Ensure 5G Network Deployments – Site Acceptance, Optimization and Benchmarking

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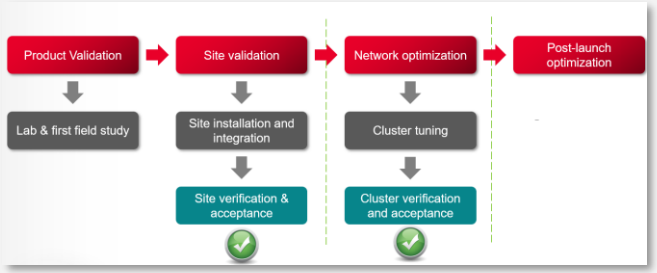
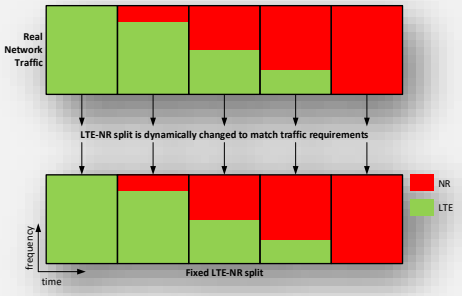
Agenda

Introduction to 5G network deployment

Network deployment process

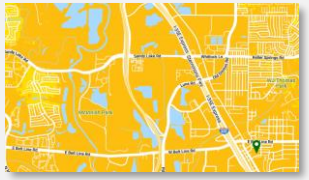


Network deployment configurations

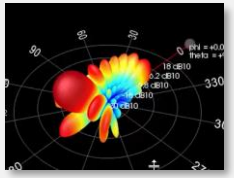


Acceptance testing

User experience

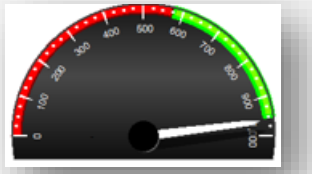


Coverage



Mobility

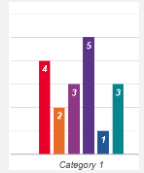
Throughputs



Site planning

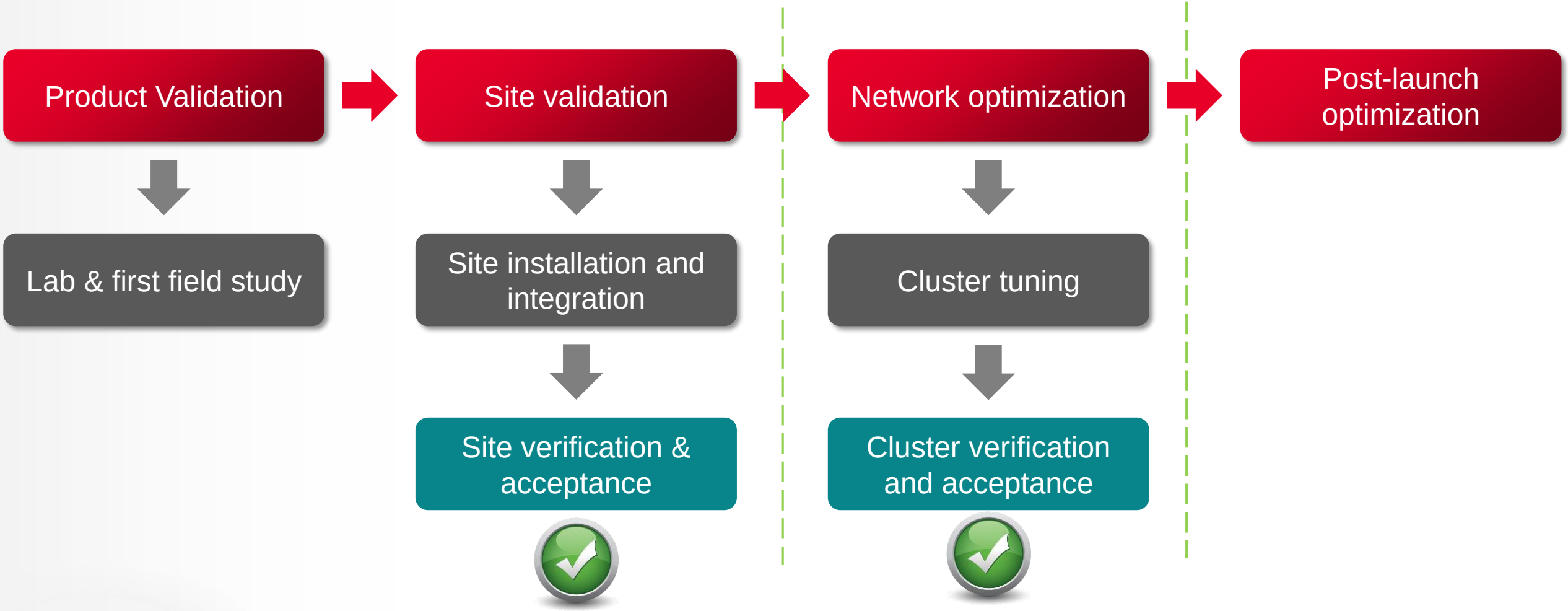
VoLTE/NR concurrency

Benchmarking



Introduction to 5G Network Deployment

Single Site Verification and Cluster Tuning are Critical Aspects of 5G Network Deployments



Frequency Range and Spectrum Availability Dictates Deployment Configurations

LTE Primary – 20 MHz

CC 1 – 20 MHz

CC2 – 20 MHz

\+ NR Carrier 60 MHz

LTE Primary – 20 MHz

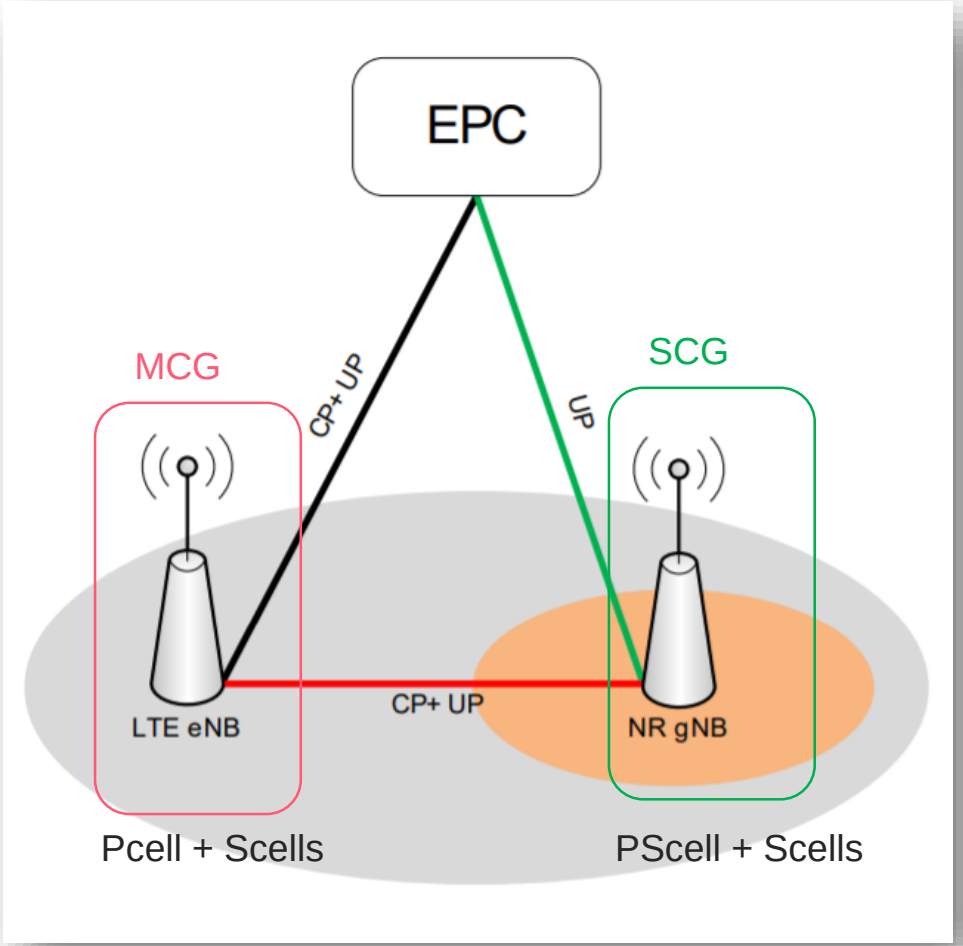
CC 1 – 20 MHz

CC2 – 10 MHz

CC3 – 10 MHz

\+ NR Carrier 5 MHz

FR1 deployment example



LTE Primary + NR primary Carrier 100 MHz

NR CC 1 – 100 MHz

NR CC 2 – 100 MHz

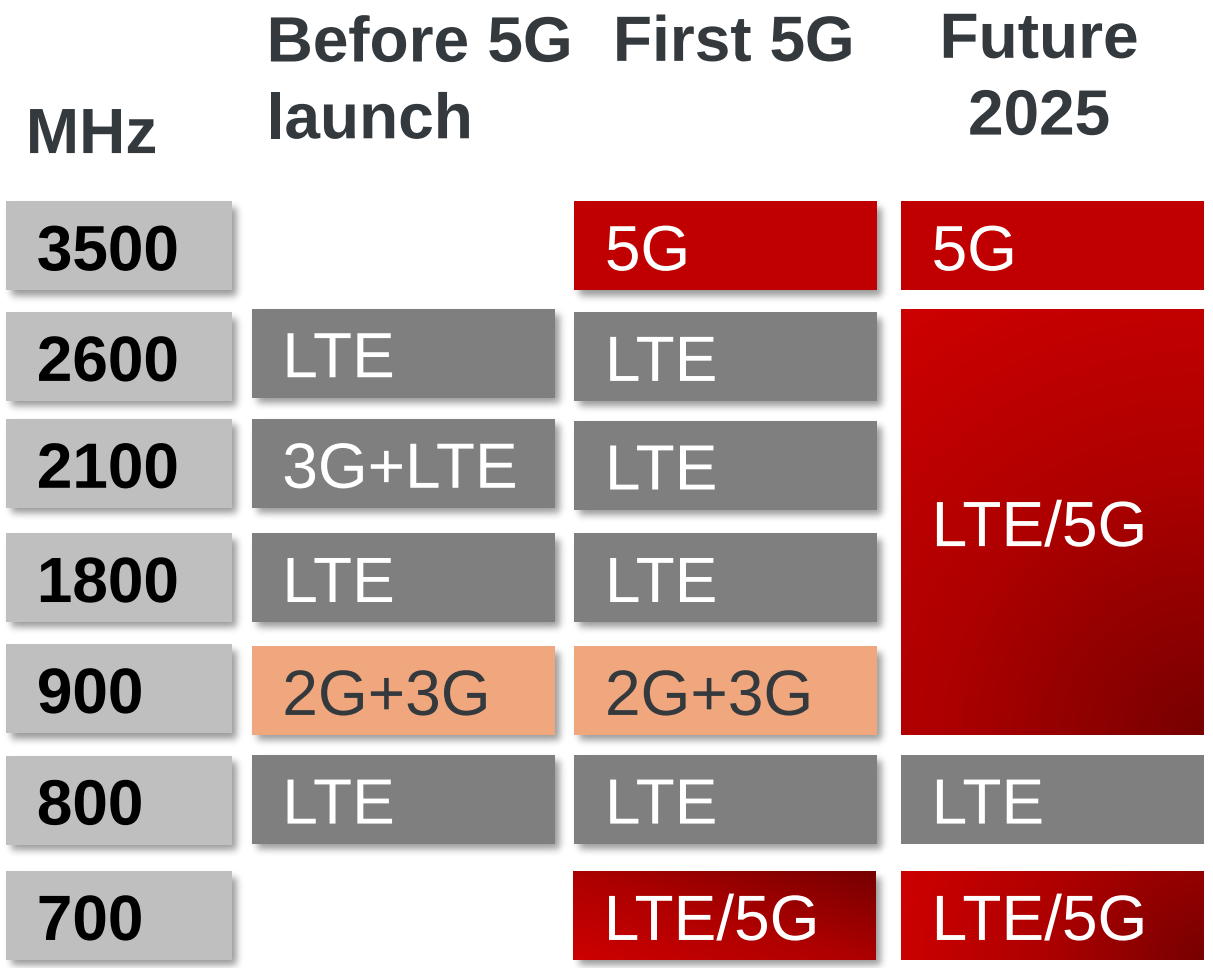
NR CC 3 – 100 MHz

NR CC 4 – 100 MHz

FR2 deployment example

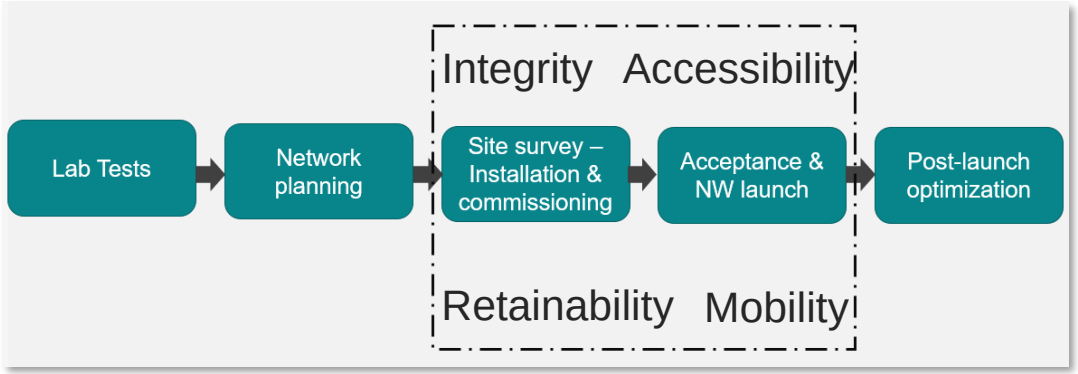
Spectrum Strategy Example- Dynamic Spectrum Sharing

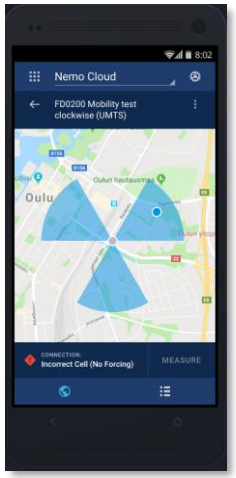
- First **5G** spectrum deployments were in **3.5 GHz** bands for capacity, and **low bands (700 MHz)** for coverage, eventually with LTE refarming
  - Low-band LTE refarming enables CA between NR in 3.5 GHz and NR in low bands
  - 800 MHz is normally left for coverage and VoLTE
- In a second phase, the **refarming of 3G 2100 MHz for LTE** would leave 900 MHz only for 2G/3G
  - 2G switch off depends on M2M utilization
- Next step would be a gradual introduction of **Dynamic Spectrum Sharing in the LTE Bands between 1800-2600 MHz**

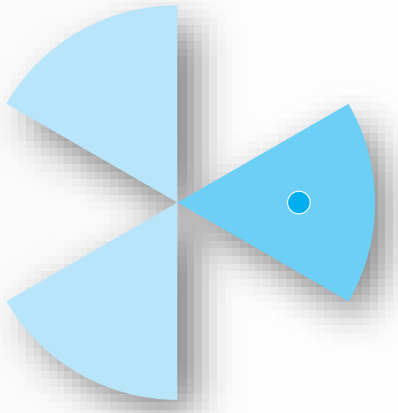


Acceptance Testing

Key to Success: Defining Acceptance Criteria Based on User Experience

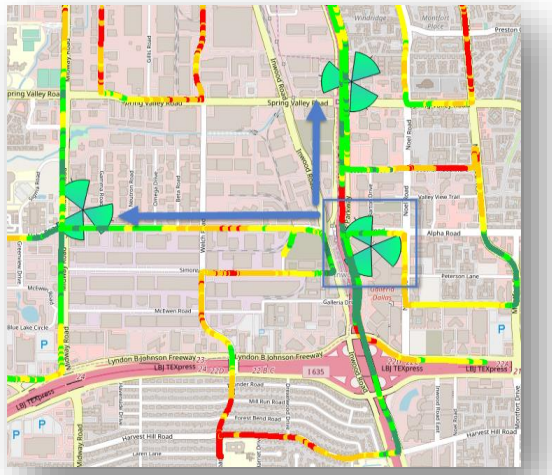






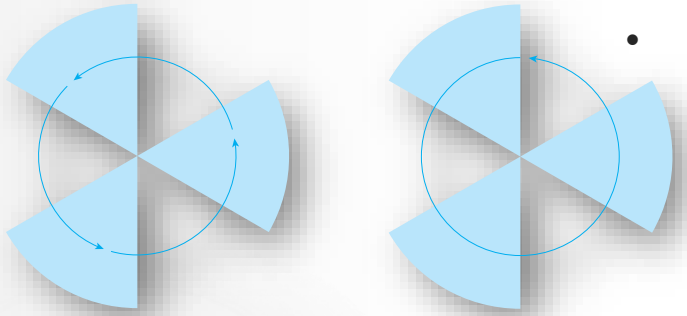
Per cell Stationary tests:

- Beam coverage validation
- Peak throughputs
- Latency
- MIMO related issues
- Modulation
- Rank
- LTE + NR bearer utilization
- RACH



Inter-site mobility tests:

- Inter-site handover success
- Handover interruption time
- Cell coverage footprint validation
- Average throughput
- RACH



Intra-site mobility tests:

- Intra-site handovers success
- Handover interruption time
- RACH

Quantifying User Experience is Key

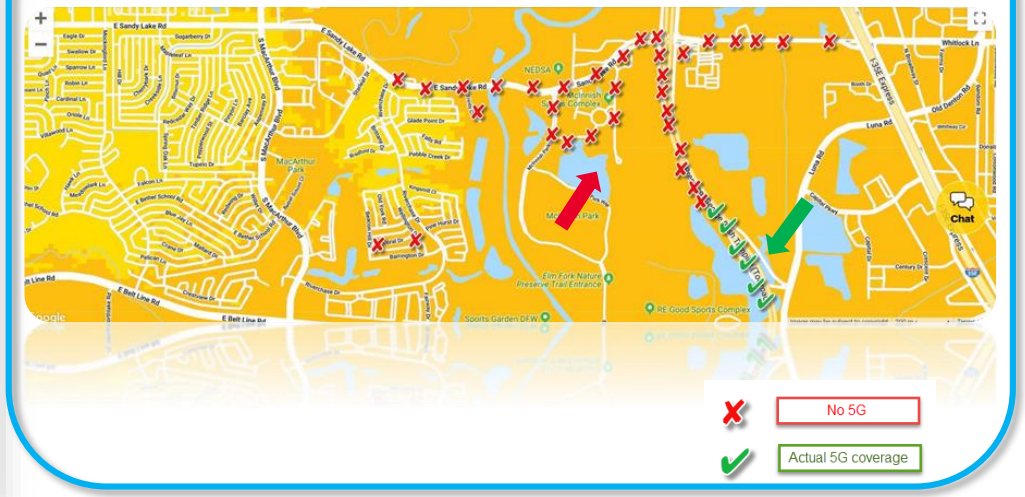
EventId	Time	RRC su...	RRC dir...	RRC message name	RACH reason
L3SM	14:39:24.267	1	Uplink	ATTACH_REQUEST	
L3SM	14:39:24.399		Uplink	PDN_CONNECTIVITY_REQUEST	
RRCSM	14:39:24.399	CCCH	Uplink	RRCConnectionRequest	
RACHI	14:39:24.399				
RRCSM	14:39:24.399	CCCH	Downlink	RRCConnectionSetup	
RRCSM	14:39:24.399	DCCH	Uplink	RRCConnectionSetupComplete	
RRCSM	14:39:24.421	BCCH-S...	Downlink	SystemInformation - SIB4	
RRCSM	14:39:24.428	DCCH	Downlink	DLInformationTransfer	
L3SM	14:39:24.428		Downlink	IDENTITY_REQUEST	
L3SM	14:39:24.428		Uplink	IDENTITY_RESPONSE	
RRCSM	14:39:24.428	DCCH	Uplink	ULInformationTransfer	
RRCSM	14:39:24.431	BCCH-S...	Downlink	SystemInformation - SIB5	
RRCSM	14:39:24.434	BCCH-S...	Downlink	SystemInformation - SIB5	
RRCSM	14:39:24.441	BCCH-S...	Downlink	SystemInformation - SIB6	
RRCSM	14:39:24.457	DCCH	Downlink	DLInformationTransfer	
L3SM	14:39:24.458		Downlink	ESM_INFORMATION_REQUEST	
L3SM	14:39:24.458		Uplink	ESM_INFORMATION_RESPONSE	
RRCSM	14:39:24.458	DCCH	Uplink	ULInformationTransfer	
RRCSM	14:39:24.810	PCCH	Downlink	Paging	
RRCSM	14:39:24.972	DCCH	Downlink	SecurityModeCommand	
RRCSM	14:39:24.973	DCCH	Uplink	SecurityModeComplete	
RRCSM	14:39:24.993	DCCH	Downlink	UECapabilityEnquiry	
RRCSM	14:39:25.032	DCCH	Uplink	UECapabilityInformation	
RRCSM	14:39:25.032		Uplink	INTER_RAT_HANDOVER_INFO	
RRCSM	14:39:26.412	D	2 Downlink	UECapabilityEnquiry	
RRCSM	14:39:26.412	DCCH	Uplink	UECapabilityInformation	
RRCSM	14:39:26.412	DC	3 Downlink	RRCConnectionReconfiguration	
RRCSM	14:39:26.615	DCCH	Uplink	RRCConnectionReconfiguration...	
L3SM	14:39:26.615		Downlink	ACTIVATE_DEFAULT_EPS_BEA...	
L3SM	14:39:26.615		Downlink	ATTACH_ACCEPT	
L3SM	14:39:27.018		Uplink	ATTACH_COMPLETE	
L3SM	14:39:27.018		Uplink	ACTIVATE_DEFAULT_EPS_BEA...	
RRCSM	14:39:27.018	DCCH	Uplink	ULInformationTransfer	
RRCSM	14:39:27.018	DCCH	Downlink	DLInformationTransfer	
L3SM	14:39:27.018		Downlink	EMM_INFORMATION	
RRCSM	14:39:27.108	DC	4 Uplink	MeasurementReport	
RRCSM	14:39:27.431	DCCH	Downlink	RRCConnectionReconfiguration	5
RRCSM	14:39:27.431	BCCH-BCH	Downlink	MIB	6
RRCSM	14:39:27.431	DCCH	Uplink	RRCConnectionReconfiguration...	
RACHI	14:39:27.431				
RRCSM	14:39:27.431	BCCH-S...	Downlink	SystemInformation - SIB4	
RRCSM	14:39:27.431	BCCH-S...	Downlink	SystemInformation - SIB5	
RRCSM	14:39:27.431	BCCH-S...	Downlink	SystemInformation - SIB6	
RRCSM	14:39:27.431	BCCH-BCH	Downlink	MIB	
RACHI	14:39:27.431			7	Channel request
L3SM	14:39:27.431		Uplink	PDN_CONNECTIVITY_REQUEST	

Layer 3/ RRC Messages - 1. Qualcomm (Filtered)

EventId	Time	RRC su...	RRC dir...	RRC message name
RACHI	11:06:42.186			
RRCSM	11:06:42.198	DCCH	Downlink	RRCConnectionReconfiguration
RRCSM	11:06:42.209	DCCH	Uplink	RRCConnectionReconfigurationComplete
RRCSM	11:06:42.209	DCCH	Uplink	MeasurementReport
RRCSM	11:06:42.237	DCCH	Downlink	UECapabilityEnquiry
RRCSM	11:06:42.250	DCCH	Uplink	UECapabilityInformation
RRCSM	11:06:42.250	DCCH	Downlink	UEInformationRequest
RRCSM	11:06:42.250	DCCH	Uplink	UEInformationResponse
RRCSM	11:06:42.280	BCCH-S...	Downlink	SystemInformation - SIB2
RRCSM	11:06:42.319	BCCH-S...	Downlink	SystemInformation - SIB5
RRCSM	11:06:42.330	DCCH	Downlink	RRCConnectionReconfiguration
RRCSM	11:06:42.346	DCCH	Uplink	RRCConnectionReconfigurationComplete
RRCSM	11:06:42.398	DCCH	Downlink	RRCConnectionReconfiguration
RRCSM	11:06:42.433	DCCH	Uplink	RRCConnectionReconfigurationComplete
RRCSM	11:06:43.387	BCCH-BCH	Downlink	MIB
RRCSM	11:06:52.464	DCCH	Uplink	MeasurementReport
RRCSM	11:06:54.504	DCCH	Uplink	MeasurementReport
RRCSM	11:06:54.594	DCCH	Downlink	RRCConnectionReconfiguration
RRCSM	11:06:54.619	DCCH	Uplink	RRCConnectionReconfigurationComplete
RACHI	11:06:54.635			
RRCSM	11:06:54.647	DCCH	Downlink	RRCConnectionReconfiguration

5G

Tier 1 operator 5G coverage map



Acceptance Criteria – Focus on Beams

- Coverage
  - **SS-RSRP -98dBm** used as out-of-coverage threshold to filter all other results
  - **Mobility**
    - Successful handovers - clockwise and counterclockwise
    - Handover interruption time

PCI-Beam Analysis

ARFCN_PCI 635322_70

Beams detected			Beam SS-RSRP Statistics						
	% of total	STATUS	Total	Passed	Average	MEAS	THRESHOLD	TARGET	STATUS
Beam_index 0	16.61%	Pass-Non mandatory	394,023	21,205	-104.08	5.38%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 1	16.39%	Pass-Non mandatory	388,971	5,062	-106.11	1.30%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 2	12.95%	Pass-Non mandatory	307,187	134,886	-95.37	43.91%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 3	9.34%	Pass-Non mandatory	221,557	9,999	-109.69	4.51%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 4	15.05%	Pass-Non mandatory	357,164	146,417	-97.12	40.99%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 5	14.93%	Pass-Non mandatory	354,275	120,842	-96.77	34.11%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 6	14.73%	Pass-Non mandatory	349,546	25,231	-100.54	7.22%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 7	0.00%	Fail-Non mandatory				--	>=-90dBm	>90%	--
Beam index unknown	0.00%					--	>=-90dBm	>90%	--

ARFCN_PCI 635322_71

Beams detected			Beam SS-RSRP Statistics						
	% of total	STATUS	Total	Passed	Average	MEAS	THRESHOLD	TARGET	STATUS
Beam_index 0	14.91%	Pass-Non mandatory	274,247	30,394	-105.09	11.08%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 1	7.62%	Pass-Non mandatory	140,040	23,799	-99.45	16.99%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 2	9.85%	Pass-Non mandatory	181,200	15,164	-102.38	8.37%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 3	16.81%	Pass-Non mandatory	309,079	7,526	-107.91	2.43%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 4	14.24%	Pass-Non mandatory	261,801	17,702	-105.28	6.76%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 5	22.33%	Pass-Non mandatory	410,575	125,777	-102.15	30.63%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 6	14.24%	Pass-Non mandatory	261,851	52,722	-102.28	20.13%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 7	0.00%	Fail-Non mandatory				--	>=-90dBm	>90%	--
Beam index unknown	0.00%					--	>=-90dBm	>90%	--

ARFCN_PCI 635322_69

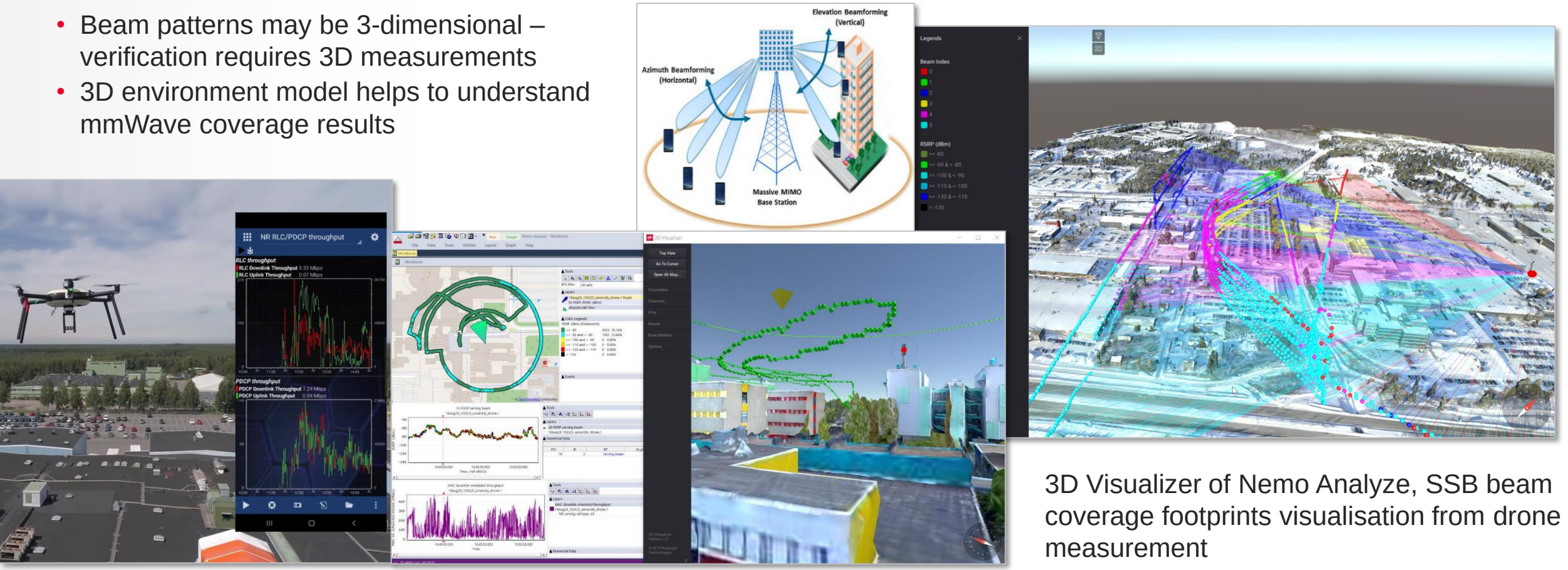
Beams detected			Beam SS-RSRP Statistics						
	% of total	STATUS	Total	Passed	Average	MEAS	THRESHOLD	TARGET	STATUS
Beam_index 0	19.81%	Pass-Non mandatory	273,683	101,846	-94.54	37.21%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 1	9.27%	Pass-Non mandatory	128,062	68,063	-92.99	53.15%	>=-90dBm	>90%	Fail-Non mandatory

5G NR Acceptance (scanner) | Beam statistics (UE) | Beam statistics (scanner) | Map plots (UE) | Map plots (scanner)

Nemo Analyze 5G acceptance report with SSB Beam check

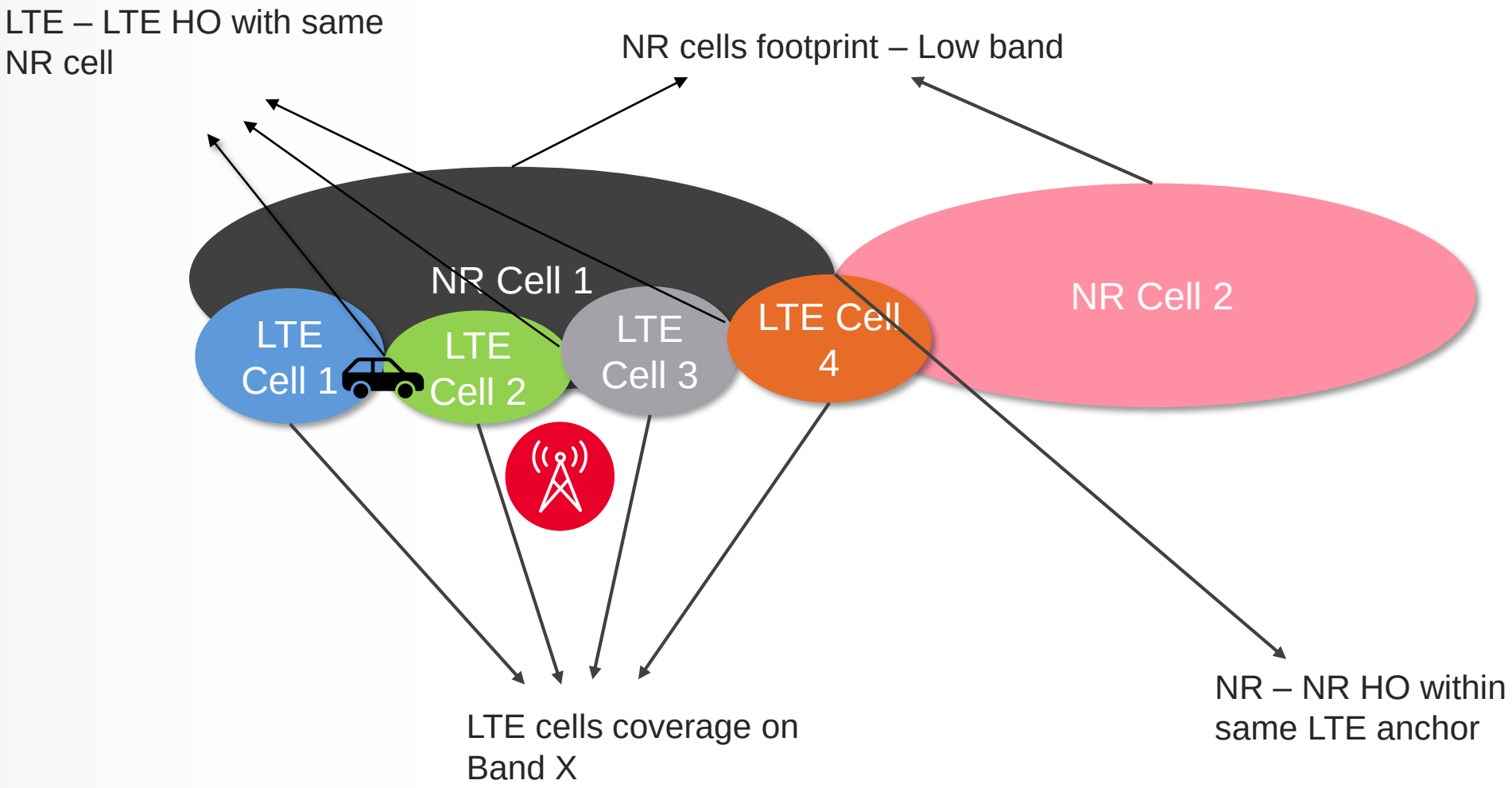
Beam Coverage Validation Requires 3D Measurements and Visualization

- Beam patterns may be 3-dimensional – verification requires 3D measurements
- 3D environment model helps to understand mmWave coverage results

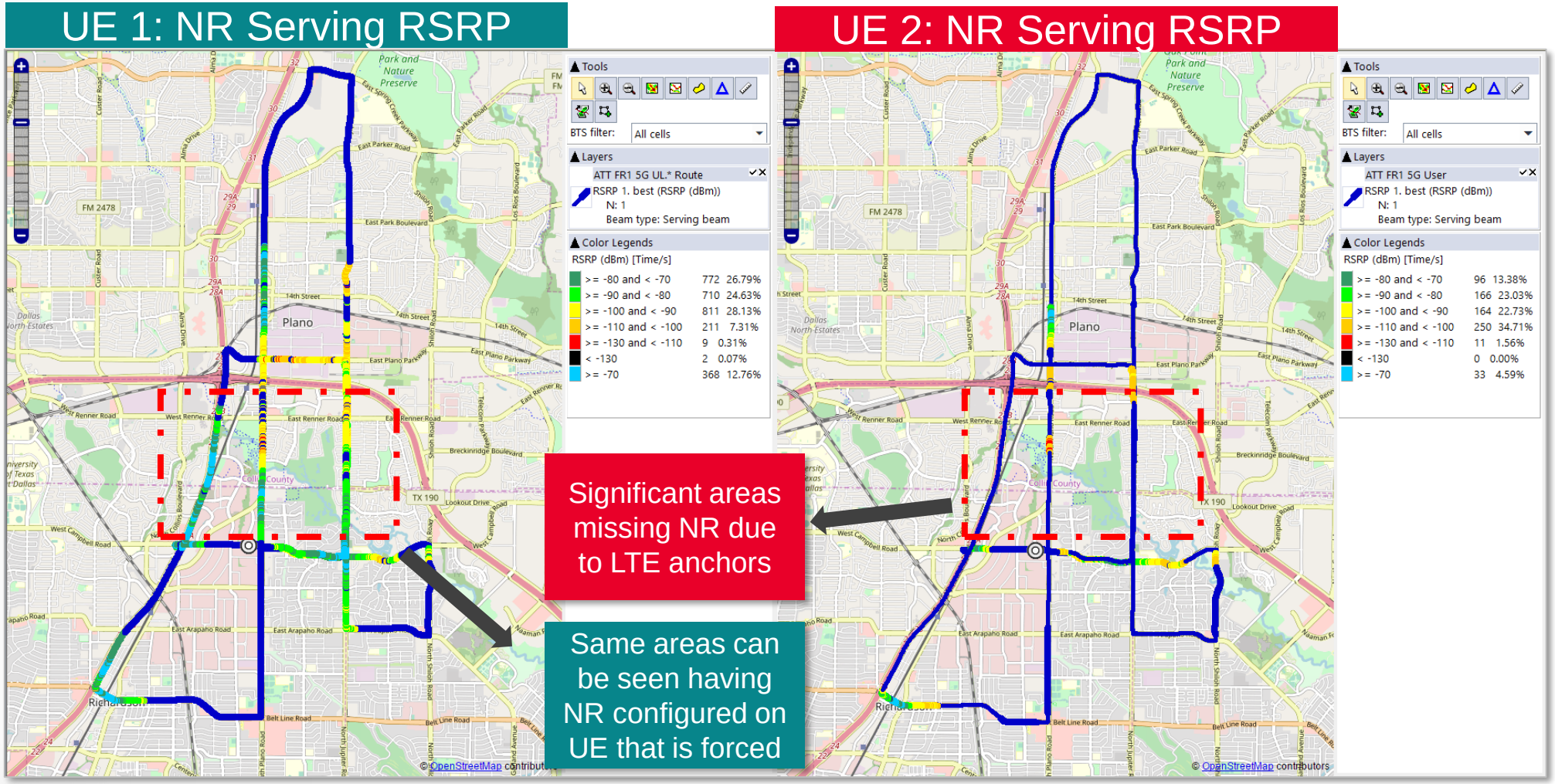


3D Visualizer of Nemo Analyze, SSB beam coverage footprints visualisation from drone measurement

Mobility Testing: NR in Lower Band Increases Complexity

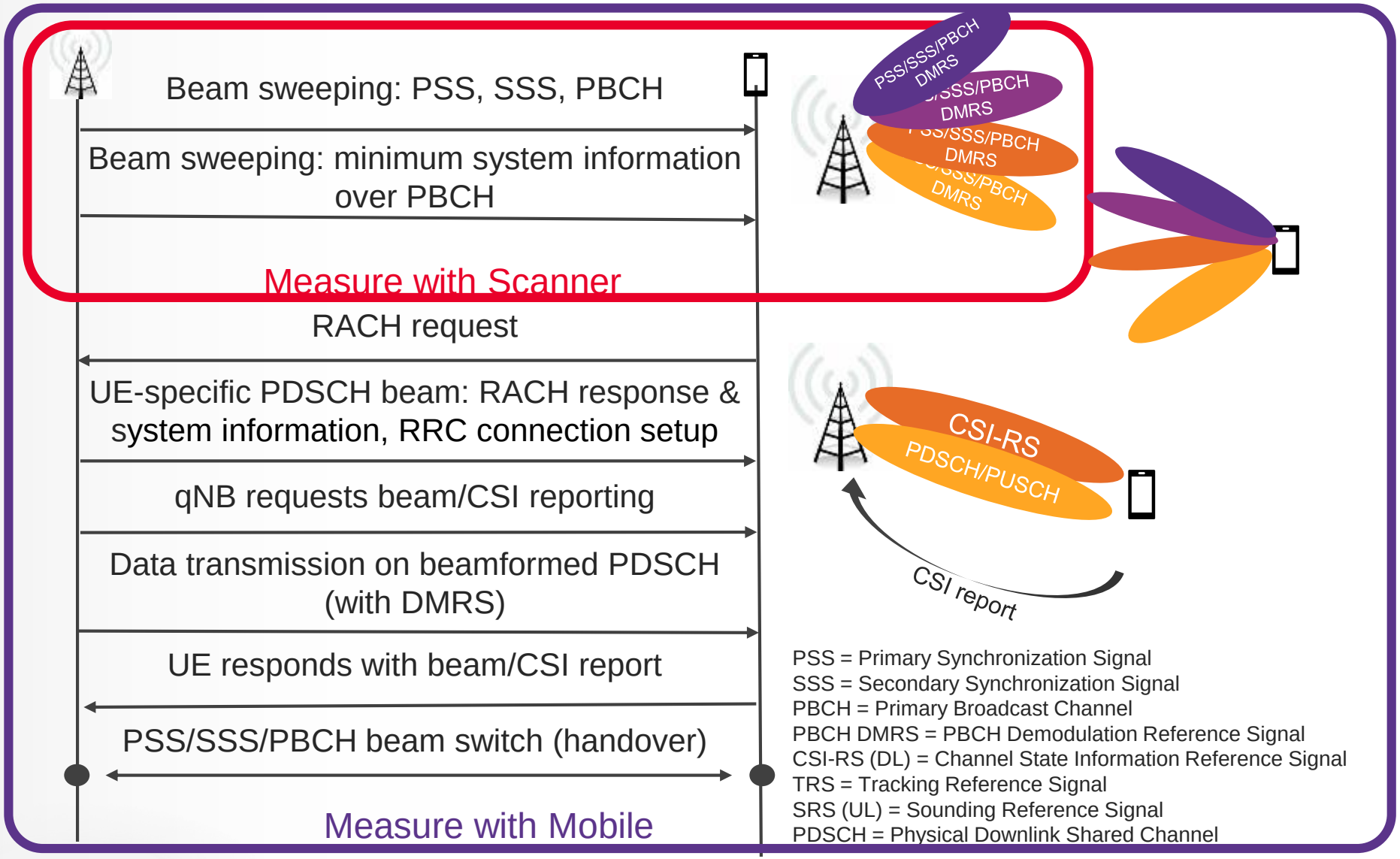


Mobility Testing: NR – LTE Pre-Defined Band Combinations Poses Coverage Challenges



UE 1– Forced to LTE NSA anchor bands + NR
UE 2– No forcing. User Experience

Scanner Measurements Capture SSB From Multiple Cells

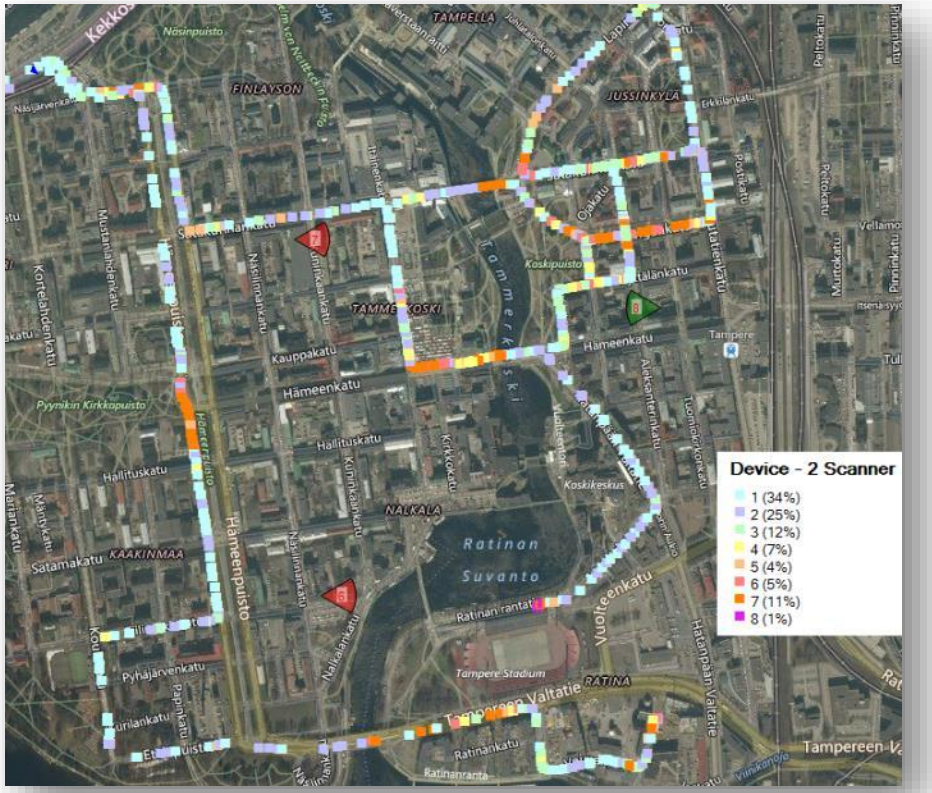


PSS = Primary Synchronization Signal
SSS = Secondary Synchronization Signal
PBCH = Primary Broadcast Channel
PBCH DMRS = PBCH Demodulation Reference Signal
CSI-RS (DL) = Channel State Information Reference Signal
TRS = Tracking Reference Signal
SRS (UL) = Sounding Reference Signal
PDSCH = Physical Downlink Shared Channel

Inter-Site Beam Pollution Increases Interference

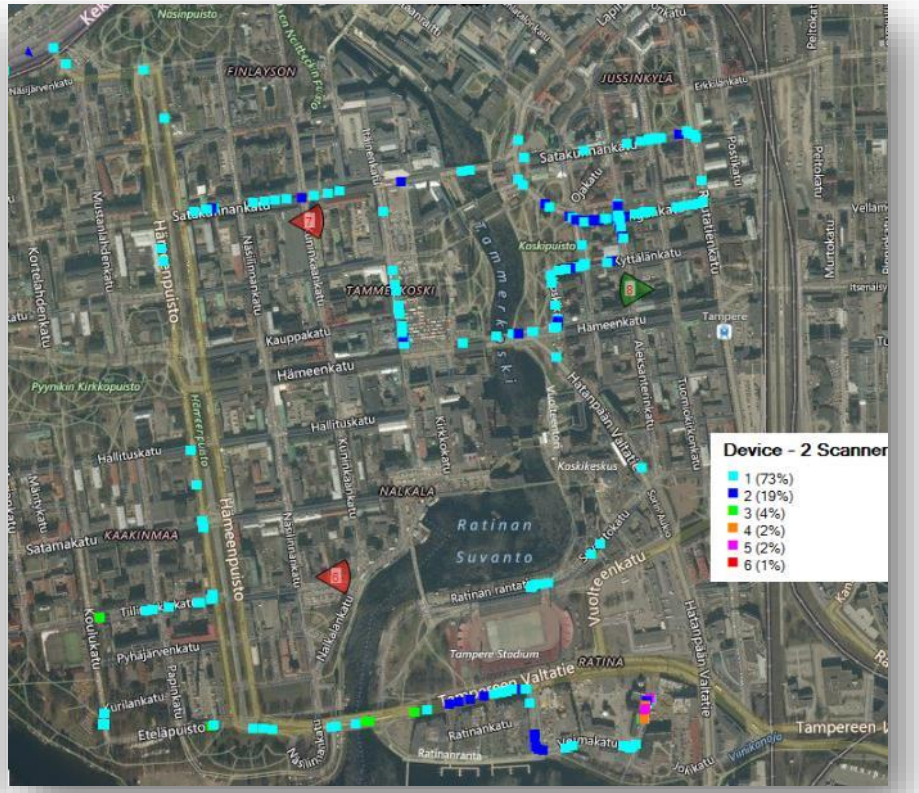
- Troubleshooting
  - Poor Coverage
  - Possible Interference
  - Numbers of Servers
  - Numbers of Beams
  - Numbers of Beams for PCI
  - Number of Servers Within Threshold
  - Number of Beams Within Threshold
  - Number of Beams for PCI Within Threshold

Number of Beams



Number of beams above coverage threshold by location

Number of Strong Beams



Number of beams above coverage threshold and within 5 dB of best server

Various Test Cases Required to Validate Throughput Performance

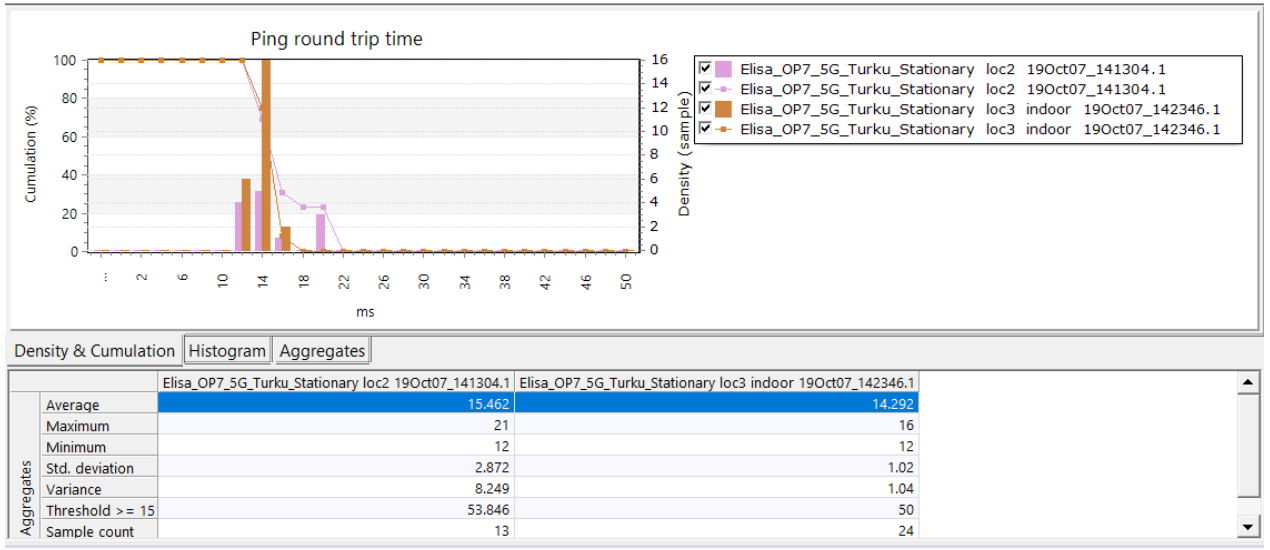
Config	Customer/test case	Peak rate DL (NR only)	Avg rate DL (NR only)	Avg rate UL (NR only)
100MHz BW, Rank 4, 256QAM, FR1	MNO1 cell centre	1.2Gbps	800Mbps	195Mbps
100MHz BW, Rank 4, 256QAM, FR1	MNO1 cell mid range	700Mbps	500Mbps	90Mbps
100MHz BW, Rank 4, 256QAM, FR1	MNO1 cell edge	400Mbps	350Mbps	50Mbs
60MHz BW, Rank 4, 256QAM, FR2, MU-MIMO LTE in use	MNO2	900Mbps (1600Mbps LTE + NR (60MHz+60MHz))		
100MHz BW, Rank 4, 256QAM, FR1	Nemo test Sep 2019, Elisa live NW, Huawei infra, Nemo Handy on Oneplus Pro 5G	736Mbps		

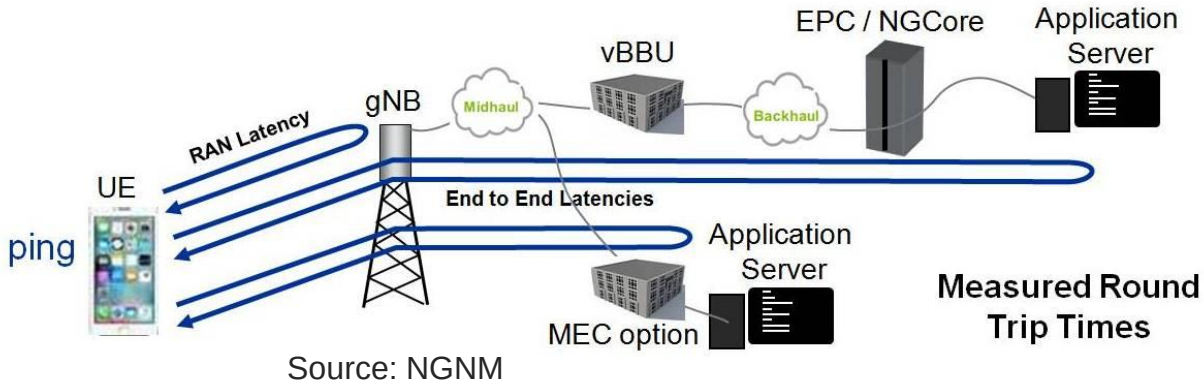
Acceptance Criteria – Latency Examples From The Field

LATENCY, EMBB USE CASE

Initial acceptance tests latency is tested as E2E round trip with ping.

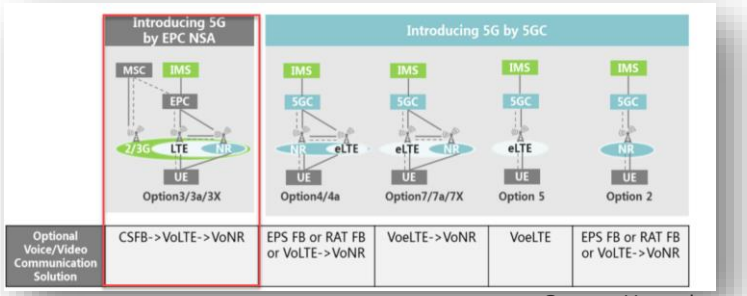
Criteria	Max E2E Latency
NGNM 200km between NR node and EPC/NGCore	10-15ms
MNO1 cell centre	10ms
MNO1 cell mid range	13ms
MNO1 cell edge	15ms
MNO2	75ms
Nemo test, Elisa live NW, Huawei infra, OnePlus Pro 5G Nemo Handy	15ms





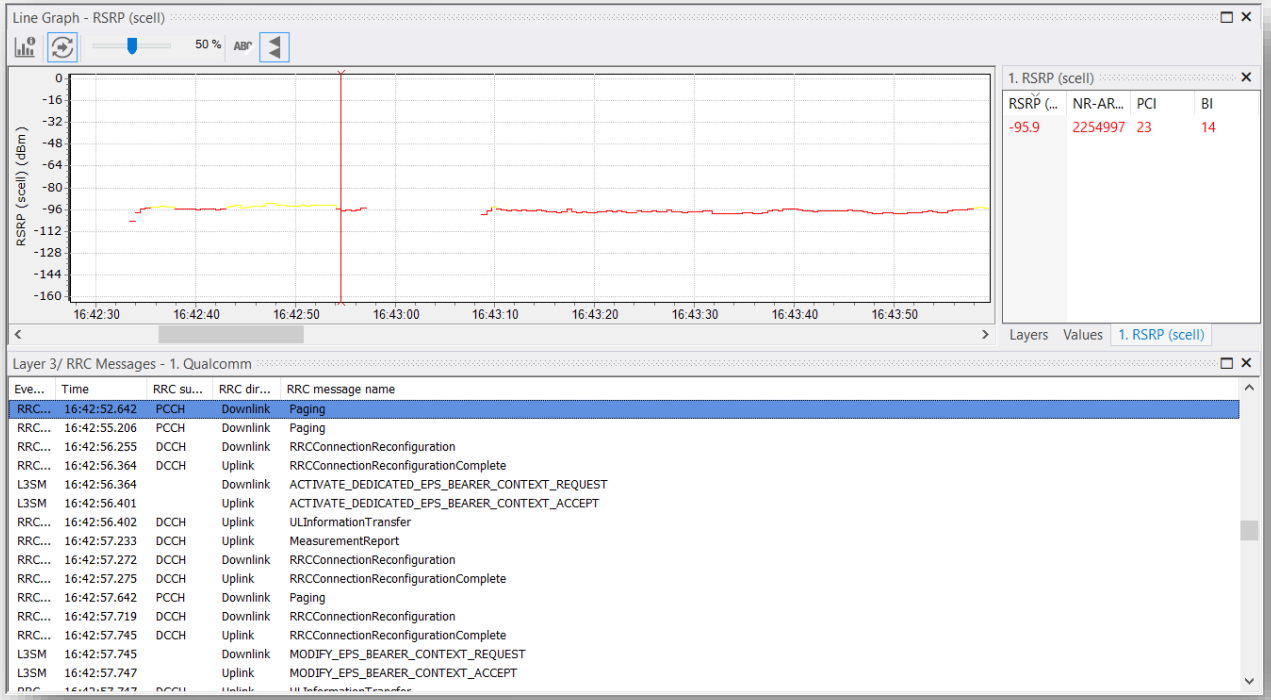
Source: NGNM

VoLTE/NR Concurrency: Measure and Ensure VoLTE Does Not Interrupt 5G

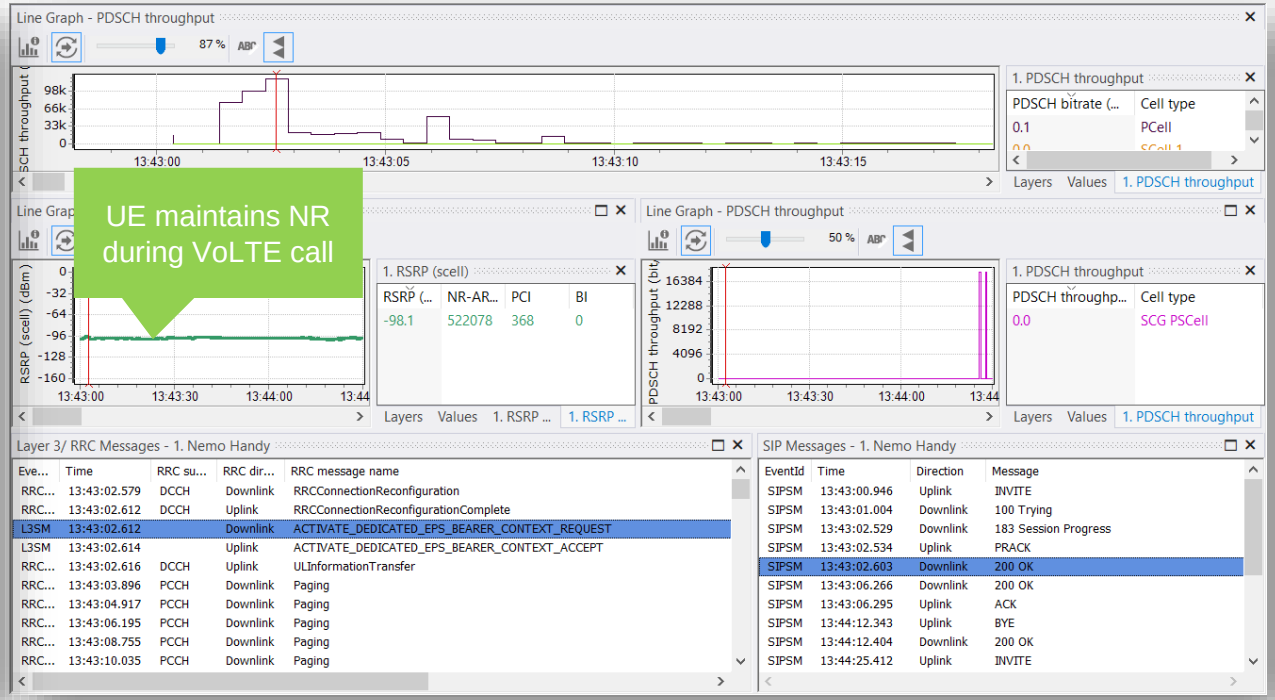


Source: Huawei

Operator 1: Loss of 5G due to VoLTE call

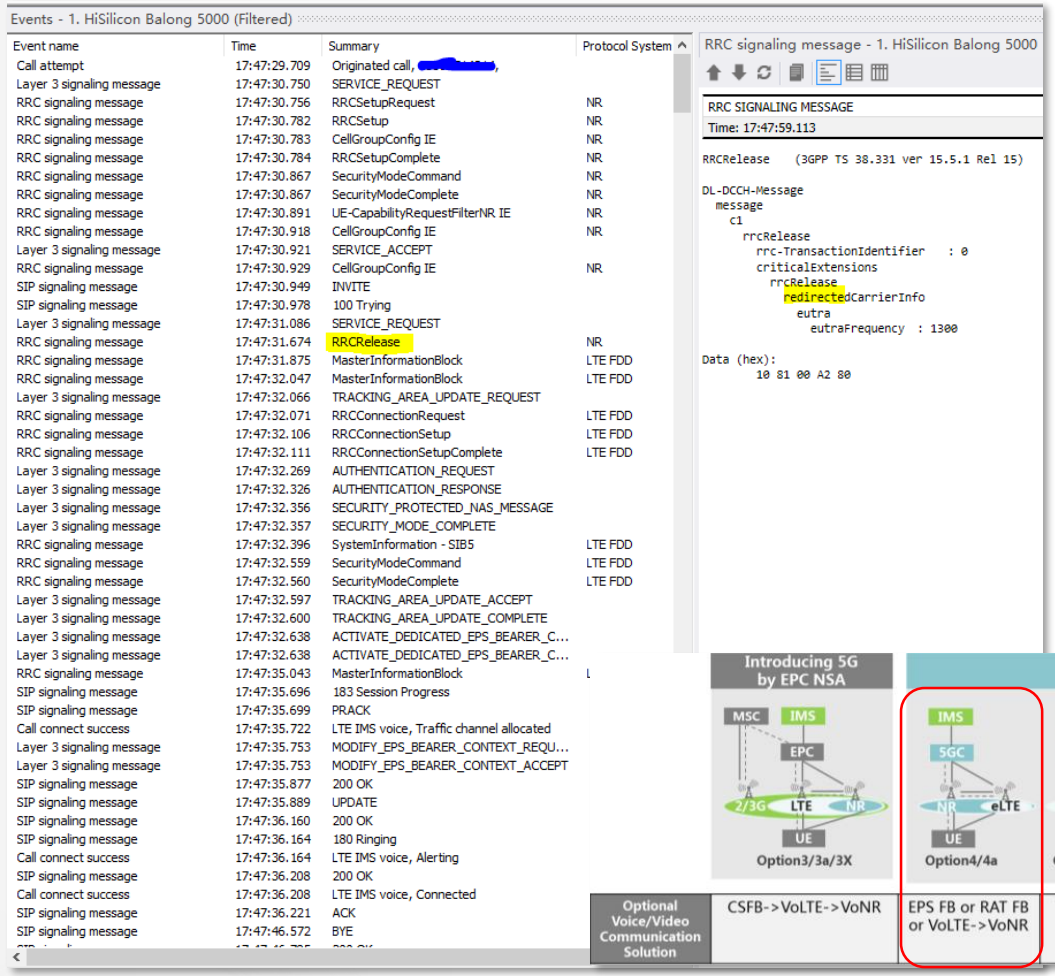


Operator 2: VoLTE – NR concurrency

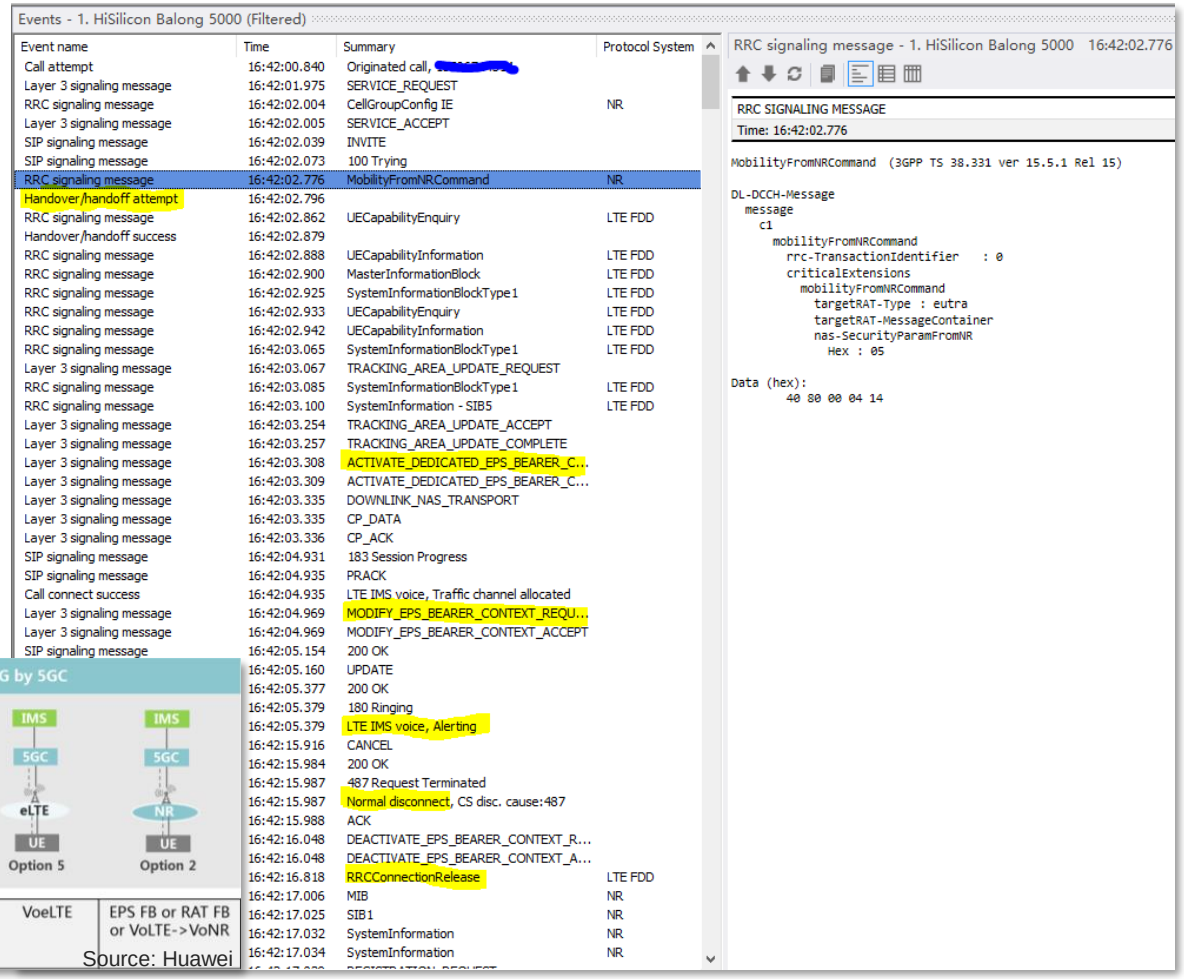


VoNR: Similar to CSFB, EPS Fallback Needs Validation

IMS call EPS FB - Redirection



IMS call EPS FB - HO



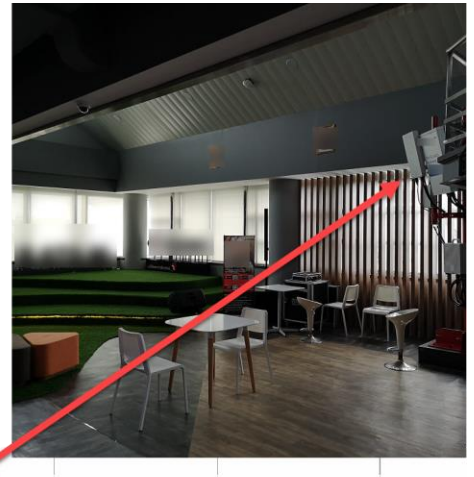
Source: Huawei

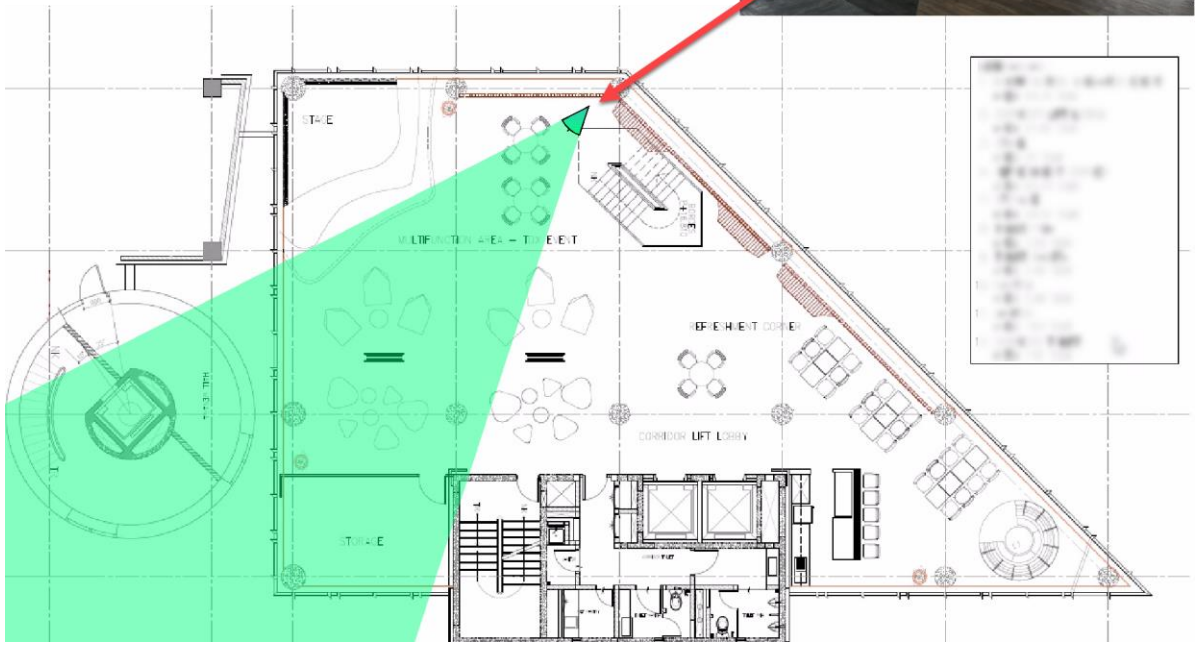
5G Indoor Testing: Site Location Planning and Baselining Ensure Good Coverage

- FR1=3.5GHz
- FR2=28GHz
- Both FR1 and FR2 gNB antenna in the same location, same direction, see picture
- gNB Tx power configuration
  - FR1 total TX power: 1W
  - FR2 total TX power: 2W
  - FR1 BW: 100MHz, FR2 BW: 4x100MHz
  - → SS-RS TX power ~-2dBm for both FR1 and FR2
- Measurement devices
  - HBFlex scanner
  - WNC router with Speedtest.net download active tests

WNC 5G hotspot

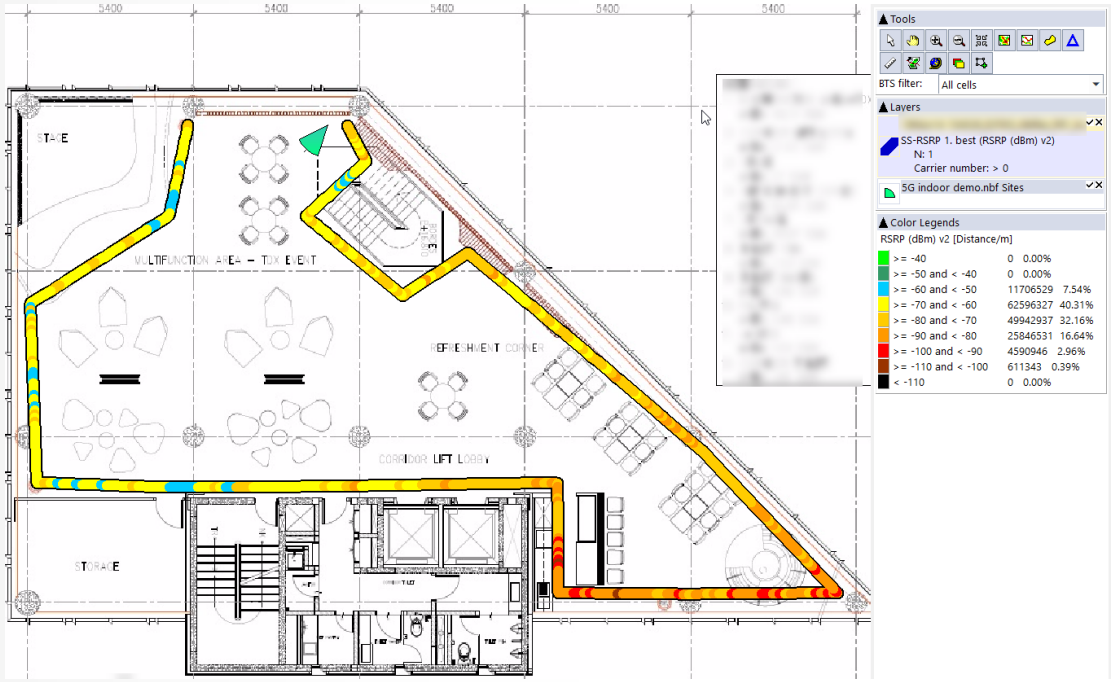
PcTel HBFlex Scanner



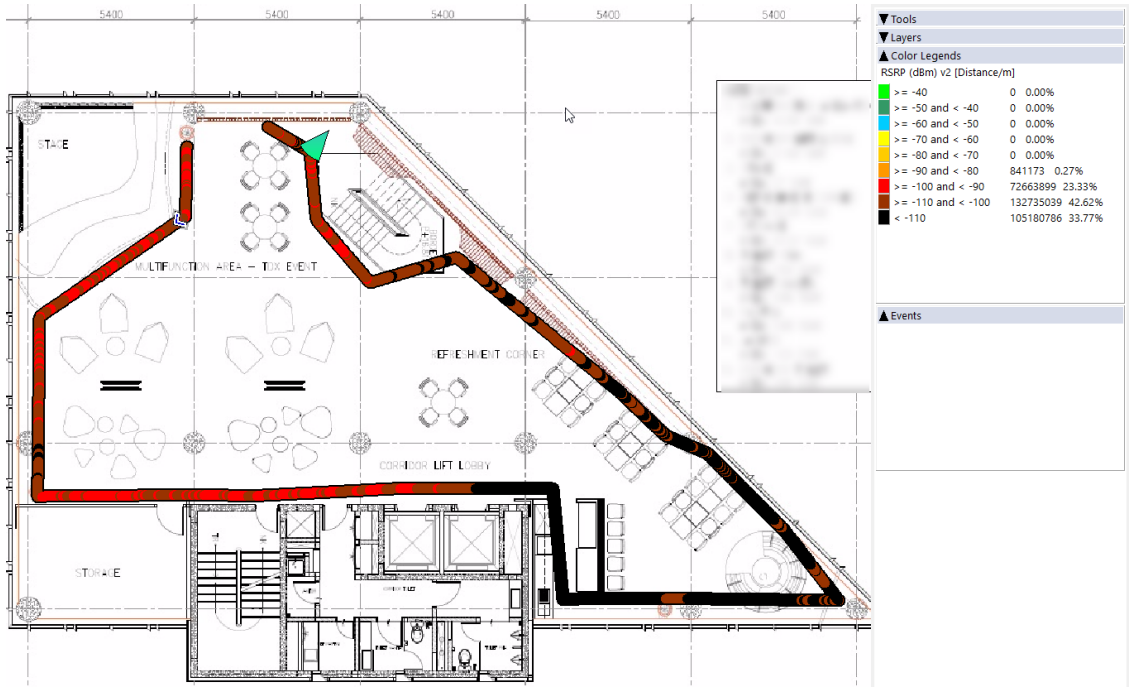


5G Indoor Test: Measurements With Active Beamforming are Required for Optimization

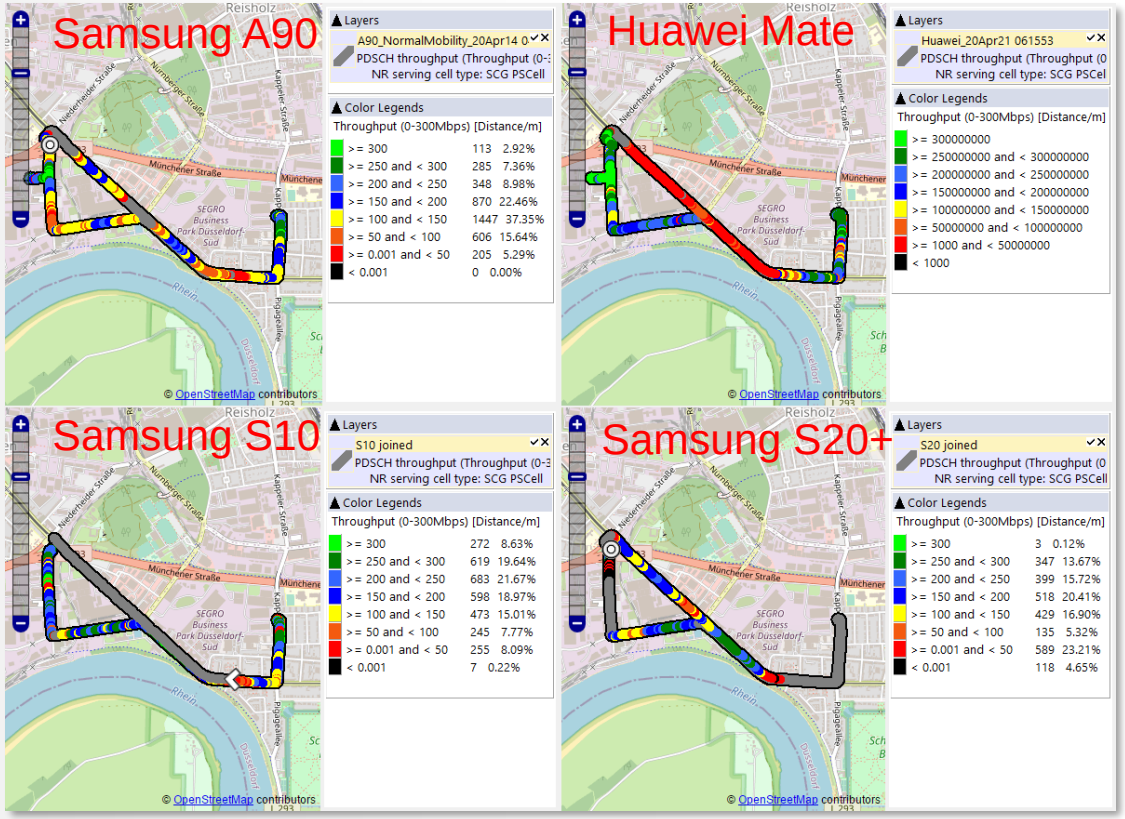
FR1: SS-RSRP Best

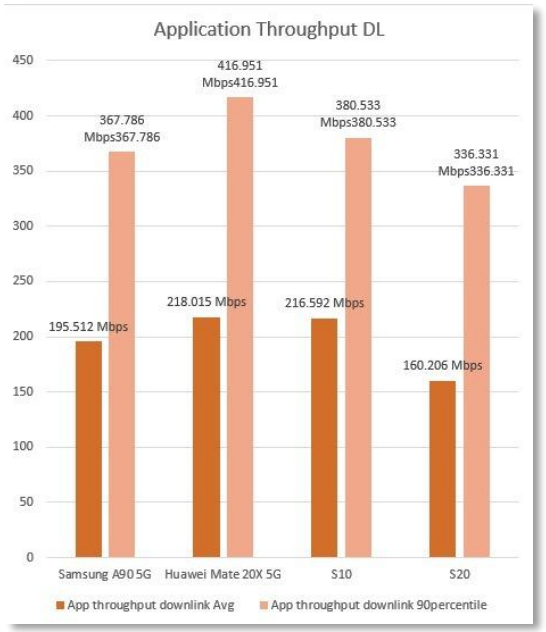


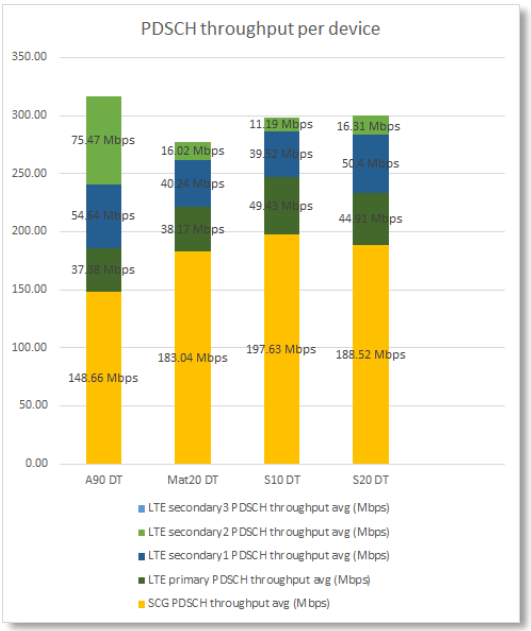
FR2: SS-RSRP Best



Benchmarking: Segue to Post-Launch Optimization



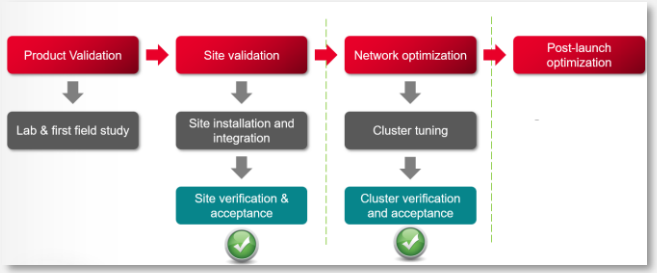




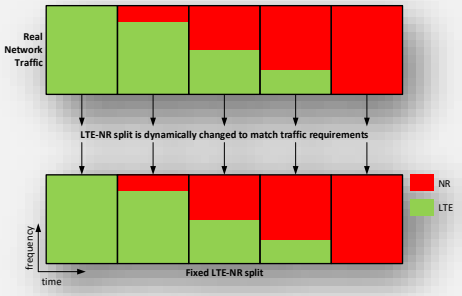
Summary

Introduction to 5G network deployment

Network deployment process

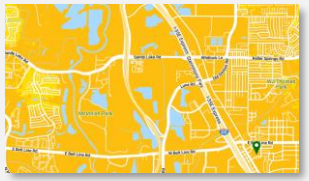


Network deployment configurations

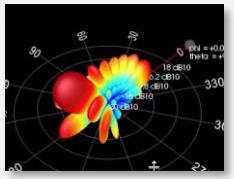


Acceptance testing

User experience

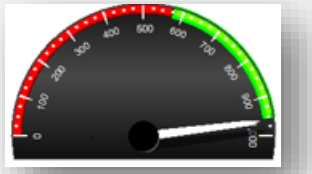


Coverage



Mobility

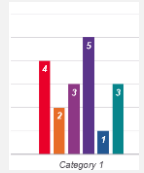
Throughputs



Site planning

VoLTE/NR concurrency

Benchmarking



Keysight Nemo Test and Measurement Products

Measurement


Nemo Handy


Nemo Outdoor


Nemo Walker Air


Nemo Walker Air


Nemo Intelligent Device Interface


Nemo Invex II


Nemo Customer Experience Monitor


Nemo Autonomous Probe

Network Rollout

Network Optimization

Network Benchmarking

Network Monitoring

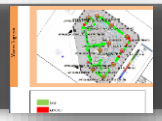
Measurement Automation

Nemo Cloud


Remote Control and Monitoring

Analytics

Nemo Xynergy


Distributed Antenna (DAS) / Small Cell

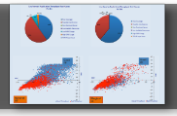

Network Management


Drive Test


Geospatial Intelligence

Post-processing and Network Analytics

Nemo WindCatcher



Nemo Analyze

Thank You!

Resources:

Finding Nemo: https://www.keysight.com/en/pc-2767981/nemo-wireless-network-solutions?cc=US&lc=eng

Understand the quality and performance of your live 5G NR network with Keysight's Nemo solutions: https://youtu.be/nPlpSKMiKjw

Taking 5G network testing to another level with Nemo Handy and Nokia drone: https://youtu.be/l4Q4VaNz5SE

5G NR SA Field Measurements with Nemo Outdoor: https://youtu.be/5UehEPUOeSA

Appendix

ACRONYMS

CSI-RS (DL): Channel state information reference signal

CP: Control plane

CSFB: Circuit switched fallback

DL: Downlink

EPS: Evolved Packet System

eNB: LTE base station

ENDC: E-UTRAN NR dual connectivity

gNB: 5G base station

MIB: Master information block

MIMO: Multiple input multiple output

MR: Measurement report

MR-DC: Multi radio dual connectivity

NR: New Radio

NSA: Non-standalone

PBCH DMRS: PBCH demodulation reference signal

PBCH: Primary broadcast channel

PDSCH: Physical downlink shared channel

PSS: Primary synchronization signal

RACH: Random access channel

RRC: Radio resource control

SRS (UL): Sounding reference signal

SSS: Secondary synchronization signal

TRS: Tracking reference signal

CPE: Customer premise equipment

UE: User equipment

UL: Uplink

UP: User plane

VoLTE: Voice over LTE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TECHNOLOGIES