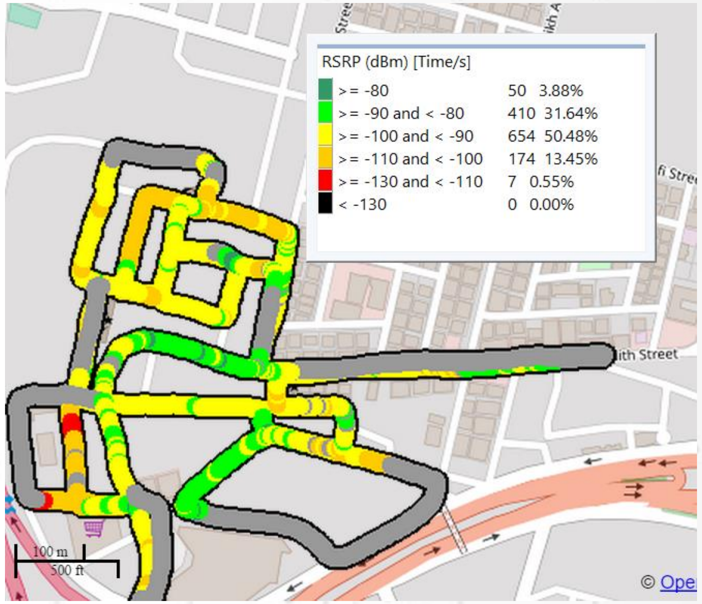
MidWex

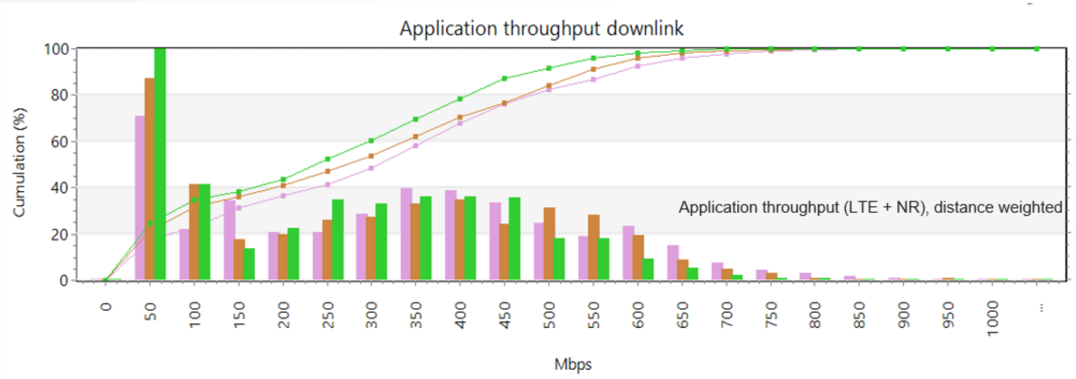
Real 5G UE QoS + QoE Benchmark

Huawei Mate 20
ZTE Axon
Samsung Galaxy Note 10 Plus 5G

- Performance of three 5G devices compared on a live 5G network
- Network: LTE 1800 10MHz + 20MHz + 5G NR 100Mhz n78 band
- ZTE Axon and Note 10 - Qualcomm X50 5G modem
- Huawei Mate 20 - HiSilicon modem

	Rank	Avg App Throughput DL	Mobility Coverage (Avg- SSB-RSRP)	Mobility Quality (Avg SSB-SINR)
Device 1	**1**	298Mbps	-87.84dBm	17.41dB
Device 2	**2**	270Mbps	-89.86dbm	11.15dB
Device 3	**3**	235Mbps	-92.72dBm	12.09dB





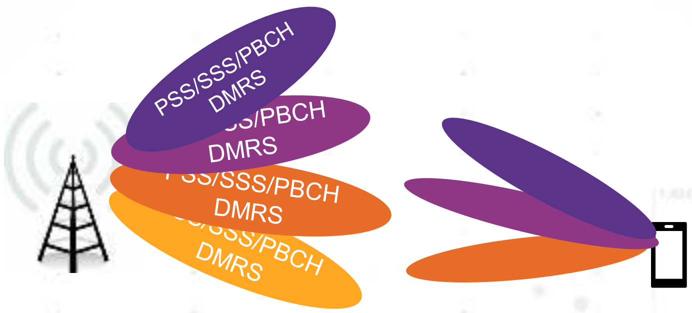
Performance differences exists between the devices, both across the chipsets, as well as devices with same chipset

Thank You

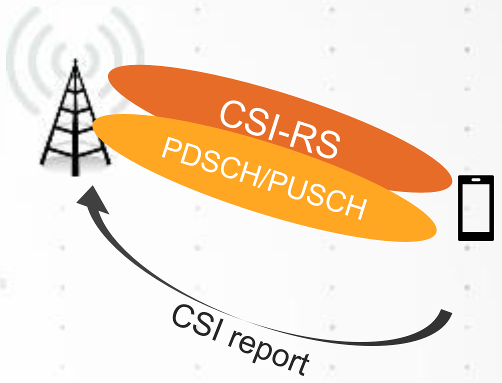
Additional Info

5G NR – Beam Based Network Coverage

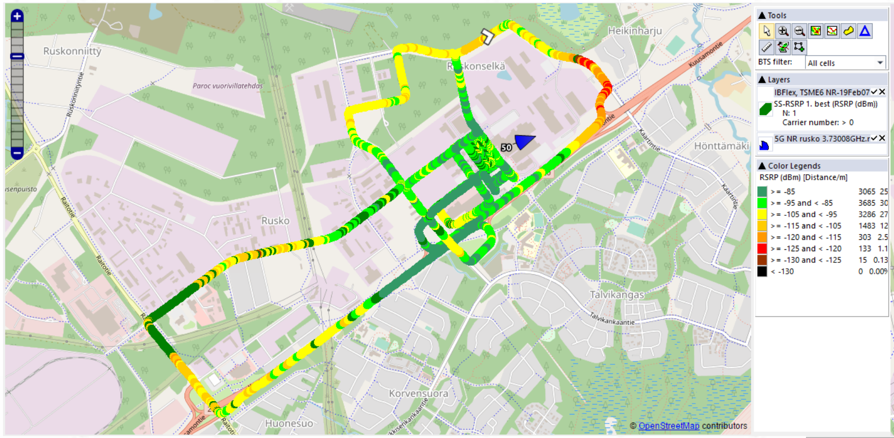
- Paradigm shift from cell based network coverage to beam based network coverage
- Major challenge for operators and NEMs to verify and understand the network coverage on the field
- Higher frequencies (FR1, FR2) and smaller cell sizes - more demanding in propagation manner and have impact on QoS - accessibility and reliability

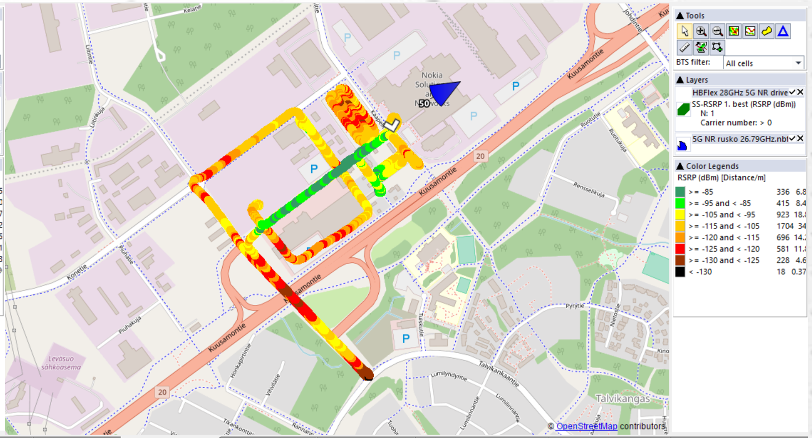


3,7 GHz



mmWave

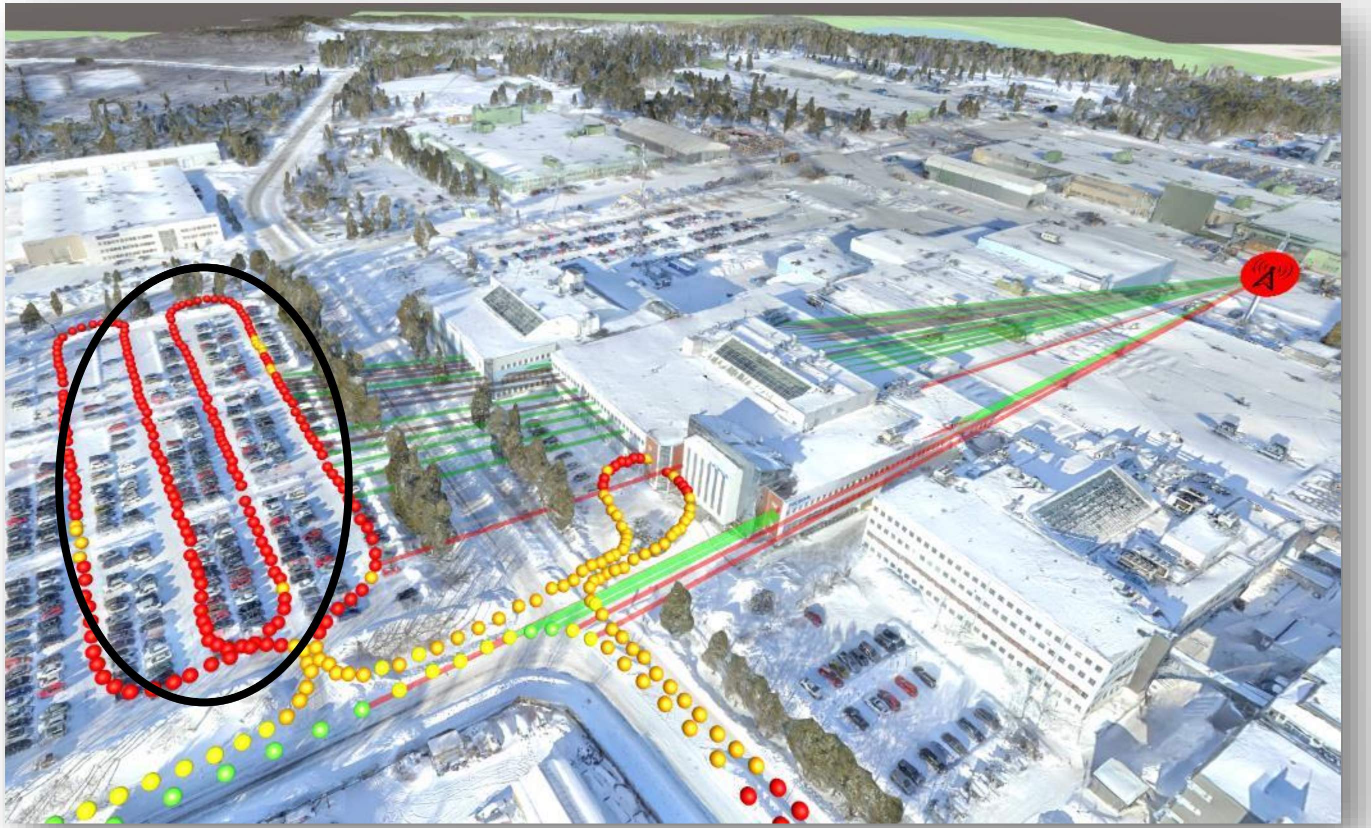




Understanding the mmWave Signal Propagation

LINE OF SIGHT, BLOCKAGE, SHADOWING

- Propagation characteristics of mmWave radio signal are getting closer to visible light
  - High blockage even from small objects such as trees
  - Strong reflections
  - High shadowing loss
- Seeing even the smallest objects of the environment in 3D together with the signal helps to understand the signal propagation



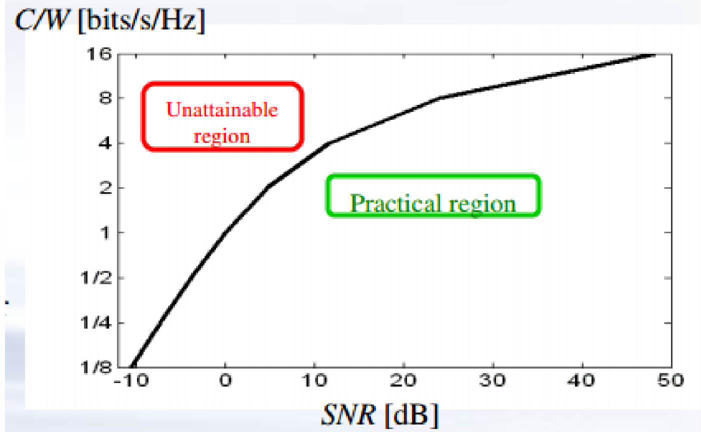
Throughput Increase of 5G – A Free Lunch?

- Spectrum is the scarce resource of telecommunications
- Link level spectral efficiency of HSDPA, LTE, and 5G is about the same - They are all close to Shannon's limit
- Link throughput can be only increased by
  1. Increasing bandwidth
  2. Add MIMO layers (new parallel radio links)
- System capacity can be increased

Claude Shannon
(April 30, 1916 – February 24, 2001)

The Shannon limit: maximum data rate at which error-free communication over the channel can be performed

$$C = W \log_2\left(1 + \frac{S}{N}\right) \quad \text{[bits/s]}$$



Various MIMO Modes

Feature	3GPP/LTE Transmission mode	Description
SU-MIMO (Single User)	5G: max 8x8 MIMO LTE Rel8: TM3,TM4 4x4 MIMO, 4x2 MIMO, 2x2 MIMO	Multiple data streams send to UE, increasing the peak throughput of individual user, 2x2 MIMO doubling, 4x4 MIMO quadrupling the throughput
MU-MIMO (Multi-User)	5G: Max 12 layers LTE; Max 8 layers (TM9)	Multiple data streams sent in same frequency/time resource block, one for each UE. Increases total cell throughput (capacity).
Massive MIMO	5G 64Tx TM9(LTE Rel9) 16TX(LTE Rel13), 32TX(LTE Rel14)	#antennas>>#users. MU-MIMO, SU-MIMO, and analog beamforming. High number of antennas improves the MU-MIMO performance

5G Theoretical Max Data Rates

$$\text{data rate (in Mbps)} = 10^{-6} \cdot \sum_{j=1}^{J} \left(v_{Layers}^{(j)} \cdot Q_m^{(j)} \cdot f^{(j)} \cdot R_{max} \cdot \frac{N_{PRB}^{BW(j),\mu} \cdot 12}{T_s^{\mu}} \cdot \left(1 - OH^{(j)}\right) \right)$$

- No UE categories with fixed data rates in 5G
- Spec allows 8x8 SU-MIMO (Rank 8), in practise devices support Rank 4.
  - Not to be confused with max 12 MU-MIMO layers defined by spec
- Chip/device vendors not indicating peak rates
- Real max data rates of **850Mbps** seen in tests @100MHz BW, 256QAM, 4x4 MIMO

- J = number of component carriers
- Rmax = 948/1024m max code rate
- v = number of SU-MIMO layers (i.e. Rank), max theoretical 8, max supported by devices currently is 4
- *Q* = Bits per modulation symbol; 1 for BPSK, 2 for QPSK, 4 for 16QAM, 6 for 64QAM, 8 for 256QAM
- f = Scaling factor (1, 0.8, 0.75 or 0.4), signaled via higher layers
- $N_{PRB}^{BW(j),\mu}$ = Max number of resource blocks. Derived directly from the available bandwidth.
- T_s^{μ} = Average symbol duration
- μ = Subcarrier spacing, 0 for 15 kHz SCS, 1 for 30 kHz SCS, 2 for 60 kHz SCS, 3 for 120 kHz SCS
- *OH* = Overhead due to signaling information
  - 0.14, for frequency range FR1 for DL
  - 0.18, for frequency range FR2 for DL
  - 0.08, for frequency range FR1 for UL
  - 0.10, for frequency range FR2 for UL

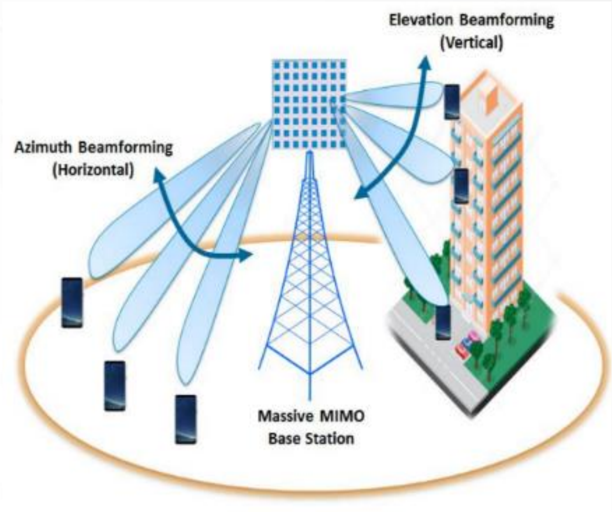
Theoretical bit rates for TDD 5G NR, 12/2 (DL/UL) symbol allocation

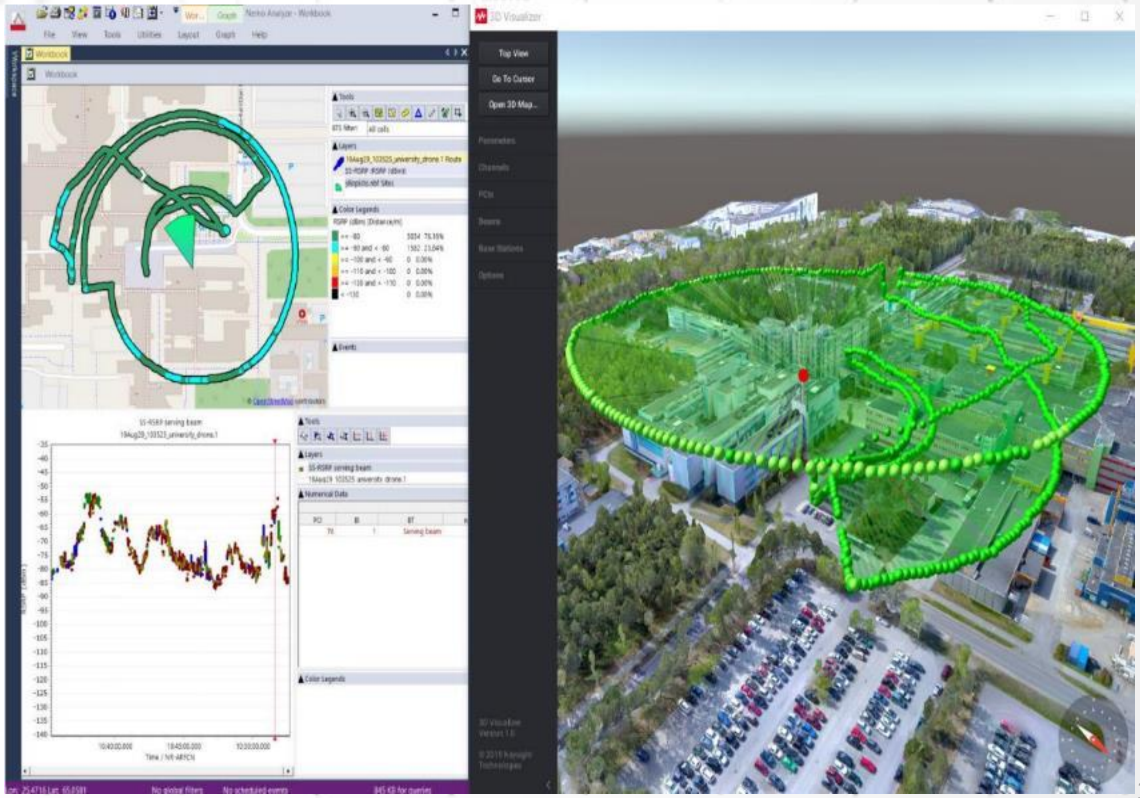
Freq	Bandwidth	SCS	Modulation	Rank	DL rate	UL rate
FR1	20MHz	15kHz	256QAM	1	98Mbps	18Mbps
FR1	20MHz	15kHz	256QAM	1	194Mbps	34Mbps
FR1	100MHz	30kHz	256QAM	1	500Mbps	90Mps
FR1	100MHz	30kHz	256QAM	4	2Gbps	358Mbps
FR2	100MHz	60kHz	256QAM	4	1.848Gbs	338Mbps
FR2	400MHz	120KHz	256QAM	4	7.388Gbps	1.352Gbps

Most common config in FR1, 850Mbps DL max seen in real-life tests

3D Visualisation of beams

- Visualize 5G beams measurements in 3D
- Measurement data collected with drive test or with drone
- Use cases
  - mmWave signal propagation verification - detailed knowledge of the environment, signal blockage of trees, buildings, etc. is needed
  - Horizontal and vertical beam's coverage verification via drone measurements
  - Verifying the coverage for drone flight paths (drones requiring cellular connection to ground station)
  - Demo purposes for gNB vendors to present their gNB's beam forming capability to their customers and public





KEYSIGHT
TECHNOLOGIES

MidWex