

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

Jason Yao

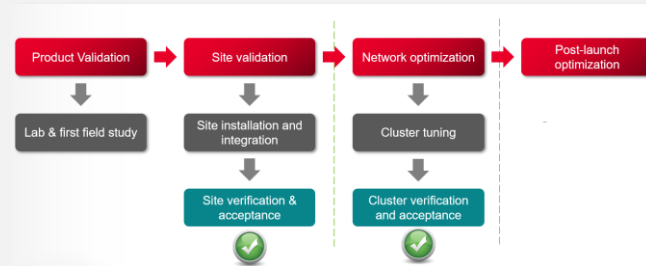
Technical Manager of Eagletek



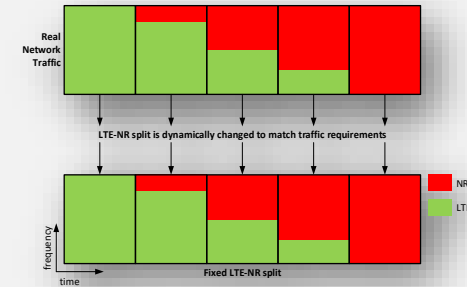
Agenda

Introduction to 5G network deployment

Network deployment process



Network deployment configurations

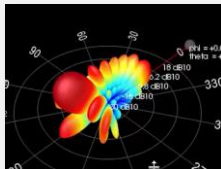


Acceptance testing

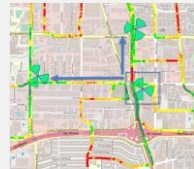
User experience



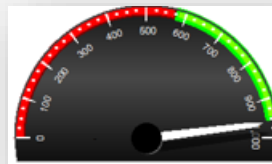
Coverage



Mobility



Throughputs



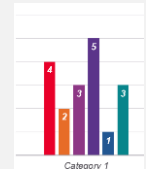
Site planning



VoLTE/NR concurrency



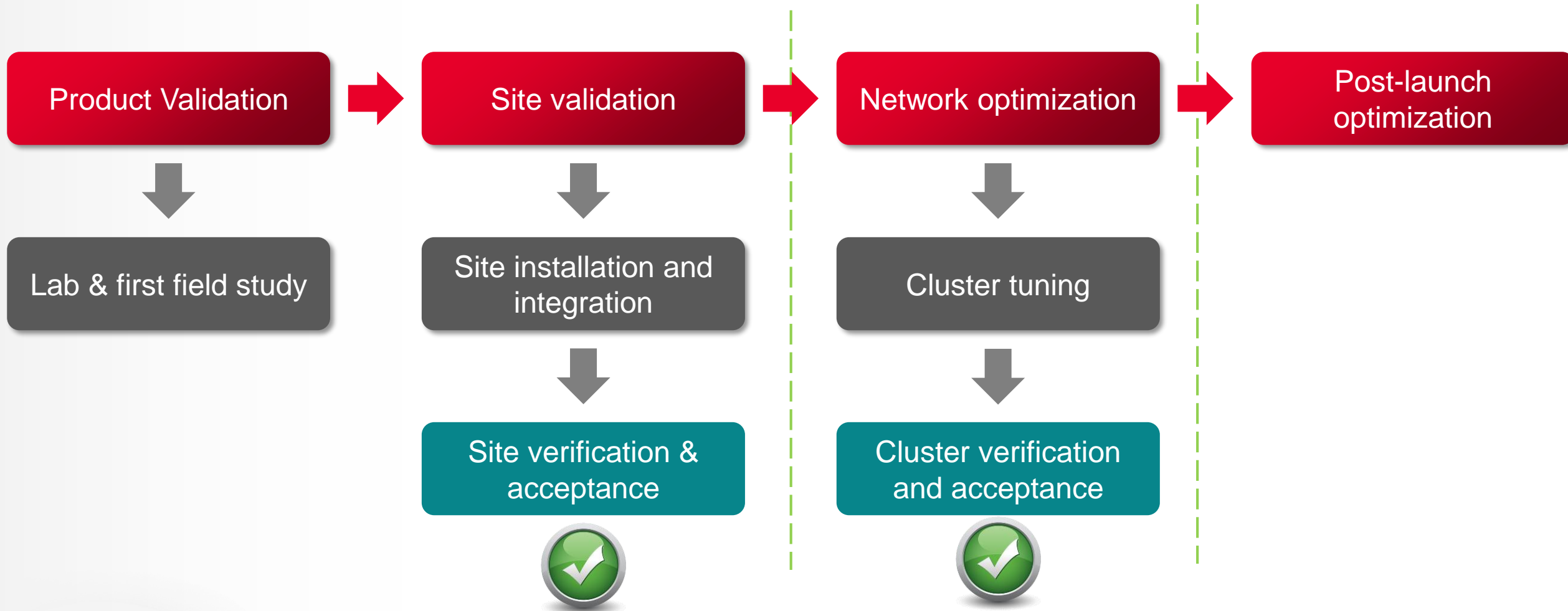
Benchmarking



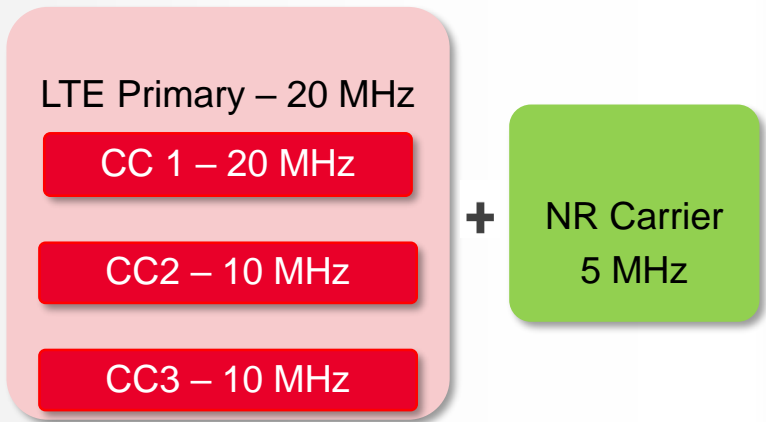
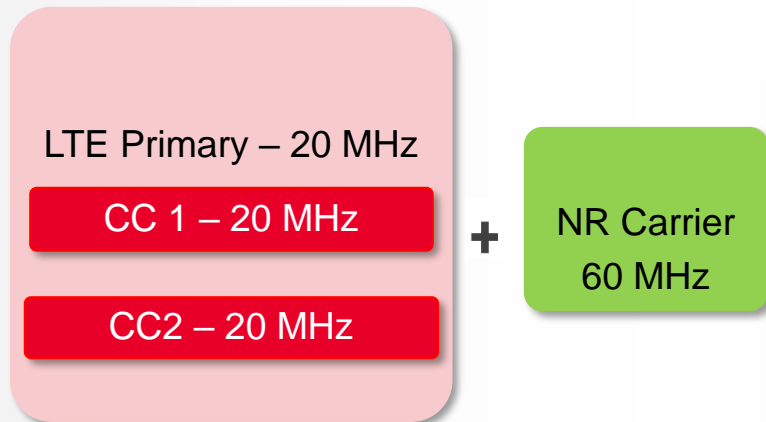


Introduction to 5G Network Deployment

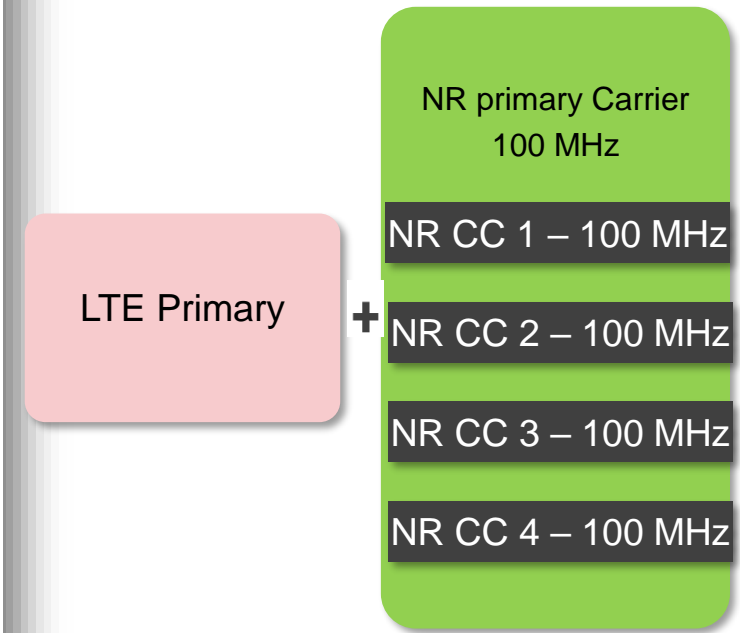
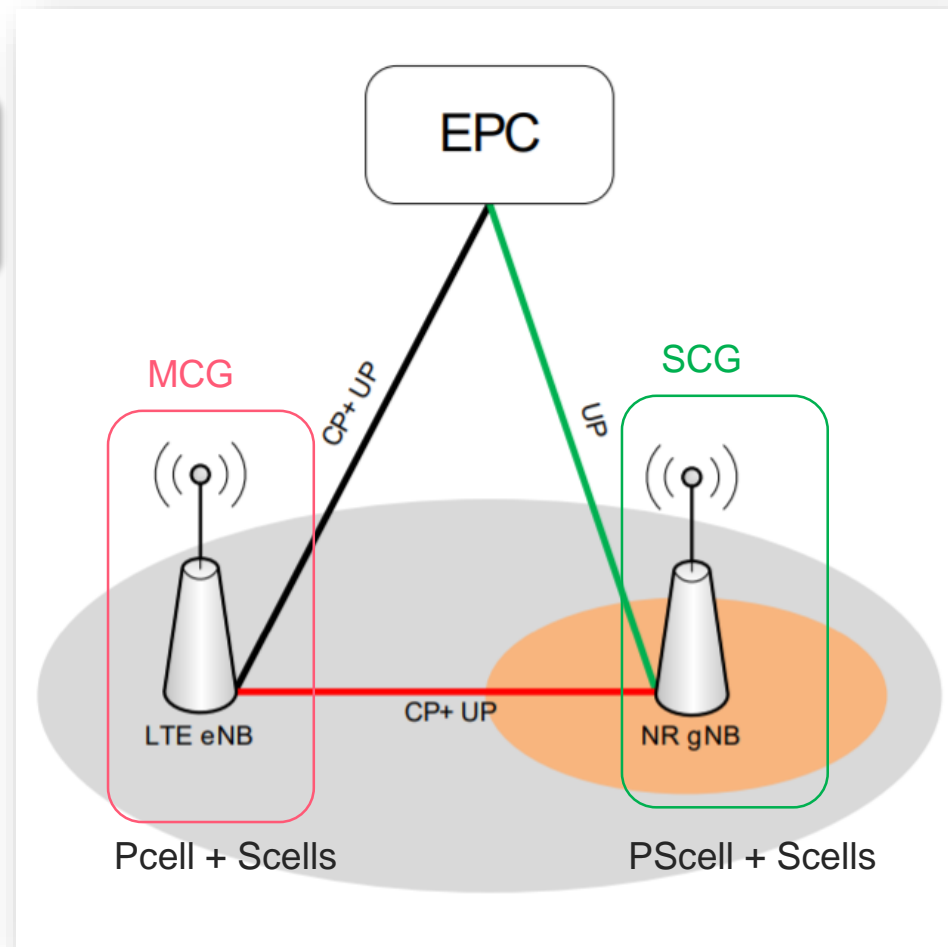
Single Site Verification and Cluster Tuning are Critical Aspects of 5G Network Deployments



Frequency Range and Spectrum Availability Dictates Deployment Configurations



FR1 deployment example



FR2 deployment example

Spectrum Strategy Example- Dynamic Spectrum Sharing

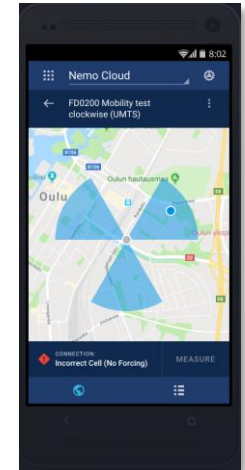
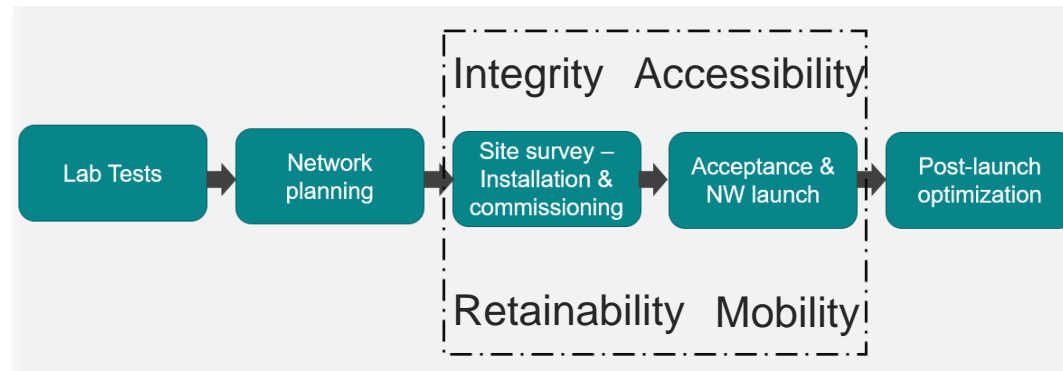
- First **5G** spectrum deployments were in **3.5 GHz** bands for capacity, and **low bands (700 MHz)** for coverage, eventually with LTE refarming
- Low-band LTE refarming enables CA between NR in 3.5 GHz and NR in low bands
- 800 MHz is normally left for coverage and VoLTE
- In a second phase, the **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**

MHz	Before 5G launch	First 5G	Future 2025
3500		5G	5G
2600	LTE	LTE	LTE/5G
2100	3G+LTE	LTE	
1800	LTE	LTE	
900	2G+3G	2G+3G	
800	LTE	LTE	LTE
700		LTE/5G	LTE/5G



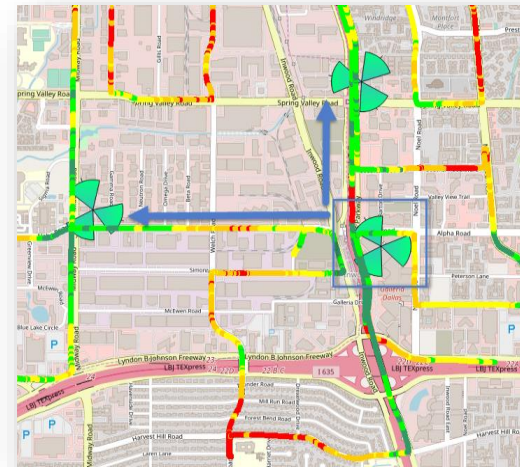
Acceptance Testing

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

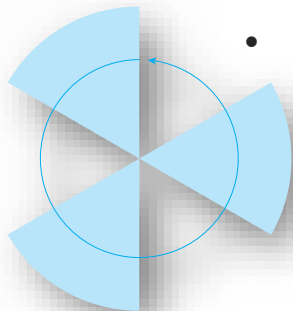
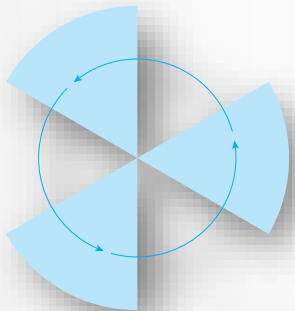


Inter-site mobility tests:

- 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

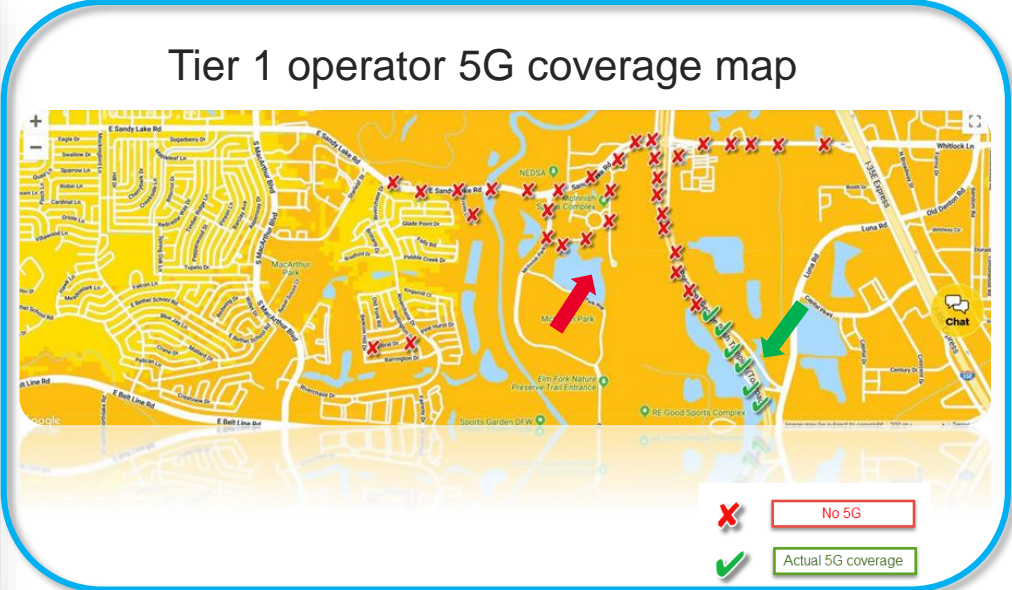
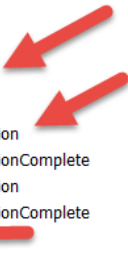


Quantifying User Experience is Key

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	RRCCConnectionRequest	
RACHI	14:39:24.399				
RRCSM	14:39:24.399	CCCH	Downlink	RRCCConnectionSetup	
RRCSM	14:39:24.399	DCCH	Uplink	RRCCConnectionSetupComplete	
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	Downlink	UECapabilityEnquiry	
RRCSM	14:39:26.412	DCCH	Uplink	UECapabilityInformation	
RRCSM	14:39:26.412	DC	Downlink	RRCCConnectionReconfiguration	
RRCSM	14:39:26.615	DCCH	Uplink	RRCCConnectionReconfiguration...	
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	Uplink	MeasurementReport	
RRCSM	14:39:27.431	DCCH	Downlink	RRCCConnectionReconfiguration	5
RRCSM	14:39:27.431	BCCH-BCH	Downlink	MIB	6
RRCSM	14:39:27.431	DCCH	Uplink	RRCCConnectionReconfiguration...	
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	RRCCConnectionReconfiguration
RRCSM	11:06:42.209	DCCH	Uplink	RRCCConnectionReconfigurationComplete
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	RRCCConnectionReconfiguration
RRCSM	11:06:42.346	DCCH	Uplink	RRCCConnectionReconfigurationComplete
RRCSM	11:06:42.398	DCCH	Downlink	RRCCConnectionReconfiguration
RRCSM	11:06:42.433	DCCH	Uplink	RRCCConnectionReconfigurationComplete
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	RRCCConnectionReconfiguration
RRCSM	11:06:54.619	DCCH	Uplink	RRCCConnectionReconfigurationComplete
RACHI	11:06:54.635			
RRCSM	11:06:54.647	DCCH	Downlink	RRCCConnectionReconfiguration



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

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%	--

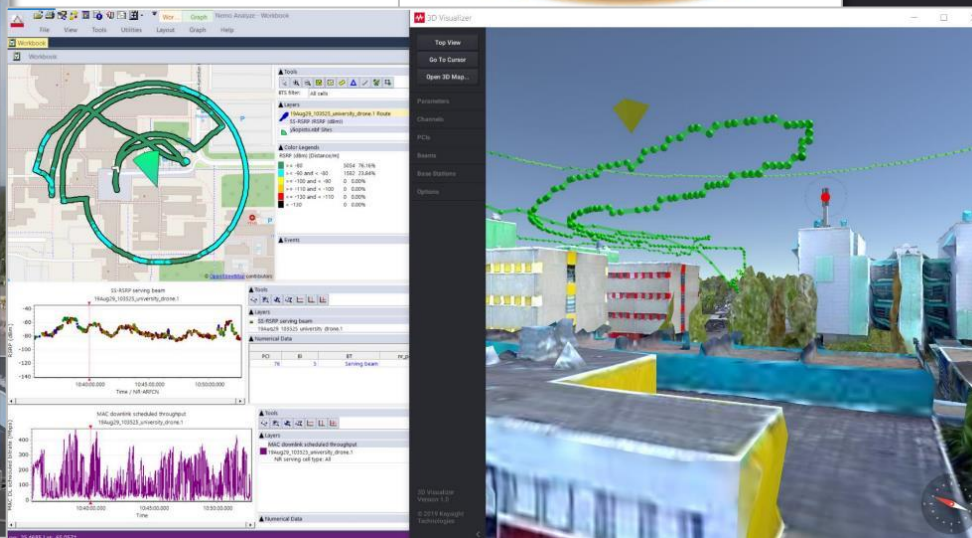
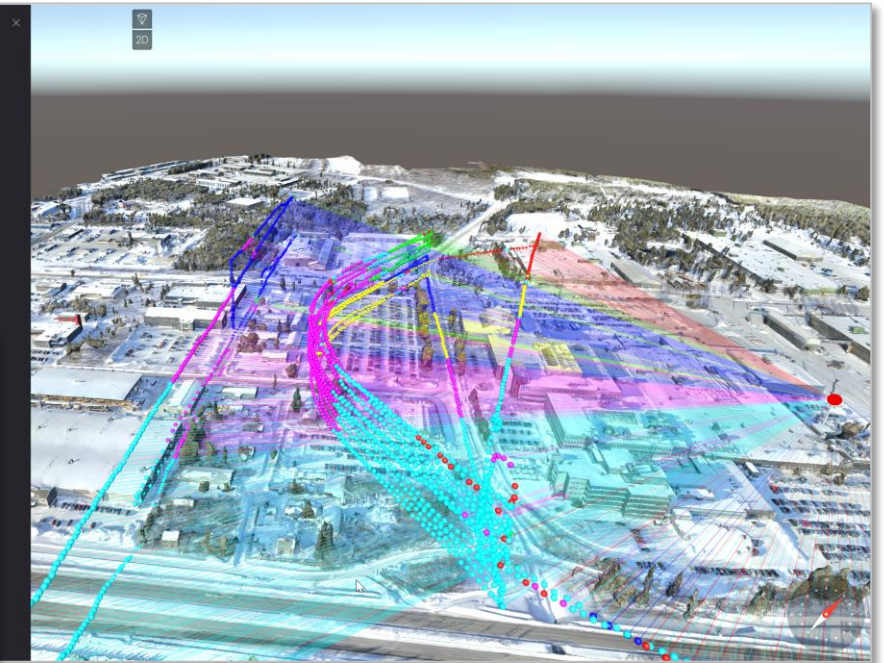
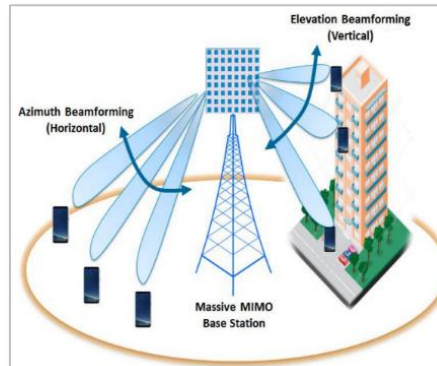
Beams detected		Beam SS-RSRP Statistics							
	% of total	STATUS	Total	Passed	Average	MEAS	THRESHOLD	TARGET	STATUS
Beam_index 0	14.91%	Pass-Non mandatory	274,247	30,394	-105.09	11.08%	>=-90dBm	>90%	Fail-Non mandatory
Beam_index 1	7.62%	Pass-Non mandatory	140,040	23,799	-99.45	16.99%	>=-90dBm	>90%	Fail-Non 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%	--

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

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

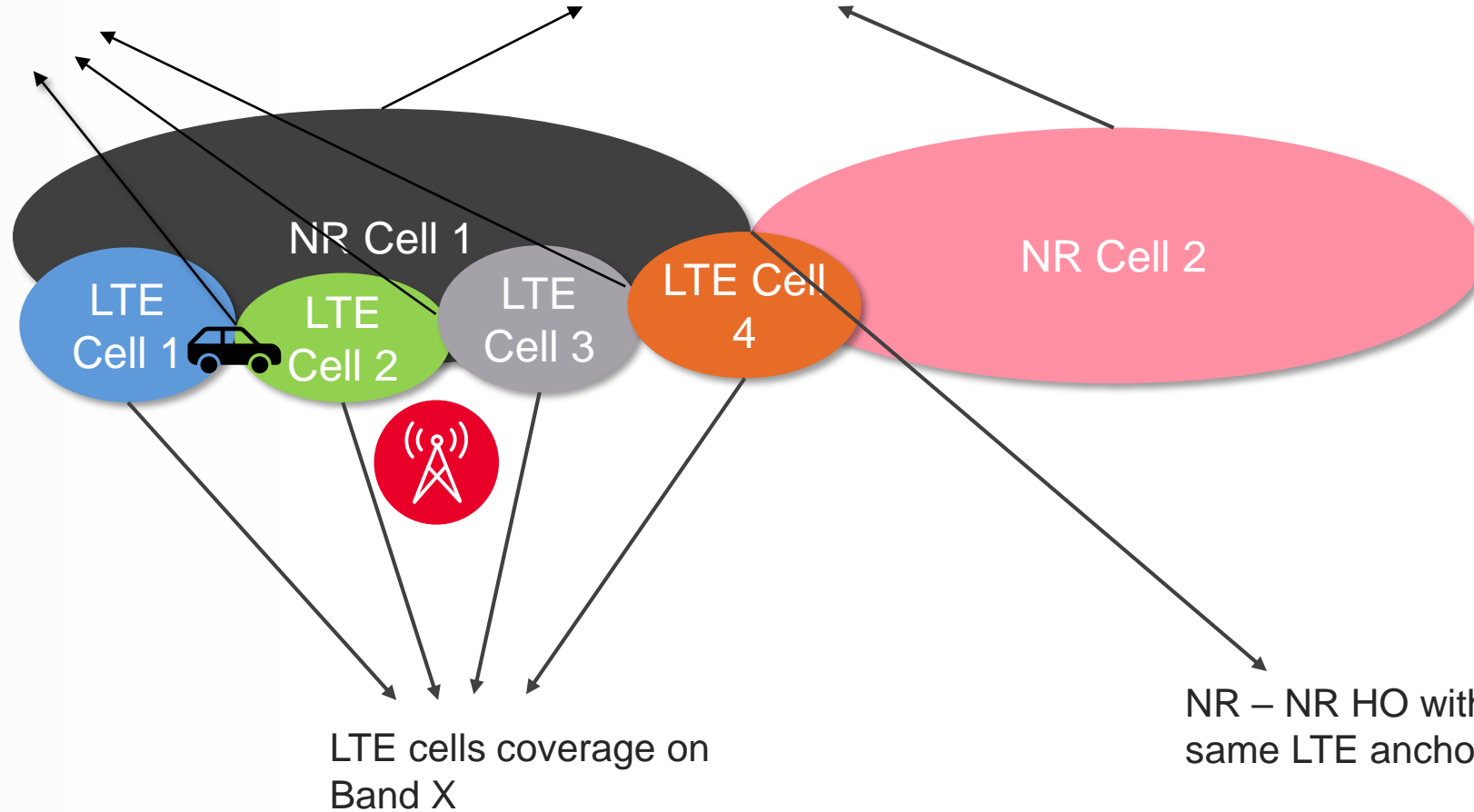


3D Visualizer of Nemo Analyze, SSB beam coverage footprints visualisation from drone measurement

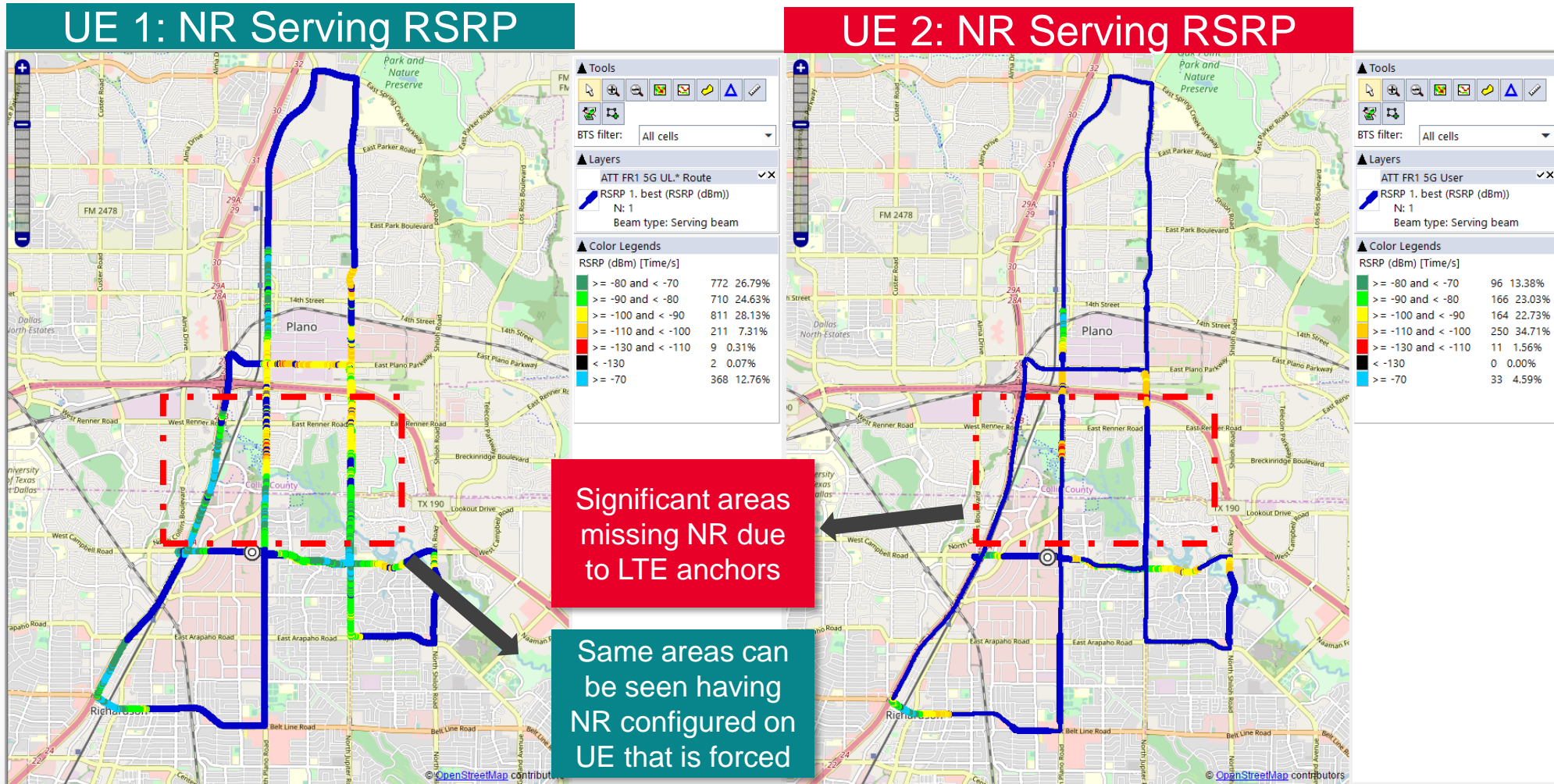
Mobility Testing: NR in Lower Band Increases Complexity

LTE – LTE HO with same NR cell

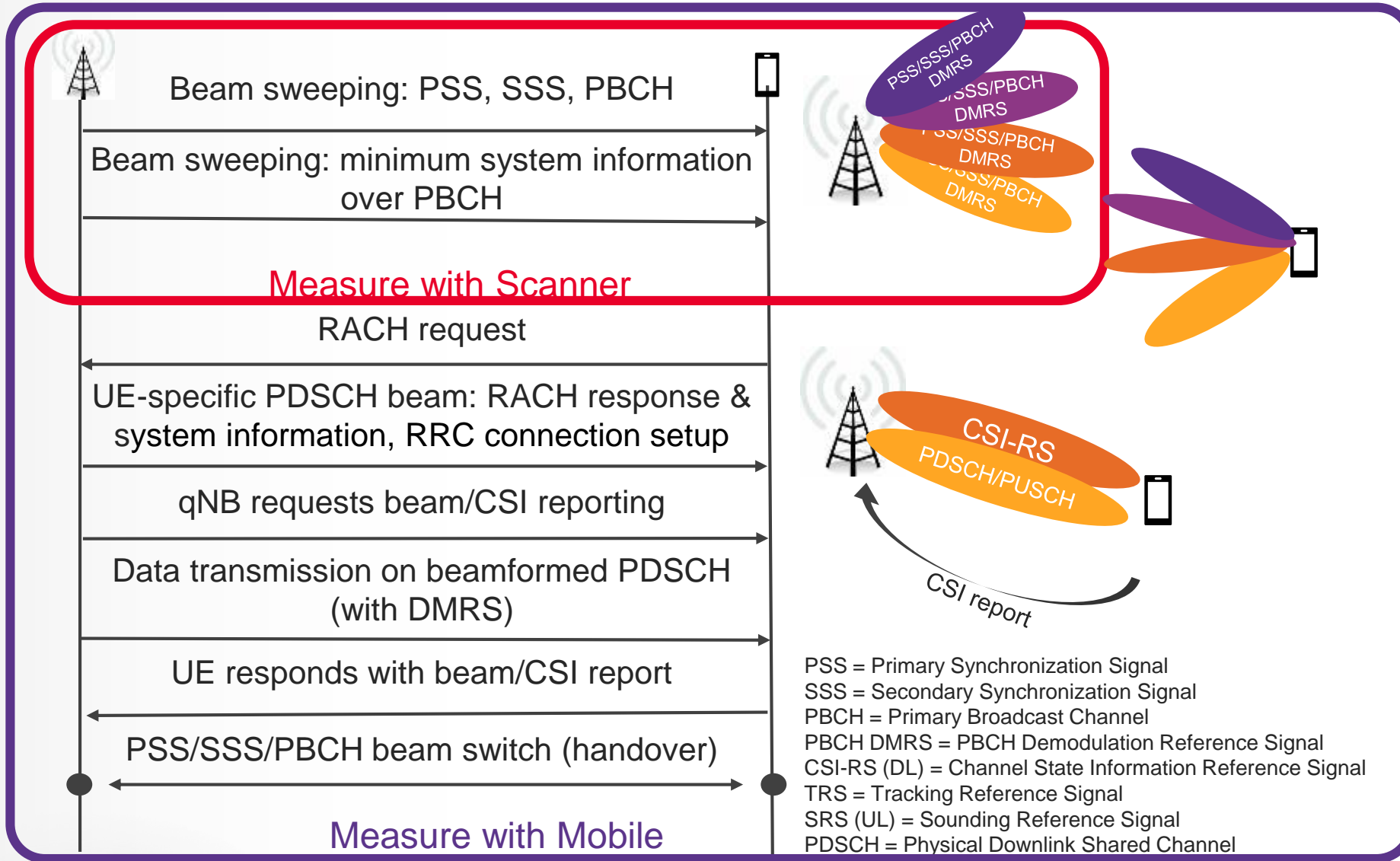
NR cells footprint – Low band



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

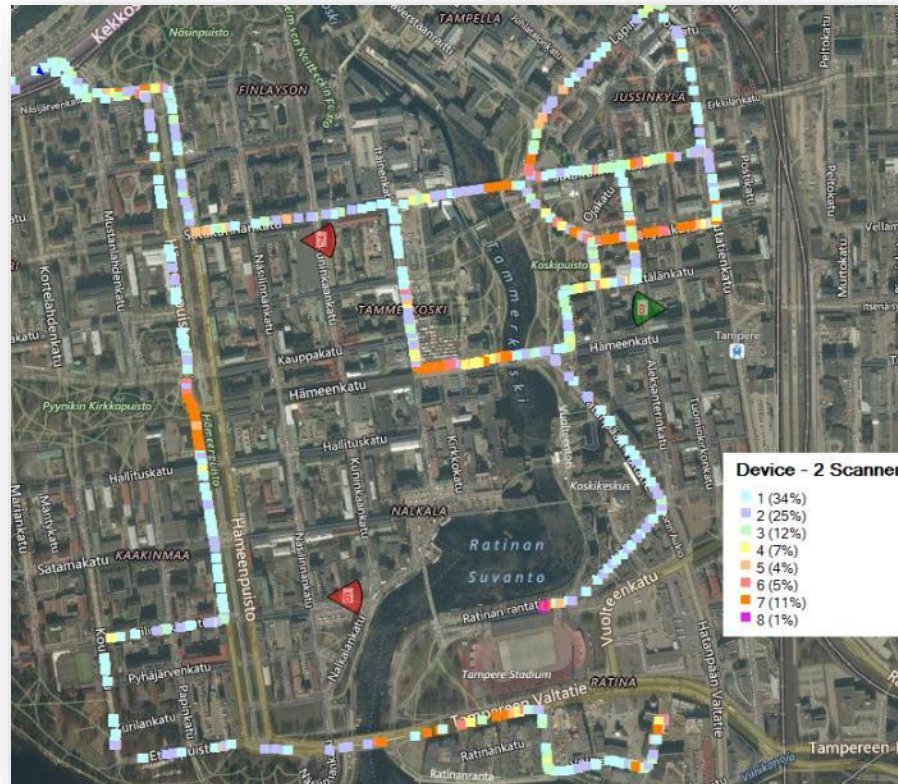


Scanner Measurements Capture SSB From Multiple Cells



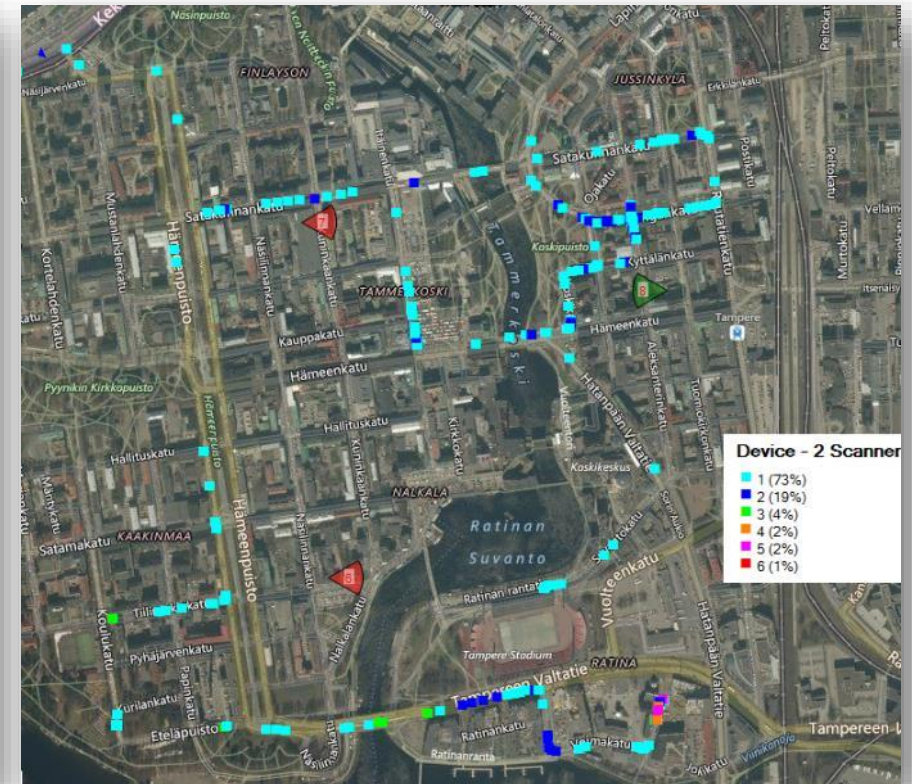
Inter-Site Beam Pollution Increases Interference

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

- 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

Various Test Cases Required to Validate Throughput Performance

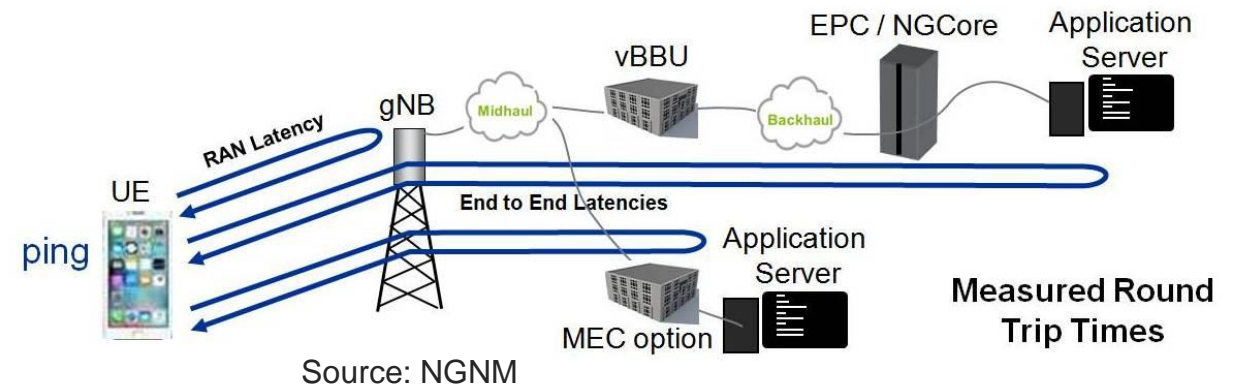
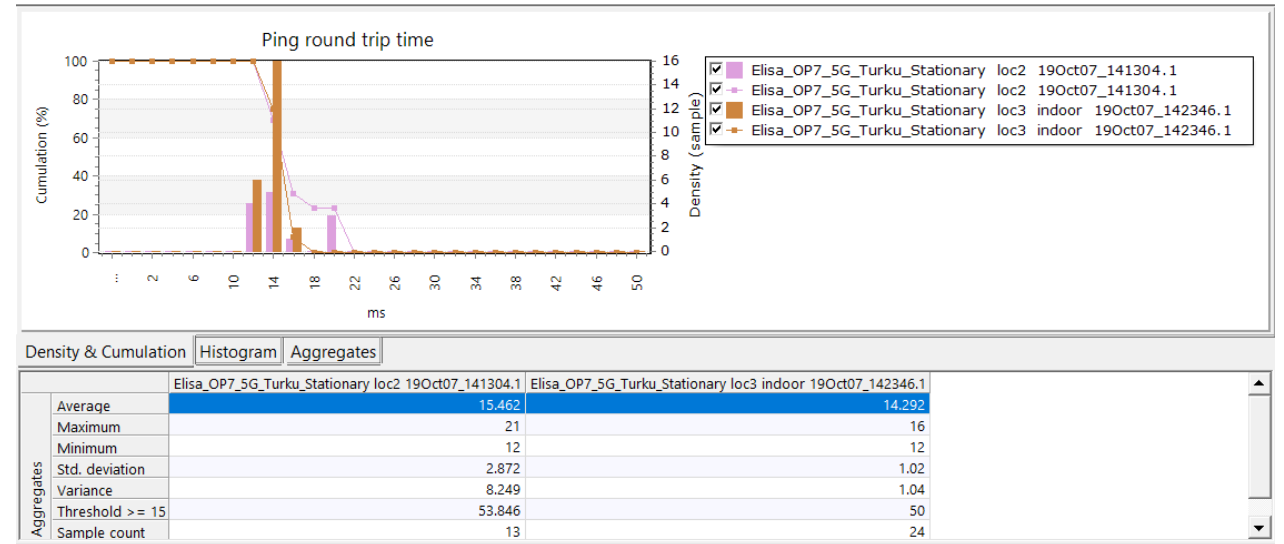
Config	Customer/test case	Peak rate DL (NR only)	Avg rate DL (NR only)	Avg rate UL (NR only)
100MHz BW, Rank 4, 256QAM, FR1	MNO1 cell centre	1.2Gbps	800Mbps	195Mbps
100MHz BW, Rank 4, 256QAM, FR1	MNO1 cell mid range	700Mbps	500Mbps	90Mbps
100MHz BW, Rank 4, 256QAM, FR1	MNO1 cell edge	400Mbps	350Mbps	50Mbps
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

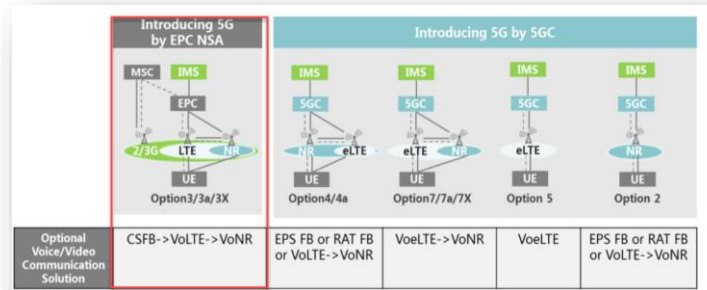
LATENCY, EMBB USE CASE

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



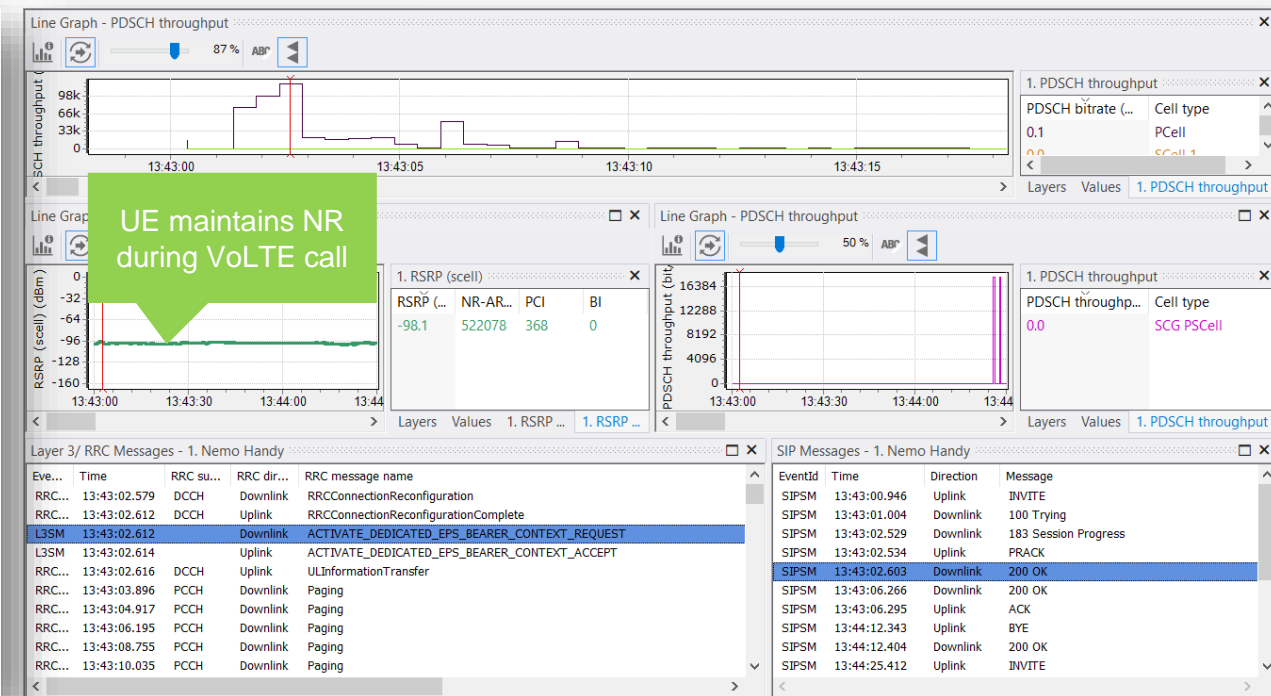
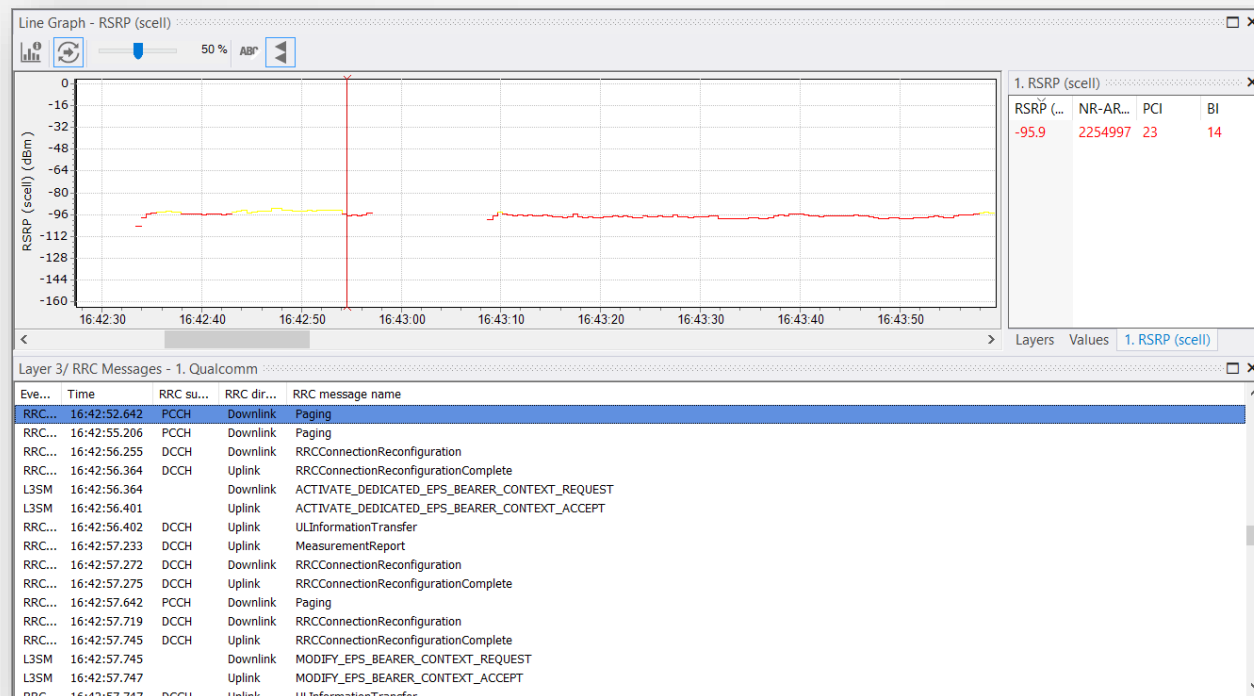
VoLTE/NR Concurrency: Measure and Ensure VoLTE Does Not Interrupt 5G



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

Events - 1. HiSilicon Balong 5000 (Filtered)

Event name	Time	Summary	Protocol System
Call attempt	17:47:29.709	Originated call, [REDACTED]	
Layer 3 signaling message	17:47:30.750	SERVICE_REQUEST	
RRC signaling message	17:47:30.756	RRCSetupRequest	NR
RRC signaling message	17:47:30.782	RRCSetup	NR
RRC signaling message	17:47:30.783	CellGroupConfig IE	NR
RRC signaling message	17:47:30.784	RRCSetupComplete	NR
RRC signaling message	17:47:30.867	SecurityModeCommand	NR
RRC signaling message	17:47:30.867	SecurityModeComplete	NR
RRC signaling message	17:47:30.891	UE-CapabilityRequestFilterNR IE	NR
RRC signaling message	17:47:30.918	CellGroupConfig IE	NR
Layer 3 signaling message	17:47:30.921	SERVICE_ACCEPT	
RRC signaling message	17:47:30.929	CellGroupConfig IE	NR
SIP signaling message	17:47:30.949	INVITE	
SIP signaling message	17:47:30.978	100 Trying	
Layer 3 signaling message	17:47:31.086	SERVICE_REQUEST	
RRC signaling message	17:47:31.674	RRCRelease	NR
RRC signaling message	17:47:31.875	MasterInformationBlock	LTE FDD
RRC signaling message	17:47:32.047	MasterInformationBlock	LTE FDD
Layer 3 signaling message	17:47:32.066	TRACKING_AREA_UPDATE_REQUEST	
RRC signaling message	17:47:32.071	RRCConnectionRequest	LTE FDD
RRC signaling message	17:47:32.106	RRCConnectionSetup	LTE FDD
RRC signaling message	17:47:32.111	RRCConnectionSetupComplete	LTE FDD
Layer 3 signaling message	17:47:32.269	AUTHENTICATION_REQUEST	
Layer 3 signaling message	17:47:32.326	AUTHENTICATION_RESPONSE	
Layer 3 signaling message	17:47:32.356	SECURITY_PROTECTED_NAS_MESSAGE	
Layer 3 signaling message	17:47:32.357	SECURITY_MODE_COMPLETE	
RRC signaling message	17:47:32.396	SystemInformation - SIB5	LTE FDD
RRC signaling message	17:47:32.559	SecurityModeCommand	LTE FDD
RRC signaling message	17:47:32.560	SecurityModeComplete	LTE FDD
Layer 3 signaling message	17:47:32.597	TRACKING_AREA_UPDATE_ACCEPT	
Layer 3 signaling message	17:47:32.600	TRACKING_AREA_UPDATE_COMPLETE	
Layer 3 signaling message	17:47:32.638	ACTIVATE_DEDICATED_EPS_BEARER_C...	
Layer 3 signaling message	17:47:32.638	ACTIVATE_DEDICATED_EPS_BEARER_C...	
RRC signaling message	17:47:35.043	MasterInformationBlock	L
SIP signaling message	17:47:35.696	183 Session Progress	
SIP signaling message	17:47:35.699	PRACK	
Call connect success	17:47:35.722	LTE IMS voice, Traffic channel allocated	
Layer 3 signaling message	17:47:35.753	MODIFY_EPS_BEARER_CONTEXT_REQU...	
Layer 3 signaling message	17:47:35.753	MODIFY_EPS_BEARER_CONTEXT_ACCEPT	
SIP signaling message	17:47:35.877	200 OK	
SIP signaling message	17:47:35.889	UPDATE	
SIP signaling message	17:47:36.160	200 OK	
SIP signaling message	17:47:36.164	180 Ringing	
Call connect success	17:47:36.164	LTE IMS voice, Alerting	
SIP signaling message	17:47:36.208	200 OK	
Call connect success	17:47:36.208	LTE IMS voice, Connected	
SIP signaling message	17:47:36.221	ACK	
SIP signaling message	17:47:46.572	BYE	

RRC signaling message - 1. HiSilicon Balong 5000

RRC SIGNALING MESSAGE

Time: 17:47:59.113

RRCRelease (3GPP TS 38.331 ver 15.5.1 Rel 15)

DL-DCCH-Message message c1

rrcRelease

rrc-TransactionIdentifier : 0

criticalExtensions

rrcRelease

redirectedCarrierInfo

eutra

eutraFrequency : 1300

Data (hex):

10 81 00 A2 80

Introducing 5G by 5GC

Option3/3a/3X

Option4/4a

Option7/7a/7X

Option 5

Option 2

Optional Voice/Video Communication Solution

CSFB->VoLTE->VoNR

EPS FB or RAT FB or VoLTE->VoNR

VoLTE->VoNR

VoLTE

EPS FB or RAT FB or VoLTE->VoNR

Source: Huawei

IMS call EPS FB - HO

Events - 1. HiSilicon Balong 5000 (Filtered)

Event name	Time	Summary	Protocol System
Call attempt	16:42:00.840	Originated call, [REDACTED]	
Layer 3 signaling message	16:42:01.975	SERVICE_REQUEST	
RRC signaling message	16:42:02.004	CellGroupConfig IE	NR
Layer 3 signaling message	16:42:02.005	SERVICE_ACCEPT	
SIP signaling message	16:42:02.039	INVITE	
SIP signaling message	16:42:02.073	100 Trying	
RRC signaling message	16:42:02.776	MobilityFromNRCommand	NR
Handover/handoff attempt	16:42:02.796		
RRC signaling message	16:42:02.862	UECapabilityEnquiry	LTE FDD
Handover/handoff success	16:42:02.879		
RRC signaling message	16:42:02.888	UECapabilityInformation	LTE FDD
RRC signaling message	16:42:02.900	MasterInformationBlock	LTE FDD
RRC signaling message	16:42:02.925	SystemInformationBlockType1	LTE FDD
RRC signaling message	16:42:02.933	UECapabilityEnquiry	LTE FDD
RRC signaling message	16:42:02.942	UECapabilityInformation	LTE FDD
RRC signaling message	16:42:03.065	SystemInformationBlockType1	LTE FDD
Layer 3 signaling message	16:42:03.067	TRACKING_AREA_UPDATE_REQUEST	
RRC signaling message	16:42:03.085	SystemInformationBlockType1	LTE FDD
RRC signaling message	16:42:03.100	SystemInformation - SIB5	LTE FDD
Layer 3 signaling message	16:42:03.254	TRACKING_AREA_UPDATE_ACCEPT	
Layer 3 signaling message	16:42:03.257	TRACKING_AREA_UPDATE_COMPLETE	
Layer 3 signaling message	16:42:03.308	ACTIVATE_DEDICATED_EPS_BEARER_C...	
Layer 3 signaling message	16:42:03.309	ACTIVATE_DEDICATED_EPS_BEARER_C...	
Layer 3 signaling message	16:42:03.335	DOWNLINK_NAS_TRANSPORT	
Layer 3 signaling message	16:42:03.335	CP_DATA	
Layer 3 signaling message	16:42:03.336	CP_ACK	
SIP signaling message	16:42:04.931	183 Session Progress	
SIP signaling message	16:42:04.935	PRACK	
Call connect success	16:42:04.935	LTE IMS voice, Traffic channel allocated	
Layer 3 signaling message	16:42:04.969	MODIFY_EPS_BEARER_CONTEXT_REQU...	
Layer 3 signaling message	16:42:04.969	MODIFY_EPS_BEARER_CONTEXT_ACCEPT	
SIP signaling message	16:42:05.154	200 OK	
SIP signaling message	16:42:05.160	UPDATE	
SIP signaling message	16:42:05.377	200 OK	
SIP signaling message	16:42:05.379	180 Ringing	
SIP signaling message	16:42:05.379	LTE IMS voice, Alerting	
SIP signaling message	16:42:15.916	CANCEL	
SIP signaling message	16:42:15.984	200 OK	
SIP signaling message	16:42:15.987	487 Request Terminated	
SIP signaling message	16:42:15.987	Normal disconnect, CS disc. cause:487	
SIP signaling message	16:42:15.988	ACK	
SIP signaling message	16:42:16.048	DEACTIVATE_EPS_BEARER_CONTEXT_R...	
SIP signaling message	16:42:16.048	DEACTIVATE_EPS_BEARER_CONTEXT_A...	
RRC signaling message	16:42:16.818	RRCConnectionRelease	LTE FDD
SIP signaling message	16:42:17.006	MIB	NR
SIP signaling message	16:42:17.025	SIB1	NR
SIP signaling message	16:42:17.032	SystemInformation	NR
SIP signaling message	16:42:17.034	SystemInformation	NR

RRC signaling message - 1. HiSilicon Balong 5000 16:42:02.776

RRC SIGNALING MESSAGE

Time: 16:42:02.776

MobilityFromNRCommand (3GPP TS 38.331 ver 15.5.1 Rel 15)

DL-DCCH-Message message c1

mobilityFromNRCommand

rrc-TransactionIdentifier : 0

criticalExtensions

mobilityFromNRCommand

targetRAT-Type : eutra

targetRAT-MessageContainer

nas-SecurityParamFromNR

Hex : 05

Data (hex):

40 80 00 04 14

Introducing 5G by 5GC

Option4/4a

Option7/7a/7X

Option 5

Option 2

Optional Voice/Video Communication Solution

CSFB->VoLTE->VoNR

EPS FB or RAT FB or VoLTE->VoNR

VoLTE->VoNR

VoLTE

EPS FB or RAT FB or VoLTE->VoNR

Source: Huawei

5G Indoor Testing: Site Location Planning and Baselineing

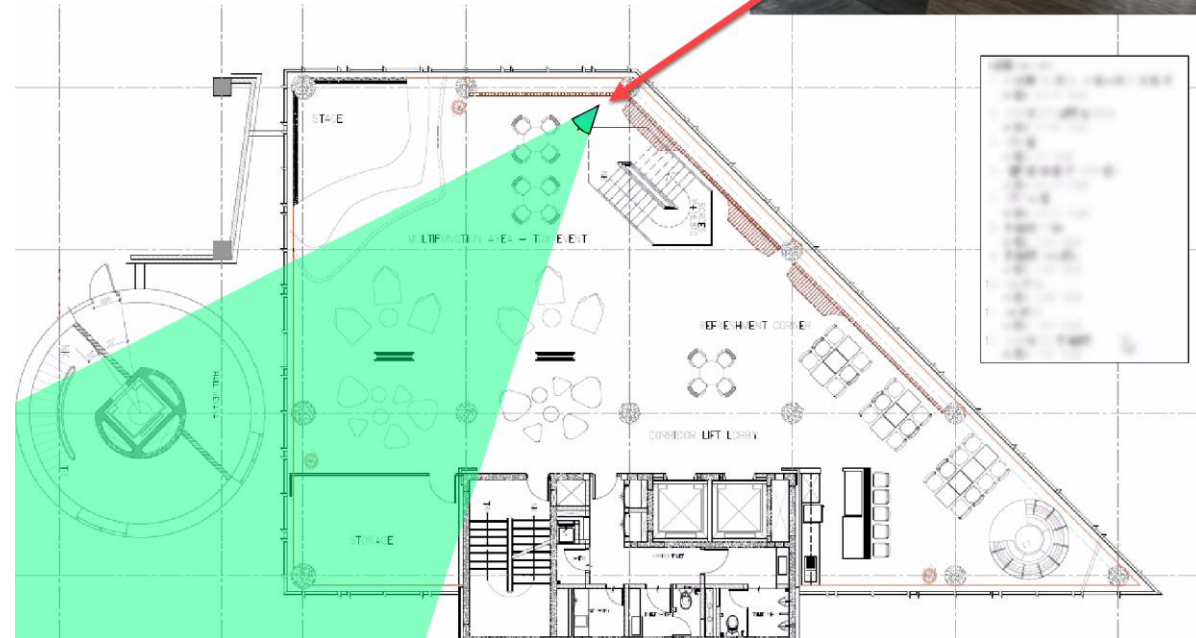
Ensure Good Coverage

- 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

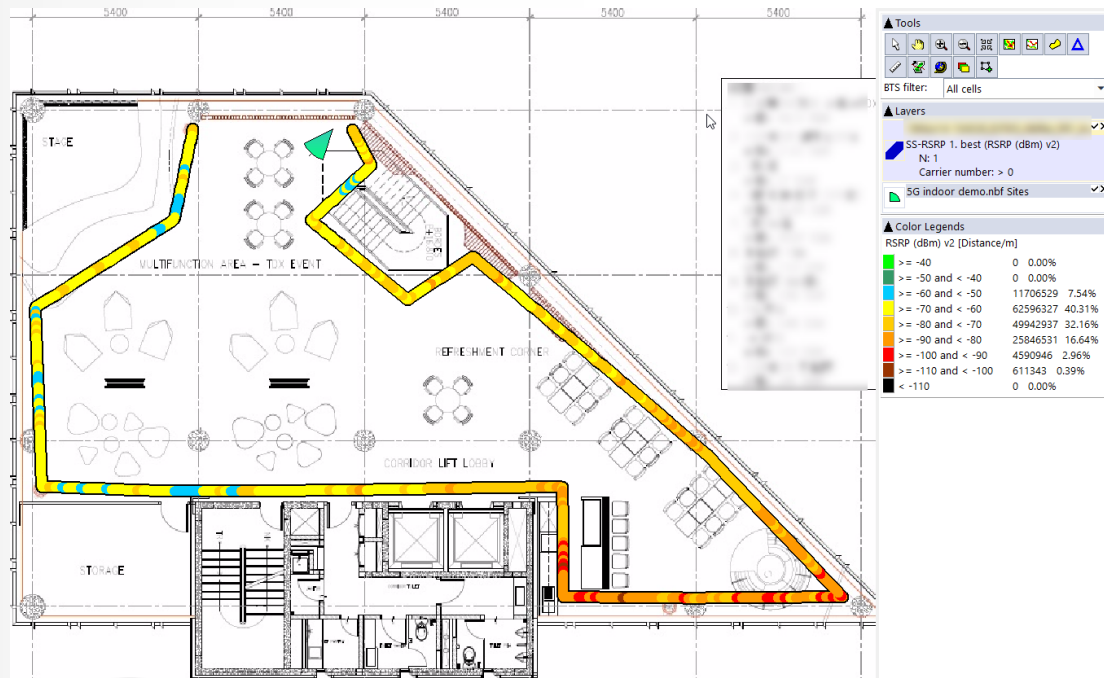


PcTel HBFlex Scanner

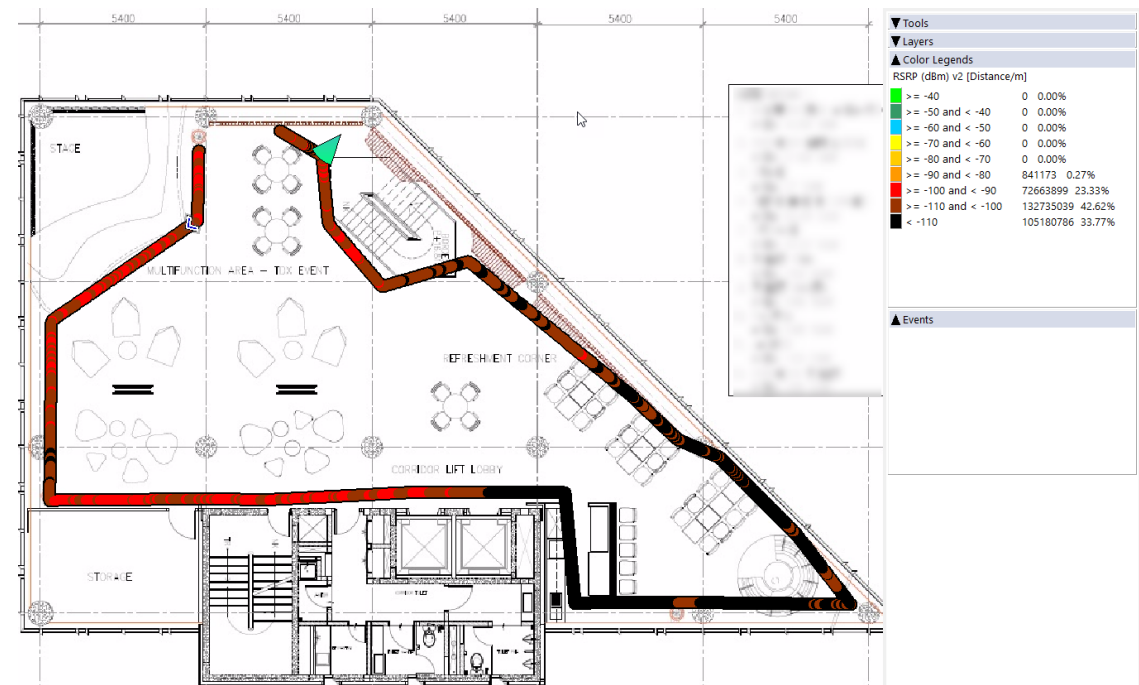


5G Indoor Test: Measurements With Active Beamforming are Required for Optimization

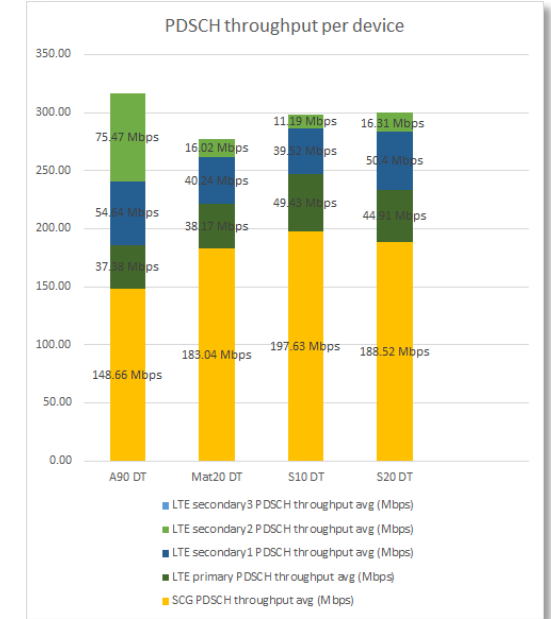
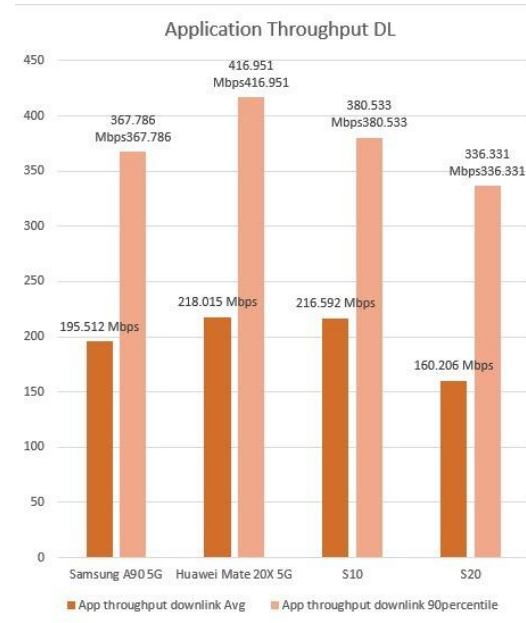
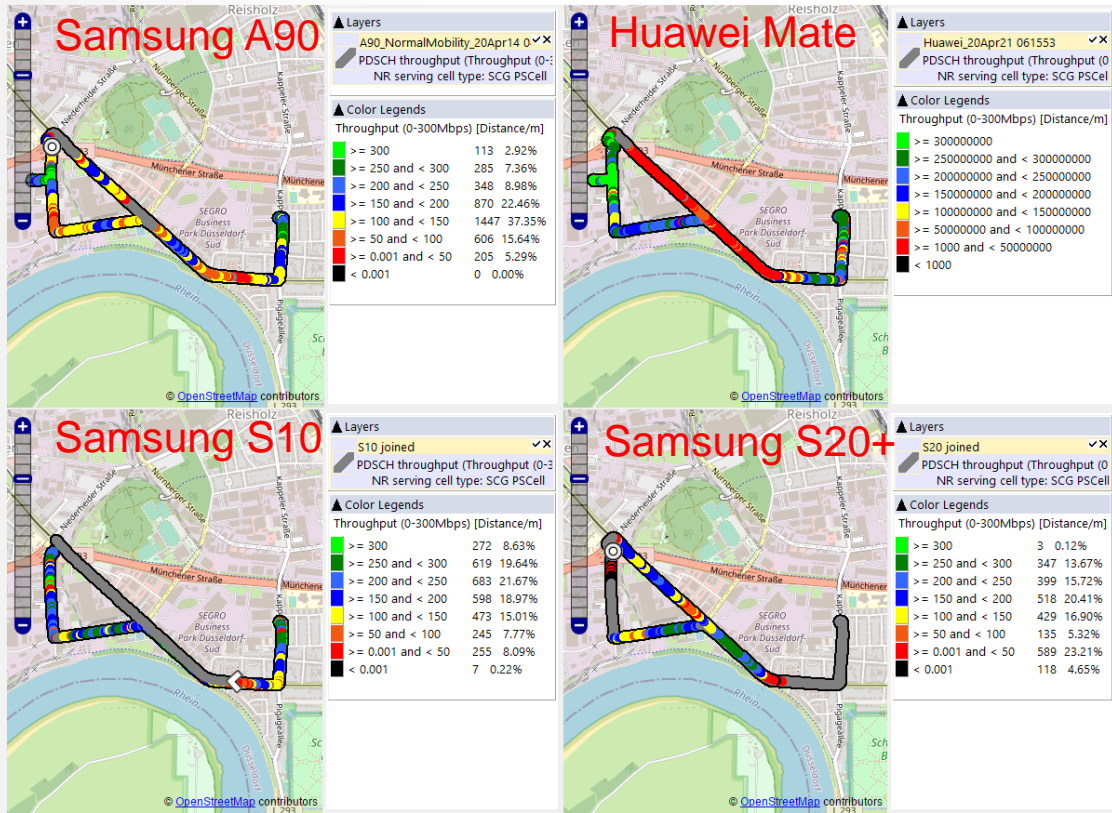
FR1: SS-RSRP Best



FR2: SS-RSRP Best



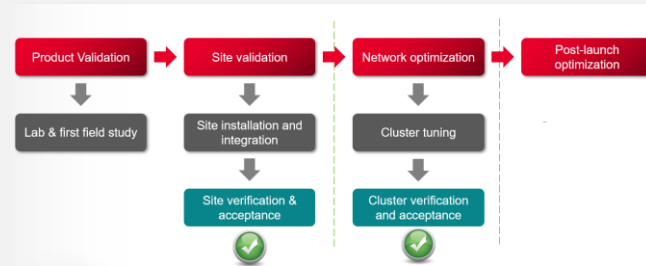
Benchmarking: Segue to Post-Launch Optimization



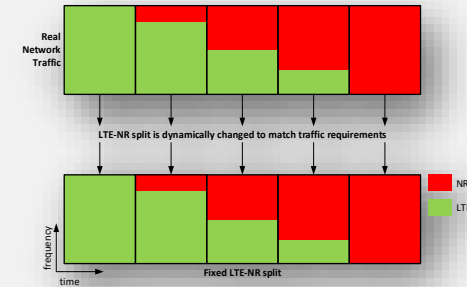
Summary

Introduction to 5G network deployment

Network deployment process



Network deployment configurations

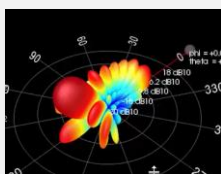


Acceptance testing

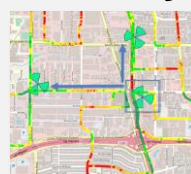
User experience



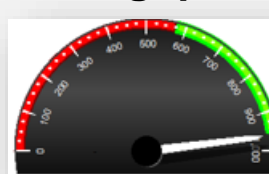
Coverage



Mobility



Throughputs



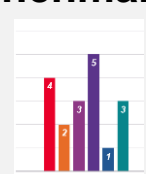
Site planning



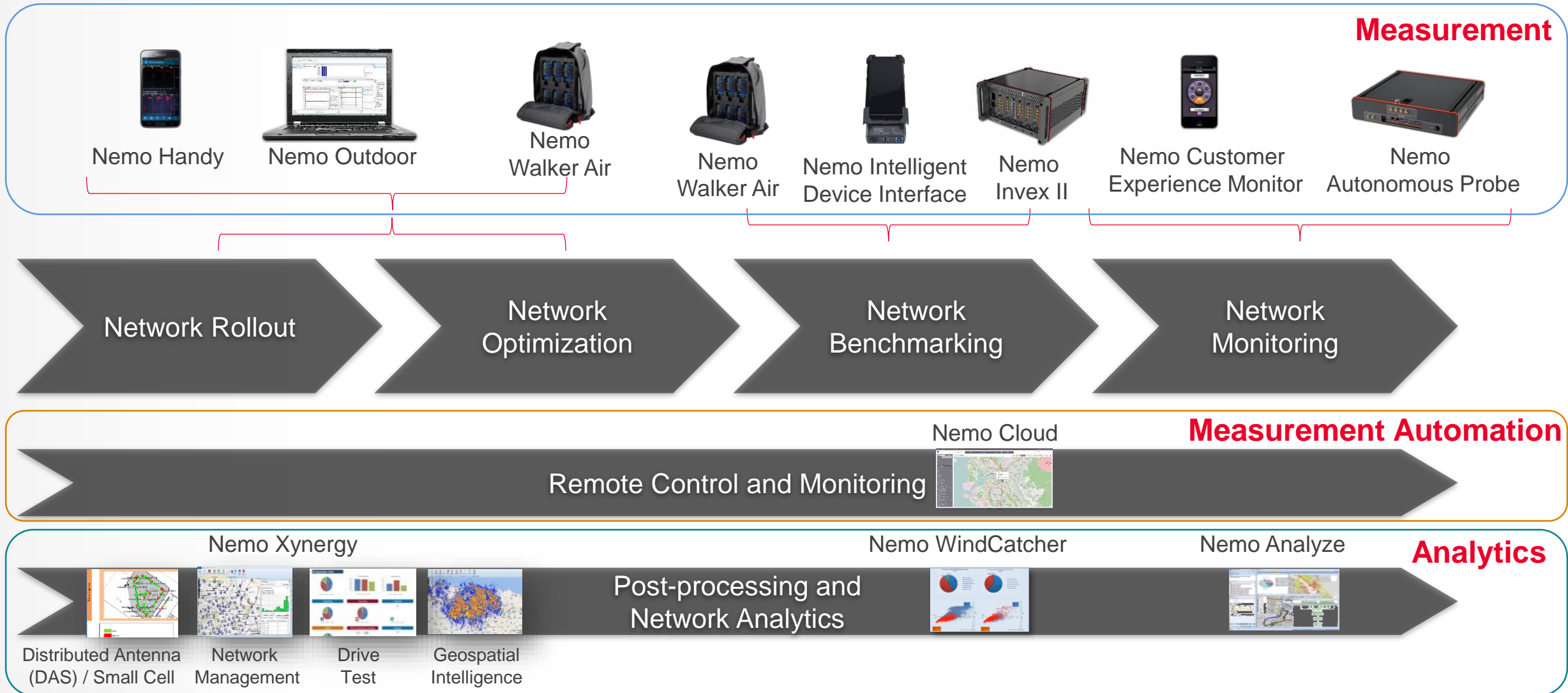
VoLTE/NR concurrency



Benchmarking



Keysight Nemo Test and Measurement Products



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/nPIpSKMiKjw>

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

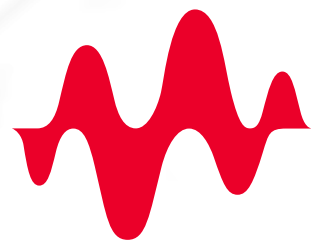
CPE: Customer premise equipment

UE: User equipment

UL: Uplink

UP: User plane

VoLTE: Voice over LTE



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TECHNOLOGIES