Mobile Network Testing

VERIFYING 5G PRIVATE NETWORKS – PERFORMANCE STATUS BASED ON REAL RESULTS

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Make ideas real

AGENDA

- **Enterprise networks and deployment status**
- **Industry applications and network impact**
- Test methods to emulate industry applications
- How do enterprise networks perform today?
(real performance measurements)
- Test solutions and summary

5G enterprise networks enable business- / mission-critical use cases with increased productivity

Manufacturing

Warehouse

Mining

Ports

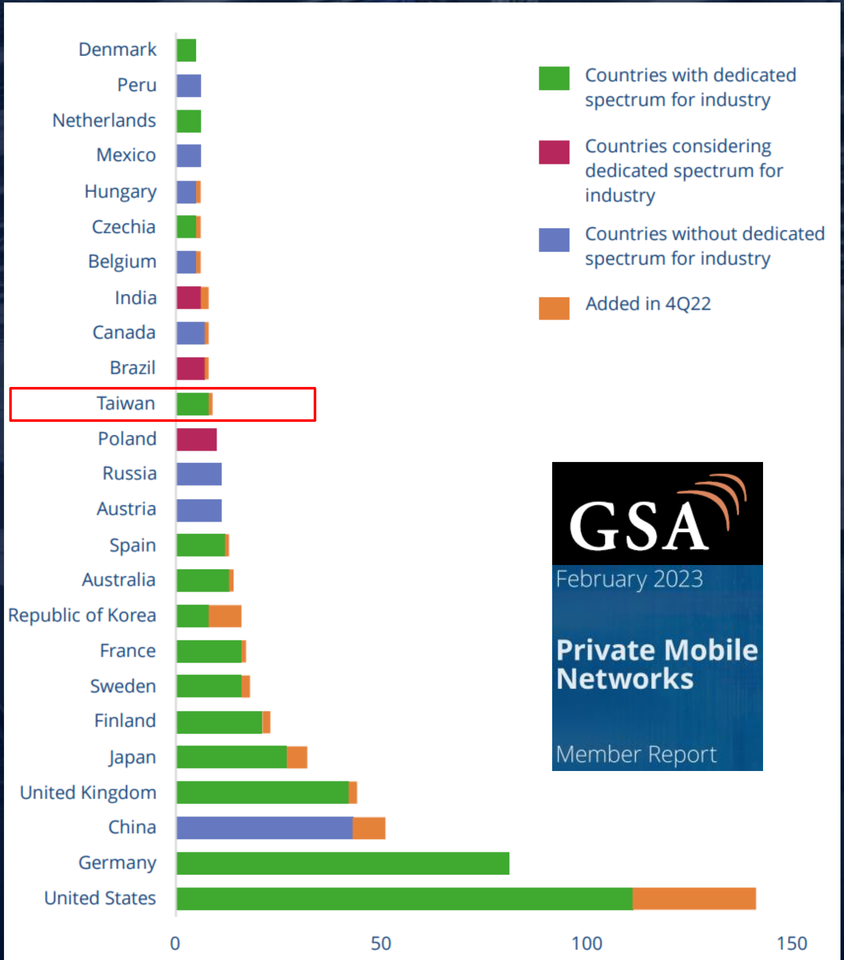
Critical Infrastructure

Oil / Gaz

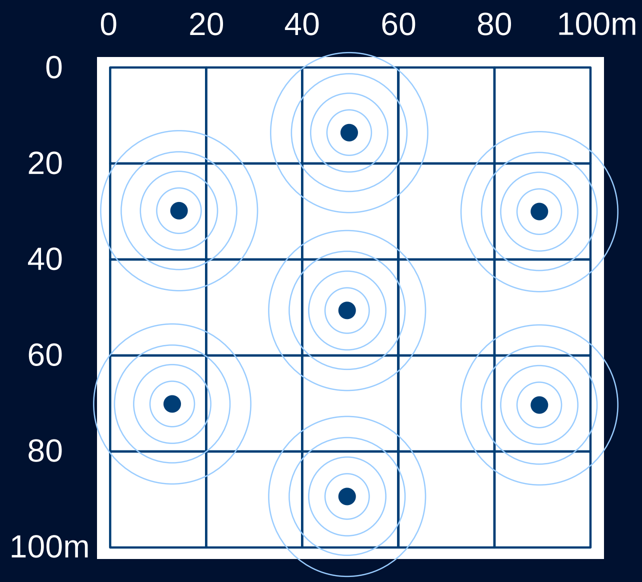
Common requirement: superior performance level (in terms of data rate and latency)

Different deployment concepts of enterprise networks

- ▶ Dedicated network offered by Mobile Network Operators (MNO)
  - Network Slicing
  - Operated by MNO resources (B2B)
- ▶ Dedicated network in dedicated spectrum for industry use
  - Spectrum owned by enterprise
  - Operated by enterprise IT or system integrator

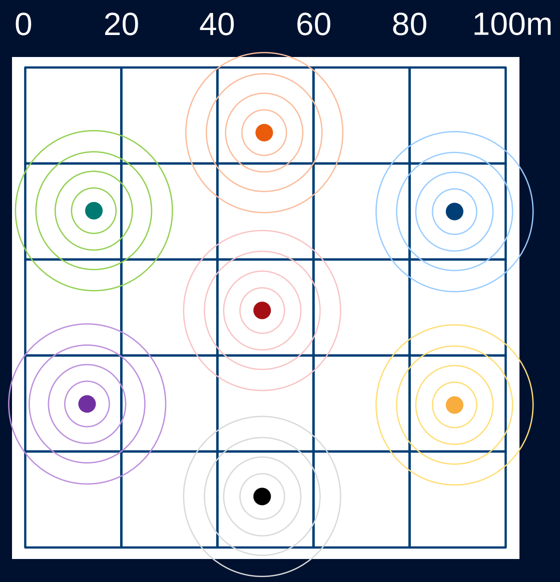


Deployment status of enterprise networks



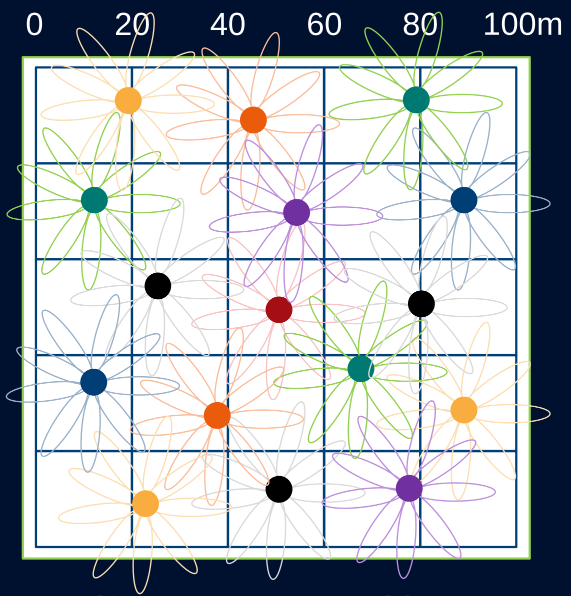
- Same PCI, same signal everywhere (omni ant.)
- Inefficient, but “Tx diversity”

At the beginning; often today



- Different PCIs, different signals
- Higher capacity, but no redundancy

Intermediate; not often seen live

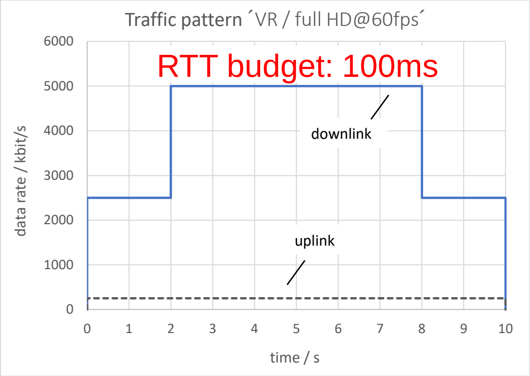


- Different PCIs and beams
- Higher capacity, incl. redundancy

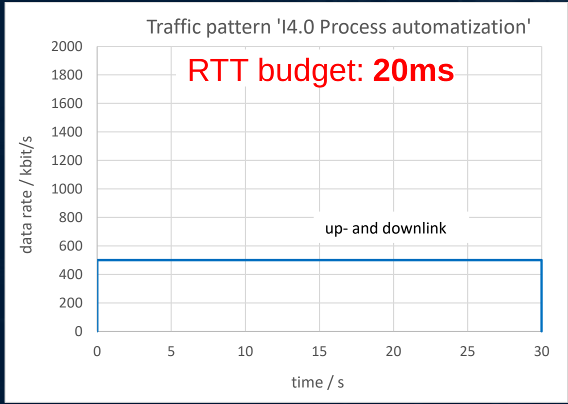
Optimized capacity + reliability → Future

Examples of industry applications

- Remote maintenance / training: Virtual Reality / full HD video
  (emulates a Full-HD@60fps video stream: 60 packets per second, 5.460 / 10.920 bytes each, PER: $2 * 10^{-3}$)



- I4.0 process automation
  (625 packets per second, 100bytes each → 500 kbps DL+UL, PER: $2 * 10^{-4}$)



- Workpiece monitoring (predictive maintenance of e.g. a drilling machine)
  (100 packets per second, 1024 bytes each → 800 kbps UL; RTT budget: 20 ms; PER: ?) – similar to I4.0 process autom.

- Large machines – safety-relevant monitoring (cranes, etc.)
  CANopen safety bus (CANopen Framework for Safety-Relevant Communication - CAN in Automation e.V.)
  (a pair of packets to be received within 20 ms; 20 packet pairs per second)

Source: CiA DSP 304 V 1.0

What happens if … latency is not sufficient and packets get lost

- ▶ Virtual Reality / Cloud-gaming HD

  → Video freezes or is jerky

- ▶ I4.0 process automation
- ▶ Workpiece monitoring (predictive maintenance of e.g. a drilling machine)

  → Industry processes or tools stop

- ▶ Large machines – safety-relevant monitoring (cranes, etc.)

  → Safety stop – manual intervention needed

- ▶ **Many industry applications require reliable network operation**
- ▶ **Interruptions in production / logistics / processes compromise productivity gains**

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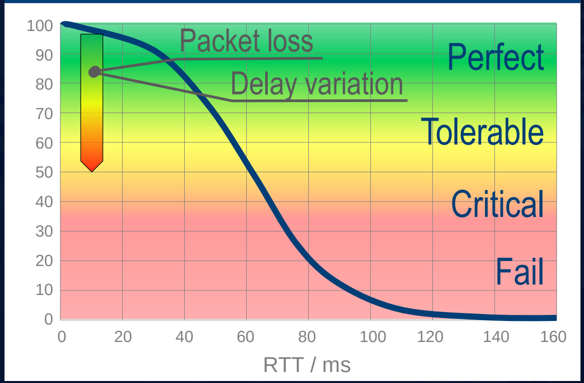
Industry applications: Packets to be sent frequently, max latency, max packet loss

- TWAMP: **T**wo-**W**ay **A**ctive **M**easurement **P**rotocol – specified by IETF (RFC 5357)
  (Traffic can be emulated; TWAMP defined for latency SLA verifications)

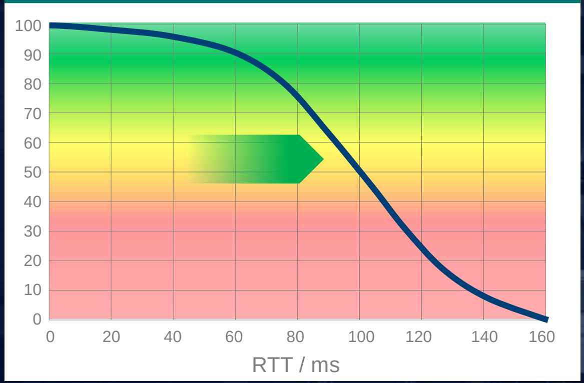
- **Interactivity Score: combines latency, delay variation and packet loss into a single score**

A scalable QoE model for interactive applications (also for machines)

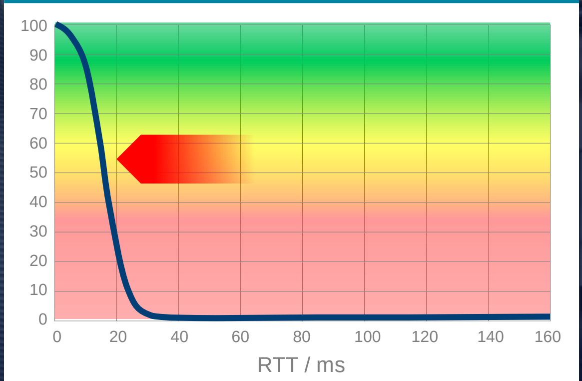
Interactivity Score: **e-Gaming real time**



Interactivity Score: **VR retail shopping**



Interactivity Score: **I4.0 process control**



Harmonized as ITU-T G.1051: Latency measurement and interactivity scoring under real application data traffic patterns (official publication will follow)

- **The parameterization of the Interactivity Test and Score is individual for each application class**
- **Interactivity Test is harmonized as ITU-T Recommendation**

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Case 1: How are these networks performing today

Throughput in relation to data settings

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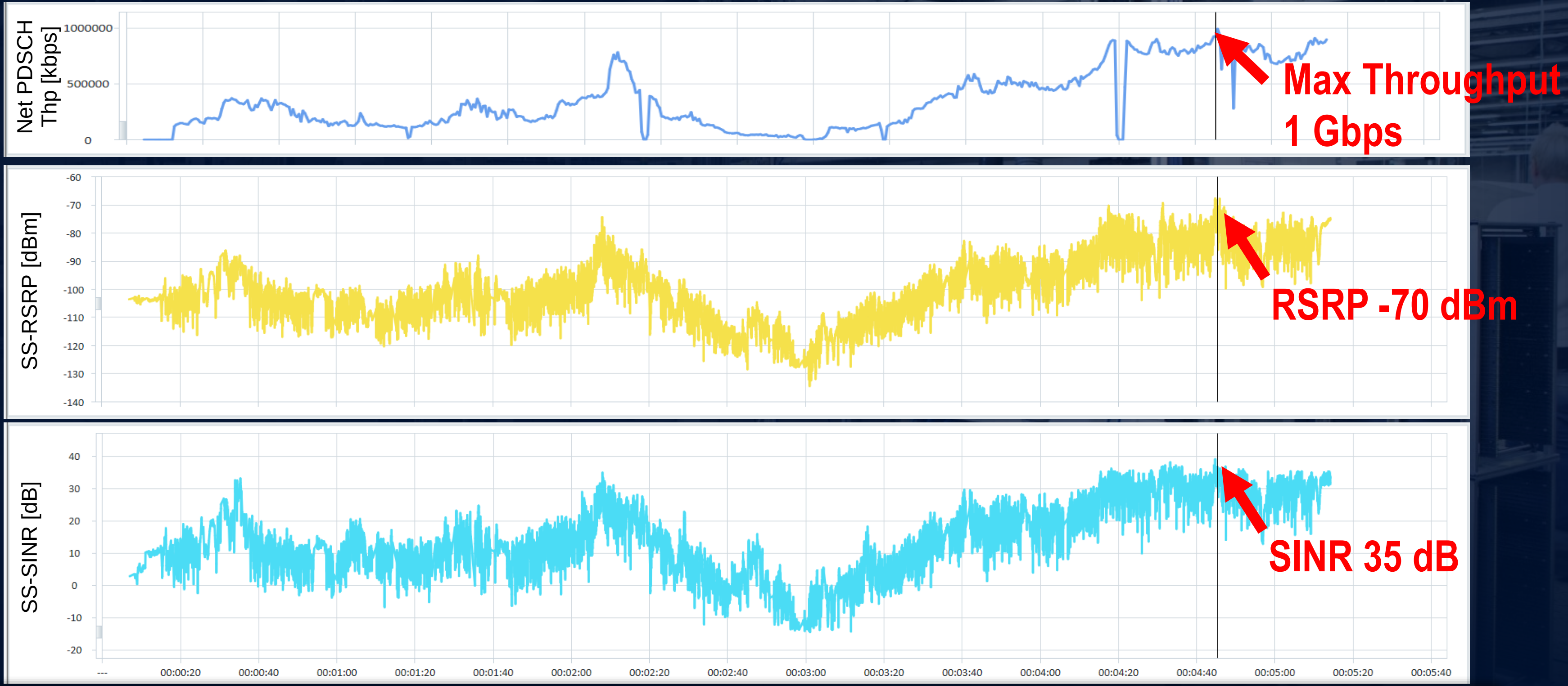
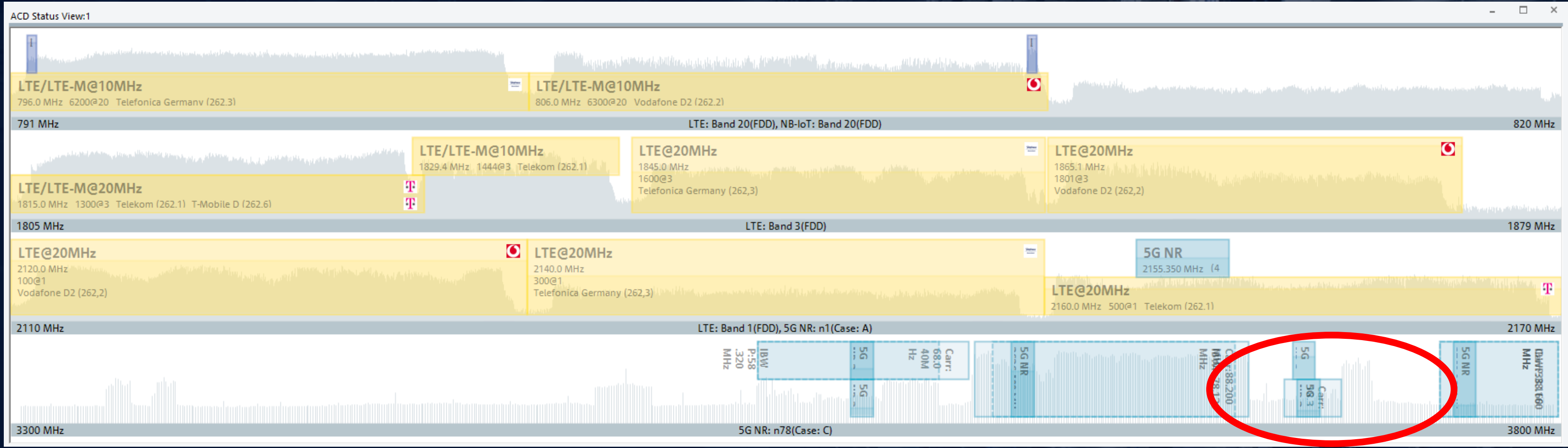
Throughput in relation radio condition



▶ **Data throughput offered by 5G is given** ✓

Case 2: Overview Network situation
Sharing the same frequencies – Automatic Channel Detection

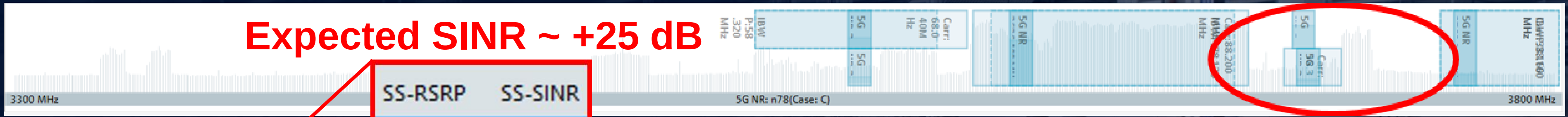


Multiple cells overlap in dedicated spectrum around 3.7GHz (private spectrum)

▶ **Let's do drill-down**

Case 2: Overview Network situation

Sharing the same frequencies – drill-down



Expected SINR ~ +25 dB

SS-RSRP	SS-SINR
-77.57	14.41

List

#	TopX	PCI	S..	RSSI	SS-RSRP	SS-SINR	SS-RSRQ	SS-RePo...	NR-ARF...	SS-Ref	ToA(PPS)	ToA(CIR)	MCC	MNC	BWP Bandwidth	BWP Center F...	5G NR ...	TDD Pattern
1	1	390	0	-68.40	-77.57	14.41	-10.40	-77.42	647808	3717.12	0.07212810	2.51008549					n.a.	-
5	5	361	0	-68.40	-92.03	-14.45	-24.85	-77.42	647808	3717.12	0.07239748	2.51034490					n.a.	-
3	3	390	1	-68.40	-79.27	17.96	-10.31	-79.20	647808	3717.12	0.28611730	2.72413909					n.a.	-
8	8	361	1	-68.40	-98.57	-19.31	-29.61	-79.20	647808	3717.12	0.28672588	2.72468258					n.a.	-

List

#	TopX	PCI	S..	RSSI	SS-RSRP	SS-SINR	SS-RSRQ	SS-RePo...	NR-ARF...	SS-Ref	ToA(PPS)	ToA(CIR)	MCC	MNC	BWP Bandwidth	BWP Center F...	5G NR ...	TDD Pattern
1	1	2	0	-84.62	-113.12	-2.32	-15.14	-108.79	647904	3718.56	4.67522709	7.11315302	999	99	18.36	3719.82	SA	DDDFU|DDFUU||DDDFU|DDFUU||DDDFU|DDFUU

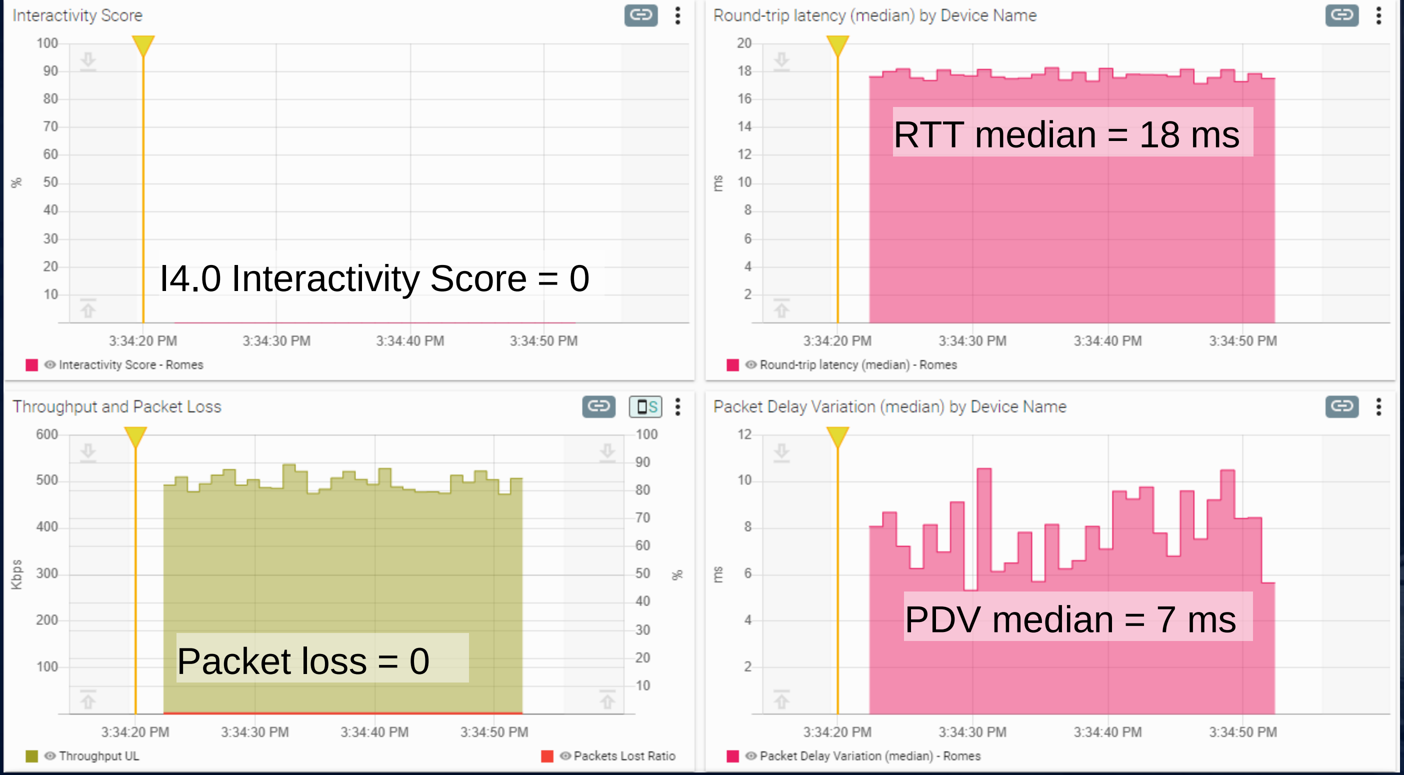
Measurements:

- SS-Ref. frequencies different, PCIs different
- Much higher SINR expected
- Networks not synchronized (4.6ms difference)

Analysis:

- Upper network interfered
- Lower network seems to be the interference source

Case 3: I4.0 process control with industry module as frontend

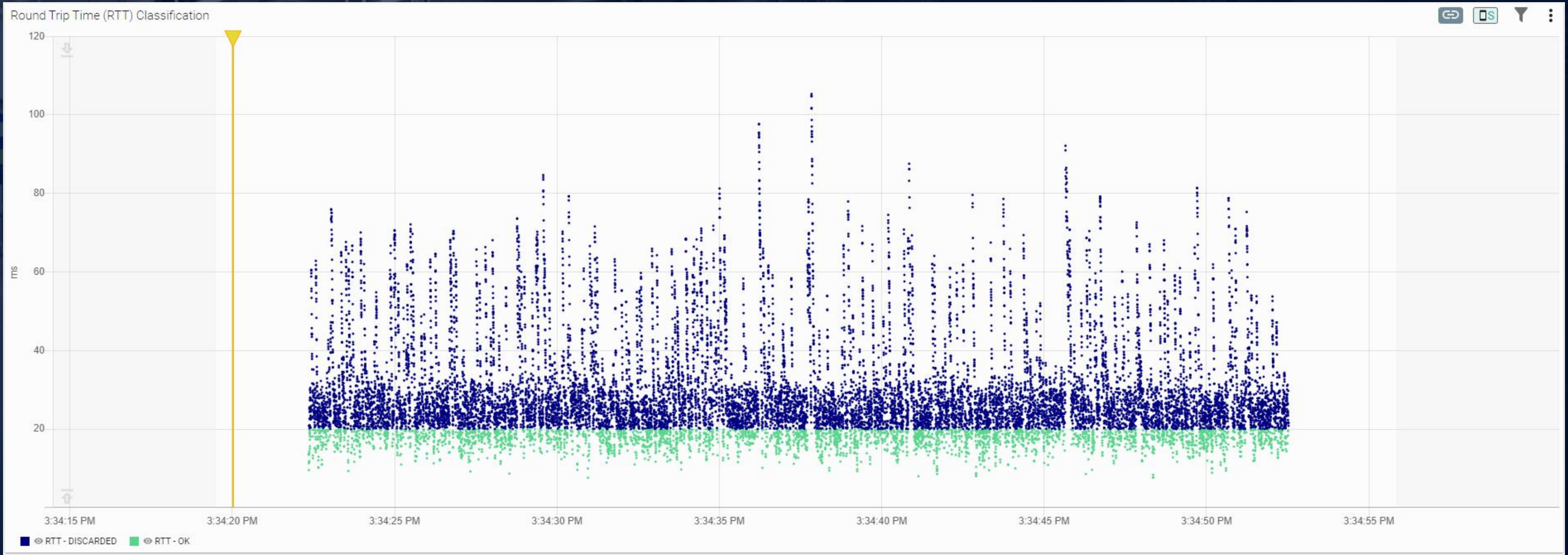


Target RTT = 20 ms

PER: $2 * 10^{-4}$

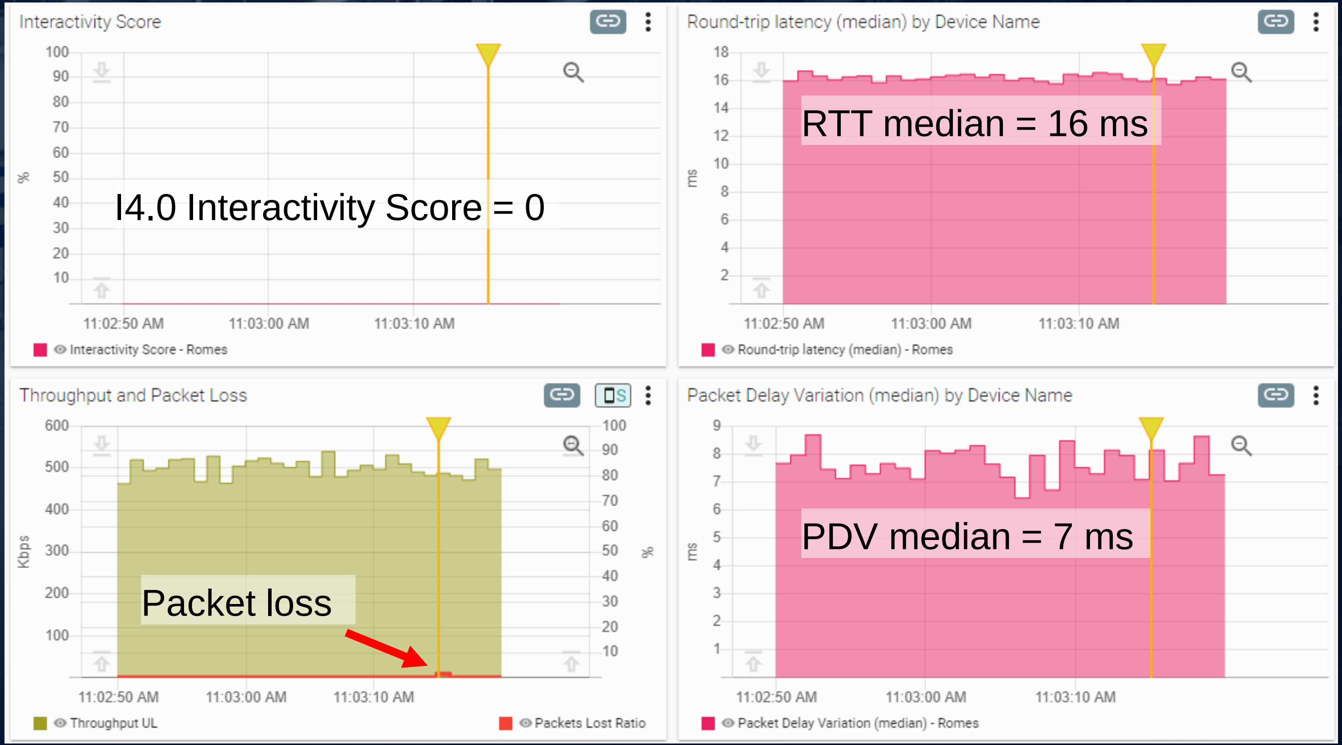
► **Let's do drill-down – packet level**

Case 3: Roundtrip Time per packet
RTT_{min} = 7.6 ms; RTT_{avg} = 17.7 ms; RTT_{max} = 105.3 ms



- **80% of packets are too late (discarded) – causing „Interactivity Score = 0"**

Case 4: I4.0 process control with industry module as frontend
Slightly better RTT results

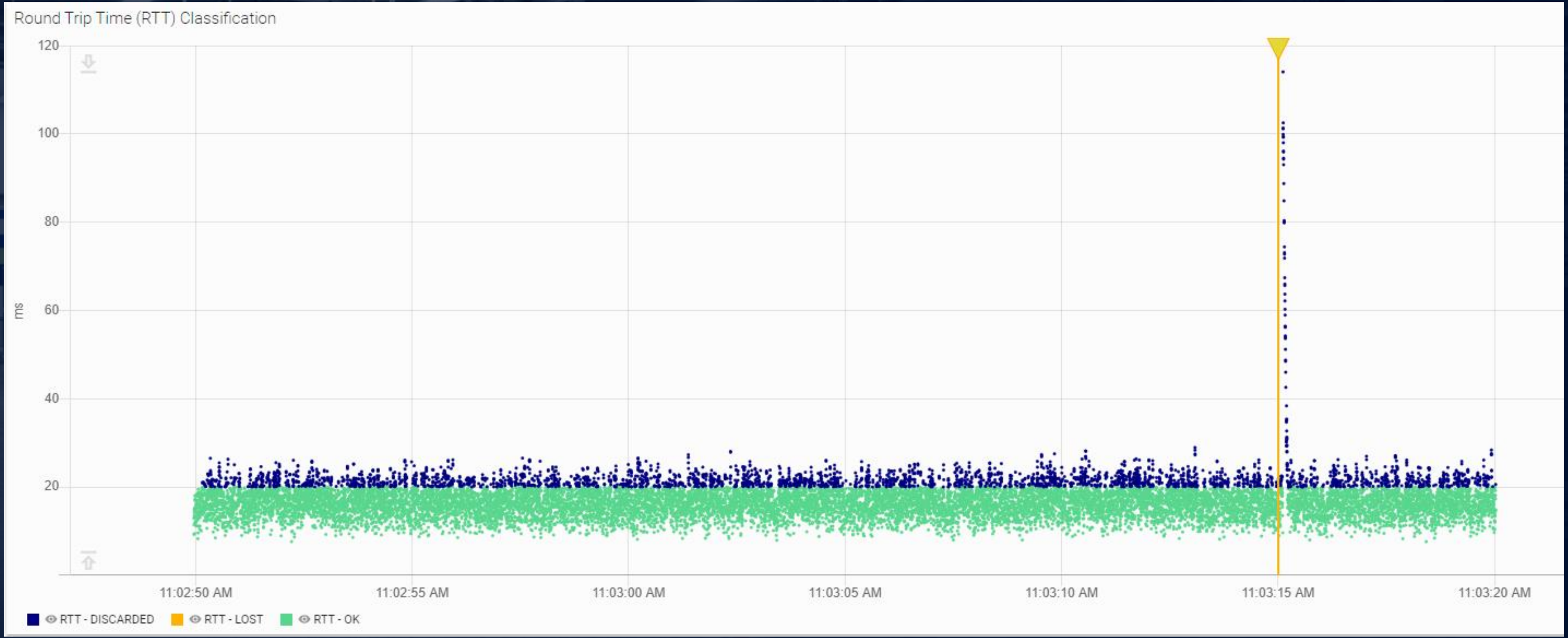


Target RTT = 20 ms

PER: $2 * 10^{-4}$

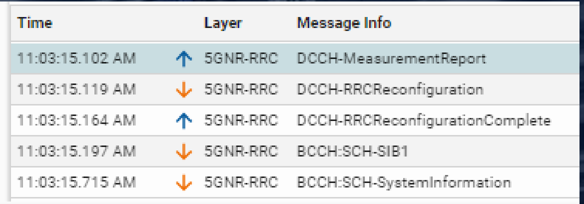
Still Interact. Score = 0 ?

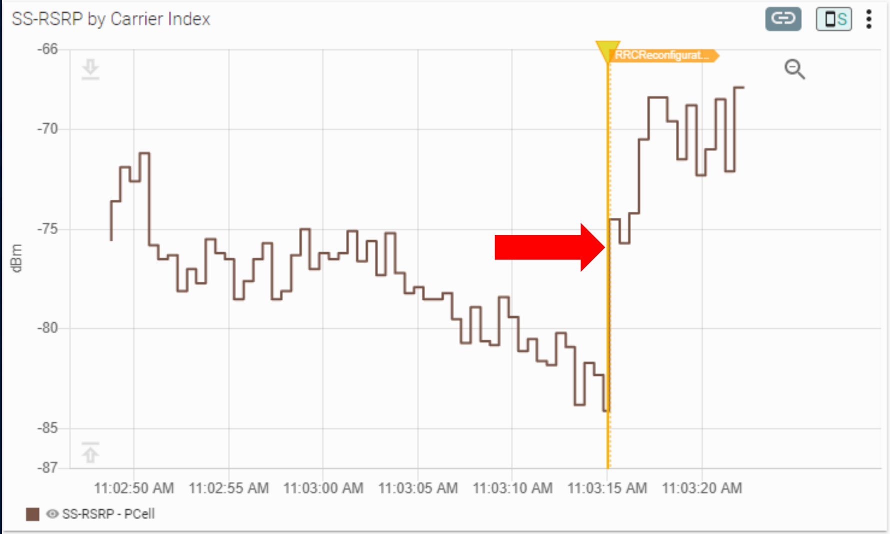
Case 4: Roundtrip Time per packet

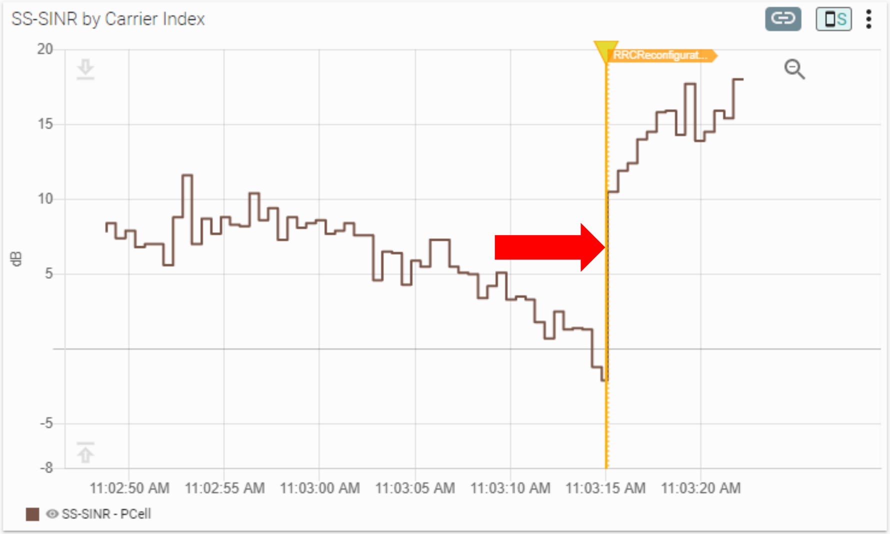


- ► More RTT samples below 20 ms
- ► One significant outlier (where also packet loss happens) → drill-down next level!

Case 4: multi-cell network

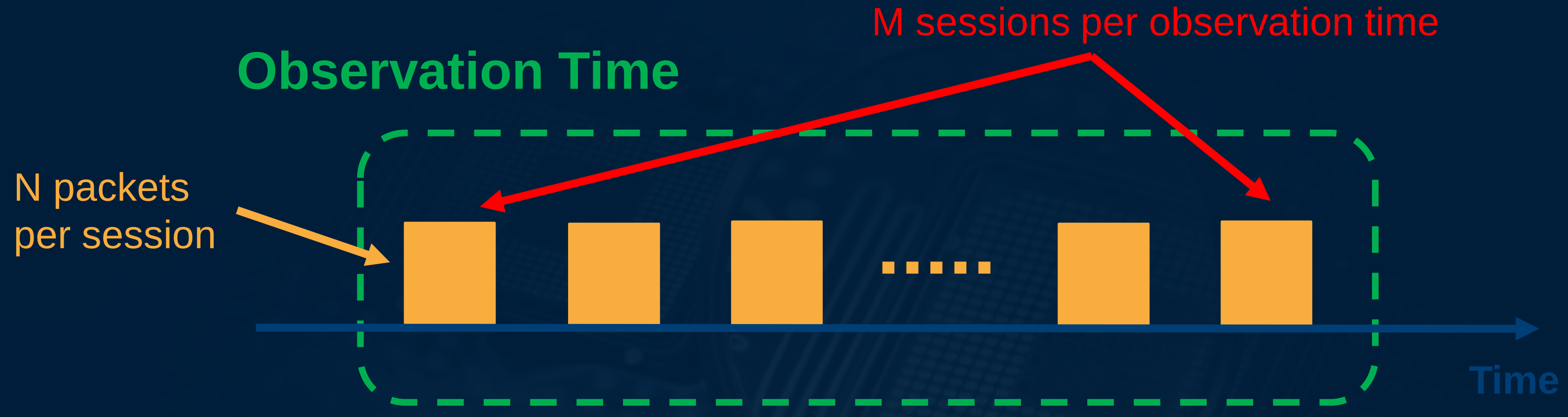






- **RRC Reconfiguration: 5G NR cell change**
- **Cell change causes packet loss and impacts RTT**

Case 5: How to measure Long-Term Stability and Service Availability?

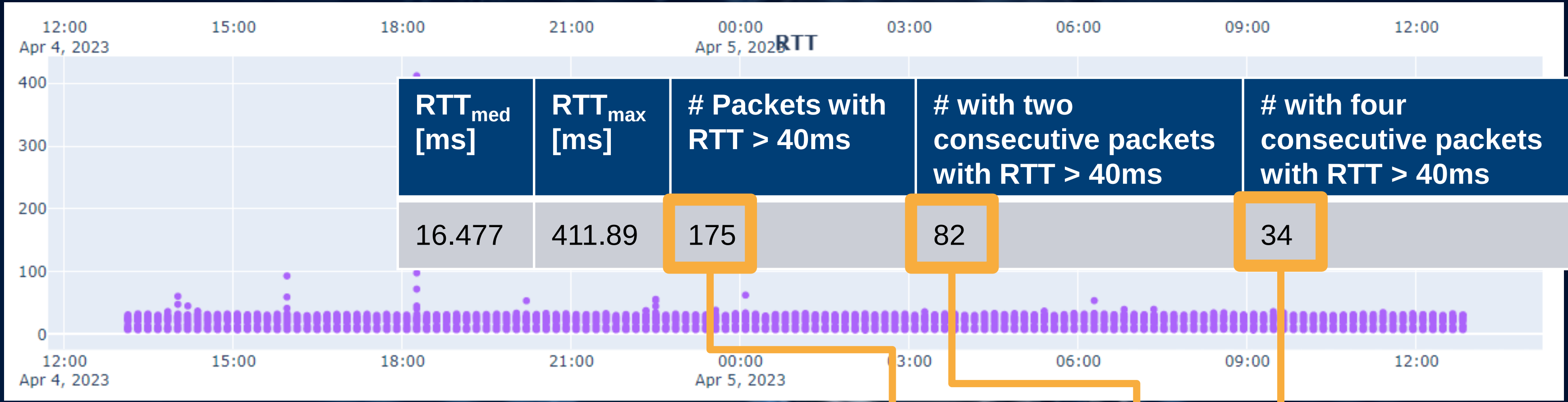


- Requirement (example): Service Availability (SA_{req}) = 99.99%
- Assumption: Service is counted "not available" if
  e.g. one/two/four consecutive packets are (E)
  lost or exceed the time delay budget

$$1 - \frac{SA_{req}}{100} \geq \frac{E}{N \cdot M}$$

WHAT ABOUT LONG-TERM STABILITY / LATENCY?

- Running a **long** data profile test session every 10 minutes over 24 hours (135 sessions a day)
- Results into 607500 packets (4500 packets per ~30s session, 250bytes, rate 6.67ms)



RTT_{med} [ms]	RTT_{max} [ms]	# Packets with RTT > 40ms	# with two consecutive packets with RTT > 40ms	# with four consecutive packets with RTT > 40ms
16.477	411.89	175	82	34

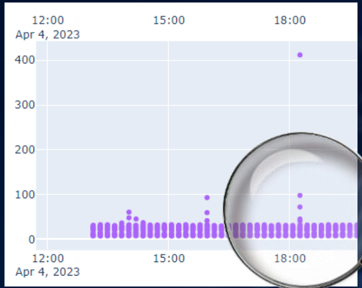
$SA = 99.971\%$

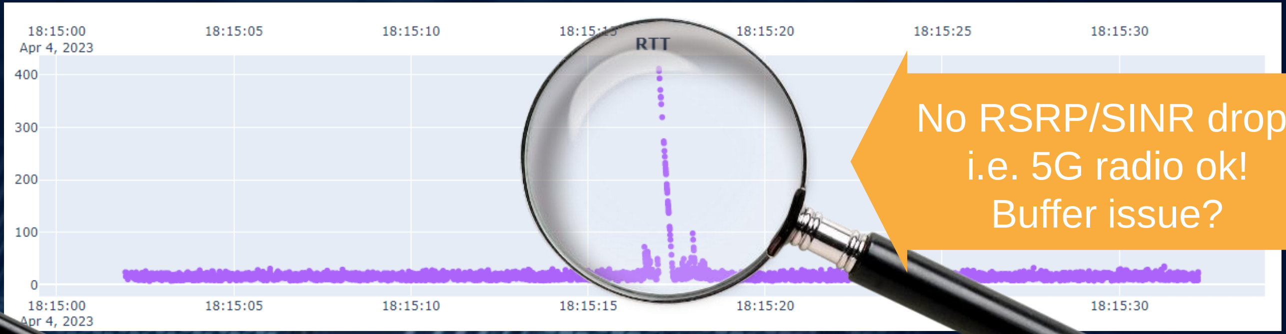
$SA = 99.987\%$

$SA = 99.994\%$

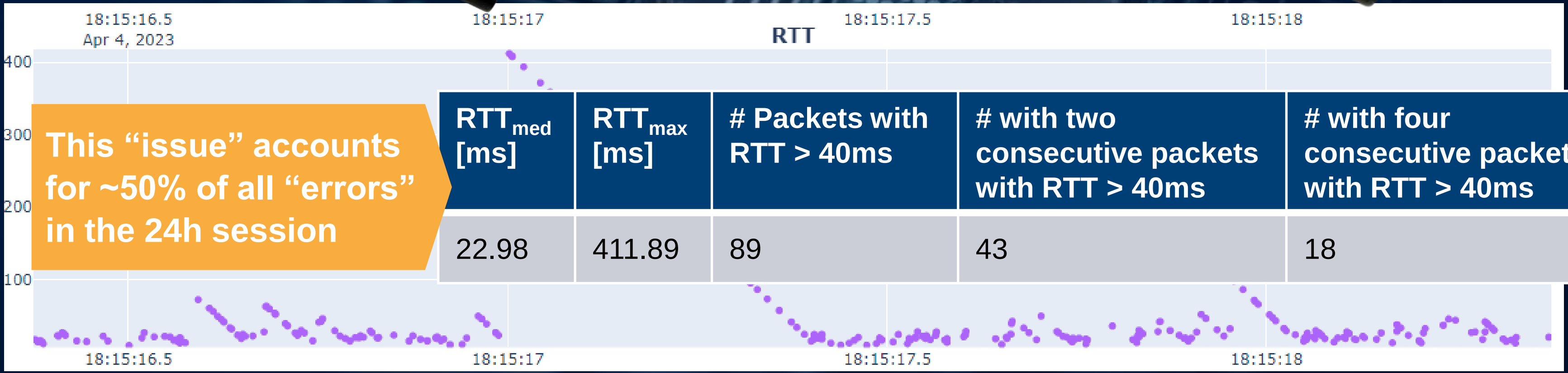
Long periods of stable performance, however occasionally high latency

WHAT ABOUT LONG-TERM STABILITY / LATENCY?





No RSRP/SINR drop, i.e. 5G radio ok! Buffer issue?



This “issue” accounts for ~50% of all “errors” in the 24h session

RTT_{med} [ms]	RTT_{max} [ms]	# Packets with RTT > 40ms	# with two consecutive packets with RTT > 40ms	# with four consecutive packets with RTT > 40ms
22.98	411.89	89	43	18

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Passive and Active

Passive Measurements without subscription

- ► Automatic Channel Detection
- ► Measurements of all DL signals on-air
- ► Decoding of Broadcast Channel Information
- ► Synchronization
- ► high accuracy and speed
- ► Cell centric
- ► Beam centric
- ► EMF

Active measurements with subscription

- ► Performance
  - ► Latency
  - ► Throughput Downlink / Uplink
  - ► Network availability
- ► Troubleshooting
- ► Signaling verification
- ► Interactivity with variation of traffic patterns

Private Network testing solutions for all user groups

▶ Deployment, site acceptance, initial performance

Easy GUI
passive + active

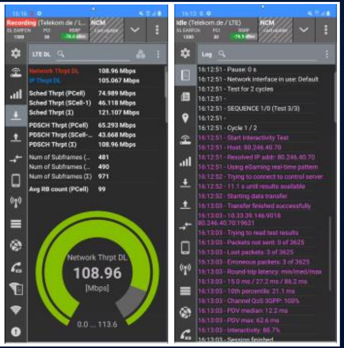
- Fast to operate

▶ Performance tuning, troubleshooting

Advanced GUI
passive + active

- Deep dive
- Engineering
- TTI resolution

▶ Network operation (e.g. factory IT)



QualiPoc Android
(e.g. Crosscall phone)

Easy GUI
Active tests

- Functional testing
- Performance test

▶ Data analytics, drill down, quality monitoring

Web-based GUI
Database

- Multiple objects campaigns
- Trend analysis

Summary

www.rohde-schwarz.com/mnt/private-networks
www.rohde-schwarz.com/mnt-5G

- 5G provides all means for business-critical use cases (URLLC, network slicing,…)
- Potential interruptions in production / logistics / processes due to too long latencies and lost packets compromise productivity gains
- Data throughput is already well underway (outlook to more busy networks and multi-cell / multi-beam approach)
- Latency is an area for optimization (URLLC features are often not yet implemented; networks are more tuned for high data rate, but not for minimized latency)
- Passive and active network testing solutions available for all enterprise user groups in deployment, site acceptance, performance tuning, troubleshooting and operation

► **Rohde & Schwarz is your One-Stop-Shop for verifying 5G enterprise network performance**