

Mobile Network Testing

# HOW NETWORK TESTING ENSURES 5G PRIVATE NETWORK PERFORMANCE



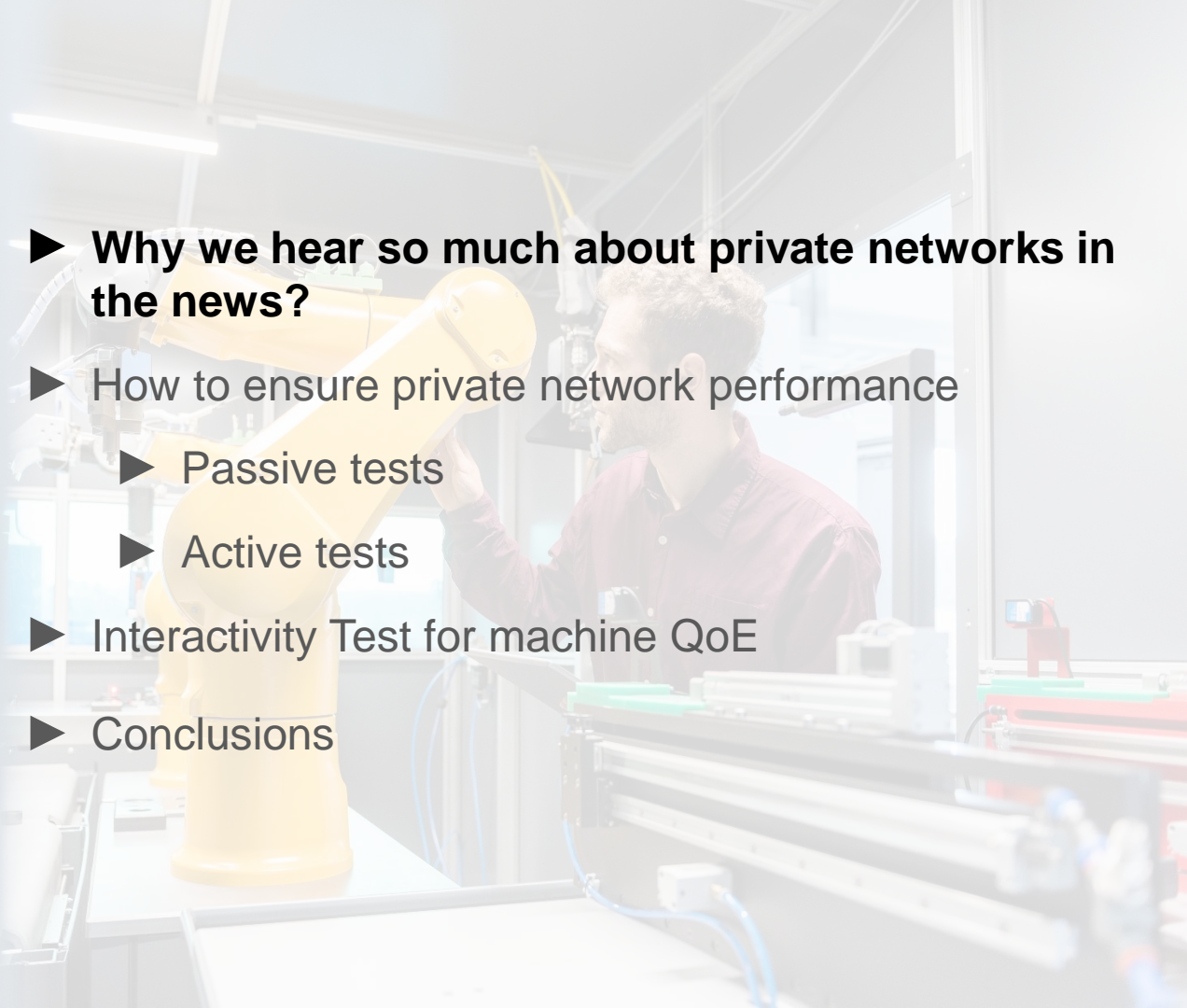
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**ROHDE & SCHWARZ**

Make ideas real



# AGENDA

- 
- A man in a red shirt is working with a yellow robotic arm in a factory setting. The background is a blurred industrial environment with various equipment and structures.
- ▶ **Why we hear so much about private networks in the news?**
  - ▶ How to ensure private network performance
    - ▶ Passive tests
    - ▶ Active tests
  - ▶ Interactivity Test for machine QoE
  - ▶ Conclusions

# 5G enables business-/mission-critical use cases with private networks

Manufacturing



Warehouse



Mining



Ports



Critical Infrastructure



Oil / Gaz



# PRIVATE 5G NETWORKS – WHY? CRITERIA

- ▶ 5G technology enables business-critical use cases
  - Higher flexibility, higher efficiency, higher productivity
  - Outage / failure can cause high material damage
  - Processes rely on 5G network
- ▶ “Guaranteed” service levels needed:
  - Capacity, data throughput, latency
  - High reliability / availability
- ▶ Limited area / limited mobility (e.g. AGV)
- ▶ Encapsulated networks (data security) – limited or no interface to public networks



# ROHDE & SCHWARZ FACTORY IN TEISNACH / GERMANY

## 5G for factory automation and new MNT test solutions



**Use Cases long-term:** Machine control, autonomous vehicles AGVs, flexible and efficient data distribution and collection, remote support AR/VR, ...

**BUT: only what improves efficiency and saves money will be realized!**

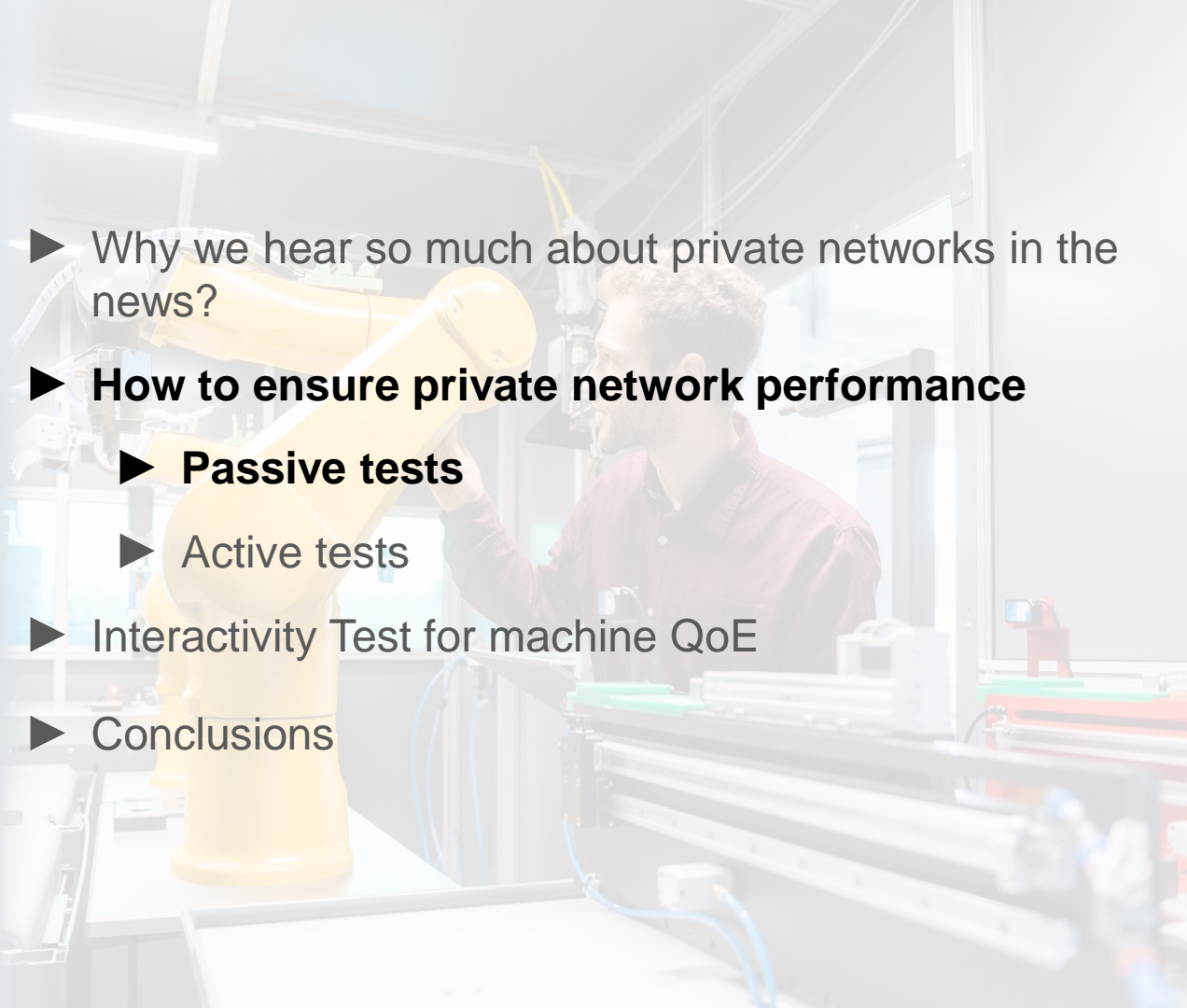


**Private 5G as ingredient to transform** own factories, but also **to innovate** MNT product and service portfolio

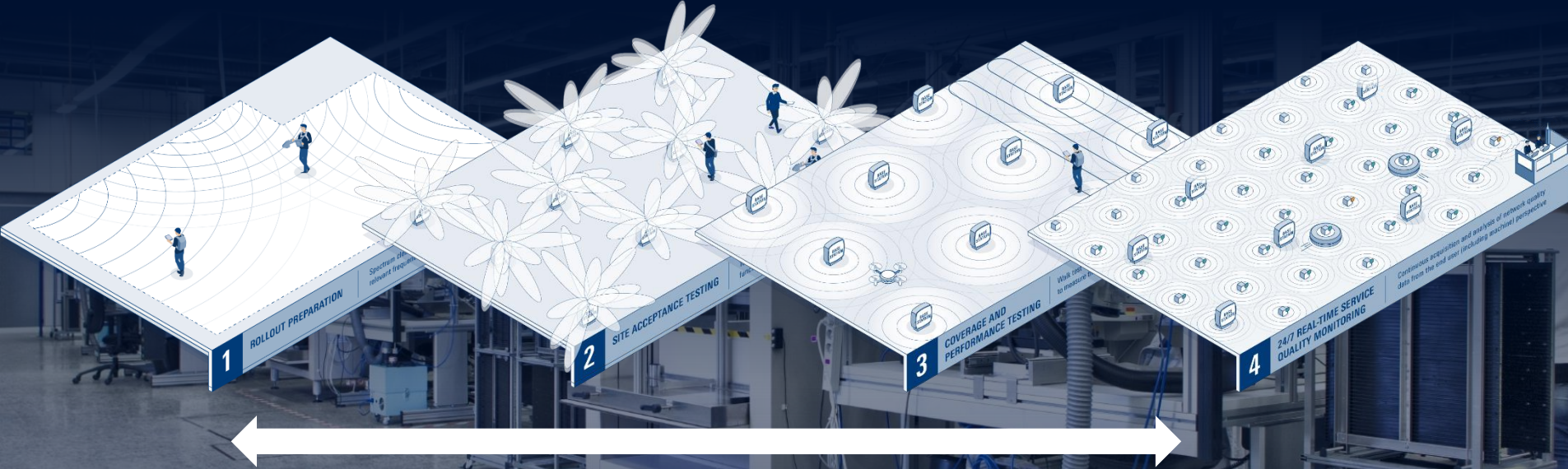
**Private 5G non-standalone network** deployed using band 40 (2.3-2.4 GHz) and n78 (Germany's local enterprise spectrum, 3.7-3.8 GHz) in a 1.500 sqm manufacturing area

**Upgrade to 5G Standalone in Feb. 2022**

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# How to ensure network performance in a factory



- Spectrum Clearance
- Interference Hunting

- Functional Testing
- OTA RF signal verification
- Signal Decoding

- Network optimization
- 5G Performance Test
- Connectivity Test

- Real-time QoE monitoring
- Data Analytics with ML
- Data Collection

► More or less one time effort; sporadically in case of issues

► After every factory modification

► Continuously, 24/7

# Performance testing after deployment

## Deployment



- Antenna verification (conducted tests)



- Ready for Service



UL Interferences

Spectrum: **Jammer detection**



**5G Downlink**

- SIB1 – SIB9
- RSRP (→ coverage)
- SINR (→ throughput)
- SSB

**Synchronization**

(impact on performance)

**EMF** (radiation, health)

*passive tests*

*Just listening mode → DL*



Smartphones Industry modules

**Signaling**

- L3
- RACH (netw. access)
- Scheduler (resources)
- PDSCH/PUSCH (data channels)

**Latency** (roundtrip)

**Data throughput**

*active tests*

*Connection to network → DL+UL*

## Devices Functional tests

- Network availability
- Latency
- Data tests (DL/UL)

- Interactivity Test



- Ready for Customer



# How to measure Uplink interference (in 5G NR TDD networks)

Complexity: Downlink covers Uplink in TDD



SIBs

BS / gNodeB

Demodulation of SIBs:

- ▶ Start/end of Uplink slots
- ▶ Start/end of Downlink slots

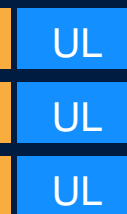
Automatic configuration of the time-gate

Configured Time-gate

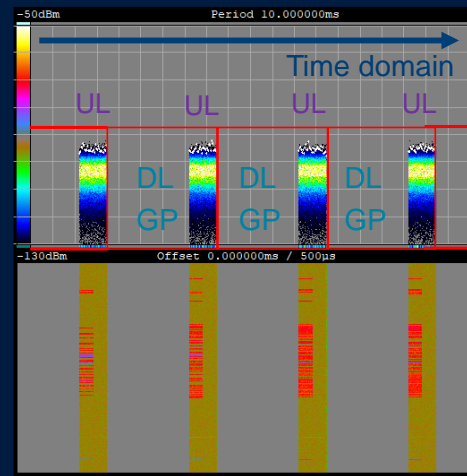


UL power spectrum

Configured Time-gate



UL power spectrum



Network scanner R&S@TSMx6

SIB: System Information Broadcast message



# DL signal overview – passive test Automatic Channel Detection (ACD)

Easy configuration:

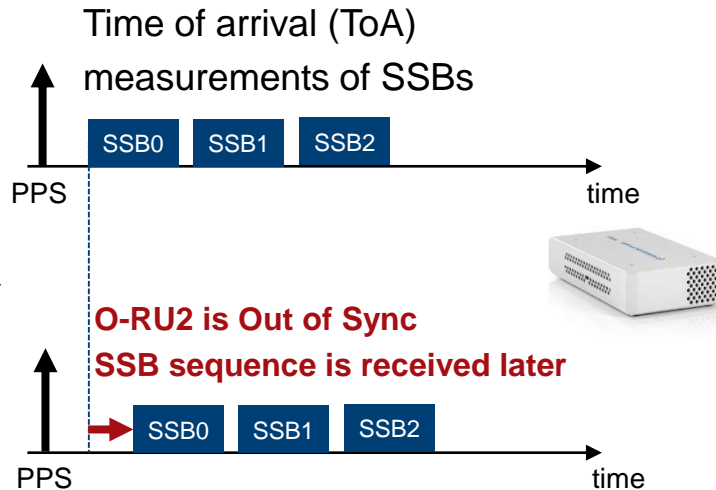
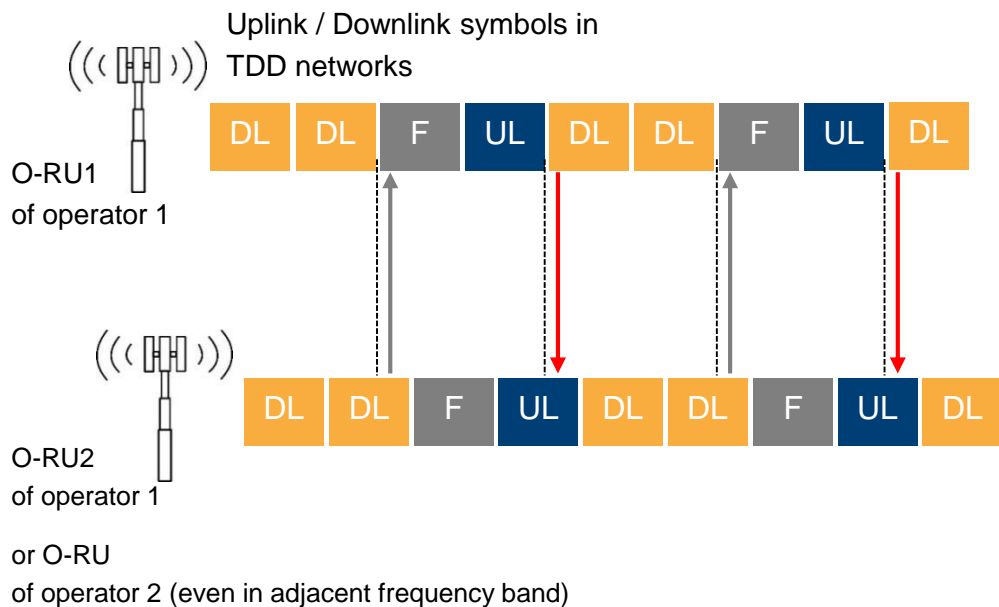
- ▶ Technologies
- ▶ Frequency bands

Dynamic Spectrum  
Sharing (DSS)



- ▶ 5G NR: Cell & Beam Centric
- ▶ ACD: all DL signals visible in seconds

# NETWORK SYNCHRONIZATION: O-RAN cell synchronization measured over-the-air



- ▶ DL of O-RU1 interferes with UL of O-RU2
- ▶ Interference in time domain

Subcarrier Spacing	Symbol length
15 kHz	66.7 $\mu$ s
30kHz	33.3 $\mu$ s
60 kHz	16.7 $\mu$ s
120 kHz	8.3 $\mu$ s
...	...

# NETWORK SYNCHRONIZATION: Measurement results (failure case)

#	PCI	SSB Idx	SS-RSRP	SS-SINR	NR-ARFCN	SS-Ref	ToA(PPS)
1	373	0	-75.61	22.58	637632	3564.48	3.07324139
2	372	0	-101.25	-25.65	637632	3564.48	3.07328682
3	716	0	-105.05	-29.46	637632	3564.48	3.07339537
4	85	0	-111.29	-4.41	637632	3564.48	0.07598861
5	603	0	-113.76	-7.67	637632	3564.48	0.07827527
8	96	0	-120.36	-13.59	637632	3564.48	0.07834053
10	629	0	-120.41	-14.85	637632	3564.48	0.08629245
7	692	0	-120.80	-15.27	637632	3564.48	0.08328950
6	29	0	-121.03	-15.93	637632	3564.48	0.07921318
11	652	0	-122.48	-16.80	637632	3564.48	0.08449997
9	304	0	-125.21	-19.91	637632	3564.48	0.07559080
12	325	0	-126.23	-21.02	637632	3564.48	0.07707206
13	574	0	-130.54	-25.21	637632	3564.48	0.07509223

ToA = the difference of  
SSB reception to PPS (GPS)

3.073 ms – 0.076 ms = 3 ms  
time difference!

Completely out of sync!

► Typically, asynchronous cells have a difference of a few 100's  $\mu$ s

# NETWORK SYNCHRONIZATION: Measurement results (successful)

ROMES (Replay ONLY)

File View Hardware Technologies Replay Tools Window Help

5G NR Scanner TopN View:1 R&S 5G NR Scanner (TSME)[1]

Top N: <Auto>@633984 Auto Width Hide Details Hide Chart

List	#	PCI	SSB Idx	SS-RSRP	SS-SINR	NR-ARFCN	SS-Ref	ToA(PPS)
	2	94	0	-108.40	-0.95	633984	3509.76	0.07673132
	1	73	0	-109.90	-3.48	633984	3509.76	0.07468142
	6	429	0	-116.34	-11.13	633984	3509.76	0.07755952
	16	403	0	-122.98	-18.05	633984	3509.76	0.08401424
	15	372	0	-124.59	-19.64	633984	3509.76	0.08148061
	13	356	0	-125.10	-20.14	633984	3509.76	0.08099457
	14	209	0	-126.16	-21.25	633984	3509.76	0.07641720
	3	372	1	-113.52	-2.65	633984	3509.76	0.29555349
	8	429	1	-116.48	-6.70	633984	3509.76	0.29134429
	10	94	1	-116.79	-7.07	633984	3509.76	0.29077441
	9	73	1	-122.38	-13.27	633984	3509.76	0.28874580
	18	403	1	-123.88	-14.80	633984	3509.76	0.29809783
	19	207	1	-129.96	-21.01	633984	3509.76	0.28878754
	29	209	1	-130.13	-21.11	633984	3509.76	0.28957665

Difference between SSB 0 and SSB 1 is ~ 200  $\mu$ s

Difference is < 9  $\mu$ s

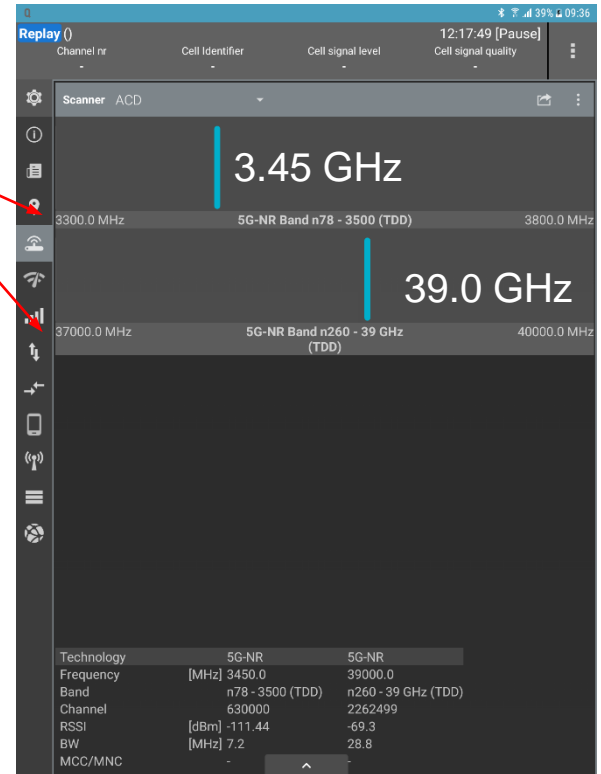
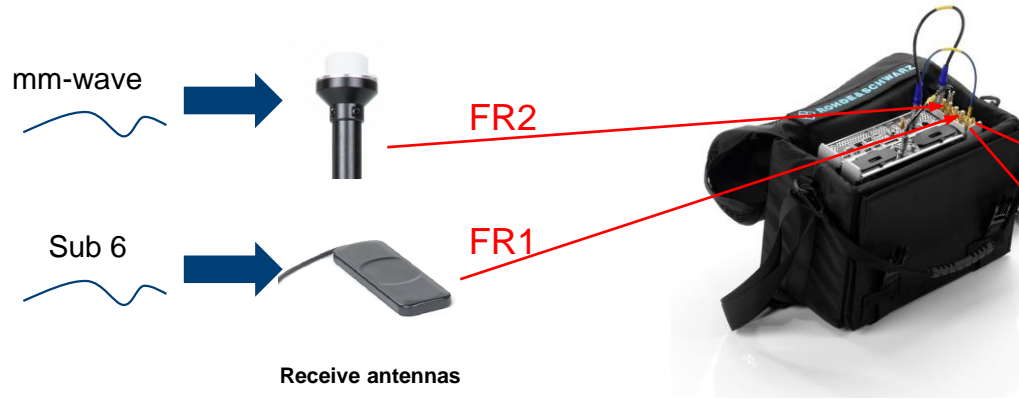
Difference is < 9  $\mu$ s

ToA measurements are done as drive tests (large area in short time) → target: detect outliers!

► Open RAN synchronization measurements suitable in field as quick feasibility check

# NETWORK TESTING - PASSIVE

## ANCHOR CELL IN FR1 (LTE) CA FR2 (5G) AND/OR FR1 (5G)



Simultaneous measurements of sub 6 GHz and mm-wave

# Network Testing solutions for PASSIVE tests (site acceptance & performance tuning)

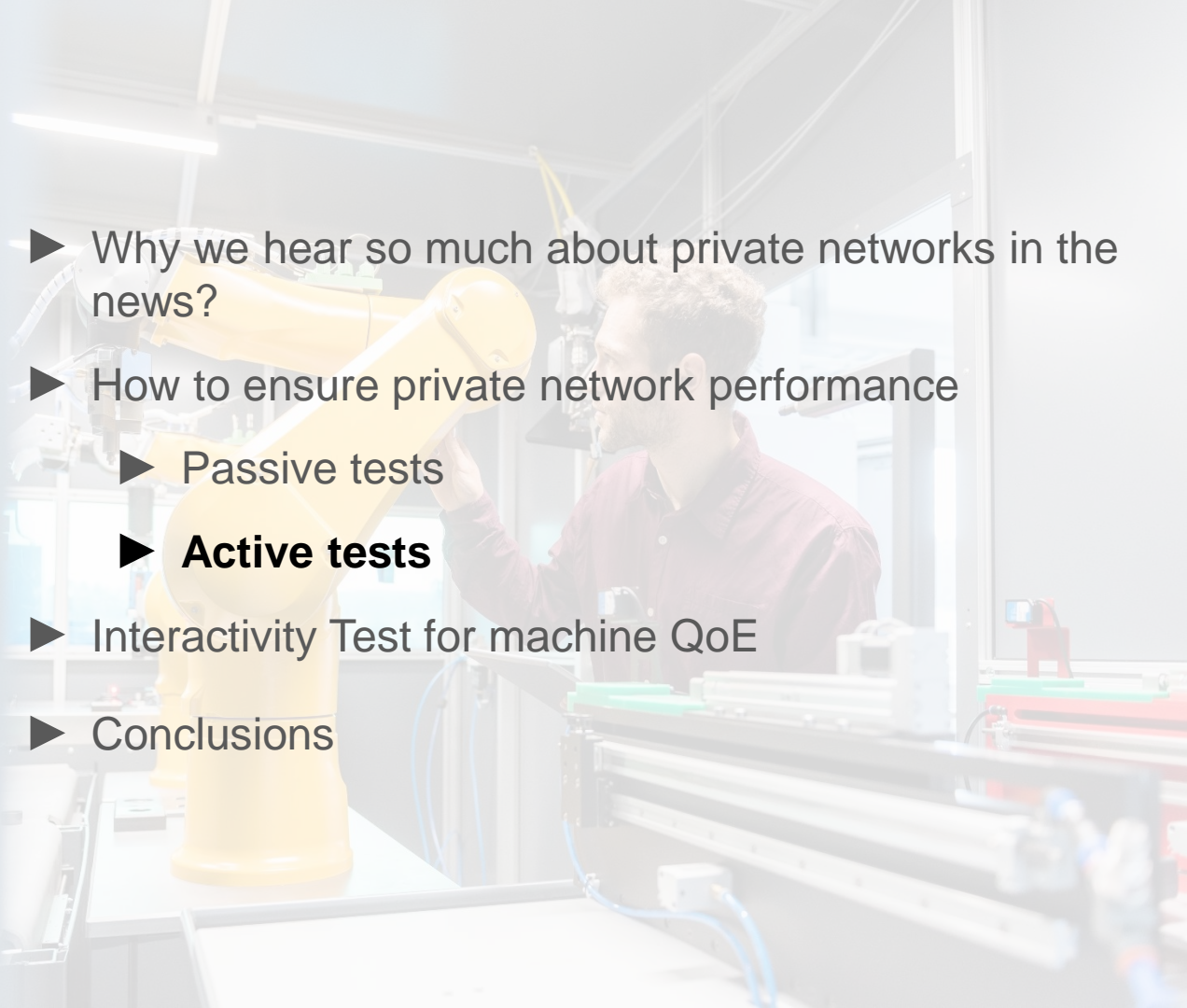


R&S®5G STS

- ▶ Passive Network Measurements in
  - ▶ Private & public networks
  - ▶ 5G Non-Standalone & Standalone networks (NSA / SA)
- ▶ No Network Access / no SIM needed
- ▶ Network Scanner:
  - ▶ 5G / LTE Signal Decoding
  - ▶ 5G / LTE Downlink tests
  - ▶ Synchronization tests
  - ▶ EMF measurements

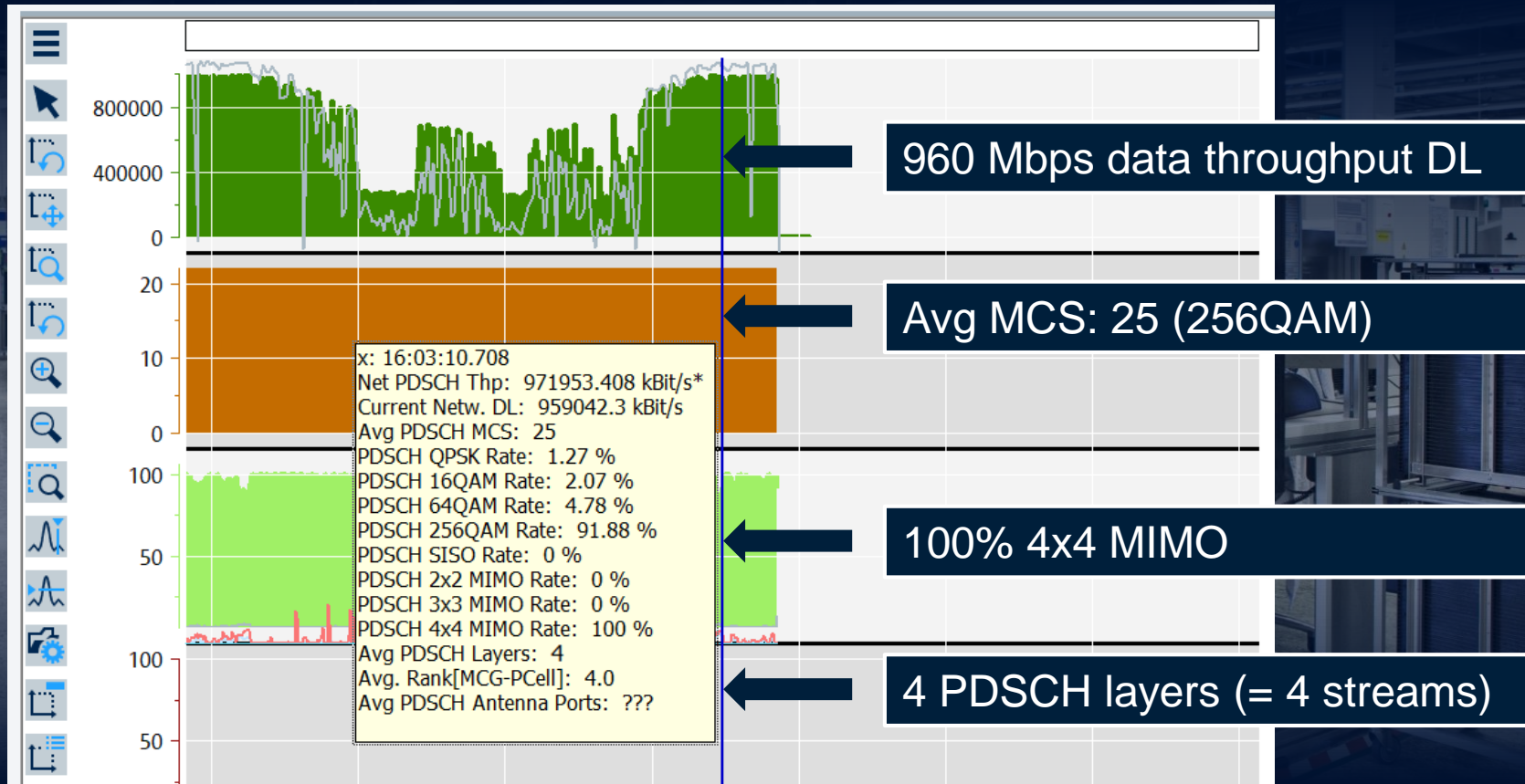
▶ RF DL Tests (Coverage & Signal Quality) provide insights into reference RF environment

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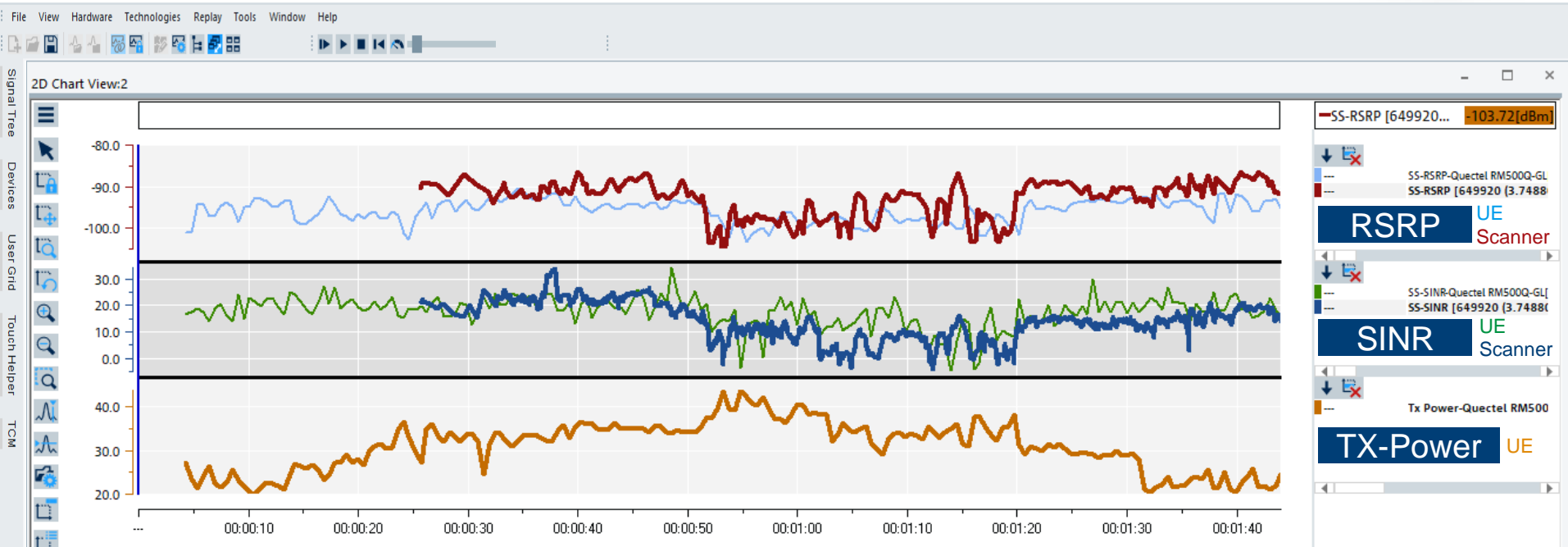
- ▶ Why we hear so much about private networks in the news?
  - ▶ How to ensure private network performance
    - ▶ Passive tests
    - ▶ **Active tests**
  - ▶ Interactivity Test for machine QoE
  - ▶ Conclusions
- 
- A man in a red shirt is working with a yellow robotic arm in a factory setting. The background shows industrial equipment and a window.



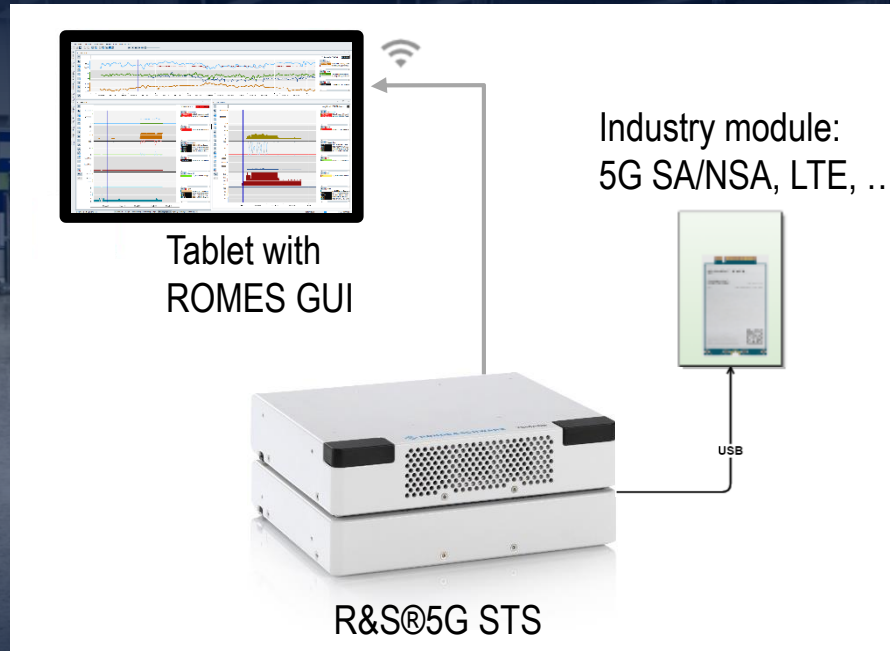
# Performance testing (DL): Active tests with industry module



# NETWORK TESTING – ACTIVE & PASSIVE UE & SCANNER COMPARISON



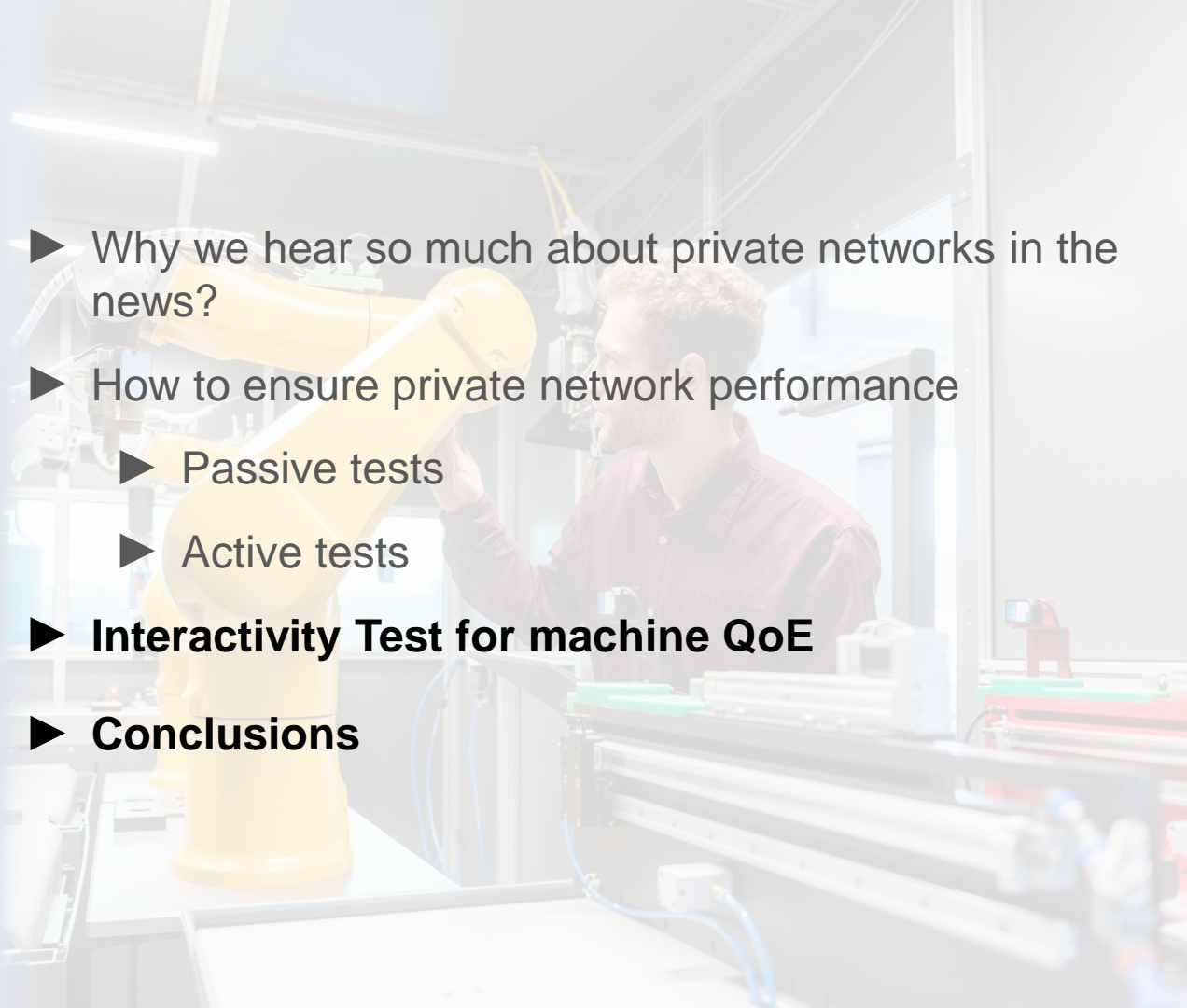
# Network Testing solutions for ACTIVE tests (site acceptance & performance tuning)



- Active Network Measurements in
- ▶ Private & public networks
  - ▶ 5G Non-Standalone & Standalone networks (NSA / SA)
  - ▶ Network Access / SIM card needed
  - ▶ Industry module as frontend:
    - ▶ Data throughput DL / UL
    - ▶ Roundtrip latency,
    - ▶ Packet delay variation,
    - ▶ Packet loss

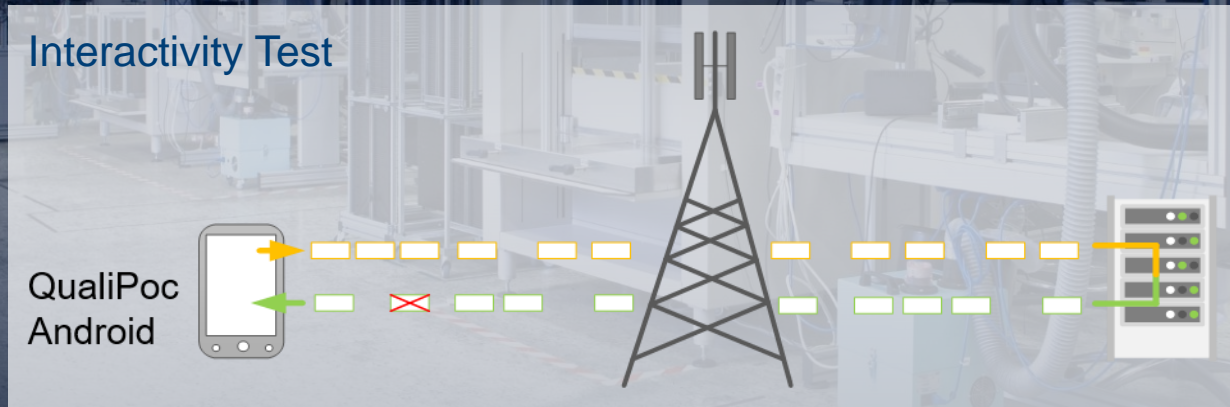
- ▶ IP layer data performance tests provide insights into 5G private network quality

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  - ▶ **Interactivity Test for machine QoE**
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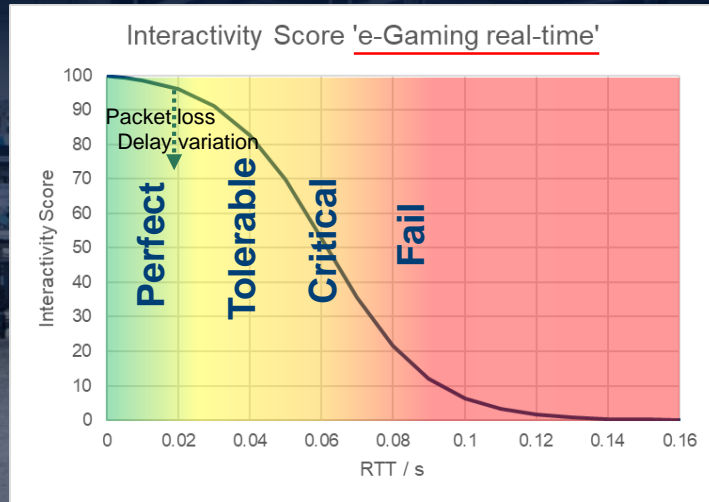
# For 5G: interactivity test to cover different use case classes

- ▶ **Interactivity** is the combination of **Bitrate + Latency + Continuity!**
- ▶ The device sends a UDP stream of unique packets to an (active) server that reflects it
- ▶ **TWAMP: Two-Way Active Measurement Protocol** – specified by IETF (RFC 5357)  
(Traffic can be emulated; TWAMP defined for latency SLA verifications)

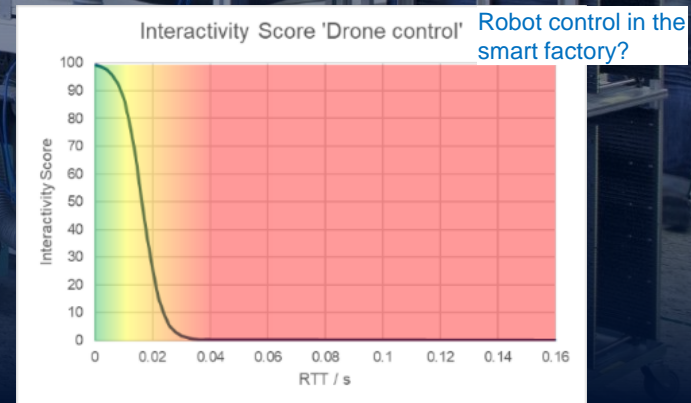
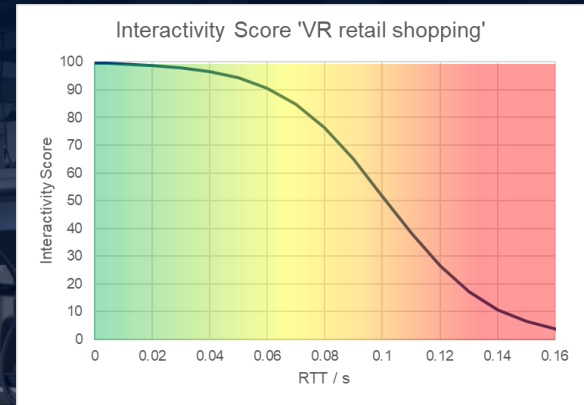


**Interactivity Score:** combines latency, delay variation and packet loss into one single score

# Interactivity Test – a scalable QoE model for interactive applications (human and machine users)



scalable



- ▶ The parametrization of the Interactivity Test and Score is individual for each application class
- ▶ Latency and interactive applications are already referenced in ETSI TR 702 103

# Supported traffic profiles

- ▶ E-gaming (multiplayer cloud-based games)
- ▶ Online Meetings
- ▶ Constant data rate (high, med, low)
- ▶ Industrial use cases and traffic patterns to be defined (AGV, Robot Control, Remote Support (AR/VR), ...)
- ▶ 5G-ACIA?

# Conclusions

5G technology enables business-critical use cases

5G private networks market is starting, mostly in experimental phase first!

Site acceptance and performance tuning fill the gap between plain deployment and “network ready for customer”

Only the combination of passive and active tests provides the full insights into private network performance → 5G STS as game changer including industry module

Interactivity test as scalable (machine) QoE model will be tuned to industry use cases

➤ **R&S is ready to enable 5G private network performance**



Learn more

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