Validate 5G End-to-End Performance by Virtual Drive Testing Toolset

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Agenda

- Release 15 Basics
- Common Functional Test
  - Max Throughput Testing
  - UL Duty Cycle- Dynamic TDD
  - BWP switch
  - IP data Throughput. Split bearer
  - VoLTE/VoNR
  - Mobility
- Real environment testing- Virtual Drive Testing Toolset

Release 15 Basics

5G Scenarios and Use Cases

Broad range of new services and connectivity paradigms

Courtesy of METIS: 2014

Amazingly Fast	Great Service In a Crowd	Best Experience Follows You	Real-Time & Reliable Communications	Ubiquitous Things Communicating

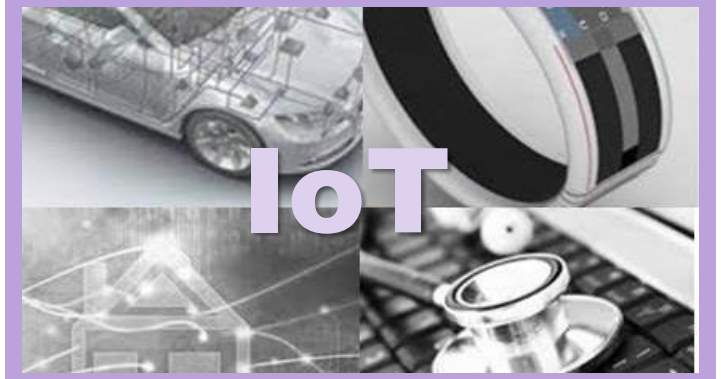
Enhanced Mobile Broadband Access

- All data, all the time
- 2 billion people on social media

Mission-Critical Machine Communication

- Ultra high-reliability
- Ultra-low latency

Massive Machine Communication



- 30 billion “things” connected
- Low cost, low energy

3GPP NR Rel-15 Scope

3GPP NR ROADMAP & INTRODUCTION

- Acceleration of eMBB Non-Standalone mode by **December'17**
  - Standalone standardization dates as expected (June'18)
- Use cases:
  - Enhanced Mobile Broadband (eMBB)
  - Ultra Reliable Low Latency Communications (URLLC)
- Carrier aggregation operation
- Inter-RAT mobility between NR and E-UTRA

✓ **IN SCOPE**

- Frequencies beyond 52.6 GHz
  - Other types of waveforms
- mMTC – Machine type communications
- Internetworking with non-3GPP systems (e.g. WiFi)
- Vehicular communications
- Multicast services and multimedia broadcast
- Unlicensed spectrum access

⊘ **OUT OF SCOPE**

Max Throughput Testing

Numerology Definition

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

- Scalable subcarrier spacing

$$\Delta f = 2^{\mu} \cdot 15\ kHz$$

- Parameters defining a numerology:
  - Subcarrier spacing (i.e. μ parameter)
  - Cyclic prefix (i.e. Normal/Extended)

	μ	Δf = 2μ·15 kHz	Cyclic Prefix	
Sync < 6 GHz	0	15 kHz	Normal	Data < 6 GHz
	1	30 kHz	Normal	
	2	60 kHz	Normal, Extended	Data > 6 GHz
Sync > 6 GHz	3	120 kHz	Normal	
	4	240 kHz	Normal	

RFE: 3gpp 38.300-200 Table 5.1-1Ref : 3GPP TS 38.211 4.2 URLLC

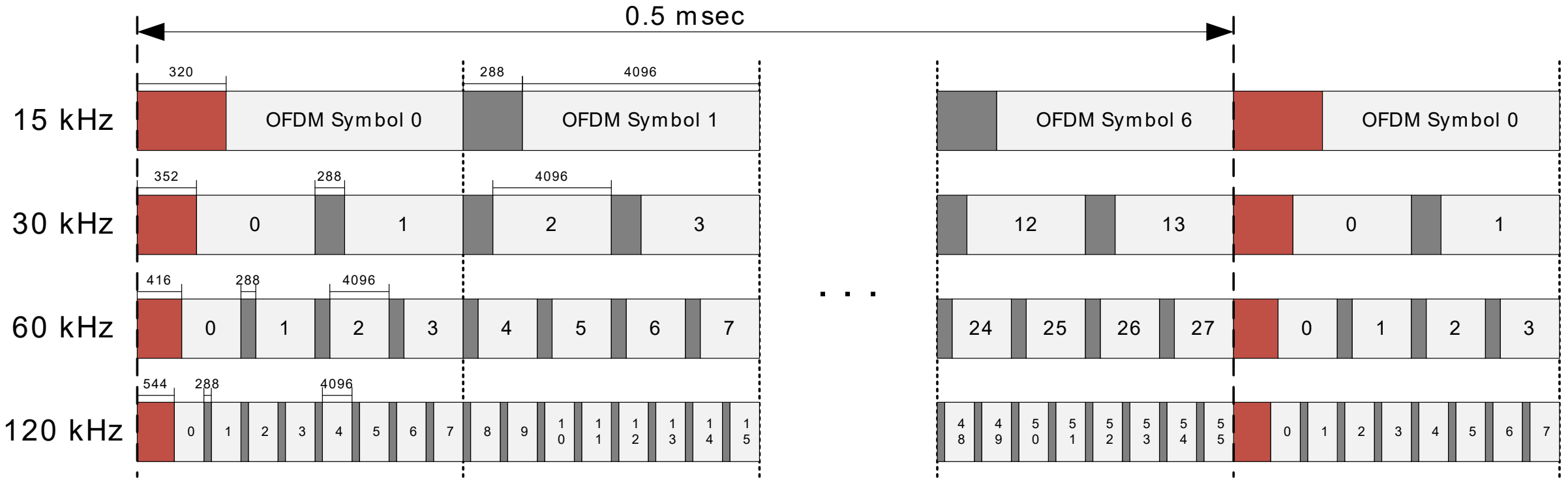
Physical Resources

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

- Resource elements are grouped into Physical Resource Blocks (**PRB**)
- Each PRB consists of **12 subcarriers**

μ	Δf	$N_{RB}^{min,\mu}$	$N_{RB}^{max,\mu}$
0	15 kHz	20 (240 subcarriers)	275 (3300 subcarriers, 49.5 MHz)
1	30 kHz	20	275 (3300 subcarriers, 99 MHz)
2	60 kHz	20	275 (3300 subcarriers, 198 MHz)
3	120 kHz	20	275 (3300 subcarriers, 396 MHz)
4	240 kHz	20	138

Numerology Example (Normal CP)



- Each symbol length (including CP) of 15 kHz equals the sum of the corresponding 2^{μ} symbols at F_s
- Other than the first OFMD symbol in every 0.5 ms, all symbols within 0.5 ms have the same length

Throughput Comparison

LTE VS NR FR1

- LTE 20MHz 4x4 256QAM: 395Mbps
- NR 20MHz FDD Band 4x4 256QAM: 423Mbps
- NR 100MHz FDD Band 4x4 256QAM: ~2100Mbps….No such BW available
- NR 100MHz TDD Band 4x4 256QAM: ~2100Mbps but need to split onto DL and UL
- n78C 200MHz? More inter-band CA to get more BW

Throughput Comparison

NR FR1 VS NR FR2

- NR FR1 100MHz vs NR FR2 100MHz

Max Throughput Testing

- Throughput per BW improvement from LTE to NR is not a lot
- NR higher Throughput can be achieved from high aggregated BW- n41,n78,n79,n257,n261…
- Throughput/BW for FR1 and FR2 is about the same
- For TDD, we are interested in Max DL and UL Throughput test
- NSA have the Throughput from LTE+NR

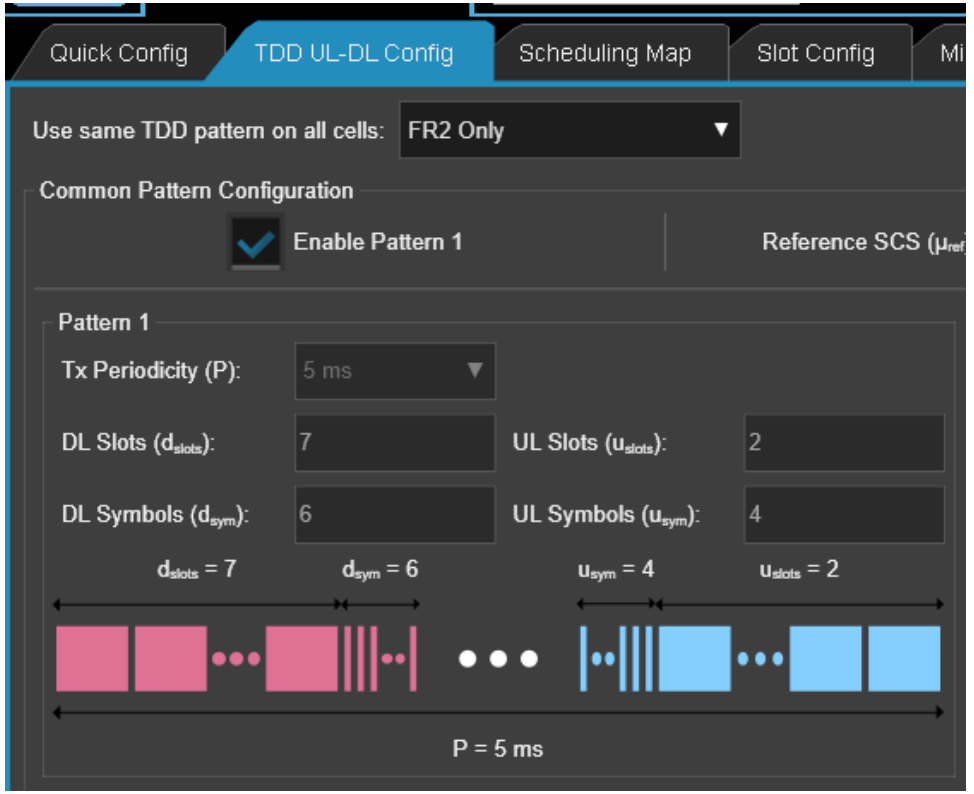
UL Duty Cycle- Dynamic TDD

Slot Format Indication

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

- Slot Format Indication informs the UE whether an OFDM symbol is ***Downlink***, ***Uplink*** or ***Flexible***
- SFI can indicate link direction over one or many slots (configured through RRC)
- The SFI carries an index to a pre-configured UE-specific table (configured through RRC)
- SFI can be either:
  - **Dynamic** (i.e. through a DCI)
    - UE assumes there is no conflict between dynamic SFI and DCI DL/UL assignments
  - **Static** or **semi-static** (i.e. through RRC)

tdd_UL_DL_ConfigurationCommon enabled => Static/semi-static
tdd_UL_DL_ConfigurationCommon disabled => dynamic



5G NR Slots Formats

TS 38.211 TABLE 4.3.2-3: SLOT FORMATS

D: Downlink symbol
U: Uplink symbol
X: Flexible symbol

Format	Symbol number in a slot													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0	D	D	D	D	D	D	D	D	D	D	D	D	D	D
1	U	U	U	U	U	U	U	U	U	U	U	U	U	U
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	D	D	D	D	D	D	D	D	D	D	D	D	D	X
4	D	D	D	D	D	D	D	D	D	D	D	D	X	X
5	D	D	D	D	D	D	D	D	D	D	D	X	X	X
6	D	D	D	D	D	D	D	D	D	D	X	X	X	X
7	D	D	D	D	D	D	D	D	D	X	X	X	X	X
8	X	X	X	X	X	X	X	X	X	X	X	X	X	U
9	X	X	X	X	X	X	X	X	X	X	X	X	U	U
10	X	U	U	U	U	U	U	U	U	U	U	U	U	U
11	X	X	U	U	U	U	U	U	U	U	U	U	U	U
12	X	X	X	U	U	U	U	U	U	U	U	U	U	U
13	X	X	X	X	U	U	U	U	U	U	U	U	U	U
14	X	X	X	X	X	U	U	U	U	U	U	U	U	U
15	X	X	X	X	X	X	U	U	U	U	U	U	U	U
16	D	X	X	X	X	X	X	X	X	X	X	X	X	X
17	D	D	X	X	X	X	X	X	X	X	X	X	X	X
18	D	D	D	X	X	X	X	X	X	X	X	X	X	X
19	D	X	X	X	X	X	X	X	X	X	X	X	X	U
20	D	D	X	X	X	X	X	X	X	X	X	X	X	U
21	D	D	D	X	X	X	X	X	X	X	X	X	X	U
22	D	X	X	X	X	X	X	X	X	X	X	X	U	U
23	D	D	X	X	X	X	X	X	X	X	X	X	U	U
24	D	D	D	X	X	X	X	X	X	X	X	X	U	U
25	D	X	X	X	X	X	X	X	X	X	X	U	U	U
26	D	D	X	X	X	X	X	X	X	X	X	U	U	U
27	D	D	D	X	X	X	X	X	X	X	X	U	U	U
28	D	D	D	D	D	D	D	D	D	D	D	D	X	U
29	D	D	D	D	D	D	D	D	D	D	D	X	X	U
30	D	D	D	D	D	D	D	D	D	D	X	X	X	U
31	D	D	D	D	D	D	D	D	D	D	D	X	U	U
32	D	D	D	D	D	D	D	D	D	D	X	X	U	U
33	D	D	D	D	D	D	D	D	D	X	X	X	U	U
34	D	X	U	U	U	U	U	U	U	U	U	U	U	U
35	D	D	X	U	U	U	U	U	U	U	U	U	U	U
36	D	D	D	X	U	U	U	U	U	U	U	U	U	U
37	D	X	X	U	U	U	U	U	U	U	U	U	U	U
38	D	D	X	X	U	U	U	U	U	U	U	U	U	U
39	D	D	D	X	X	U	U	U	U	U	U	U	U	U
40	D	X	X	X	U	U	U	U	U	U	U	U	U	U
41	D	D	X	X	X	U	U	U	U	U	U	U	U	U
42	D	D	D	X	X	X	U	U	U	U	U	U	U	U
43	D	D	D	D	D	D	D	D	D	X	X	X	X	U
44	D	D	D	D	D	D	X	X	X	X	X	X	U	U
45	D	D	D	D	D	D	X	X	U	U	U	U	U	U
46	D	D	D	D	D	D	X	D	D	D	D	D	D	X
47	D	D	D	D	D	X	X	D	D	D	D	D	X	X
48	D	D	X	X	X	X	X	D	D	X	X	X	X	X
49	D	X	X	X	X	X	X	D	X	X	X	X	X	X
50	X	U	U	U	U	U	U	X	U	U	U	U	U	U
51	X	X	U	U	U	U	U	X	X	U	U	U	U	U
52	X	X	X	U	U	U	U	X	X	X	U	U	U	U
53	X	X	X	X	U	U	U	X	X	X	X	U	U	U
54	D	D	D	D	D	X	U	D	D	D	D	D	X	U
55	D	D	X	U	U	U	U	D	D	X	U	U	U	U
56	D	X	U	U	U	U	U	D	X	U	U	U	U	U
57	D	D	D	D	X	X	U	D	D	D	D	X	X	U
58	D	D	X	X	U	U	U	D	D	X	X	U	U	U
59	D	X	X	U	U	U	U	D	X	X	U	U	U	U
60	D	X	X	X	X	X	U	D	X	X	X	X	X	U
61	D	D	X	X	X	X	U	D	D	X	X	X	X	U
62 – 255	Reserved													

Ref : 3GPP TS 38.211 Table 4.3.2-3

BWP switch

Bandwidth Adaptation / Bandwidth Part

Channel bandwidth → **BS Channel bandwidth**

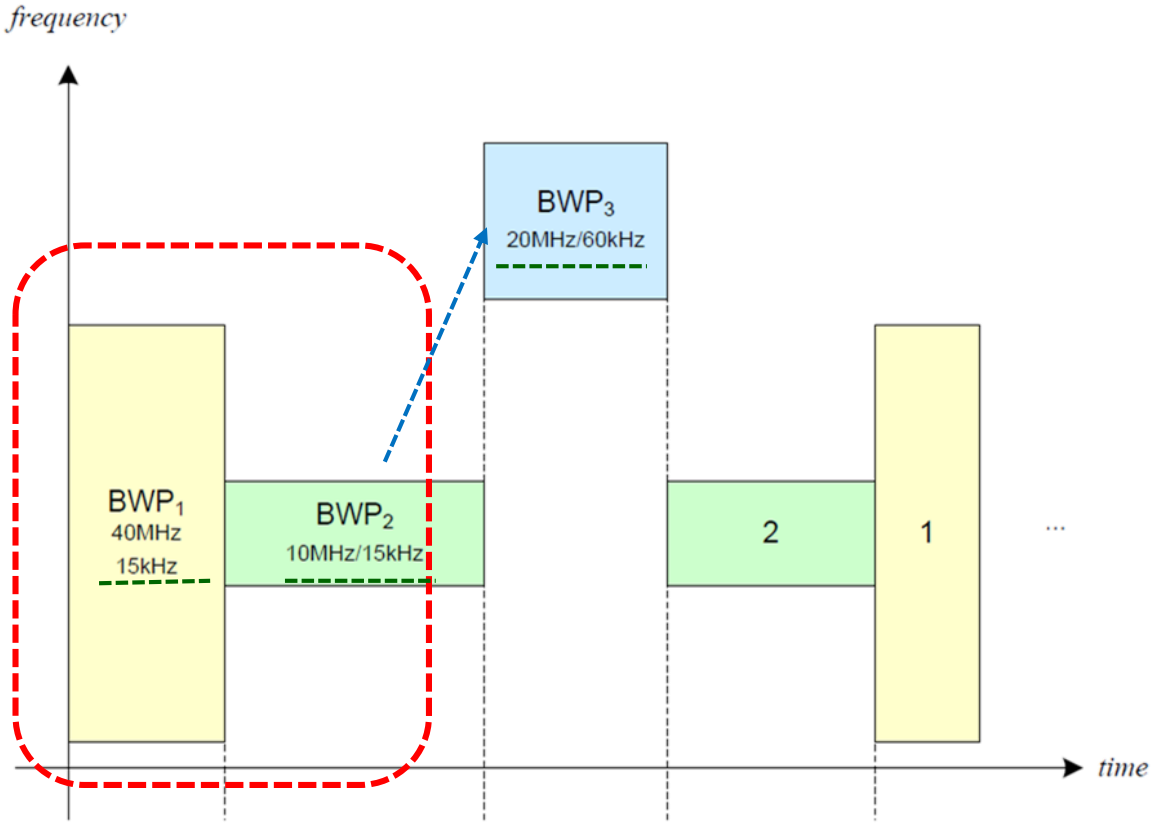
UE Channel bandwidth

UE transmission bandwidth → **UE Bandwidth part**

- the width can be ordered to change (e.g. to shrink during period of low activity to save power)

- the location can move in the frequency domain (e.g. to increase scheduling flexibility)

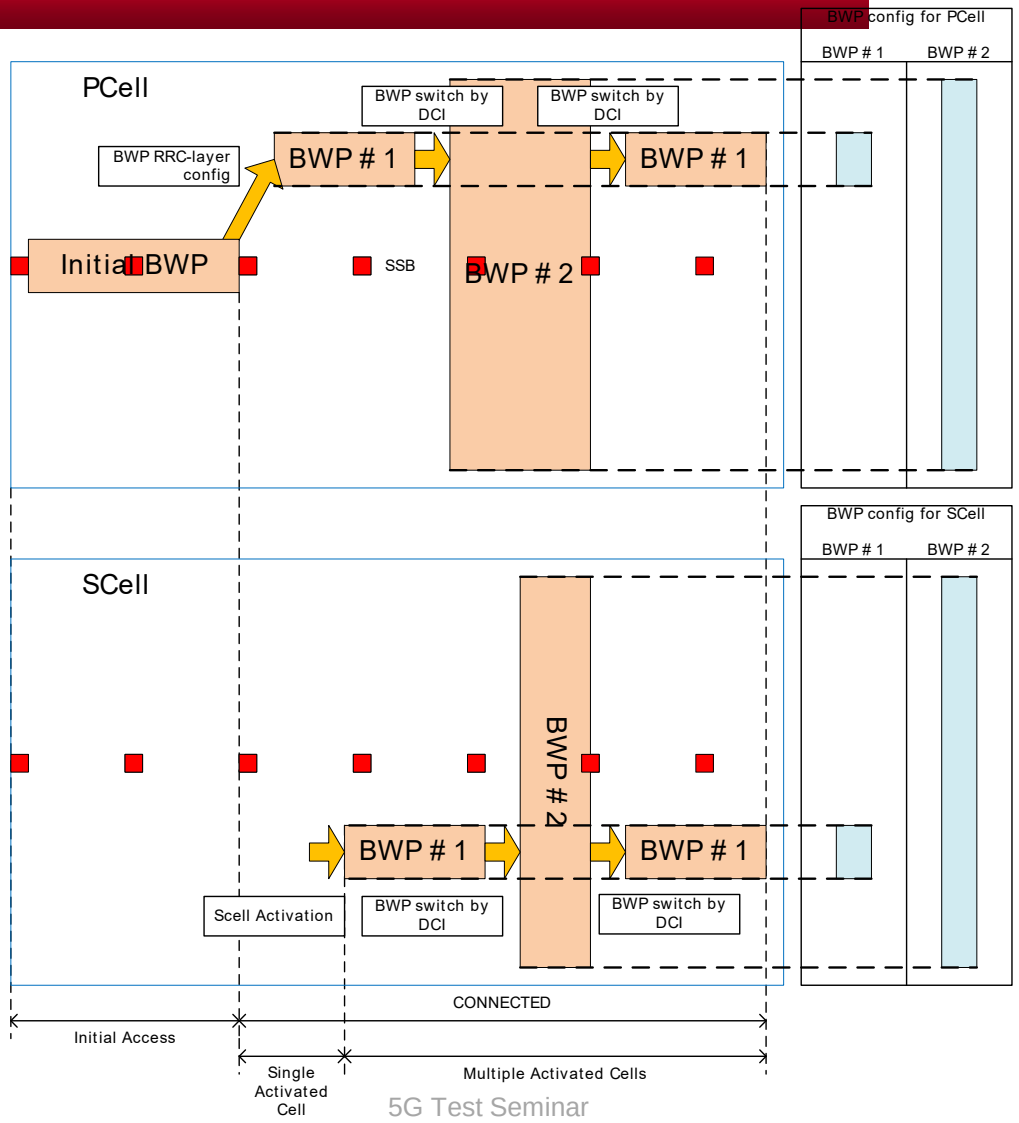
The subcarrier spacing can be ordered to change (e.g. to allow different services).



Ref: 3gpp 38.211

Example of Bandwidth Part Operation

BANDWIDTH PARTS



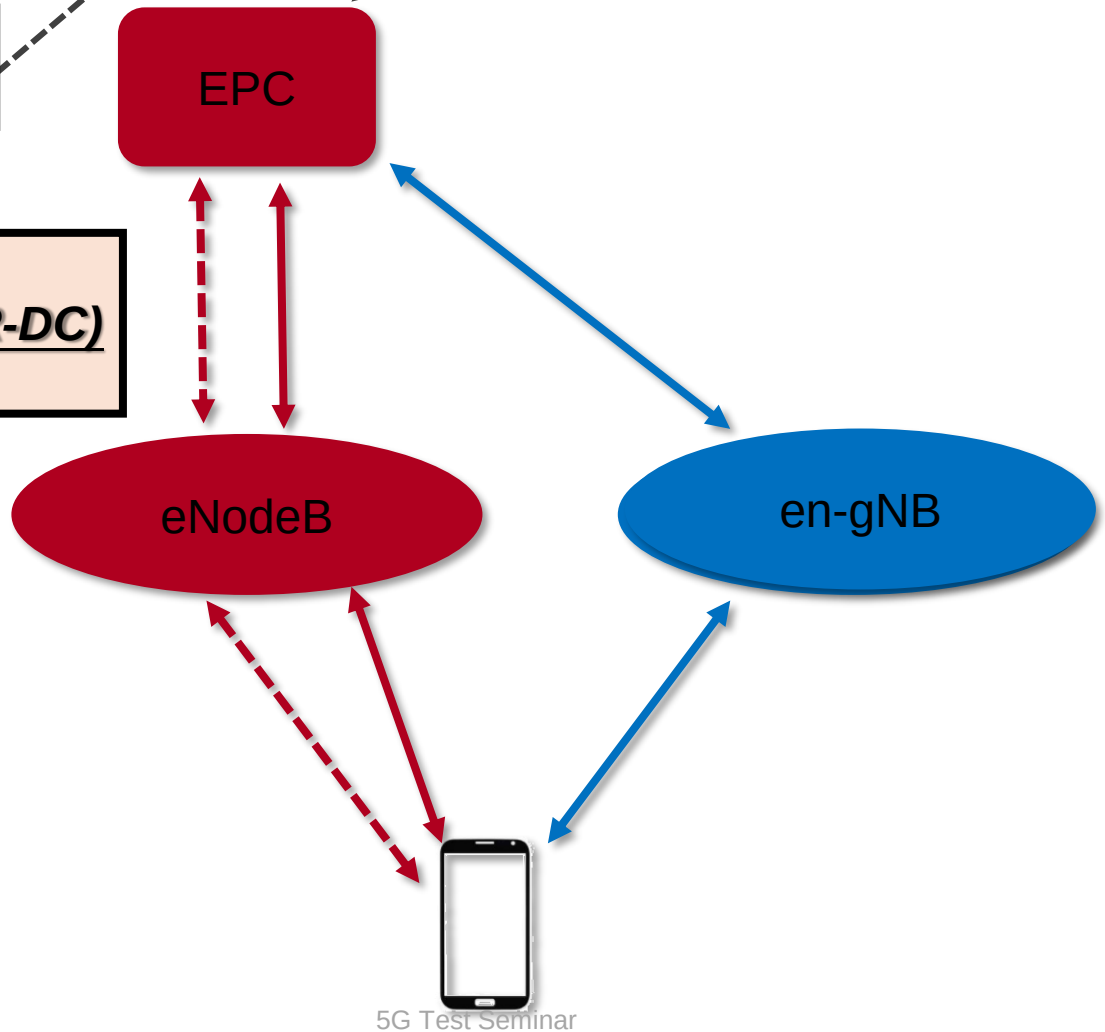
IP data Throughput. Split bearer

Option 3

EN-DC with EPC

EUTRAN (master) + NR (second)

Multi-RAT Dual Connectivity (MR-DC)



Ref: 3GPP 37.340

NSA split bearer

- PDCP split bearer
- Split ratio. BSI method.
- Challenge in NR split bearer

VoLTE/VoNR

VoLTE/VoNR

- in NR split bearer

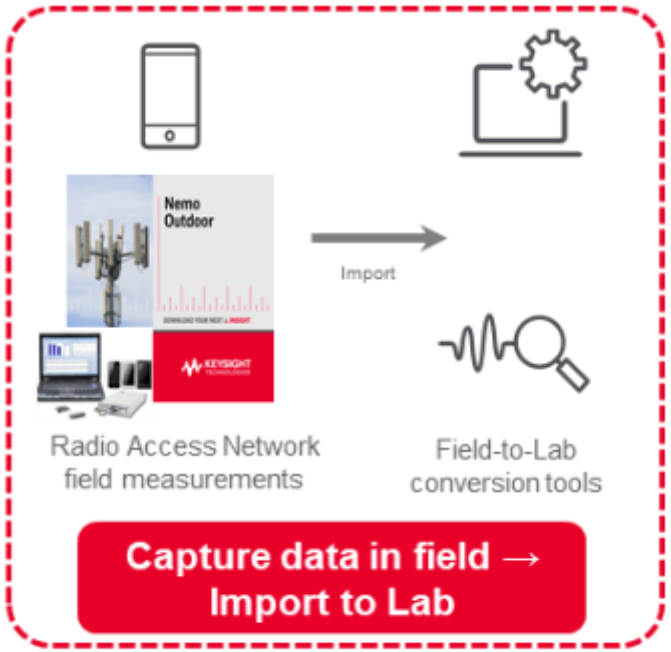
Mobility

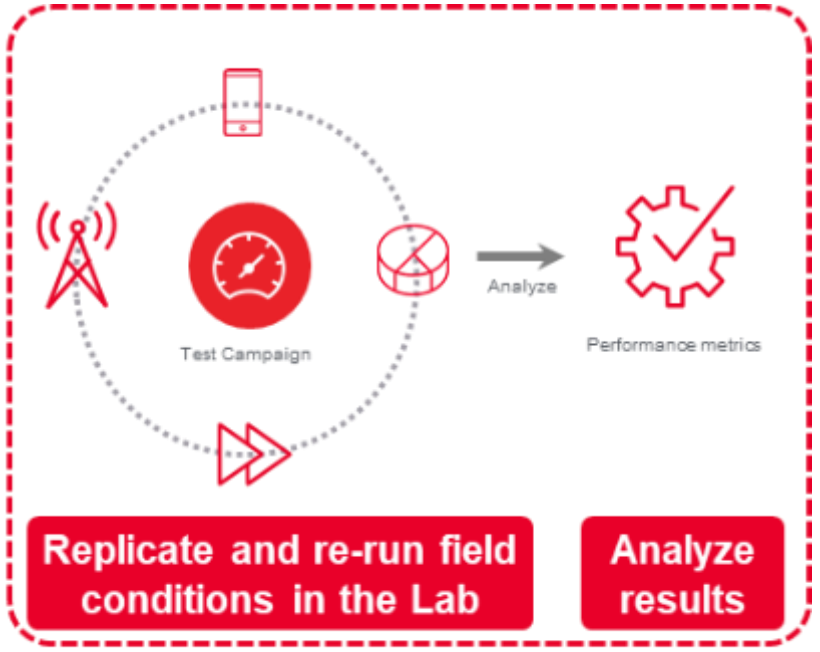
Show different example for mobility case

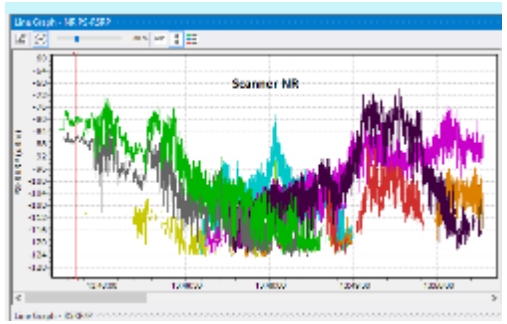
- in NR split bearer

Real environment testing- Virtual Drive Testing Toolset

5G Device Performance Challenges







5G Device Performance Challenges

Benchmark Device Performance in Field Conditions

- Benchmark devices (UE's) performance in repeatable and realistic field conditions
- Validate device (UE) in MNO specific signaling and radio channel environment
- Verify Device (UE) operation in advanced mobility scenarios such as High-Speed Train

Ready and Validated Tests

- Stress test of Device (UE) against measured field conditions in repeatable and controlled test environment
- Run verified test cases and access the quick KPI metrics with confidence for decision making
- Verify Device (UE) maximum data throughput performance and mobility under real world fading and signaling conditions
- Debug Device performance in multiple test runs under rapidly changing RF channel and signaling conditions recorded in different locations around the world

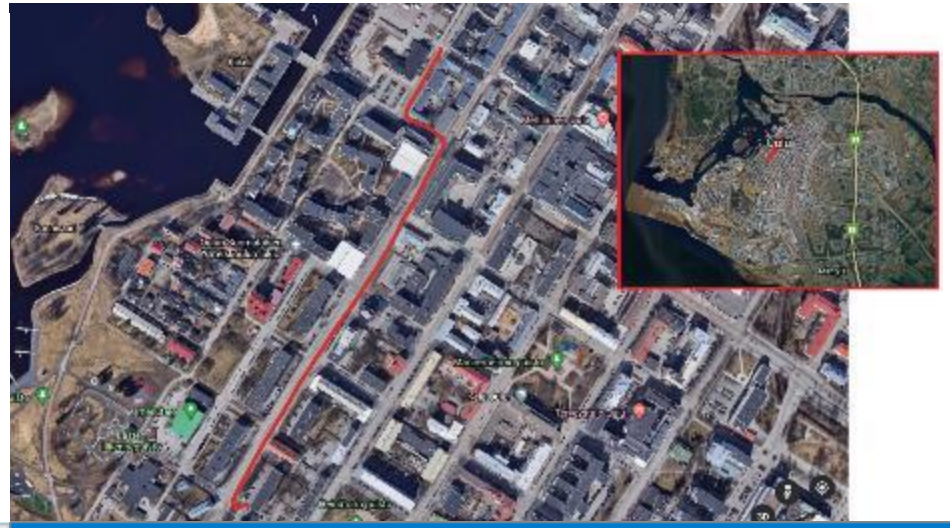
S8709A Virtual Drive Test Toolset Solution Overview

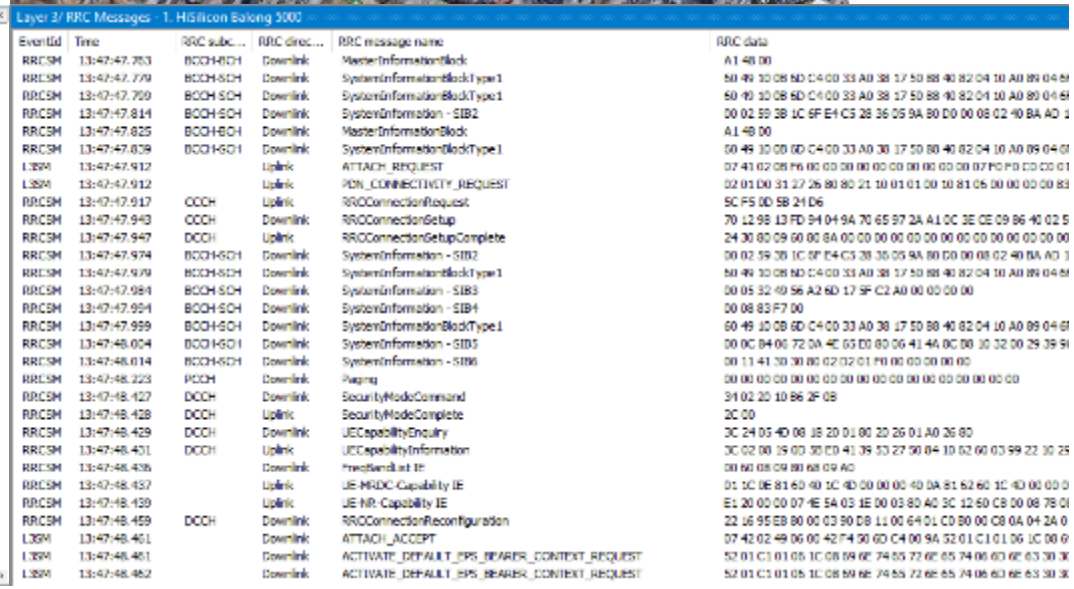
Nemo Tools
Records the field conditions

S8709A Virtual Drive Test Toolset Solution Overview

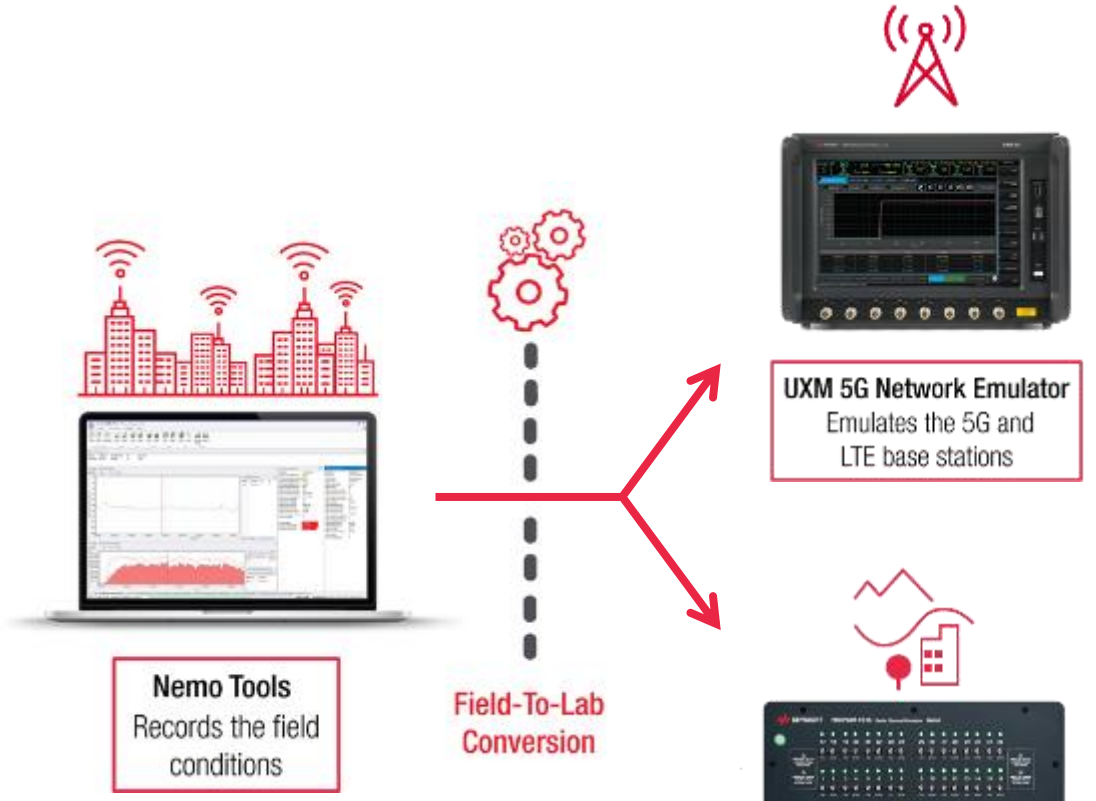
Detailed Data from Live network

- Channel Modelling
  - RSRP
  - 5G NR Channel Impulse Response
  - GPS data
- Signaling
  - Layer 3/RRC signaling
  - NR + LTE handovers





S8709A Virtual Drive Test Toolset Solution Overview



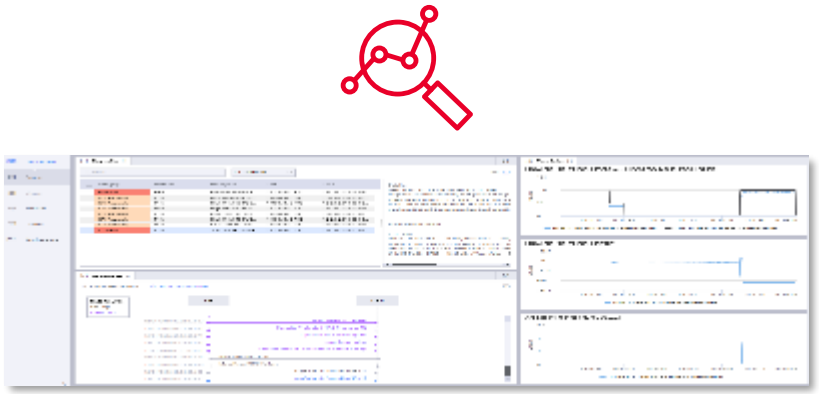
S8709A Virtual Drive Test Toolset Solution Overview

UXM 5G Network Emulator
Emulates the 5G and LTE base stations

PROPSIM 5G Channel Emulator
Replicates the field-measured channel conditions

Nemo Tools
Records the device under testing logs

Test System PC
Test case execution, analysis and reporting



Device Troubleshooting
Debugging/Analytics

Supported Tests

- The flexible and user-friendly UI enables effective testing for users with different levels of experience
  - Push button solution to replicate field scenario
  - Customization options for advanced users
- Virtual Drive Test builds on top of Keysight's NEMO field testing tools and global presence.
- Test case customizing is possible with state of the art signaling and channel modelling tools available for UXM and PROPSIM
  - Protocol R&D Toolset for network signalling script create/edit.
  - PROPSIM Geometric Channel Modeling tool for spatial (CDL, Umi/Uma) 3D models
- Capabilities for effective benchmarking to speed up the time-to-revenue of new 5G NR devices.

Network Operator Test Plans

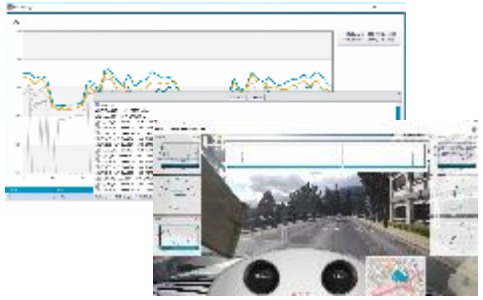
FIRST CLASS PERFORMANCE

- High performance in an advanced propagation environment set the first class of network operators
  - Verify new devices prior to market launch
  - Assure device and software interoperability
- Keysight can help network operators to benchmark success in real-world implementations
  - show case network segments, such as high-speed train.
  - Launch test plans based on field tests in the selected network segments.

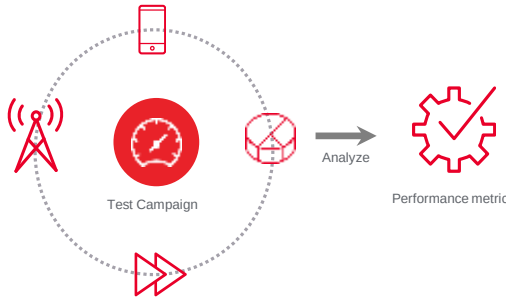
VDT 5G NR TC-01: Urban City test cases (NSA FR1)

Test Case Package

- Network operators have unique configurations.
  - Validate device combability and performance in different network signaling configurations
  - Network site planning and geography results result in varying Radio Channel Conditions
- Test scenarios resembling the conditions of typical urban areas in different parts of the world. test case package including the following groups of tests:
  - Urban city in Europe
  - City centers in US
  - Highways in US
  - Downtown with skyscrapers in Asia

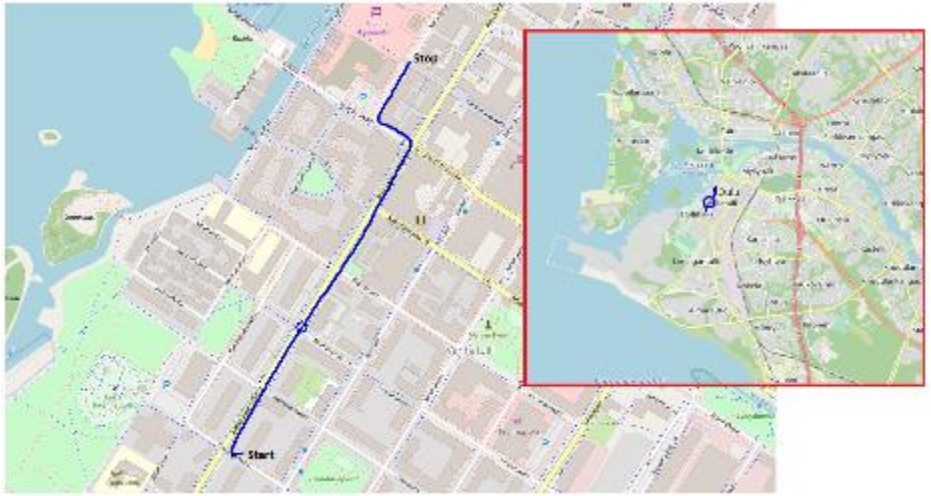


Keysight test case package



Replicate and re-run field conditions in the Lab

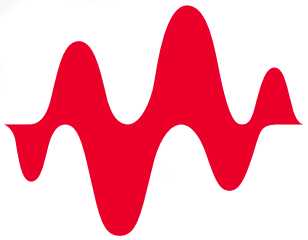
Analyze results



Duration: 2min 30s
Log: Oulu_City_2
Handovers: 3 x LTE+NR and 4 x LTE only

E7515B UXM 5G wireless test platform

PROPSIM FS16 5G RF Channel Emulator



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