5G - mastering new technology

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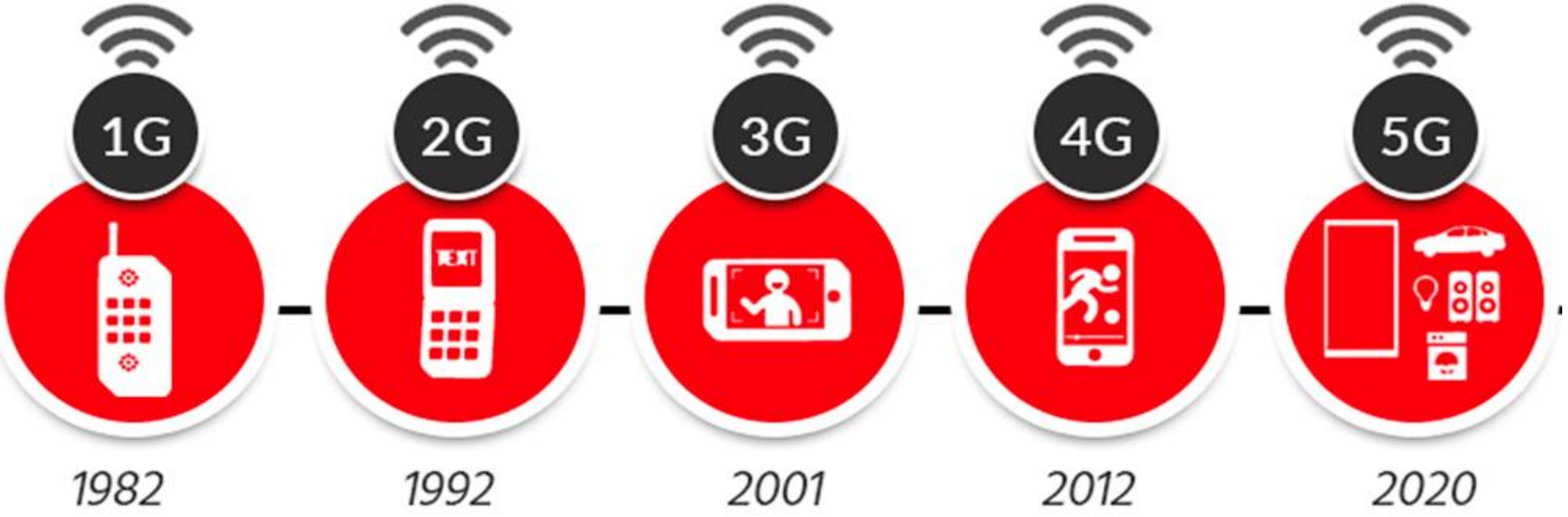
5G Storytelling

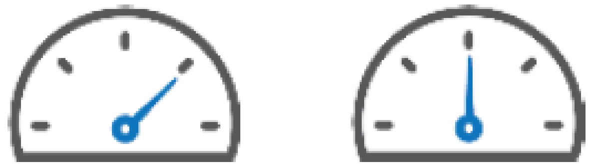
Why is it called 5G?



2.4Kbps - AMPS/TACS	64 Kbps ETSI GSM/IS95	2Mbps IMT-2000 UMTS/CDMA200	>100 Mbps IMT-Advance LTE/LTE-A/Wi-Max	>1 Gbps IMT-2020 5G-NR

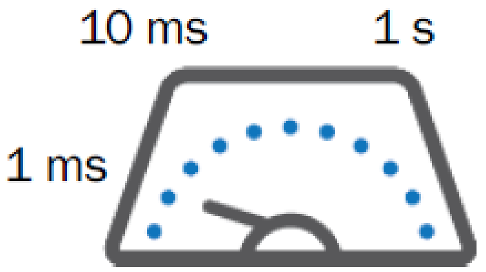
Performance Targets

Peak Data Rate



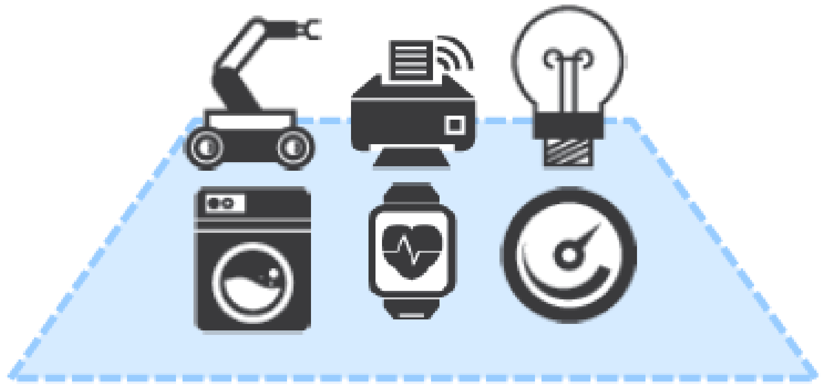
Downlink: 20 Gbps Uplink: 10 Gbps

Radio Network Latency



Less than 1ms

Number of Devices

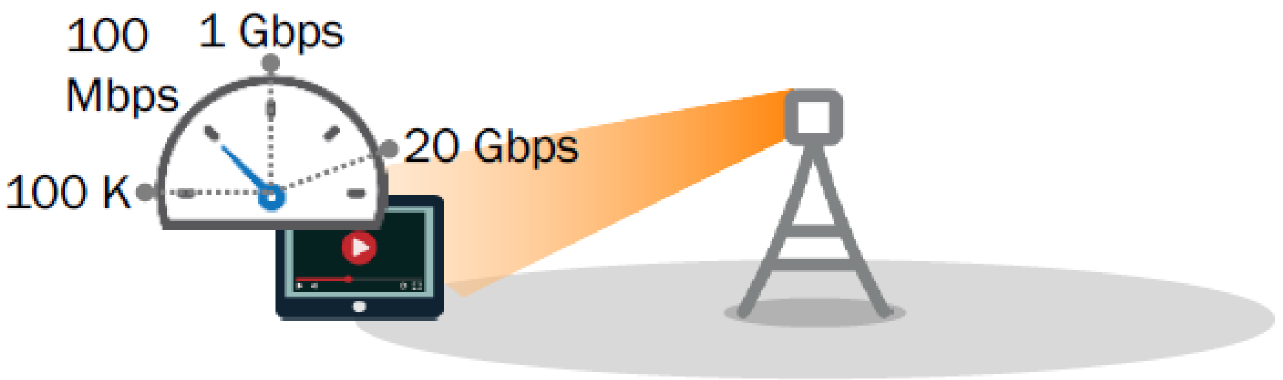


1,000,000/sq km

Cell Throughput

10 Mbps/sq meter

Cell Edge Data Rate



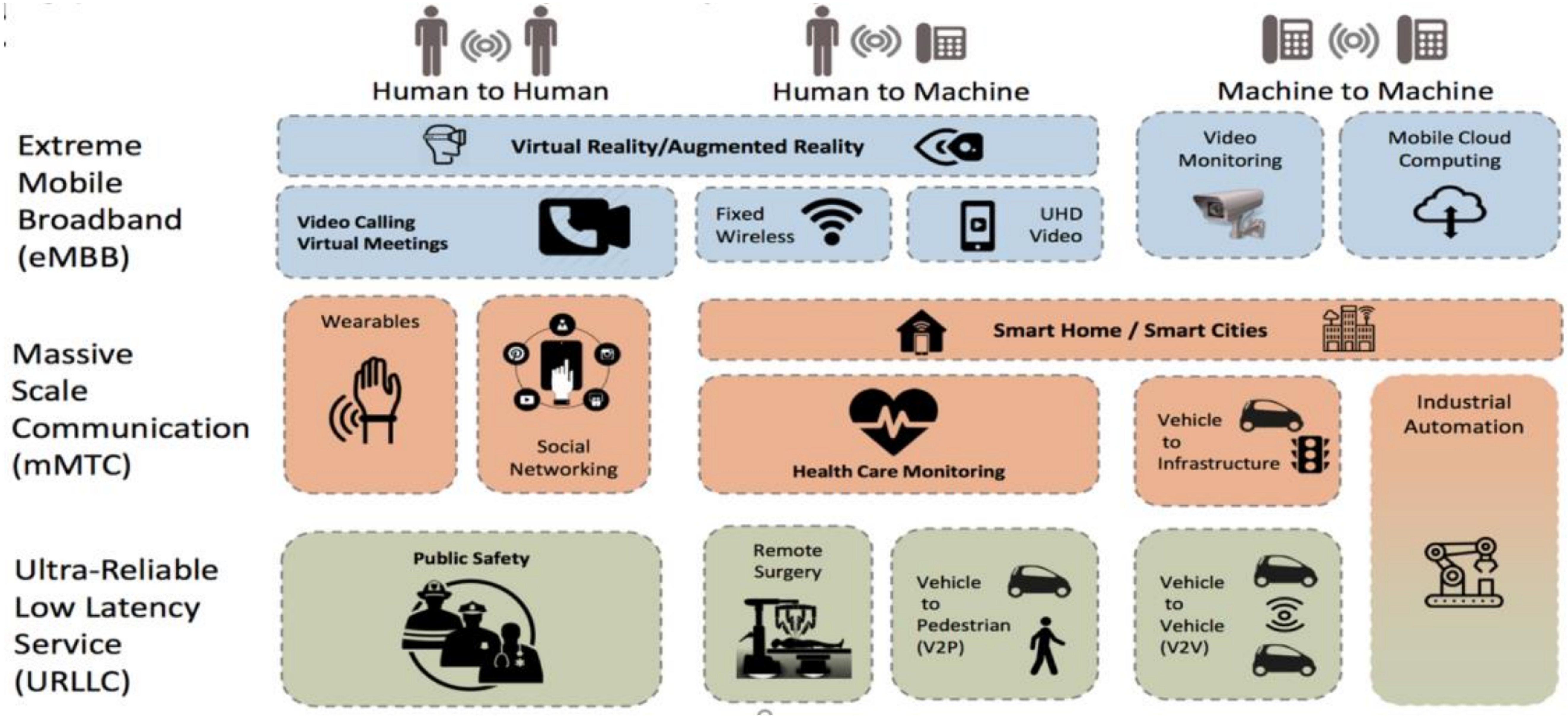
DL: 100 Mbps
UL: 50 Mbps

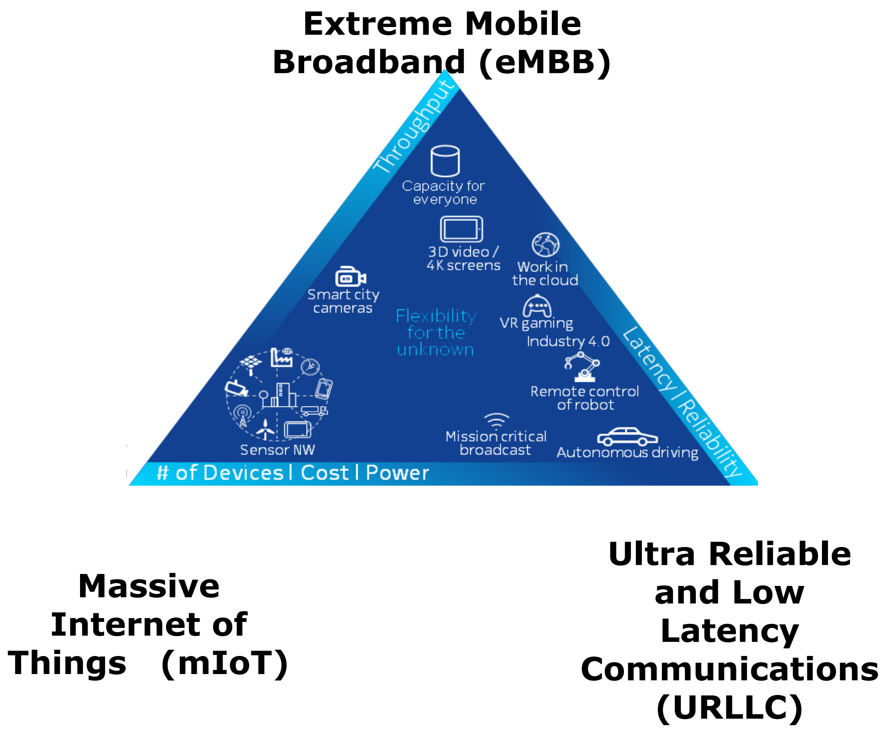
Award Solutions

20 times the peak data rate, 10 times lower latency, 3 times more spectrum efficency

5G Use Cases

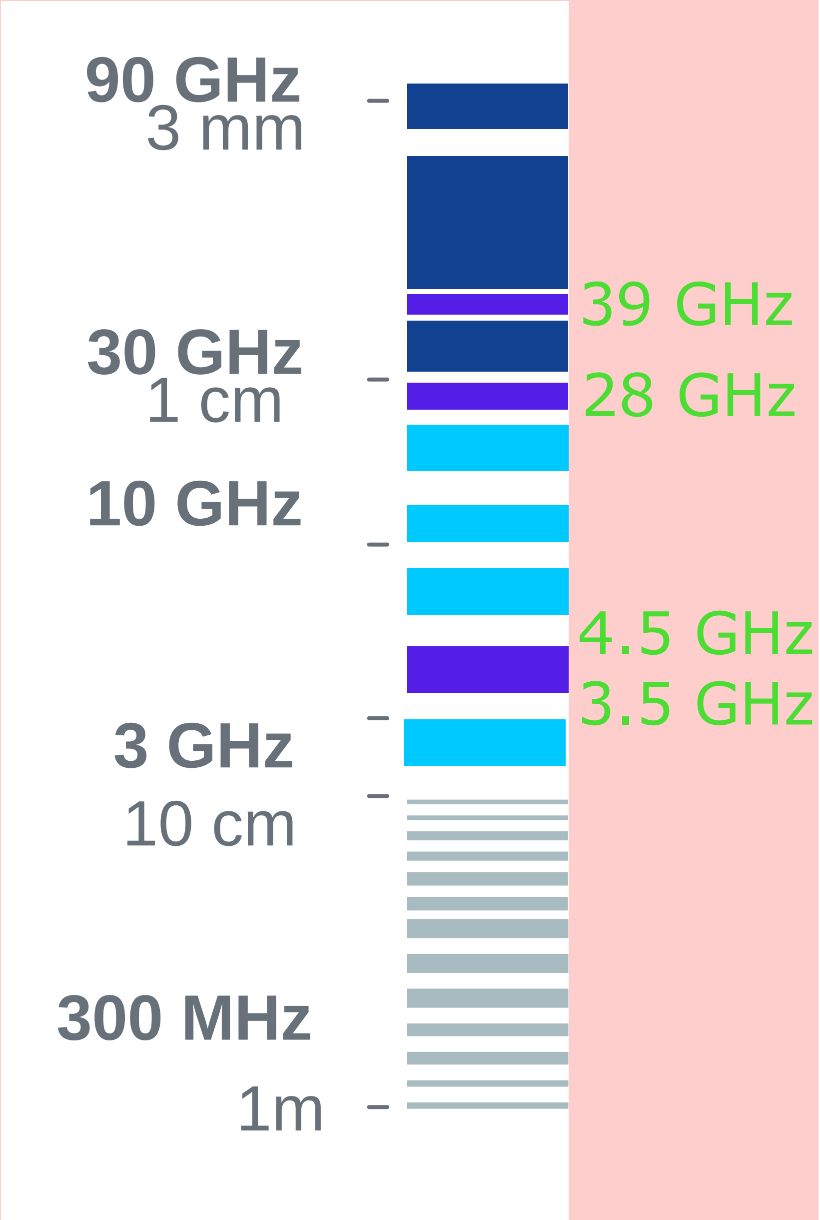
What are use cases our markets will explore initially?



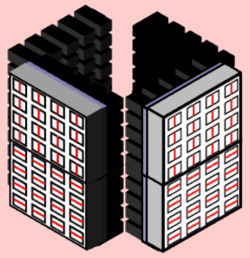


The key technology bricks 5G is built on

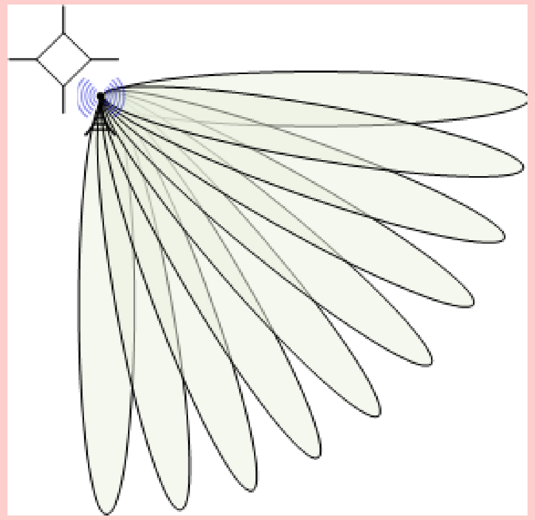
#1 New spectrum options



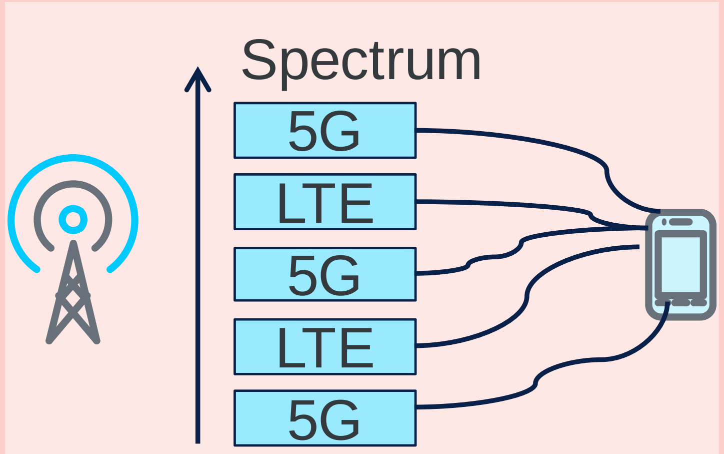
#2 Beamforming & massive MIMO



Up to 16 transmission layers

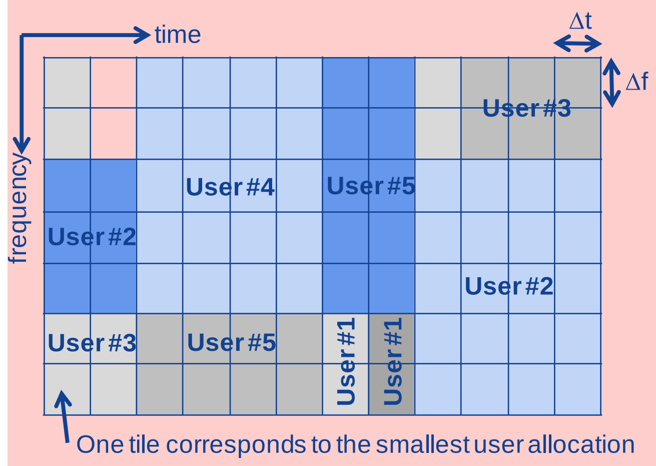


#4 Multi-connectivity



Standalone and non-Standalone operation
Dual connectivity with LTE

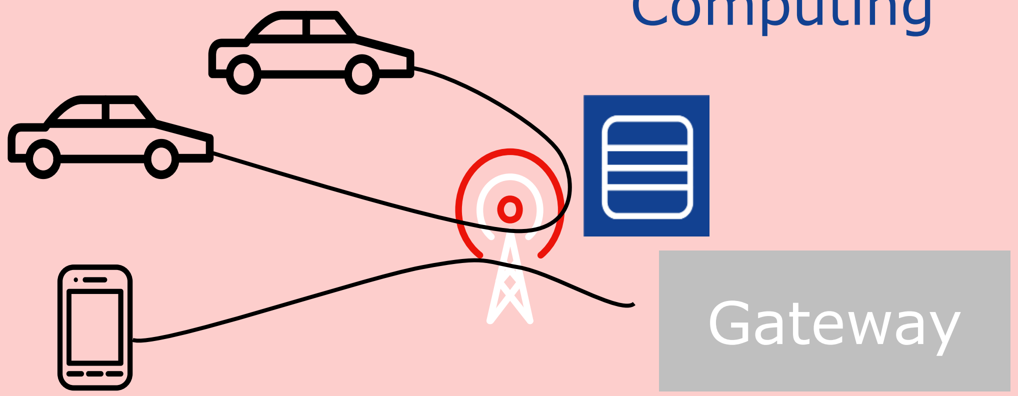
#3 flexible frame design & slicing



Flexible size, control, TDD, FDD, scalable bandwidth, minislots, numerologies

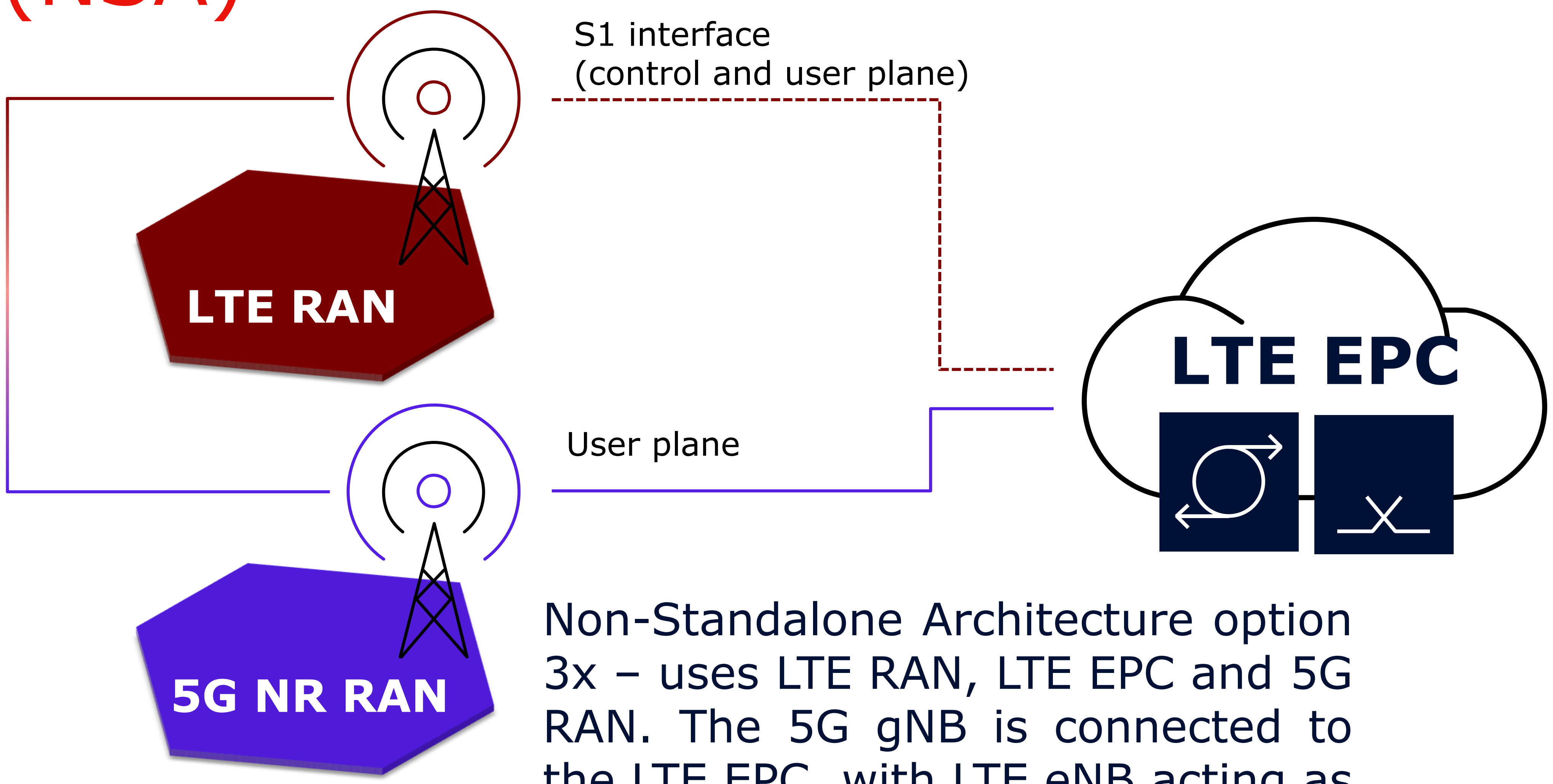
#5 Distributed flexible architecture

In-built Virtualization & CloudRAN, Edge Computing



Non-Standalone Architecture (NSA)

3GPP Release 15 introduces the concept of Non-Standalone Architecture (NSA) as one of the options for deploying 5G network.
In NSA deployment two radio access network technologies operate together, served by common core network.
One of the technologies (Master) provides its own Control and User Plane, and also serves as an anchor for Control Plane procedures of the other technology (Secondary)
The 5G can also be deployed as 5G Standalone Architecture, with just 5G radio and 5G core (5GC)



Non-Standalone Architecture option 3x – uses LTE RAN, LTE EPC and 5G RAN. The 5G gNB is connected to the LTE EPC, with LTE eNB acting as anchor for the Control Plane

NSA 3x capitalizes on the LTE installed base, and offers fast time-to-market - 5G services without needing to deploy 5G core network (5GC).

3GPP radio evolution in Rel-16, Rel-17 and Rel-18

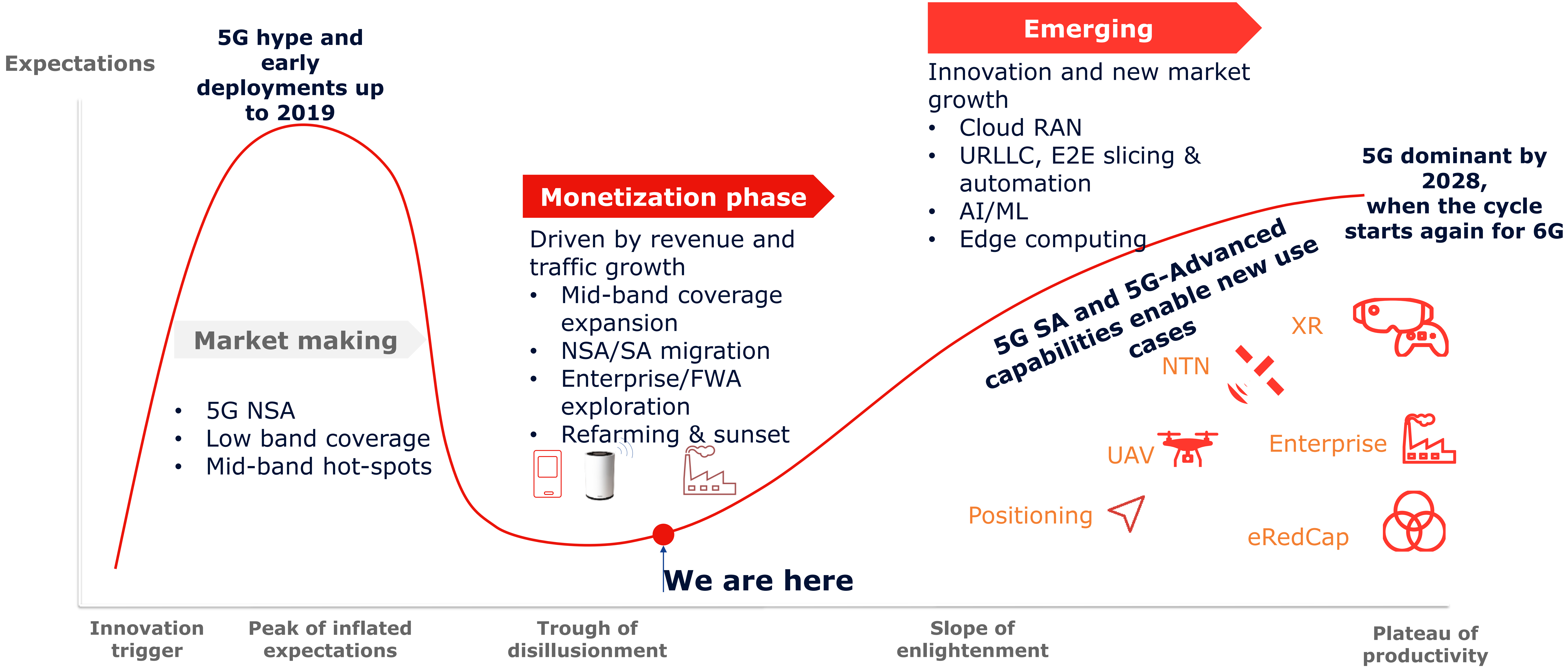
		Rel-16 / Rel-17 / Rel-18
URLLC	Ultra-reliable and low latency communication	URLLC was completed in Rel-17
Radio boosters	Extreme radio performance	Radio improvements continue in every release with focus moving to uplink in Rel-18
Automation and energy saving	Fast rollout and minimized energy usage	Self optimization (SON), relays, AI/ML usage, energy saving evaluations
New verticals	New use cases with 5G radio	Car-to-car, satellites, high altitude platforms, GSM-R, public safety, drones
IoT optimization	Low cost IoT connectivity	RedCap 100 Mbps and 10 Mbps capability with low cost IoT device
Position and time	Accurate position, accurate timing	Sub-10 cm position and timing service with Rel-18
XR/AR/VR	Extended reality power consumption, cost and performance enhancements	XR optimized radio interface

XR Extended reality
AR Augmented reality
VR Virtual reality

Global trends in 5G

Each "G" will follow the S curve, 5G was the quickest to date

Monetizing 5G requires a phase shift

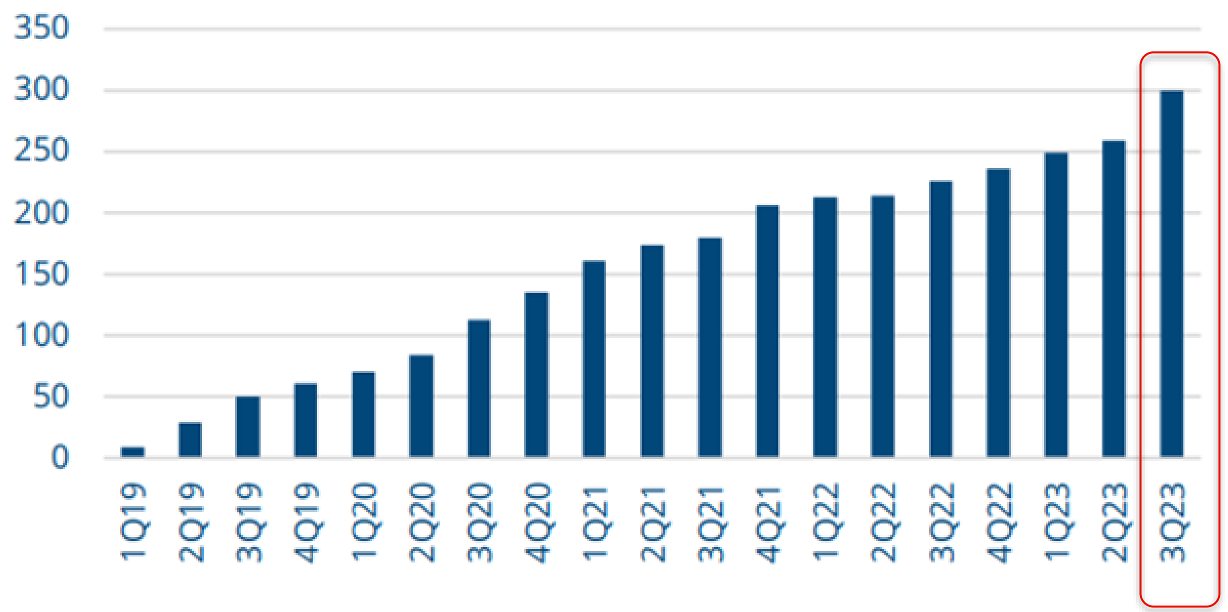


Source: Gartner Hype Cycle

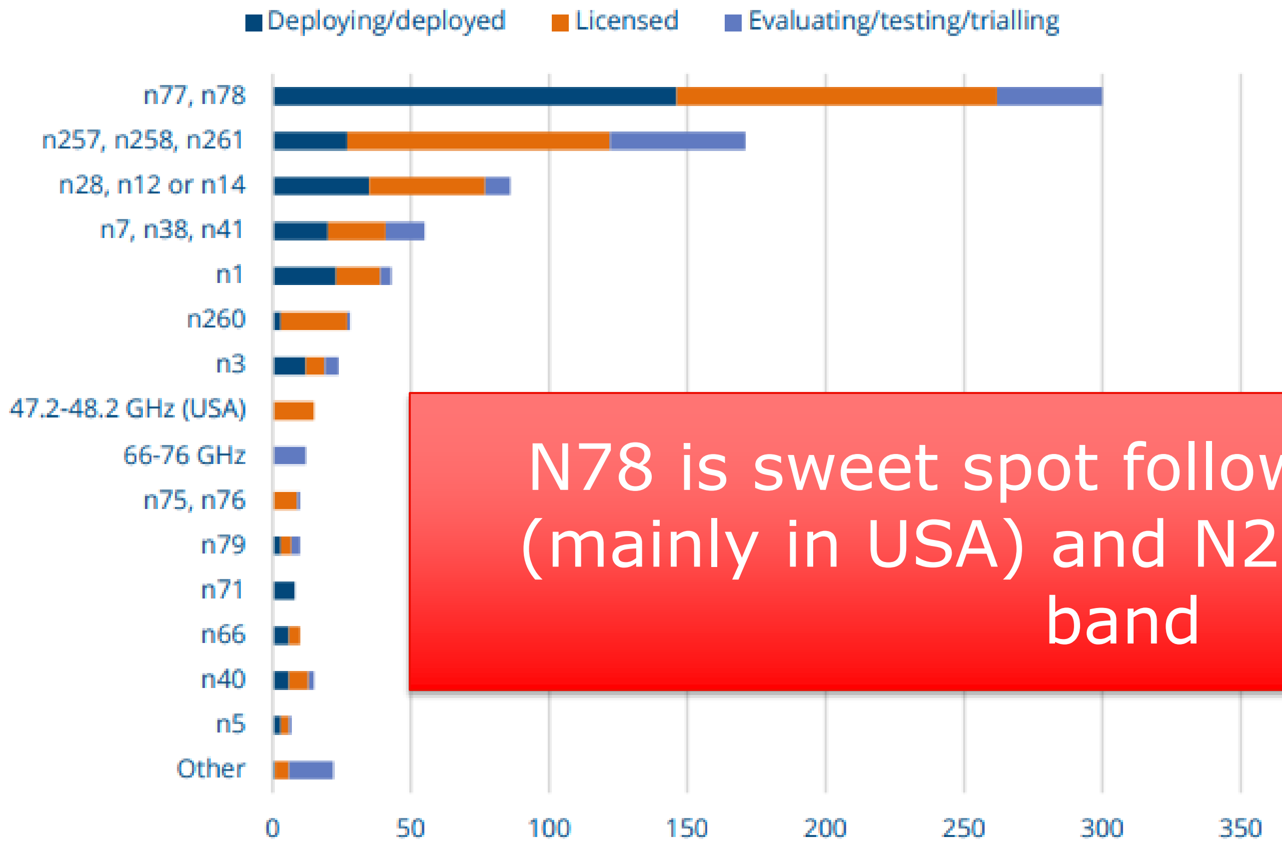
In 4 years only…

Over 300 5G deployments over the globe already

Operators with commercial 5G services

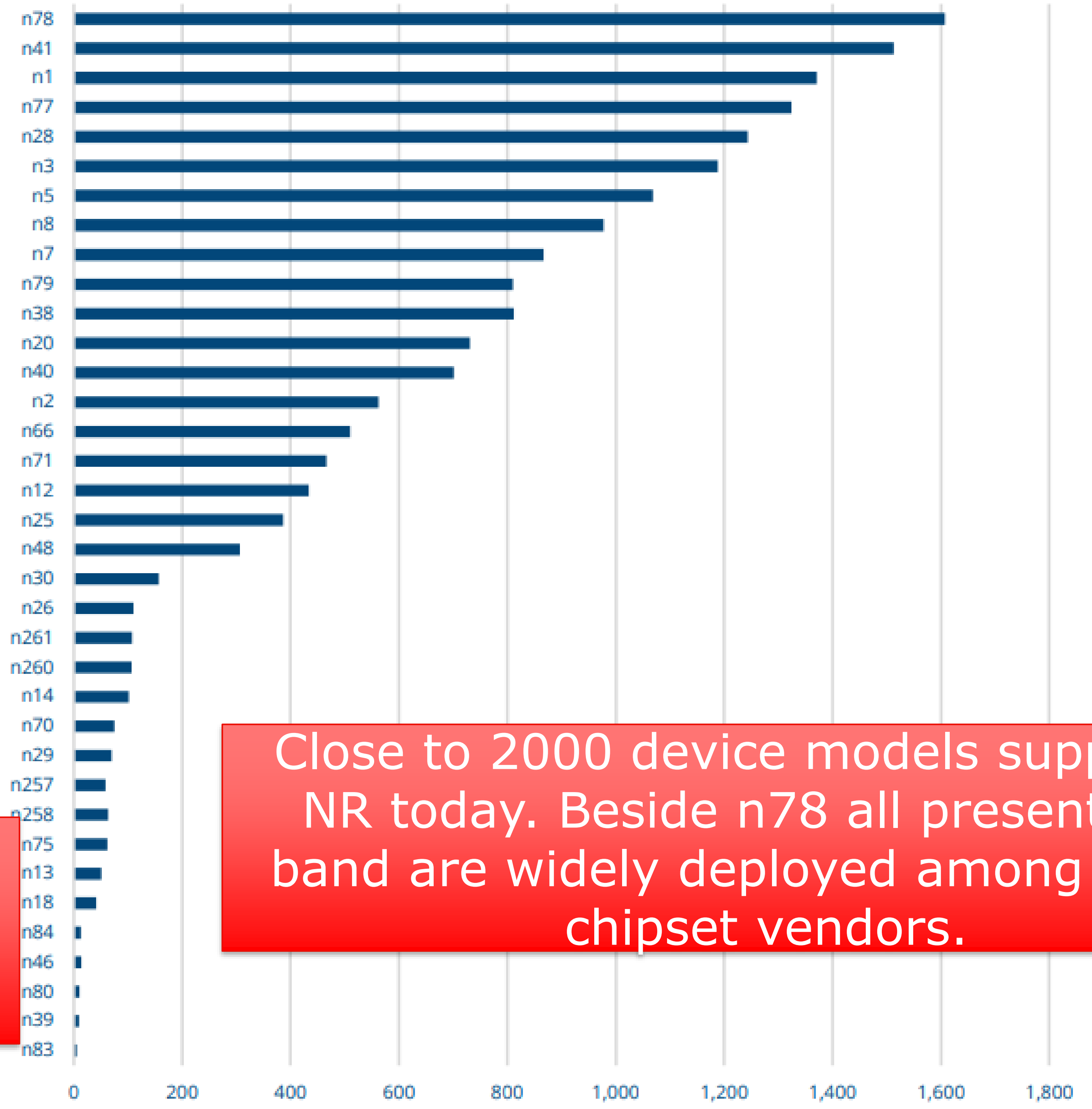


Operators investing in key 5G spectrum bands (end September 2023)



N78 is sweet spot following by mmW (mainly in USA) and N28 as coverage band

Announced 5G device models supporting key 5G spectrum bands (end September 2023)



Close to 2000 device models supporting NR today. Beside n78 all present <3G band are widely deployed among major chipset vendors.

Source: GSA 5G Report

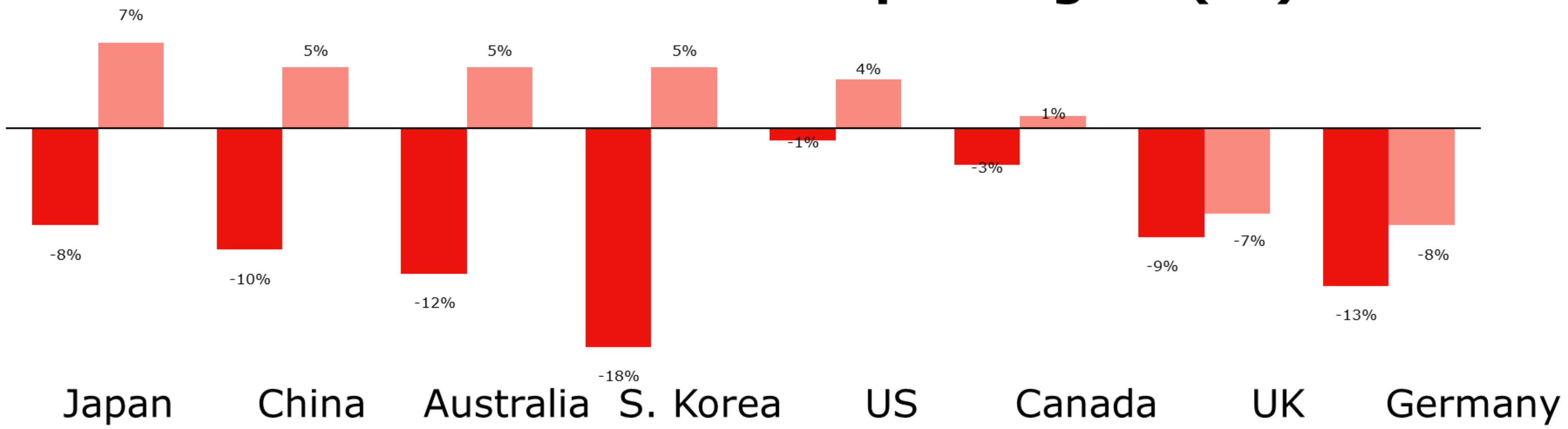
Positive ARPU trend in markets with solid 5G deployment

Insights from leading 5G markets: 5G seems to be one of the main factors behind ARPU growth

- Regions where operators have been able to reverse ARPU decline typically have high performing 5G networks with good coverage and throughput
- 5G Availability with 5G users in leading markets approaching half of time spent with an active 5G connection like in South Korea 48,4%
- Drivers contributing to the ARPU uplift
  - Satisfaction with 5G experience
  - Data consumption increase
  - Content bundling

5G experience is one of the main factors behind revenue growth in leading 5G markets. 5G monetization remains generally untapped

Mobile ARPU trend per Region (%)

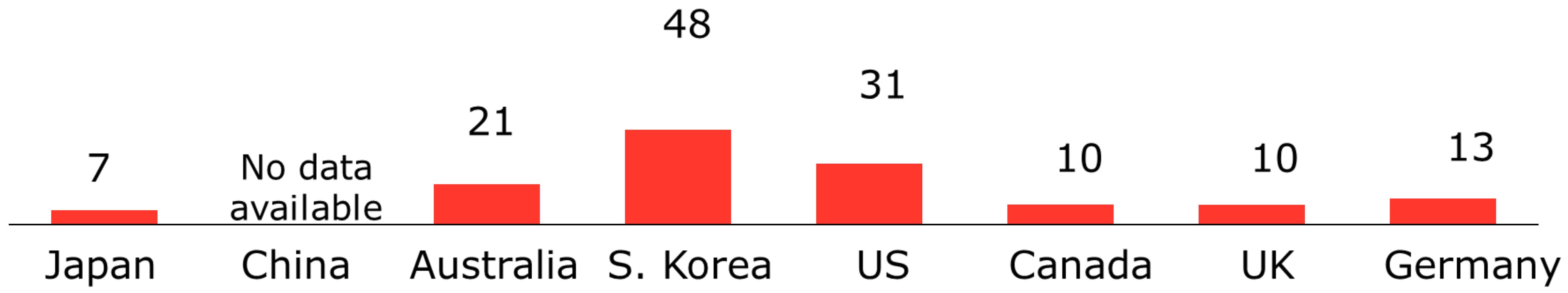


Source: GSMA Intelligence,, 2023

ARPU change 12 quarters before 5G launch

ARPU change 12 quarters after 5G launch

Time spent with an active 5G connection (%)



Source: OpenSignal, 2023

A1 Group status and testing

| A1 Serbia

Spectrum Auctions & Spectrum acquired in A1 Markets

5G launched in **Austria, Bulgaria, Croatia, Slovenia and Macedonia**, following 5G spectrum acquisition.

All awarded spectrum in all markets is **technology neutral**, can be reused for 5G as well.

Upcomming 5G spectrum acquisition:

- Serbia 2024?
- Bulgaria mmW, 2023
- Austria mmW, 2024

AUSTRIA: AUT

Pre-5G spectrum:

800MHz: 2x20MHz
900MHz: 2x15MHz
1800MHz: 2x35MHz
2100MHz: 2x20MHz (exp.)
2600MHz: 2x20MHz

5G Spectrum acquired:
***Sep.2020**
1500MHz SDL: 30MHz
2100MHz: 2x25 (extended)
***Apr.2019**
3500MHzTDD: 120-140MHz

5G Commercial launch:
January 2020

Current 5G Deployments:

~5000 (1400 with C-Band) of ~8700 Geo. sites

BULGARIA: BUL

Pre-5G spectrum:

900MHz: 2x11.2MHz
1800MHz: 2x15MHz
2100MHz: 2x15MHz
2600MHz: 2x20MHz

5G Spectrum acquired:
***Apr.2021**
3500MHzTDD: 100MHz
*** Dec.2022**
3500MHzTDD: 20MHz

5G Commercial launch:
May 2021

Current 5G Deployments:

~1500 (all C-Band) of ~3900 Geo. sites

SLOVENIA: SLO

Pre-5G spectrum:

800MHz: 2x10MHz
900MHz: 2x15MHz
1800MHz: 2x35MHz
2100MHz: 2x15MHz (exp)
2600MHz: 2x35MHz

5G Spectrum acquired:
***Apr.2021**
1500SDL: 40MHz
700MHz: 2x10MHz
3500MHzTDD: 100MHz
26GHz mmW: 400MHz

5G Commercial launch:
September 2021

Current 5G Deployments:

~600 (400 with C-Band) of ~1200 Geo. sites

CROATIA: CRO

Pre-5G spectrum:

800MHz: 2x15MHz
900MHz: 2x14.4MHz
1800MHz: 2x20MHz
2100MHz: 2x20MHz
2600MHz: 2x20MHz

5G Spectrum acquired:
***Aug.2021**
700MHz: 2x10MHz
3500MHzTDD: 100MHz
26GHz mmW: 200MHz

5G Commercial launch:
August 2021

Current 5G Deployments:

~1000 (300 with C-Band) of ~2000 Geo. sites

MACEDONIA: MKD

Pre-5G spectrum:

800MHz: 2x10MHz (2x)
900MHz: 2x12.5MHz
1800MHz: 2x35MHz
2100MHz: 2x10MHz

5G Spectrum acquired:
***Aug.2022**
2100MHz: 2x10MHz
700MHz: 2x10MHz
3500MHzTDD: 100MHz

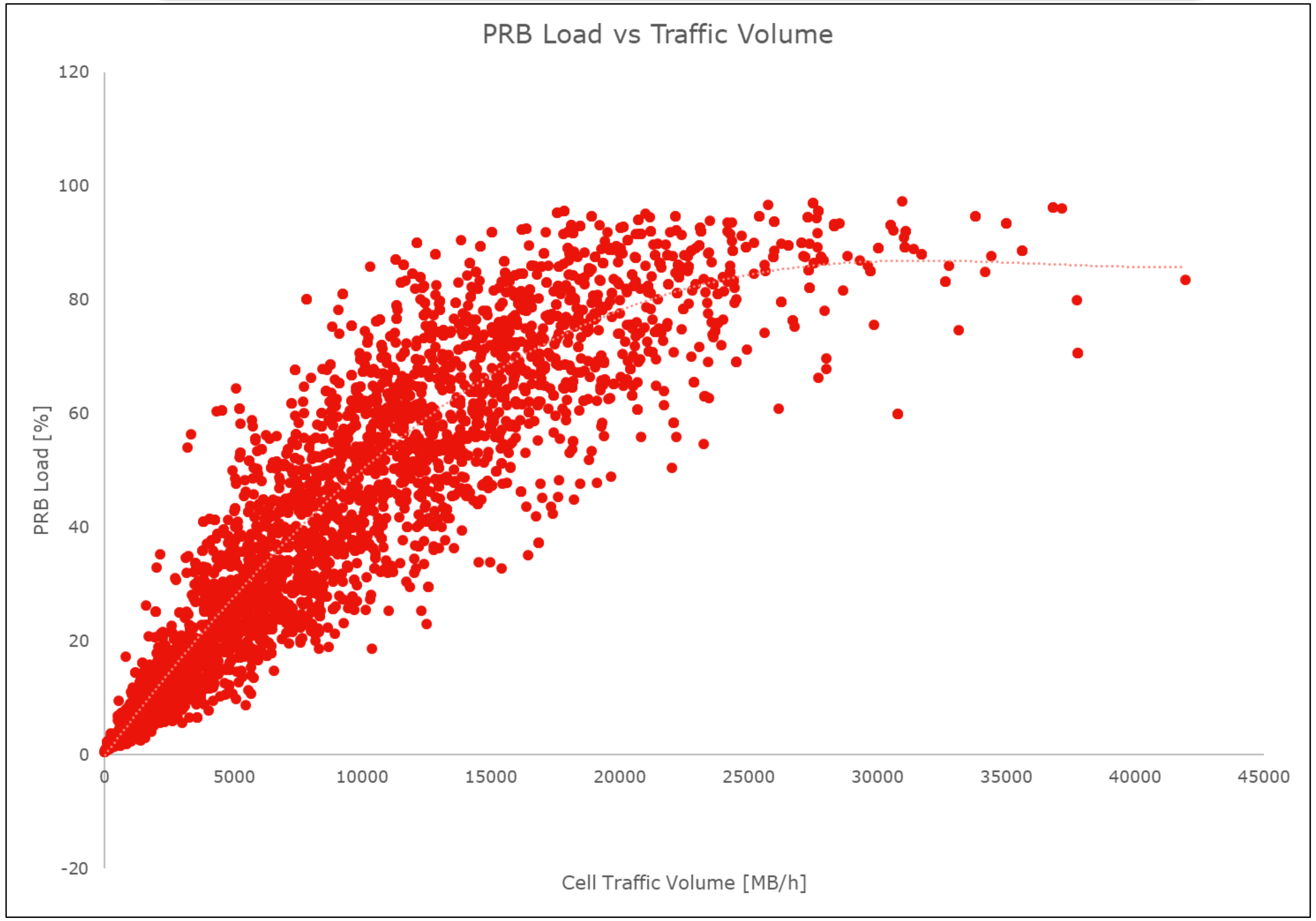
5G Commercial launch:
September 2022

Current 5G Deployments:

~600 (80 with C-Band) of ~900 Geo. sites

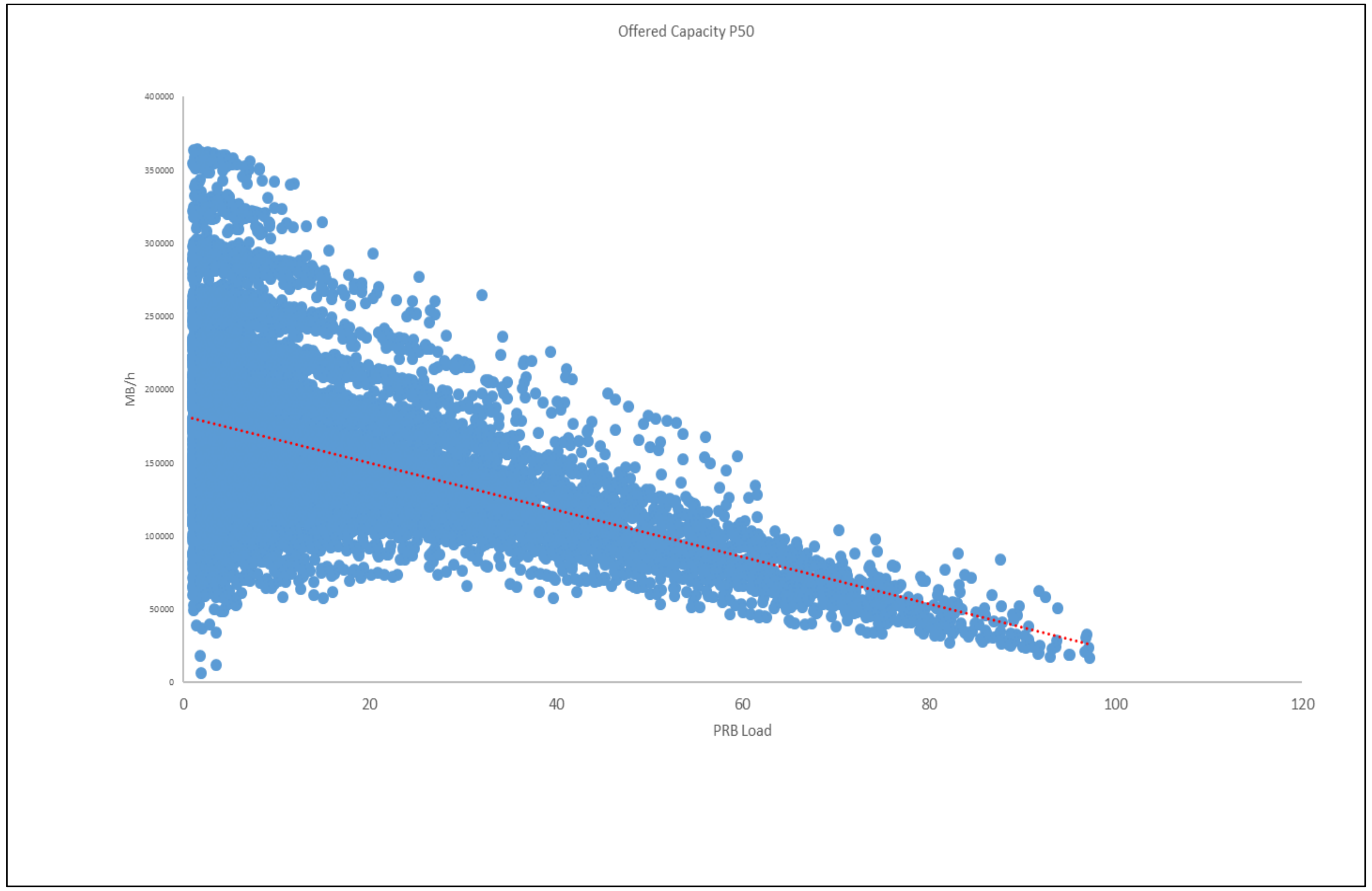
eMBB – what are LTE boundaries?

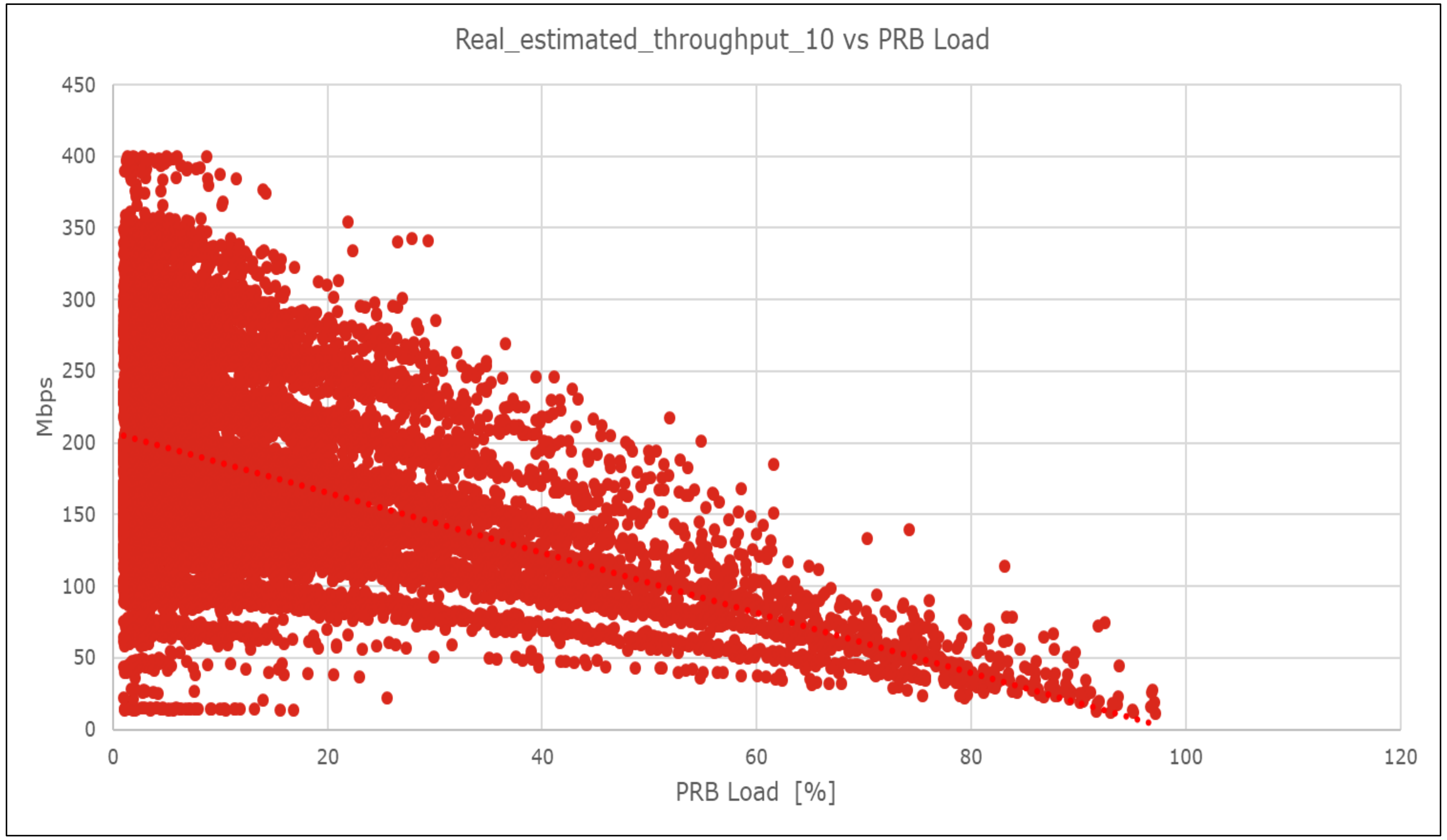
With 80% of load typical LTE 20MHz call can absorb not more than 20 GB of data in BH



eMBB – 5G can bring at least 2 times higher spectral efficiency than LTE

100MHz TDD NR cell without MU-MIMO can handle between 120 and 200 GB/h depending on the load
With MU-MIMO it can get 50% traffic on top

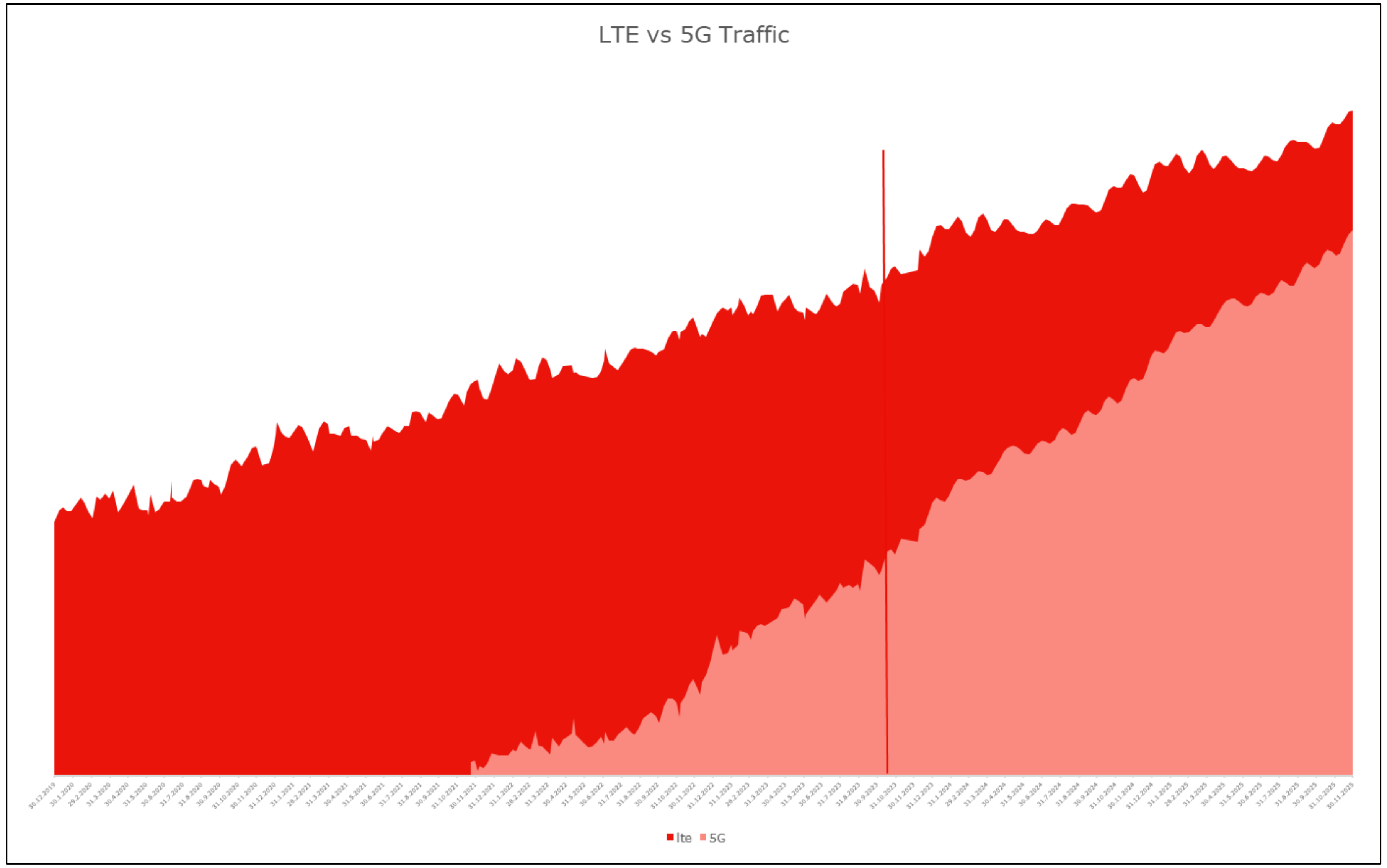


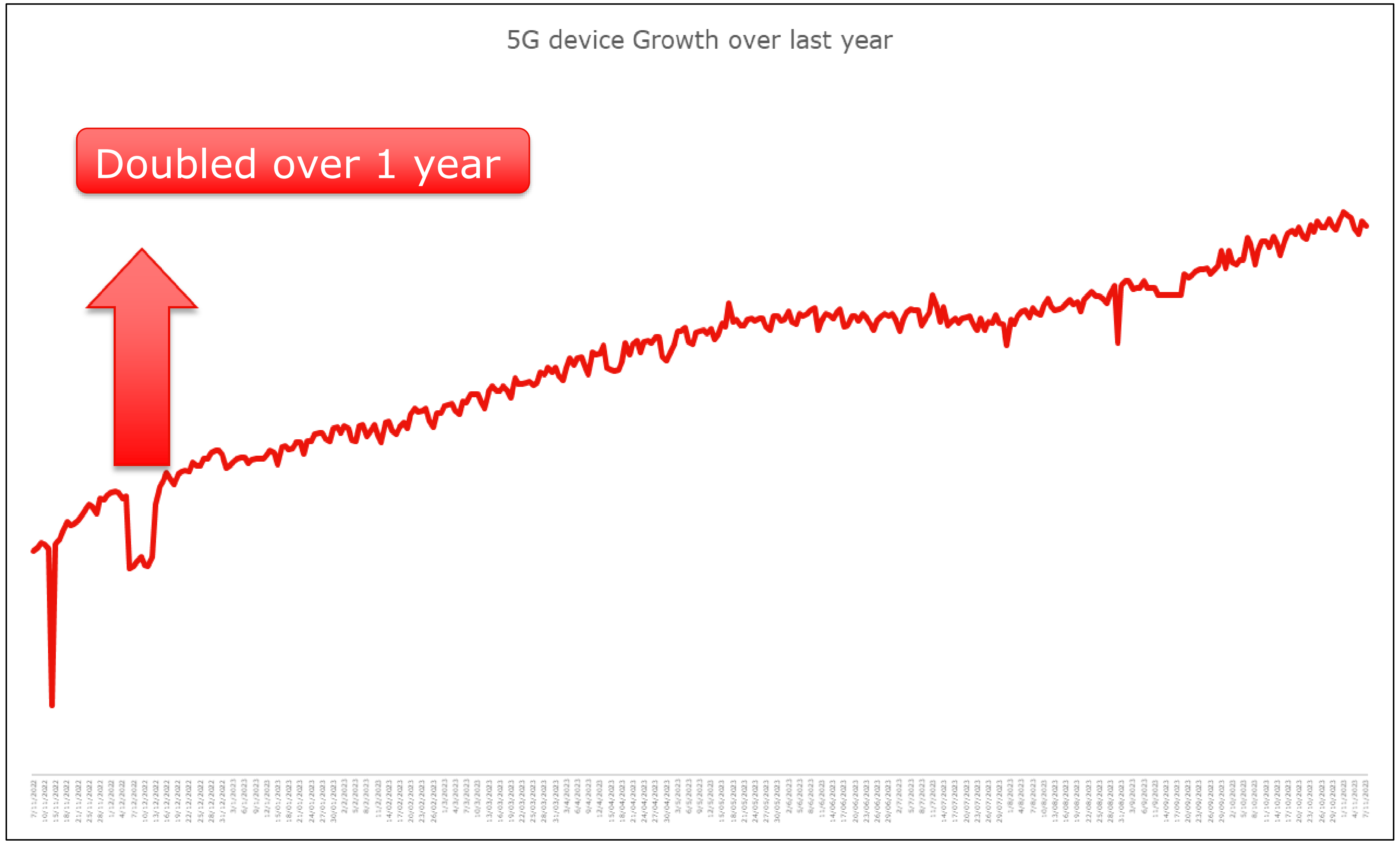


Traffic and devices

One of A1 markets - 2 years after 5G launch 5G traffic takes 55% of overall traffic and in 2 years estimated it will take >85% of overall transferred traffic through MNO infrastructure.

In Serbia we can see volume of 5G devices is doubled within last year even there is no commercial 5G available in the country.

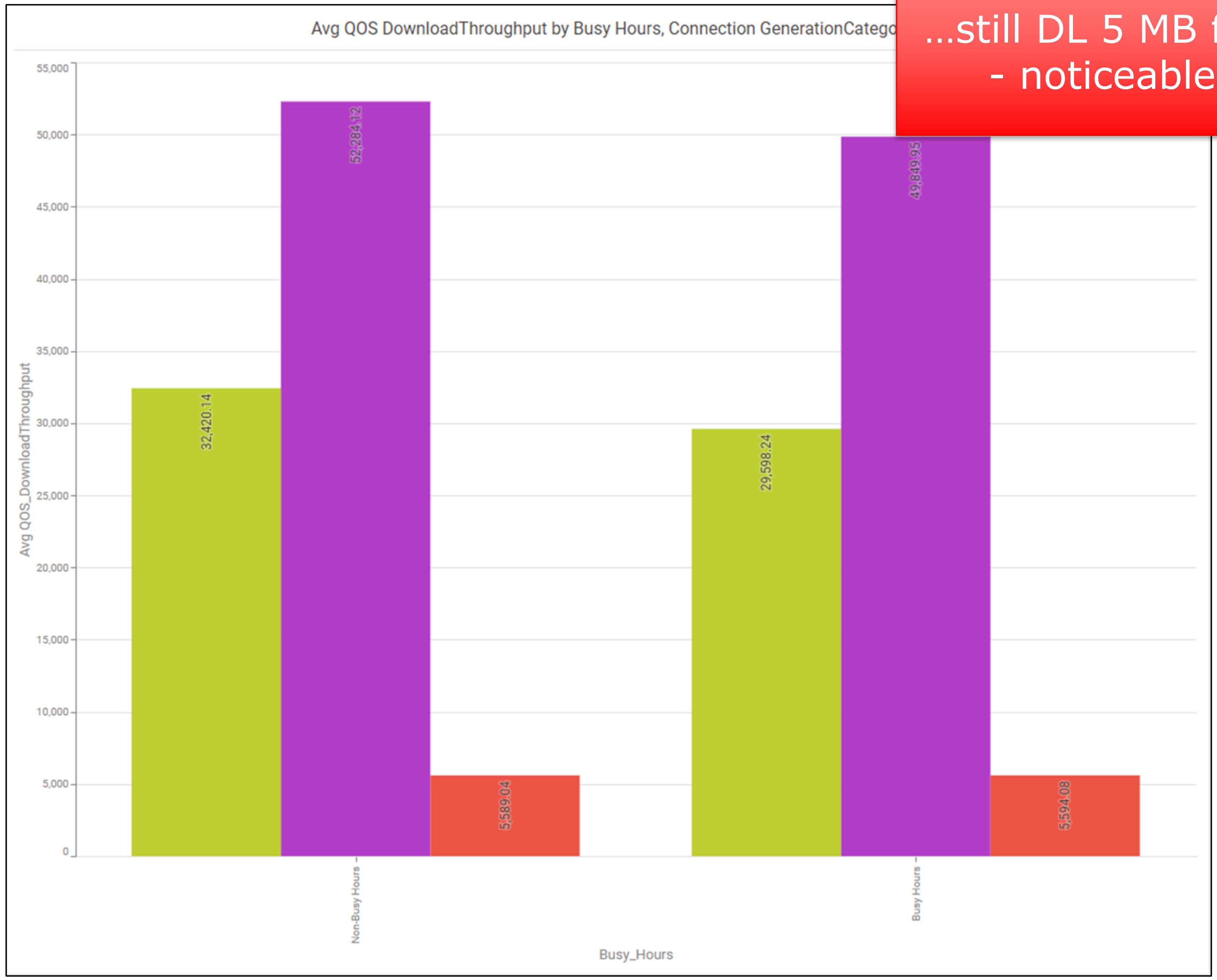




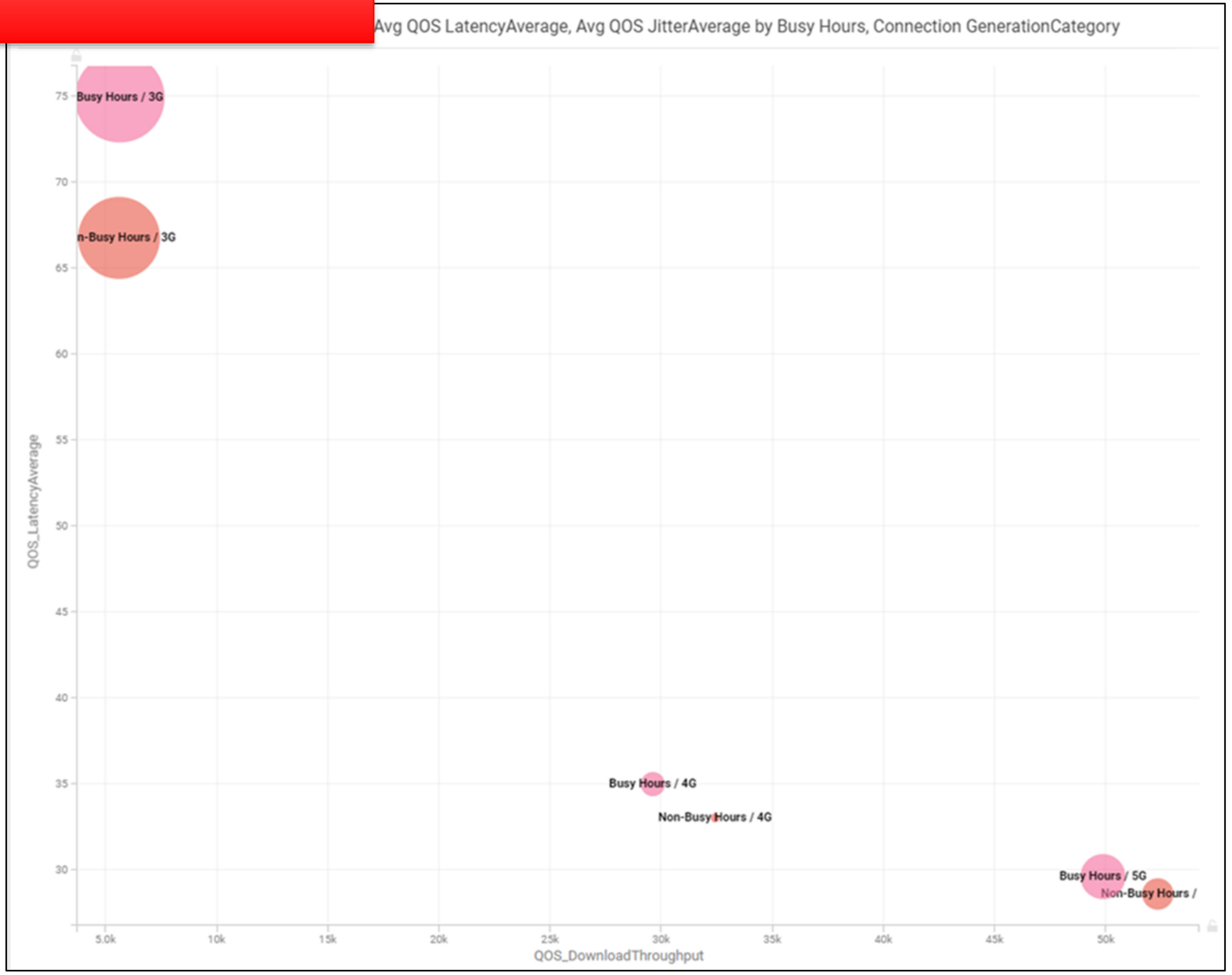
LTE vs NR - how average User sees the difference?

Download of 5MB file brings no much difference when comparing LTE and NR as LTE vs UMTS

...and reason is hidden in latency figures.



...still DL 5 MB file download throughputs - noticeable improvement with NR

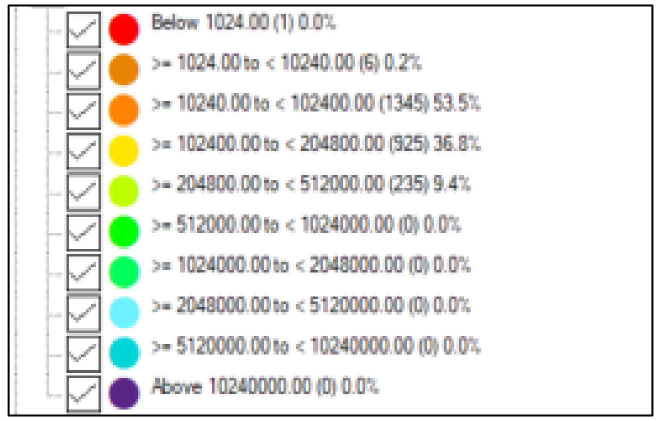


A1 test and trial

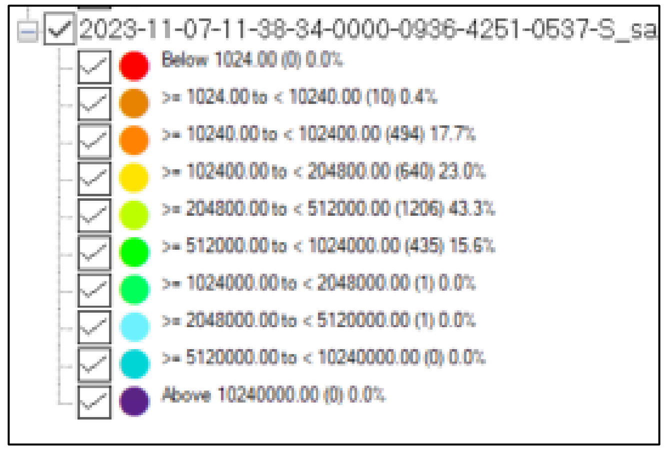
The most important 5G Planning Steps

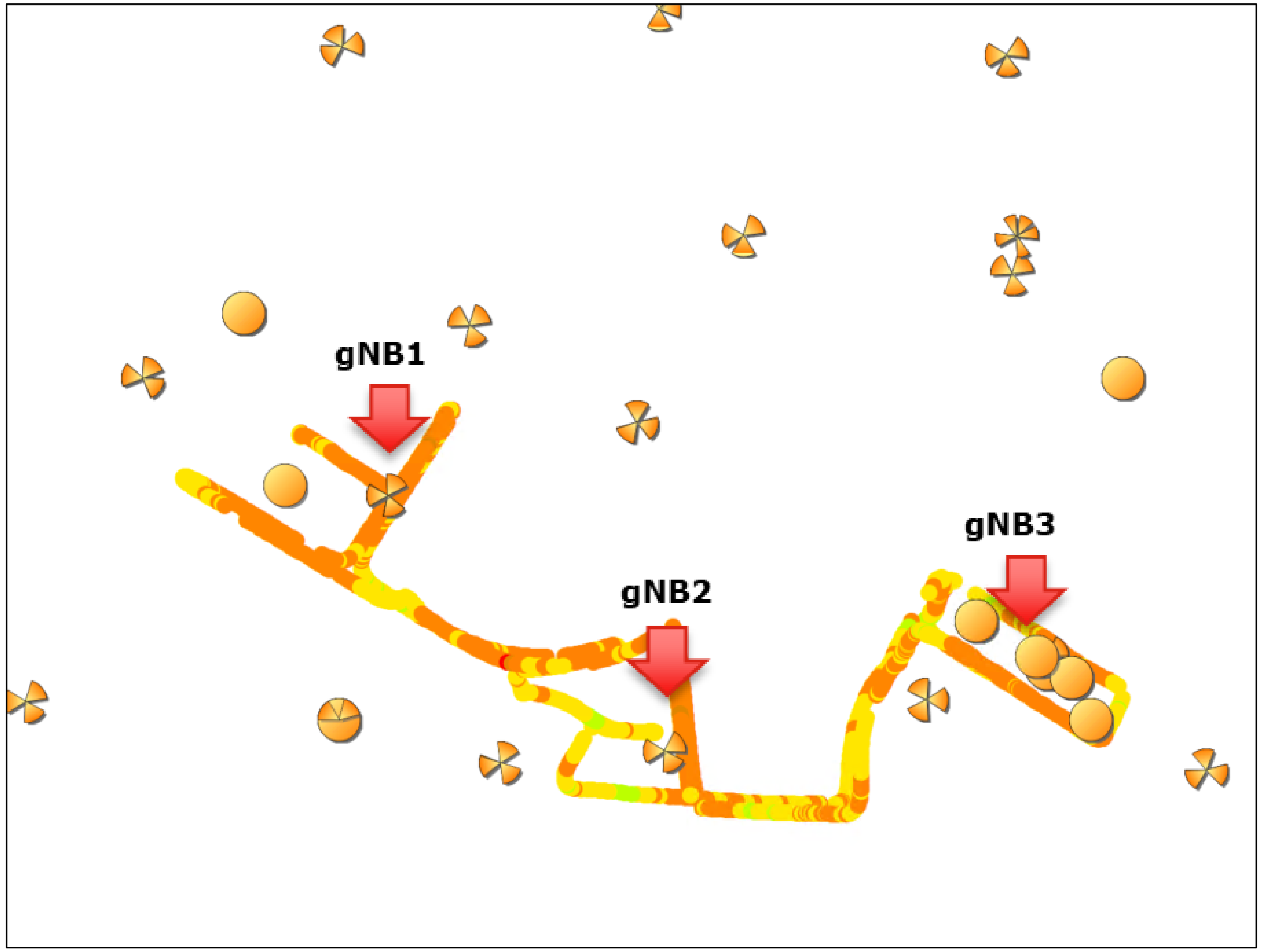
Coverage and Slot Format	Capacity and Coverage	Throughput and Latency
Slot Format	BWP definition	Mobility Parameters
Power Setting	Beam Forming Method Selection	DL and UL dynamic path split
RACH and Cell Range	MIMO option selection	QoS
DMRS and CSI-RS planning	PUCCH Capacity Planning	Inactivity timer planning
SS/PBCH Beam Selection	Admission Control Parameters	DRX
PCI Planning	B1/A2 Thresholds for NSA coverage	Carrier Aggregation

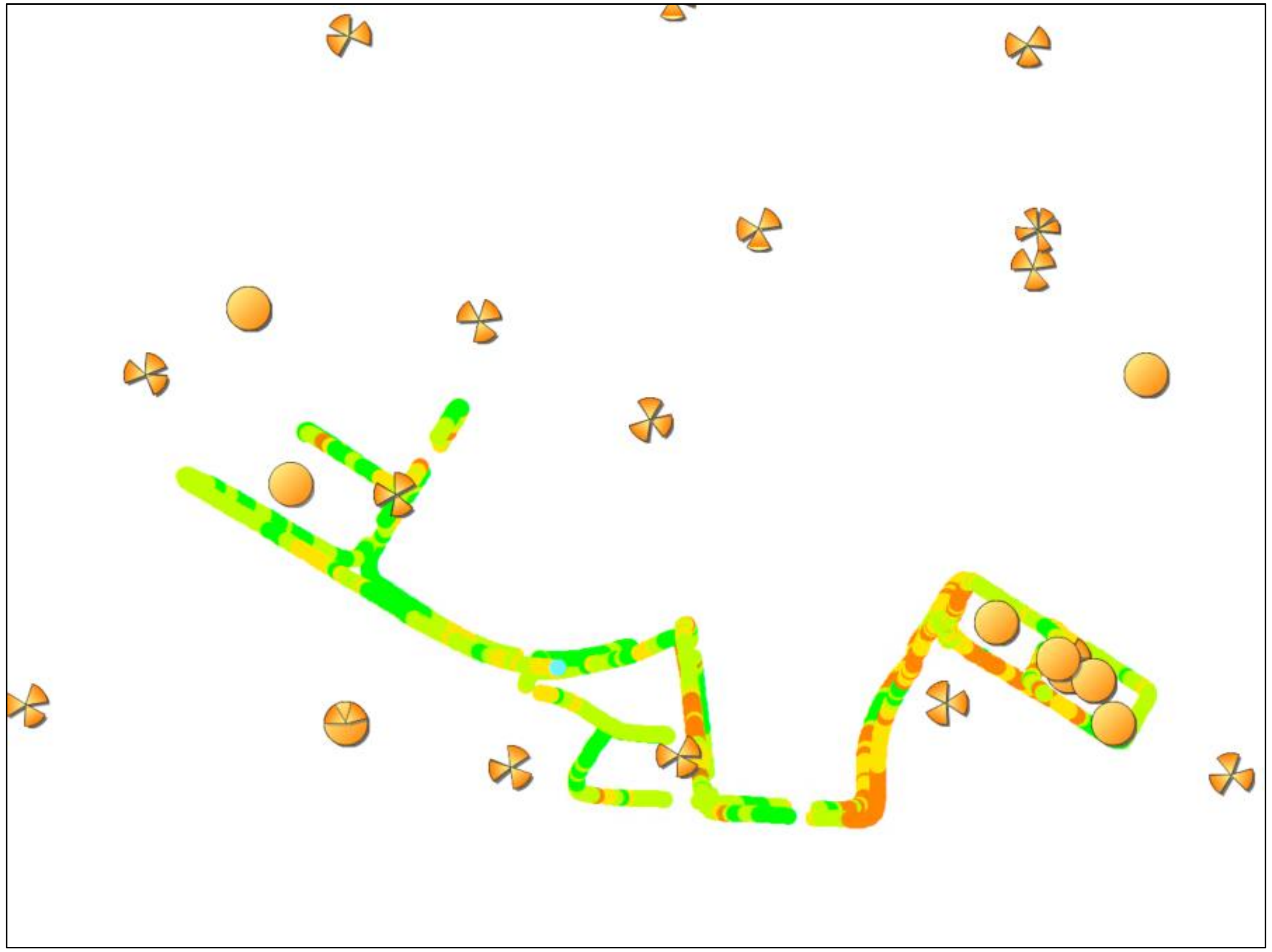
LTE vs ENDC Throughputs – Live cluster A1 Serbia



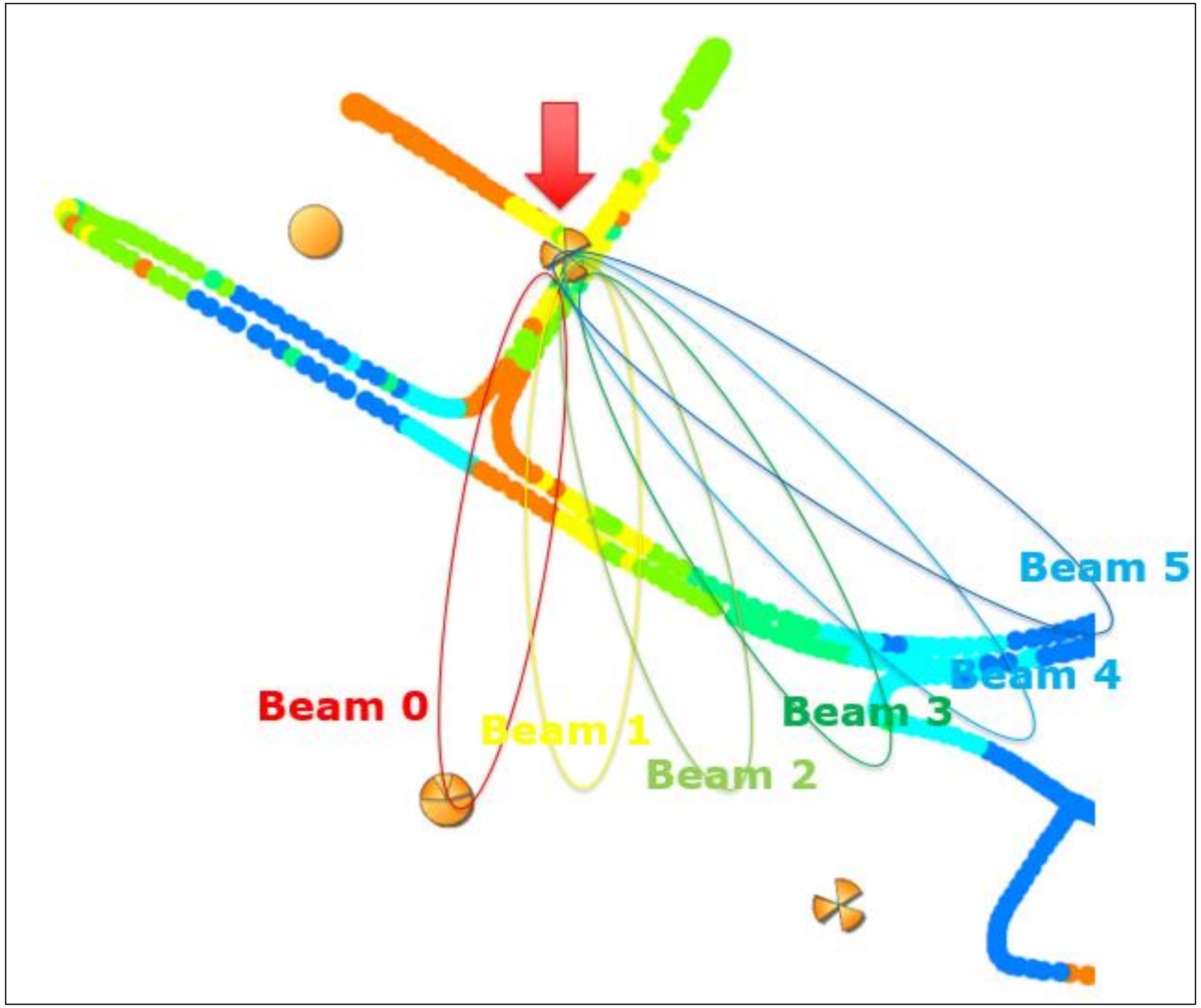
Full Buffer Download - There is substantial difference between NR and LTE throughputs despite NR pilot grid consisted of 3 gNBs only.



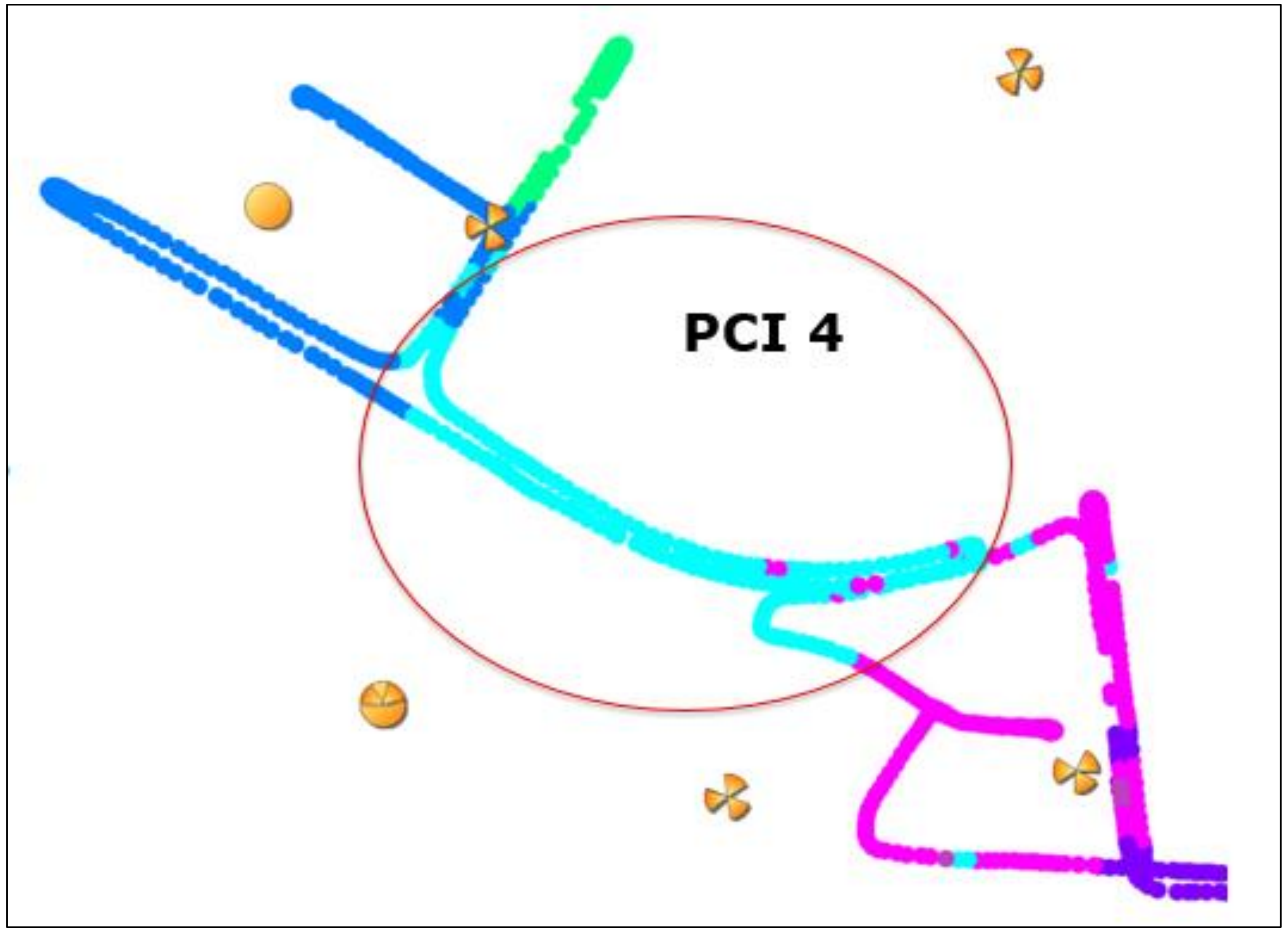




SS/PBCH Beamforming



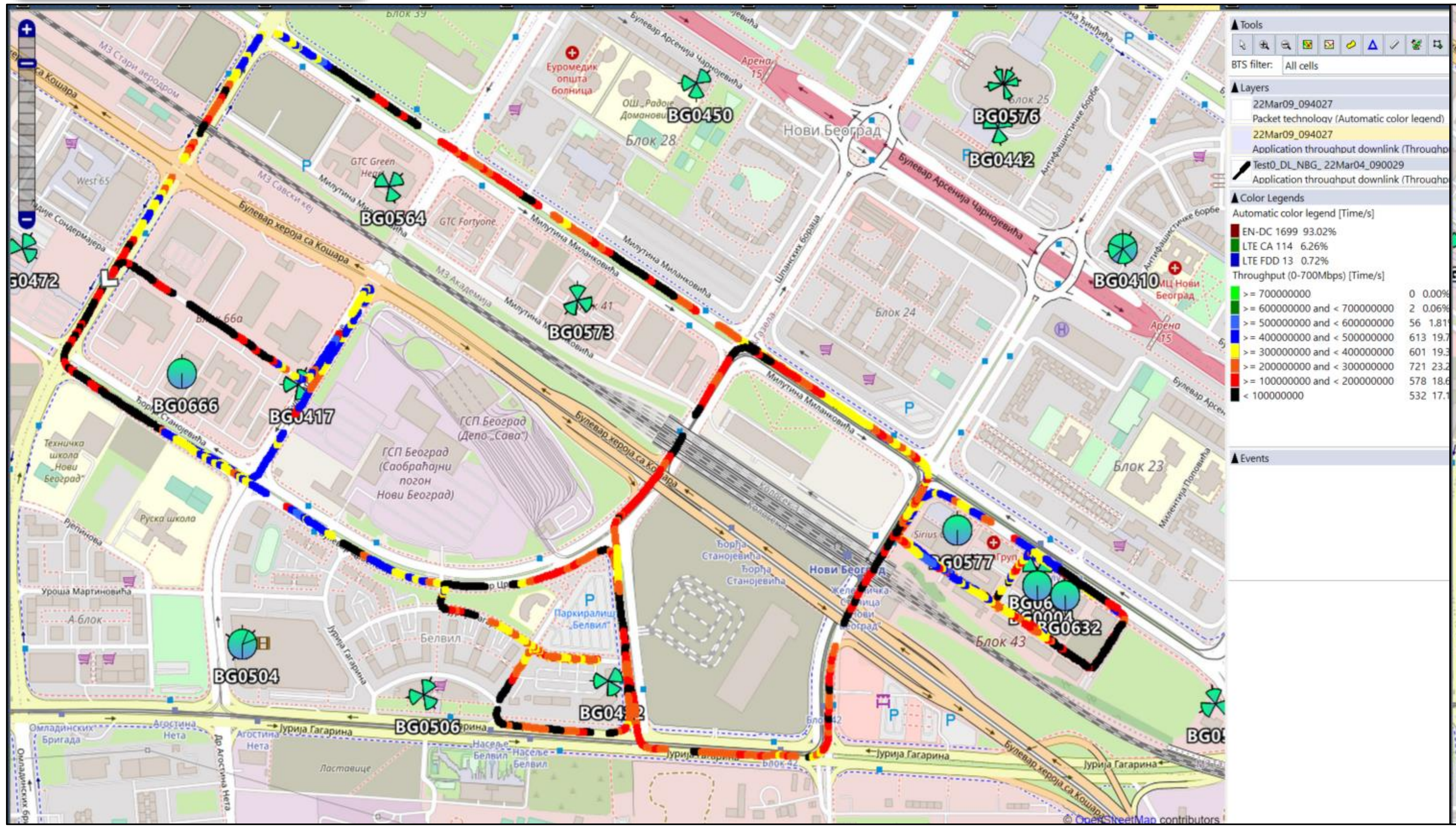
Proper Choice of Beam set is very important to minimize Beam change failures and optimize idle mode coverage.



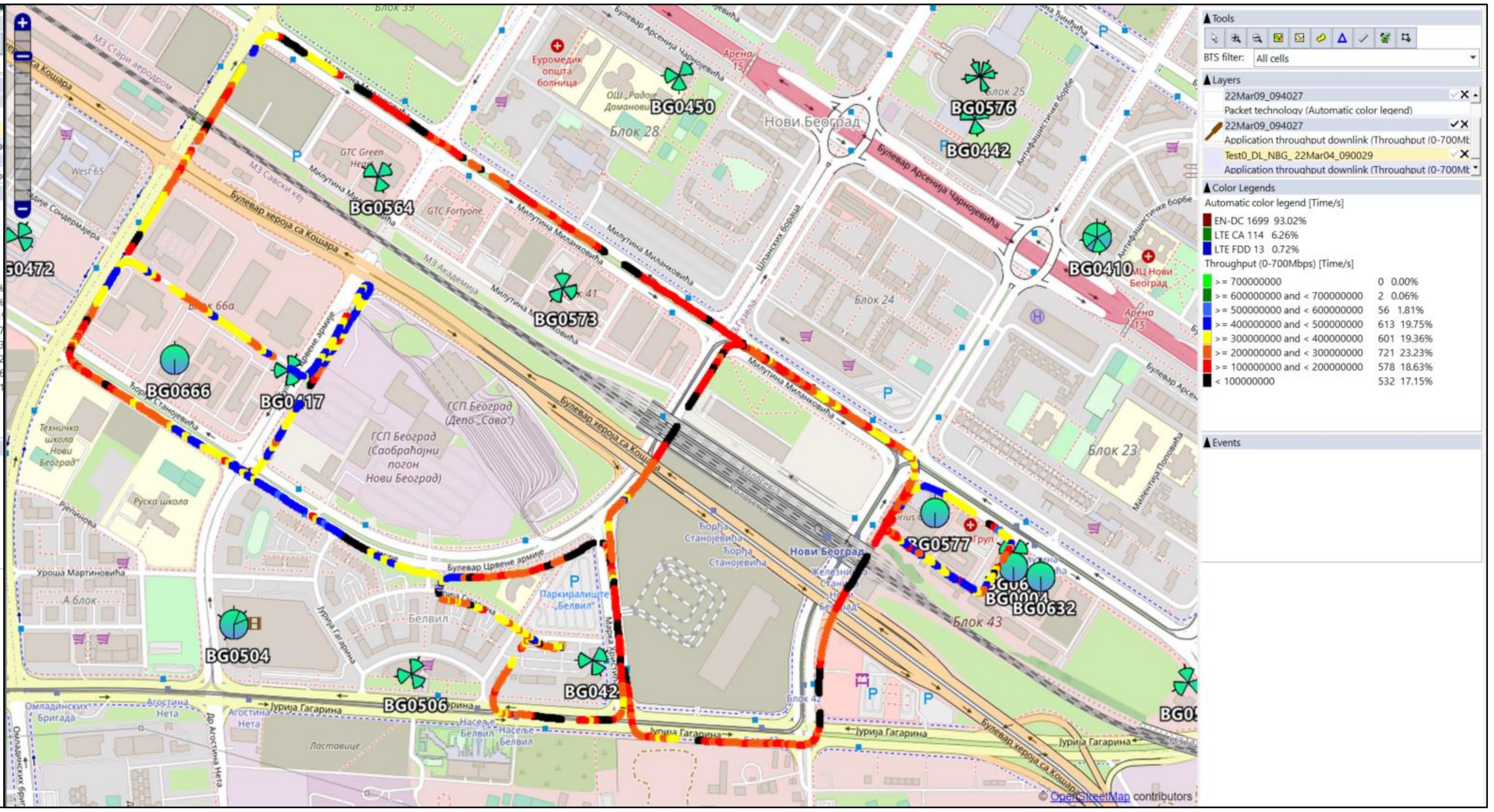
ENDC Neighbor optimization

Adding inter site anchoring

Set0



Set2

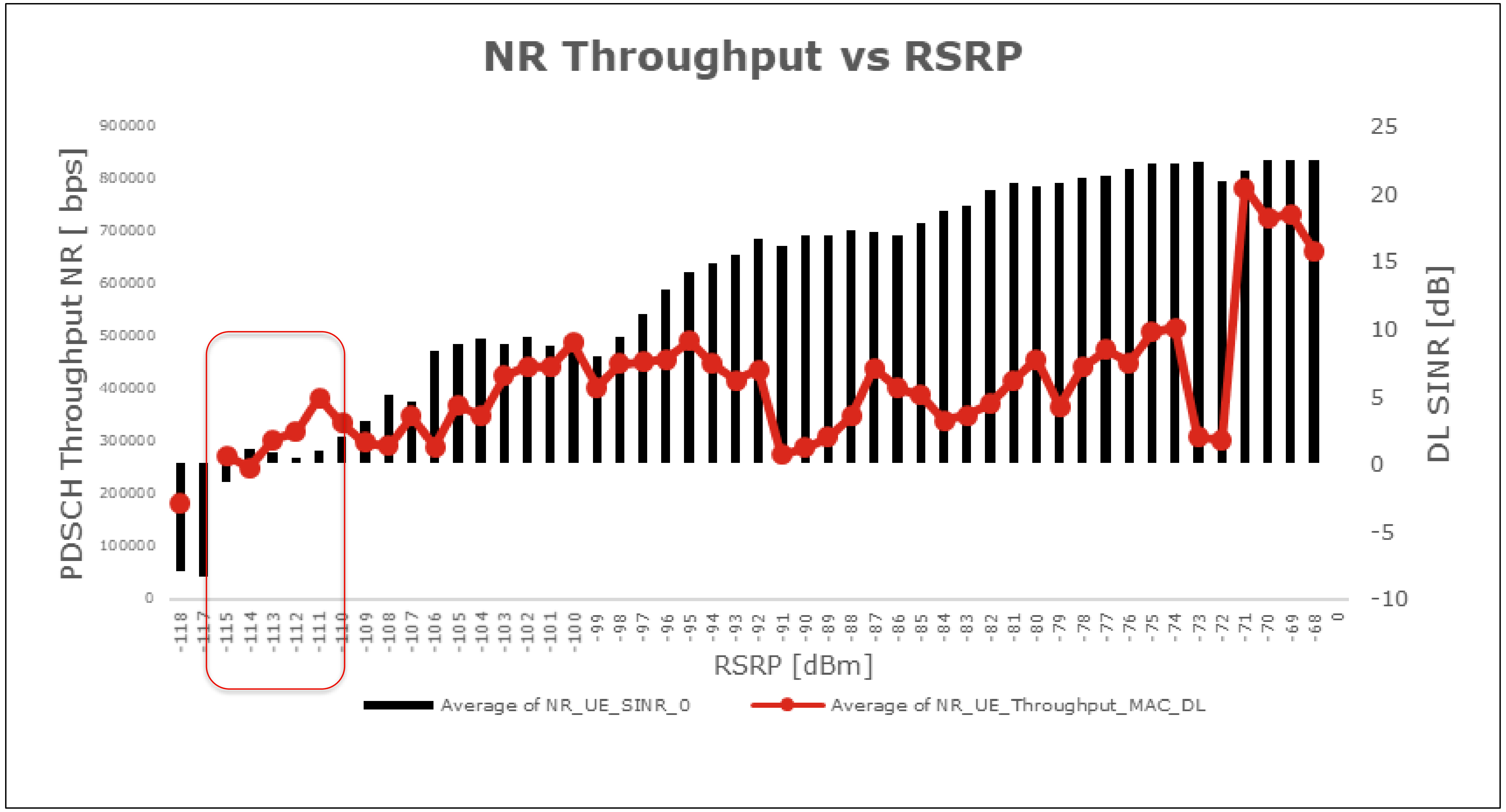


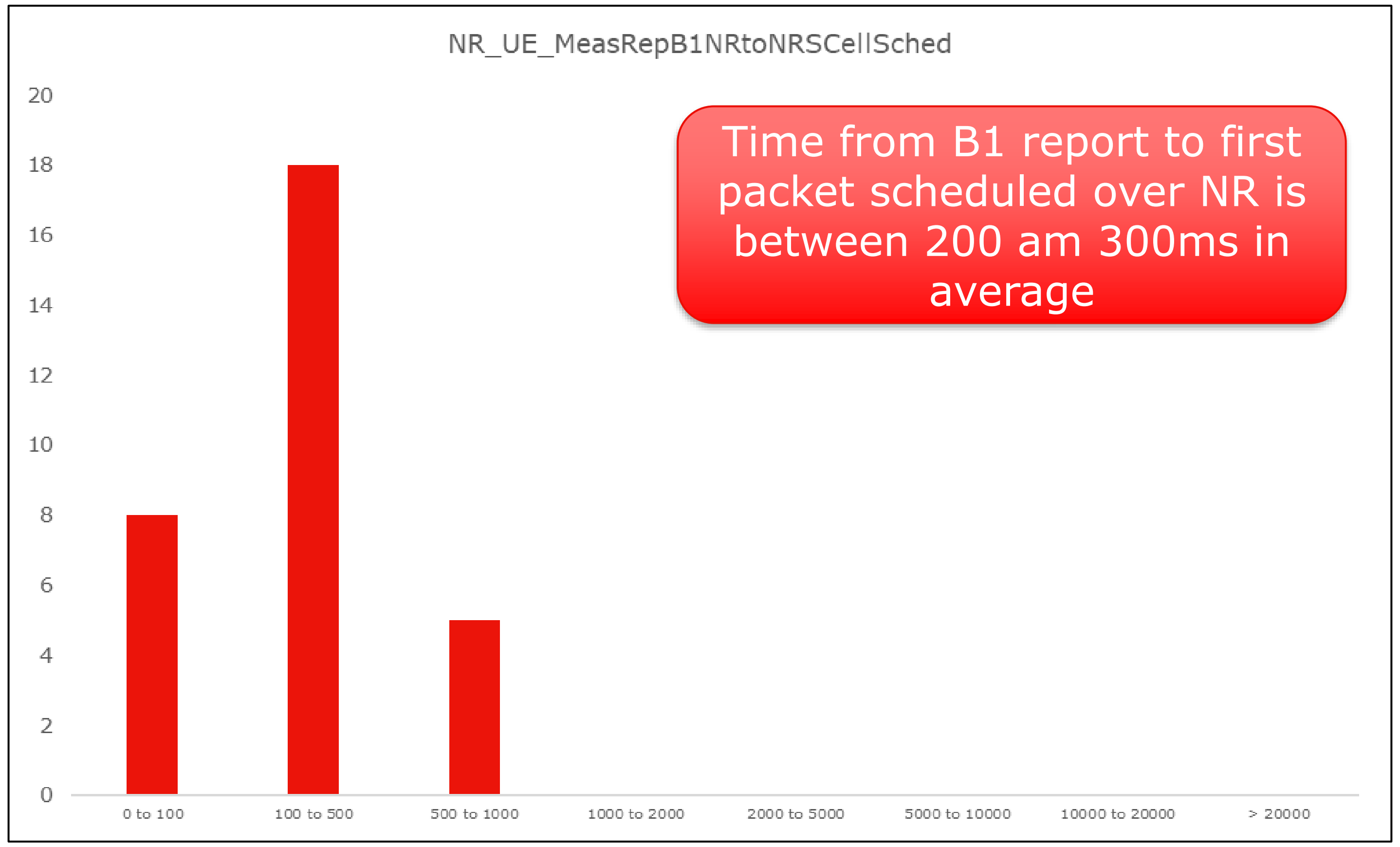
Aggregates	22Mar09_094027.1	Test0_DL_NBG_22Mar04_090029.1
Average	275381934.311	244057781.941
Maximum	568144896	627070593
Minimum	5956	75294
Std. deviation	129595966.405	153472290.789
Variance	16795114508449328	23553744039939520
Threshold < 10000000	0.826	6.15
Time (ms)	1566604	1535750

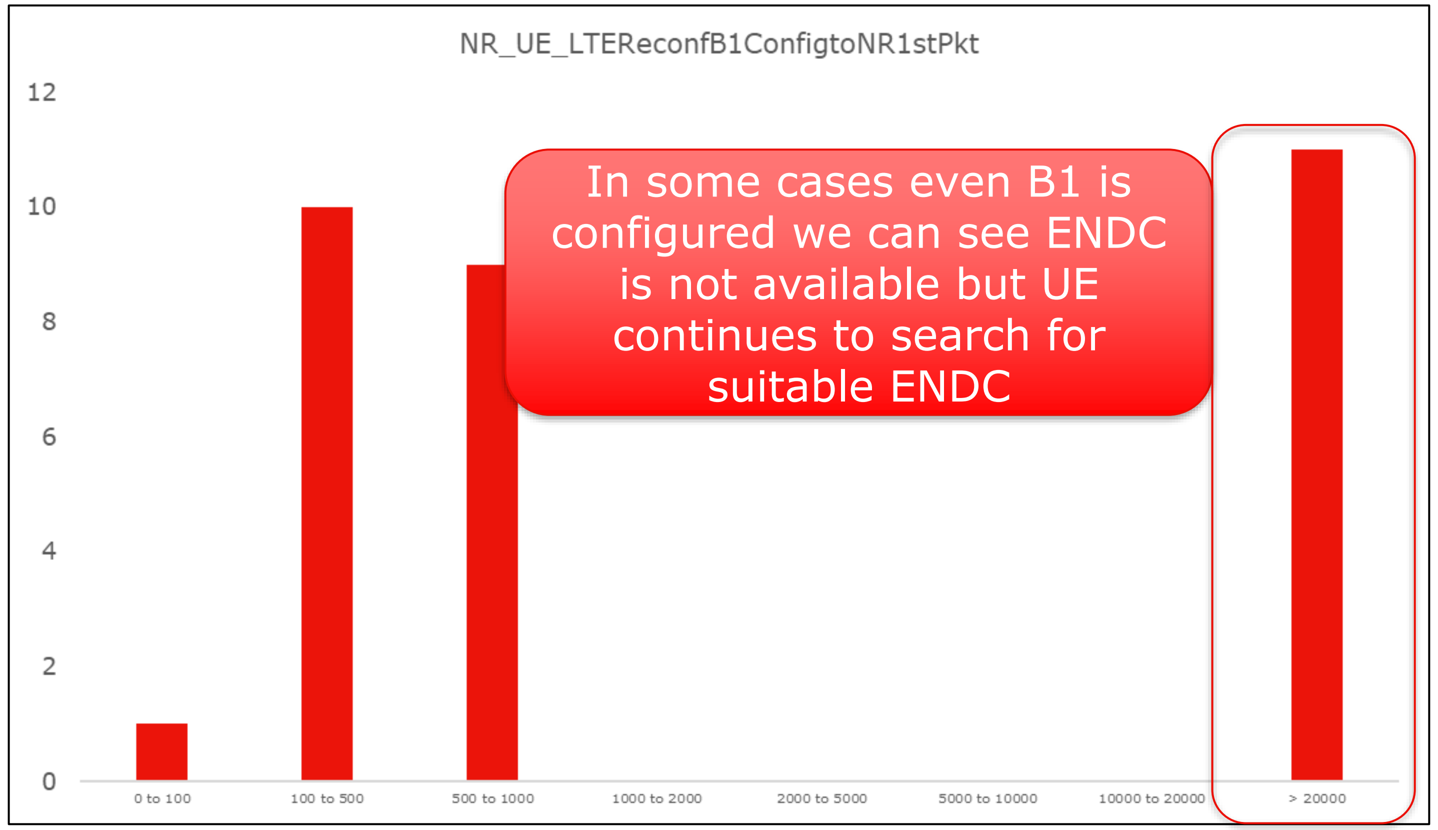
30Mbps average application throughput increased (15%) 244->275 Mbps

NR coverage

NR MAC DL Throughput is rather good even with RSRP levels of -113 dBm. This is because of the fact that network is experimental (no load) but shows big potential of 5G even in challenging radio conditions.





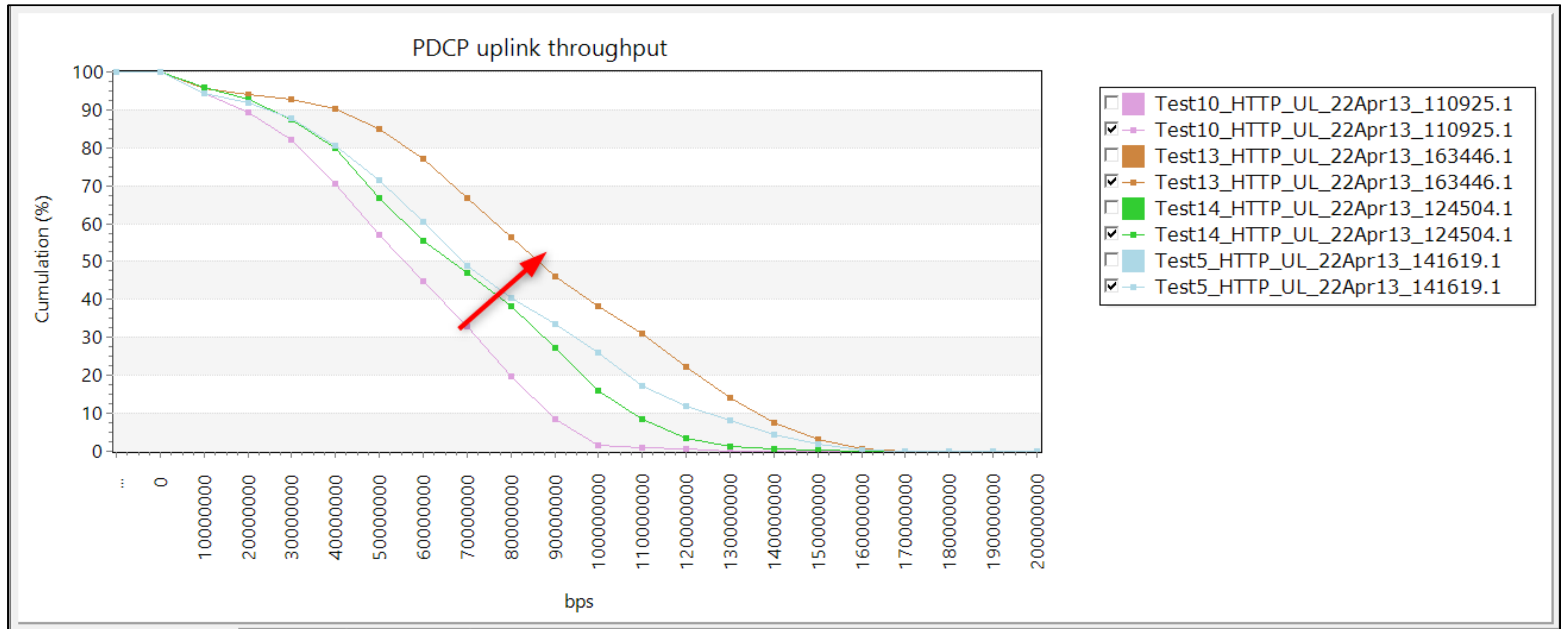


Optimization of HTTP Upload

UL App. Throughput 50% Improved

Date	Test Cases	Scope	Device	Measurement System	Cluster	Type of Tests	Antenna Type
13.4. Third	Test 5	4RX IRC for Beamforming and Non-beamforming Cells	Xiaomi 11T Pro	NEMO	NBG n78	drive test	64T64R
13.4 First BASELINE	**Test 10**	**23Rx upgrade + ABIO Validation - Referent**	**Xiaomi 11T Pro**	**NEMO**	**NBG n78**	**drive test**	**64T64R**
13.4. 4th	**Test 13**	**Additional UL DMRS**	**Xiaomi 11T Pro**	**NEMO**	**NBG n78**	**drive test**	**64T64R**
13.4. Second	Test 14	Test 6 + Test 7, 256 QAM for PUSCH+FDM of DMRS & PUSCH data in the UL of FR1 cells	Xiaomi 11T Pro	NEMO	NBG n78	drive test	64T64R

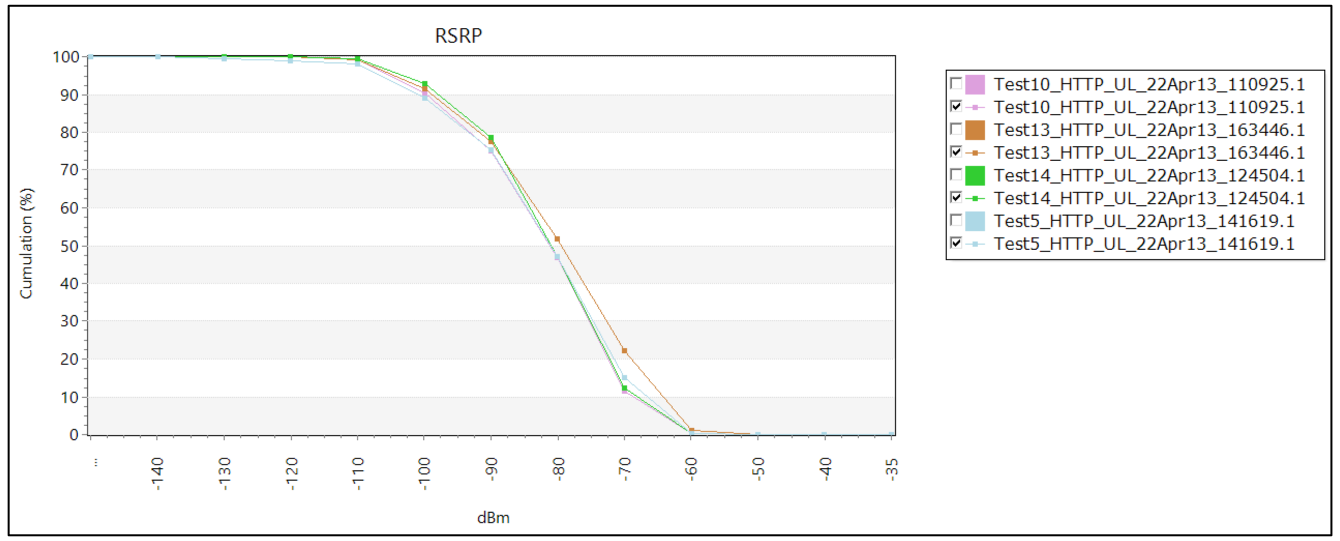
Baseline 55 Mbps in UL over NR
With every change improvement is visible
256QAM and PUSCH DMRS Multiplexing brought huge gain 55->67 Mbps
Later 4RX additional gain 67→72 Mbps and latest change Additional UL DMRS 72→87 Mbps*



Density & Cumulation | Histogram | Aggregates

Aggregates	Test10_HTTP_UL_22Apr13_110925.1	Test13_HTTP_UL_22Apr13_163446.1	Test14_HTTP_UL_22Apr13_124504.1	Test5_HTTP_UL_22Apr13_141619.1
Average	54996406.214	86903590.085	66975450.396	72703840.081
Maximum	132342124	174365714	161299643	166918688
Minimum	0	0	0	0
Std. deviation	26325366.765	37742525.533	31709458.467	37549229.308
Variance	693024935299100.5	1424498233571935	1005489756261081	1409944621627884
Threshold < 40000000	29.372	9.71	19.984	19.386
Time (ms)	3502132.007	3205157.003	3762038.003	3339471.004

RSRP of test 13 (last one) is 2dB better



Optimization of HTTP Download

32% HTTP Download Improved

Date	Test Cases	Scope	Device	Measurement System	Cluster	Type of Tests	Antenna Type
19.4. - first	Test 8	Long PUCCH for FR1 TDD Cells feature	Xiaomi 11T Pro	NEMO	NBG n78	drive test	64T64R
19.4. - second	Test 9	Aperiodic CSI Reporting on PUSCH for Beamforming FR1 TDD Cells	Xiaomi 11T Pro	NEMO	NBG n78	drive test	64T64R
19.4. - third	Test 11	NRCELL.actDlLowPAPRoptimizedPrecoding=TRUE	Xiaomi 11T Pro	NEMO	NBG n78	drive test	64T64R
19.4. - fourth	Test 15	micro DTX test	Xiaomi 11T Pro	NEMO	NBG n78	drive test	64T64R

HTTP DL 20 sec test - App throughput

Overall 32% DL throughput gain with all changes implemented

PAPR brings ~8% Throughput gain

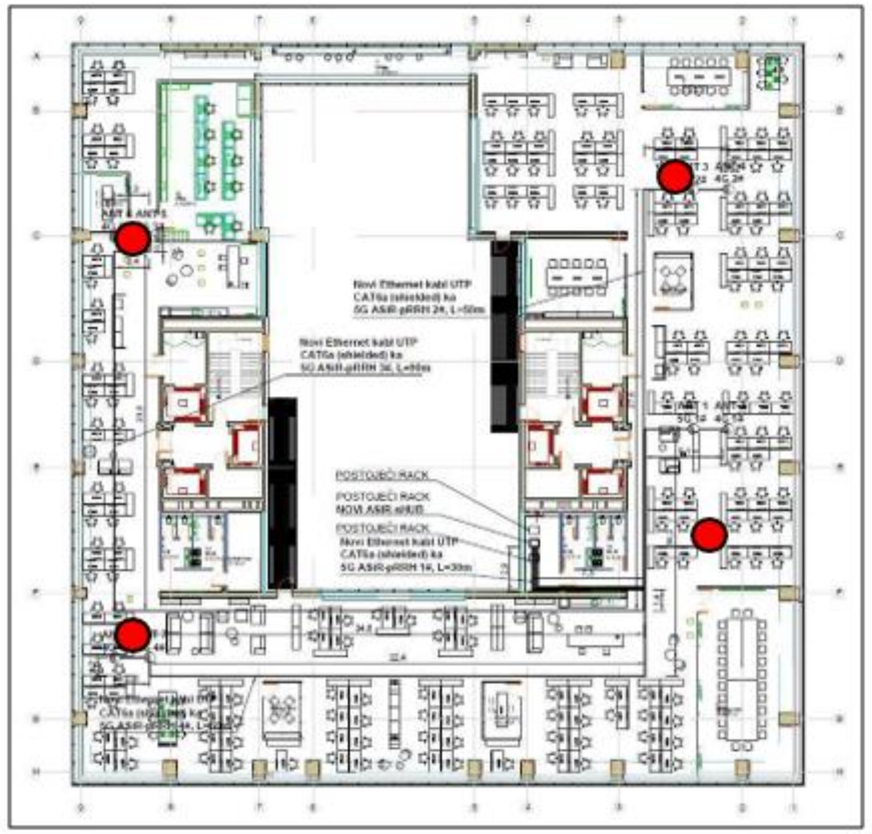
Long PUCCH brings improvement over Baseline

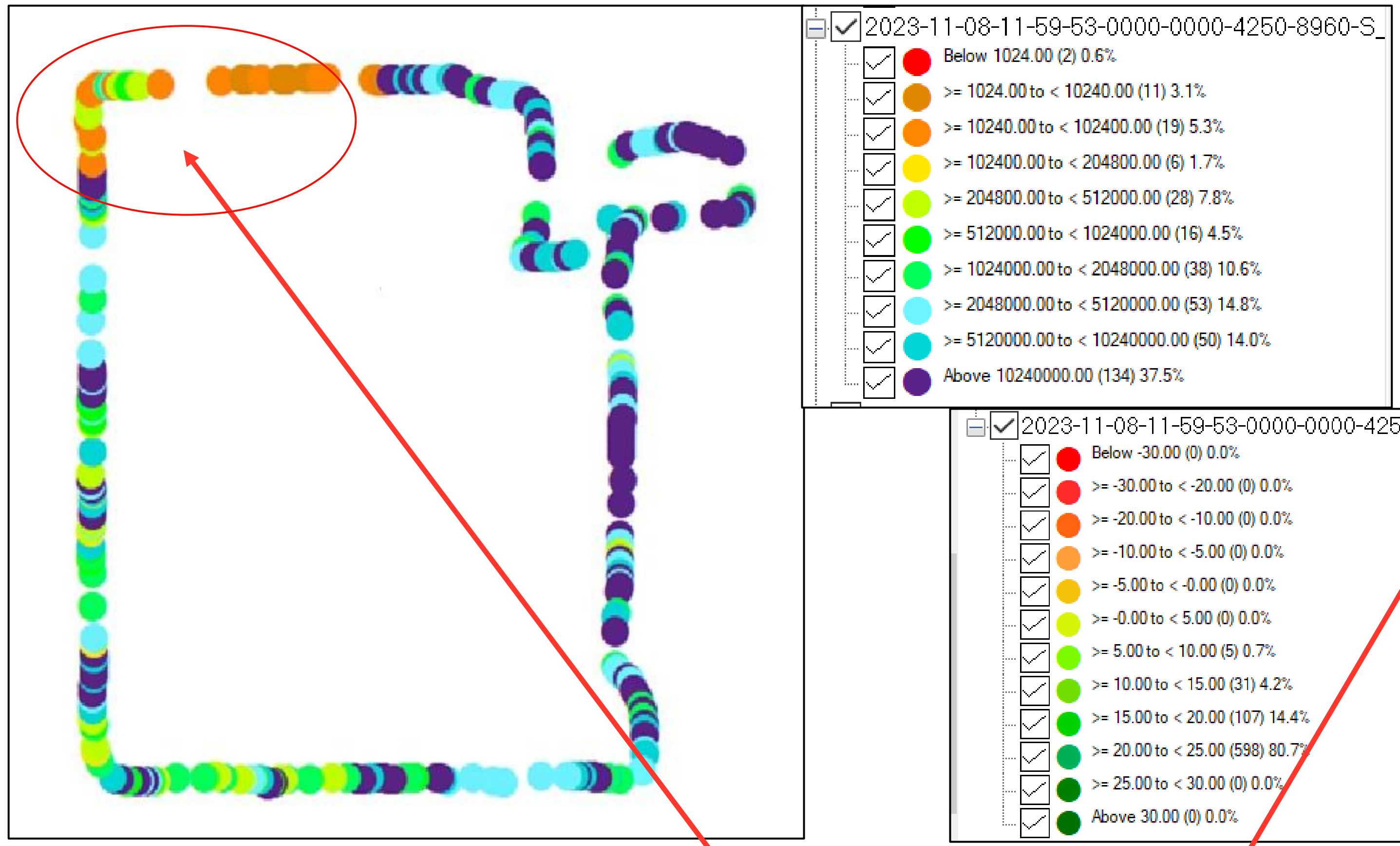
Aperiodic CSI brought 3.2% of additional gain.

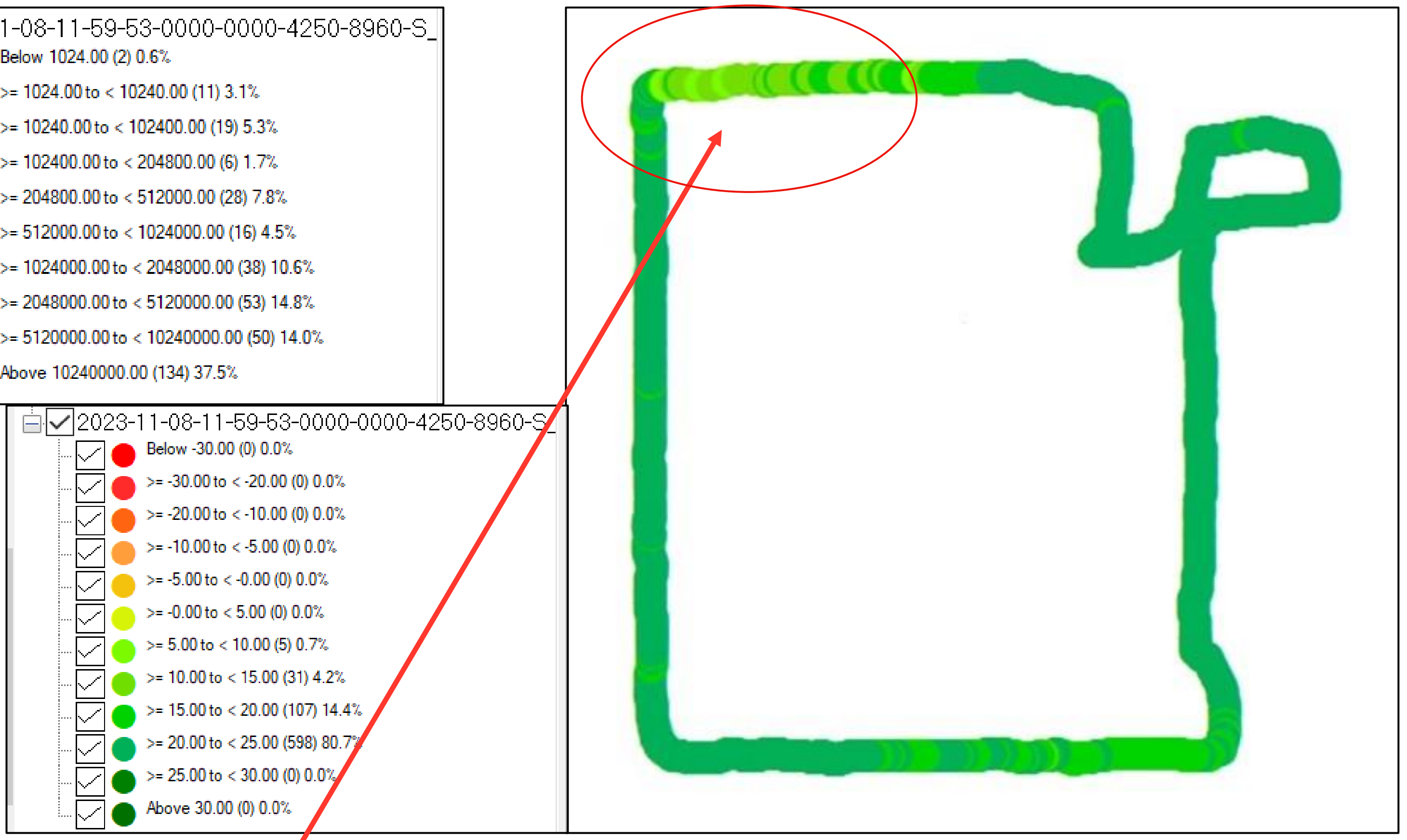
No drawback of micro DTX activation – energy saving 200Wh per site AEQE

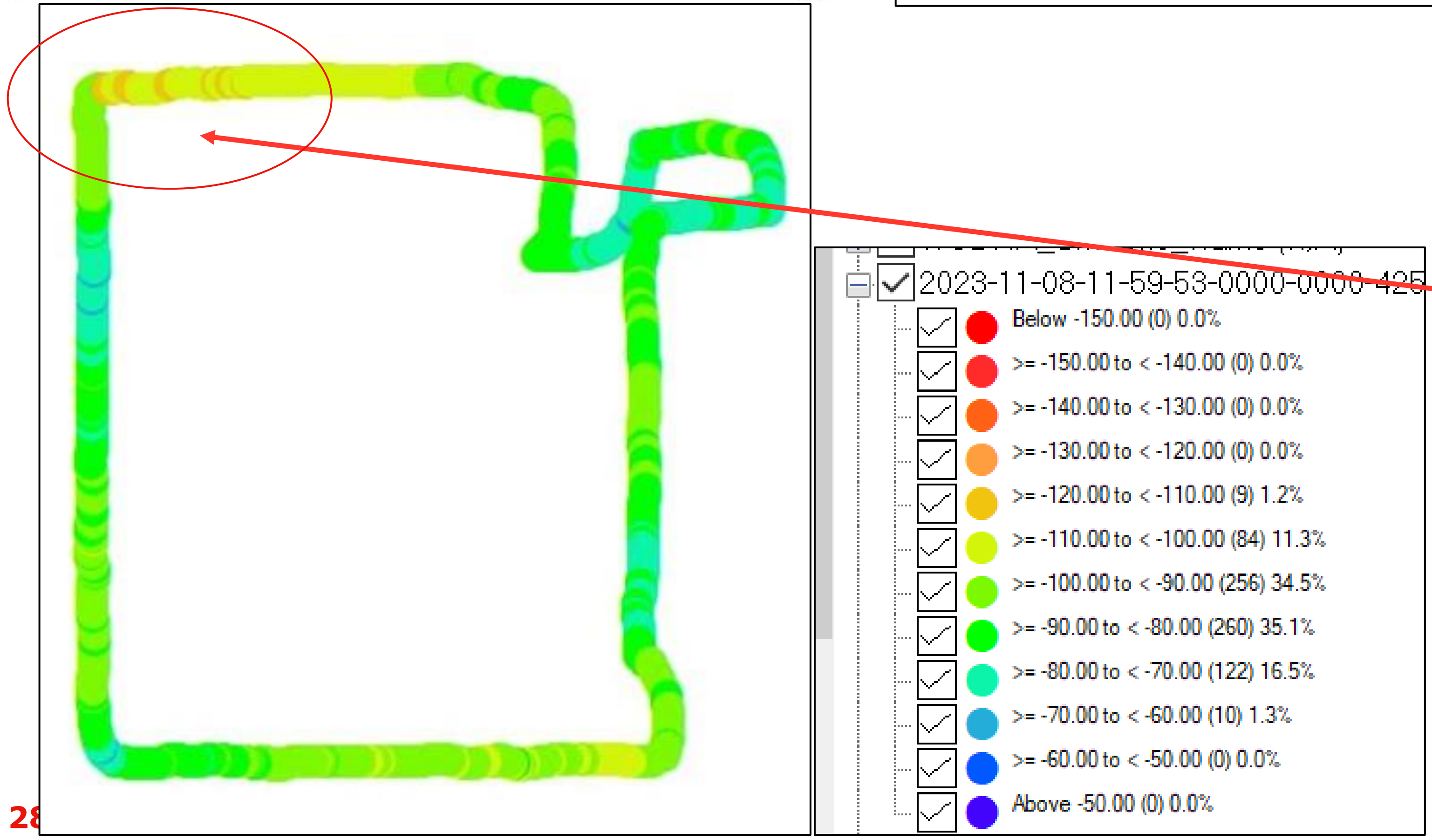
		PAPR	PAPR+micro DTX	Baseline	Long PUCCH	Aperiodic CSI
		Test11_HTTP_DL_22Apr19_143751.1	Test15_HTTP_DL_22Apr19_154651.1	Test3_DL_NBG_ 22Mar14_141041.1	Test8_HTTP_DL_22Apr19_090808.1	Test9_HTTP_DL_22Apr19_123130.1
Aggregates	Average	338487232.675	357043427.326	272651986.983	318086722.974	329566618.371
	Maximum	628375912	645241734	564944664	610486272	656101940
	Minimum	44876	735	30498	76417	47056
	Std. deviation	113665659.38	127004834.81	97909268.697	121620860.689	124314747.619
	Variance	12919882122227392	16130228065198736	9586224896733712	14791633754762960	15454156475537712
	Threshold < 10000000	0.851	0.692	0.592	0.568	0.574
	Time (ms)	3073537	3080571	1673640	3093671	3083151

In-building measurements









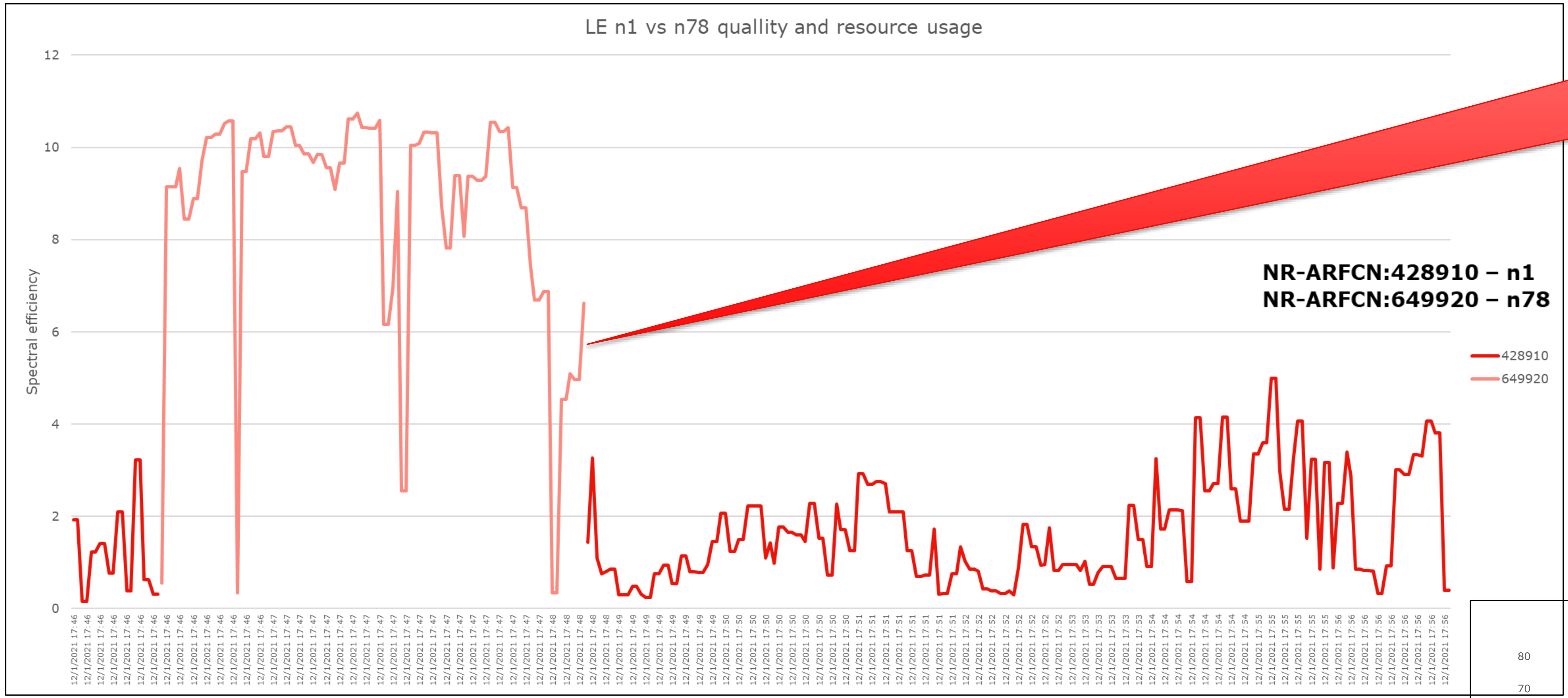
Challenging radio conditions, but we are still on NR with fair DL throughputs

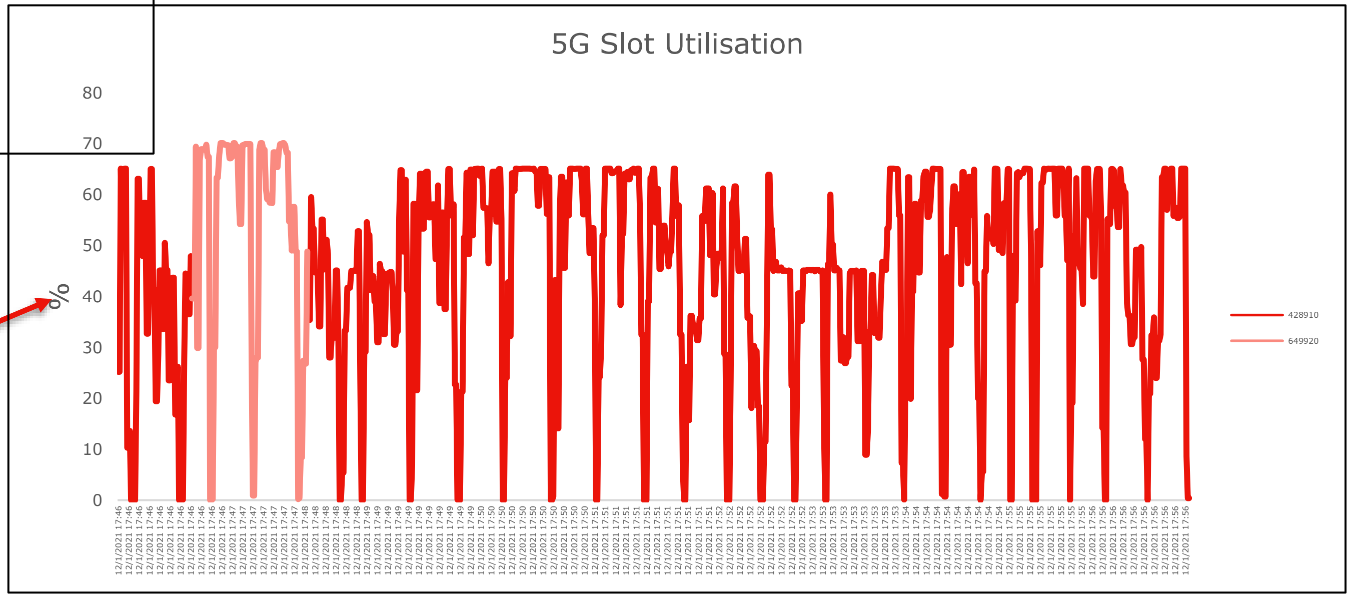
2x2 MIMO, NR78, 4xpico eNB

DL Spectrum Efficiency

100MHz of channel really makes difference

N78 SE 10.5 b/s/Hz while n1 DSS has between 1.5 and 3.5 b/s/Hz





DSS Throughput DL [Mbps] = 10 MHz * 0.6 slot utilization * SE

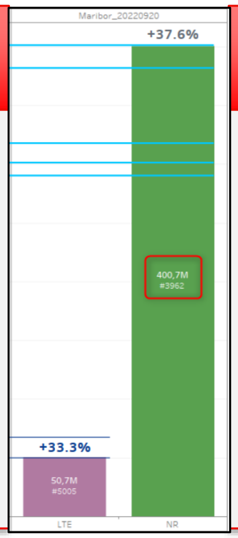
Summary

5G Today - Key Learnings

Related to NSA deployment only

End User Throughputs are comparable with Fixed Network

Average Drive test throughput is ~ 400 Mbps in car vs 100 Mbps of LTE
Indoor (cell edge) end user throughputs on 5G are bellow 100 Mbps



Latency is close to 1ms

Not True. NSA latency is comparable with LTE Latency. Moreover NSA addition causes initial delay (CP delay).
1ms is possible only with MEC
.

Energy Consumption in 5G is very high

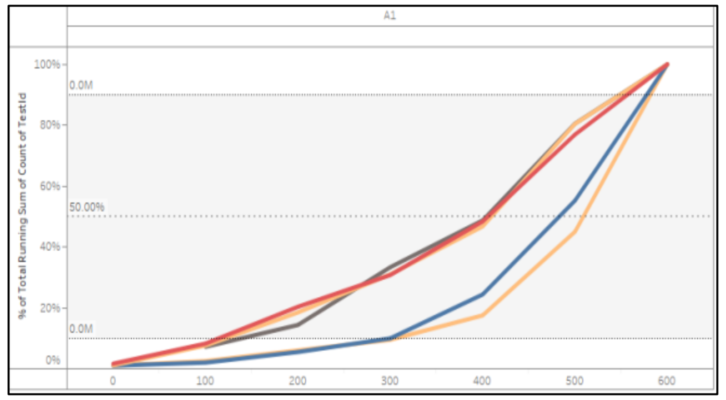
Not True. For instance AHEGB (4Tx) consumes 740W/h in medium load and 5G 64T antenna AEQE consumes 715 W/h in medium load. AEQE can provide 6-8 times more capacity than AHEGB.

5G is Plug and play

Not True. 5G integration due to many variations can take much more time to test and assess prior the activation.

Cell Capacity is 20 times higher than for LTE

Cell Capacity from 200 to 285 GB/BH depending on configuration and features. Typical 50MHz LTE sector 45GB/BH (no 4x4 MIMO)



5G requires massive network densification

Not true. Existing grid can be re-used but indoor coverage is challenging and higher speeds cannot be guaranteed.

5G Is more reliable for data transfer than LTE

Not True. NSA seems to be less reliable from call drop perspective due to complex Dual connectivity signaling.

5G is already self optimized

Not True. 5G introduces additional complicity due to ENDC and BF, neighbors, latency, transport must be well optimized.

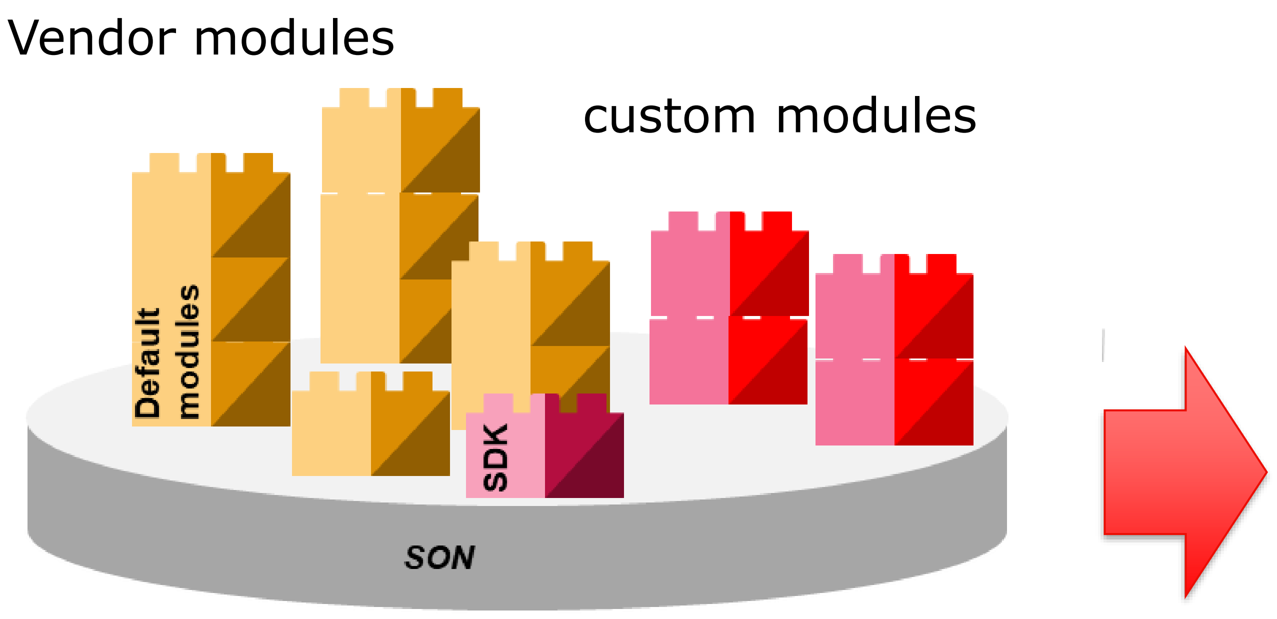
Let's do some Maths!

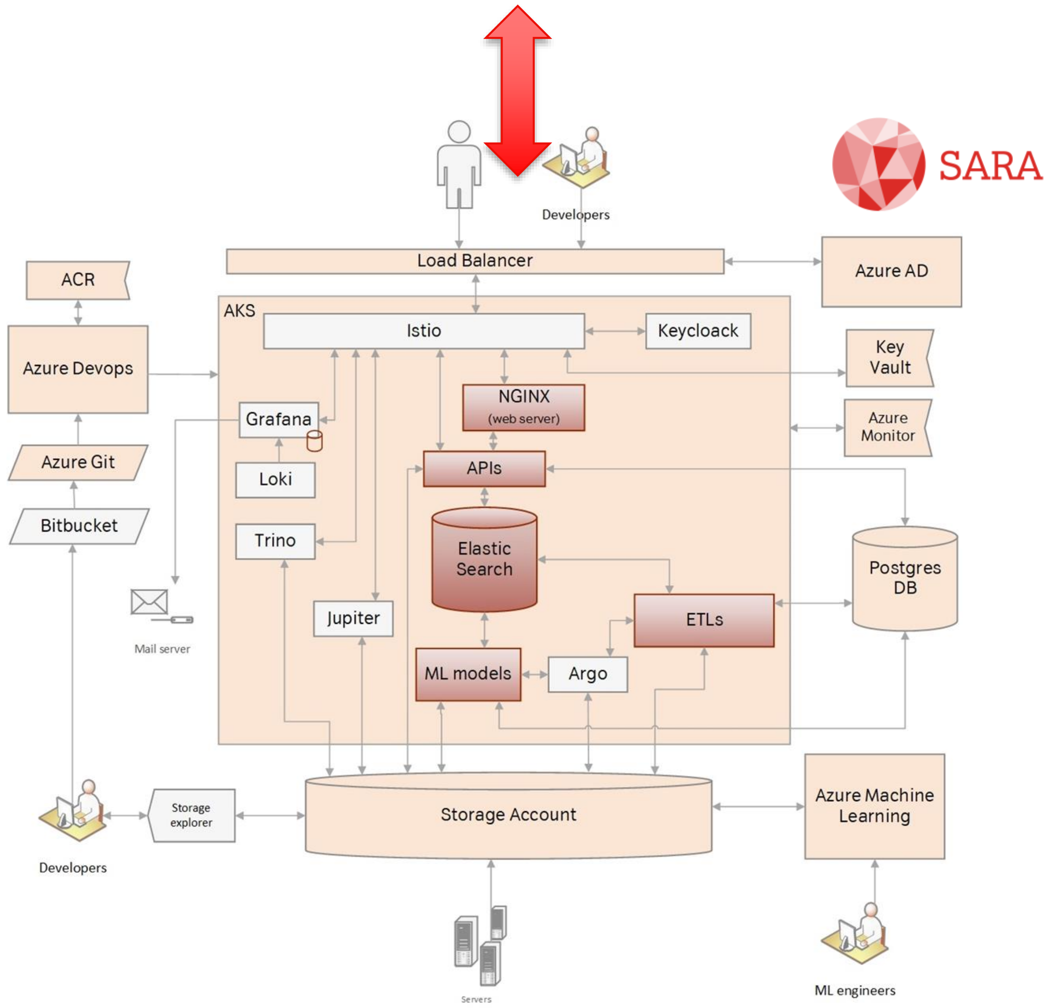
SARA

1 mobile base station	3,000 KPIs / hour
4,000 mobile base stations	12,000,000 KPIs / hour
50,000 mobile base stations	2,000,000,000 KPIs / day
	+
1 mobile subscriber	150 KPIs / call segment
2,500,000 mobile subscribers	375,000,000 KPIs / call segment
200 Call segments a day	75, 000, 000,000 KPIs / day
	=
	79,000,000,000 KPIs / day

5G Cannot come without …

Network Analytics and Automation





Capacity/ Coverage optimization

Long RACH Planning
Plan RSI for Long PRACH

GCCO
RFFP based Coverage and Capacity planning Optimization

Consistency enforcement

RSI/PCI Planning verification of redirection parameter in lnrelq object

ANR update of 2G frequencies inside different LTE mobility objects

Crossed Sector Detection
Detection of crossed feeder

Ethernet interface Packet drop Detection and Optimization

Automatic Cell Acceptance
Detection of New 5g cell and generating acceptance report automatic way

New cell detection and alignment
detection of new cells in nw and automatic run of modules set

Energy efficiency

NSA coordinated SES
Prediction based Smart Energy Saving

Operational

Parameter Consistency Enforcement
Keep more than 1500 parameters always aligned with templates

NR LB Non Anchor Enforcement
Optimize inter site ENDC performances

Self Healing
Detection of Anomaly cell and generating reset if needed

Thank you

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