INTERACTIVITY TEST

White paper | Version 01.00 | Dr. J. Berger, J. Sochos

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CONTENTS

1 INTRODUCTION

1.1 New and evolving applications in 5G networks

Most users are under the impression that 5G will simply provide higher data rates. This is true; the transport capacity will increase due to the additional spectrum made available by licensing 5G frequencies to operators. It will surely improve the download experience, especially in heavily loaded areas.

But 5G is more than just higher data rates. The main advantage lies in the scalable network slices that support the individual transport requirements for critical and less critical applications. These network slices can be tuned for extremely short latencies, especially for reliable connections and peak transport rates.

5G is prepared to be a technology for more than humans using smartphones, outdated paging and modem services. 5G is intended to be the digital transport backbone for industries and the automotive sector.

With the new capabilities of 5G networks, we see some key points worth noting:
- Human users will be just one user class among others (industry, automotive, IoT)
- These new user classes place different demands on the network than humans
- For human users, the most popular applications will remain, but evolve
- New application areas and use cases for all user classes will be launched

Today's applications and use cases work with today's network capabilities. They require a certain throughput, but they can cope with temporary low bit rates or interruptions due to buffering data and are moving away from real-time interaction. The fact that today's networks and technologies are not able to transport data with ultra high reliability and very short latencies limits users to more download-oriented services and away from seamless real-time applications. This will and must change with the deployment of 5G.

1.2 QoS/QoE measurement in 5G

With the evolving network capabilities, some significant changes need to be made in measuring network quality.

The fundamental concept of quality of experience (QoE) and its basic dimensions remain the same, even if the importance for the user and the acceptability thresholds change:
- **Accessibility and sustainability:** Do I have access to the service at all and is the connection technically maintained?
- **Waiting time** for action (task is started and/or completed): How long does the access take (e.g. call setup time, setup of the IP service)?
- **Quality:** How is the experience during active use?

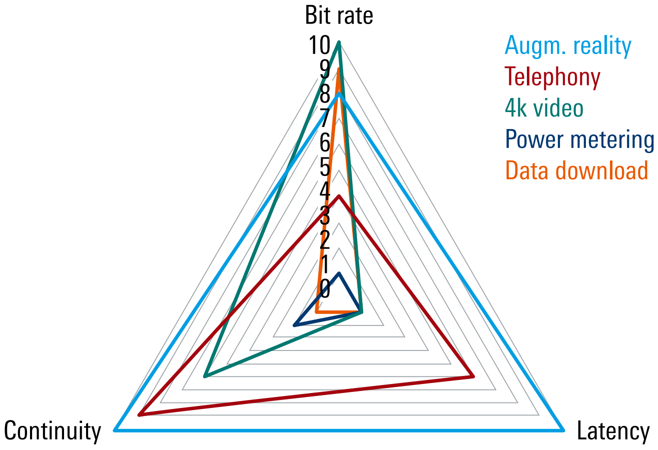
In 5G, accessibility and sustainability will be a given and the very rare fails will be more annoying to the affected user than they are today, but they will be so rare that they will have a low impact on the overall QoE. The same applies to access and waiting times; they will become very short and have little influence on the QoE. The key challenge is to measure experience during the active use of an application, for instance:
- How is the perceived quality (e.g. video quality)?
- How is the response time to an action or an instruction (e.g. to a machine)?
- How fluent is the service? Are there interruptions, undercuts, or is the other end temporarily unavailable?

Considering that data throughput is not the only key parameter for new, interactive applications and real-time control services, the underlying key network parameters are:

- Transport capacity (bit rate)
- Transport latency
- Transport continuity

Of course, different types of applications and use cases will have different requirements in these three dimensions. A data download such as updating maps requires mainly a high bit rate. For telephony and/or real-time surveillance, the focus is on continuity. And for real-time interaction like in augmented reality (AR), the requirements are high in all dimensions.

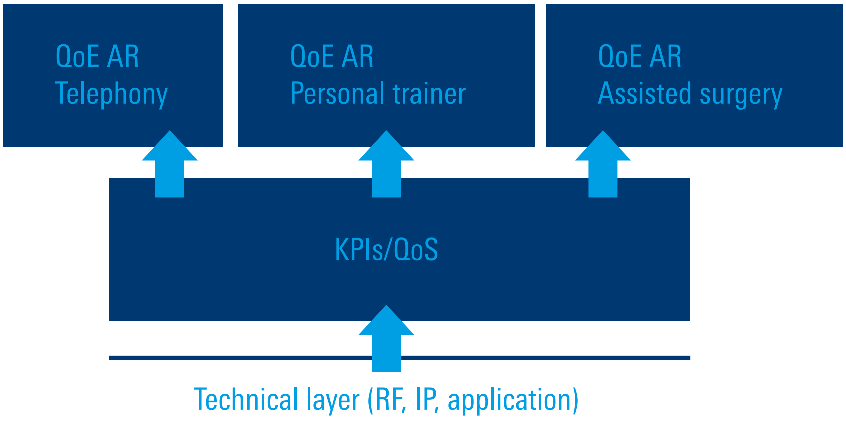
Fig. 1: Aspects of interactivity



The measurable continuity and latency for a given bit rate or even the entire setup, including the backbone and far-end server or device, can be called the interactivity of the network. The QoE depends on the use case and the associated transport expectations and requirements. However, the underlying key performance indicators (KPI) and technical parameters are the same; the difference is how they are weighted in a QoE model.

Therefore, measuring one set of technical KPIs can serve as input to different QoE models and effectively measure the channel quality for different applications at the same time. The only requirement is that these applications create a similar network traffic pattern.

Fig. 2: KPIs and QoS parameters as input to QoE models



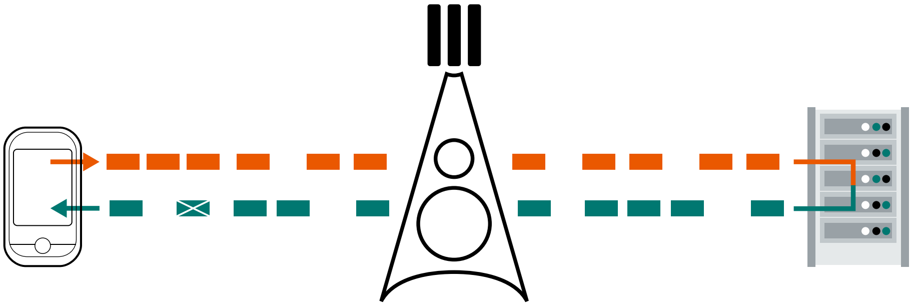
Finally, we have to rethink the term QoE. A non-human use case such as an industrial use case may not fall into a QoE classification where quality is perceived by a user. But even for non-human applications, there will be a tolerance range where the applications fulfill their demands, and a declining range where the functionality continually degrades until the applications eventually become unusable. Consequently, there will be an evaluation model for non-human use cases that follows principles similar to a QoE model for human use cases.

2 INTERACTIVITY TEST CONCEPT

In order to measure bit rate, latency and continuity at the same time, an integrative test concept was developed and implemented: the interactivity test.

The idea is that the user equipment (UE) acts as a client that sends a stream of packets to an active remote station, for example a server or partner UE that acts as the responder and reflects the packets back to the UE.

Fig. 3: Packet stream exchange



The client and server are connected via a mobile network and exchange a continuous stream of packets that are sent by the client and reflected by the server. The packets have an individual round trip latency or might get lost because the protocol used is UDP.

In order to derive realistic measurement results like in real applications, it is important to emulate traffic and load patterns during the measurement as they would occur in real applications. It is not sufficient to just send a few packets to measure latency and rate the transmission quality. The implemented test case is designed to emulate real traffic patterns and to create data streams like in real-time applications. The client sets the sent traffic pattern – packet size and frequency – and thus controls the data rate.

The packet sending rate is in the range of 100 to 1500 packets per second, which creates a quasi-continuous packet flow. Since the client controls the packet payload as well as the sending and receiving time, it is possible to measure:

- TX and RX data rates
- Round trip latency of the packets
- Packet delay variation (jitter) as the latency variation over time
- Packet loss rate
- Packet corruption rate (roadmap feature)

Data exchange is based on UDP. Not only is UDP the main protocol for real-time applications, it is also the protocol that comes closest to the physical layer, and it avoids any additional, uncontrollable traffic caused by acknowledgements and retransmissions. The higher layer protocol for the data flow between the client and server is TWAMP, the two-way active measurement protocol. This is a state-of-the-art protocol specified by the IETF to be implemented in components like firewalls, routers and IP gateways for performance measurements.

Along with installations of mobile network testing products, Rohde & Schwarz will provide and deploy its own server installations, offering more measurement opportunities, but the test – at least in the basic configurations – is compatible with public TWAMP responders.

The client on the UE is implemented under Android native in order to minimize OS influence and achieve a high measurement accuracy for real ultra-reliable low latency communications (URLLC) measurements.

There is an important difference between the interactivity test and a ping test. A simple ping test uses a separate protocol and is designed to check availability of an IP device in the network. It creates almost no load and the transport system might be protocol-aware.

The methodology used for the interactivity test emulates a realistic use case. Like most real-time applications, it uses UDP. Even more important than being close to the physical layer is the ability to generate traffic load patterns that are typical to real use cases. Transmitting a heavy flow of packets at high frequency when simulating a real use case will place different demands on the network than a series of pings and will result in a more realistic picture of latency, latency jitter and packet losses.

3 INTERACTIVITY TEST CONFIGURATION

At the technical level, the test definition controls the following parameters
- Packet rate
- Packet size
- Packet delay budget (if exceeded, the packet counts as lost)
- Test duration

In order to minimize the configuration effort at this lower definition level, typical traffic patterns were preconfigured for selection by a user. These are not only based on constant packet rates, they also emulate bursty shapes in which the packet rate changes over time, as is typical for applications with temporary highly interactive phases.

The patterns listed in the table below are currently available. This list will be extended with future releases to include new application types such as cloud gaming, augmented reality, virtual reality and more.

Name	Traffic shape	Packets per second	Packet size	Resulting target bandwidth	Packet delay budget	Max. packet error rate	Test duration
Constant low	constant low rate	125	100 byte	0.1 Mbit/s	2 × 250 ms	2×10^{-2}	2 s
Constant medium	constant medium rate	200	650 byte	1 Mbit/s	2 × 250 ms	2×10^{-2}	2 s
Constant high	constant high rate	1300	1450 byte	15 Mbit/s	2 × 250 ms	2×10^{-2}	2 s
eGaming real-time	bursty medium rate	125/375/1250	100 byte	0.1 Mbit/s to 1 Mbit/s	2 × 50 ms	2×10^{-3}	10 s

3.1 Constant traffic patterns

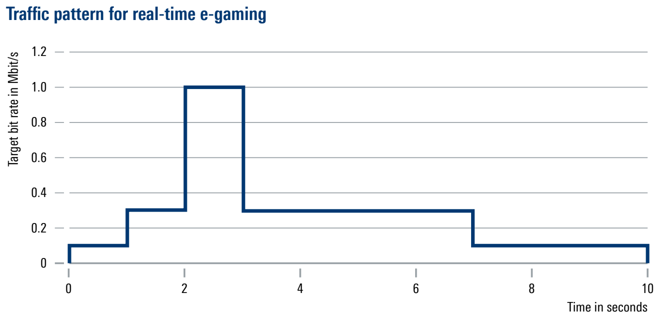
The three available constant traffic patterns are the basic test cases for quickly measuring the network channel interactivity and latency. They differ in the packet sending rate and packet size and therefore the resulting target bandwidth. They have a high packet delay budget and a high maximum packet error rate and should usually lead to successful tests if the network is able to handle the target bandwidth in both the uplink and downlink directions. The test duration of two seconds is based on the standard averaging window for evaluating the quality of service (QoS) class of the radio network. The resulting tests are very short and can provide strong insight into the network quality with little data and without consuming a lot of time.

3.2 Real-time eGaming traffic pattern

This traffic pattern is designed to mimic the traffic shape of today's most demanding real-time online games from a network's point of view. Analyses have shown that in highly complex multiplayer scenarios with more than 100 simultaneous players, the data rate is around 100 kbit/s to 300 kbit/s with singular data peaks of 500 kbit/s to 1000 kbit/s. The following traffic pattern has been defined as a challenging, but realistic scenario for the network:

- Initial phase
- Highly interactive phase
- Sustainable phase
- Trailing phase

Fig. 4: Shape of the scheduled traffic



4 INTERACTIVITY TEST RESULTS

4.1 Technical KPIs

4.1.1 Latency

The two-way latency is measured as the median round trip time (RTT) of all individual RTTs of the packets that successfully arrived back at the session sender in time.

Additionally, the 10th percentile of the RTTs is calculated and represents the best case RTT of the current channel.

4.1.2 Packet delay variation

In line with RFC 5481, the packet delay variation of an individual packet is defined as

$$PDV(i) = D(i) - D(min) \text{ where } PDV(i) \in \mathbb{R}_+$$

where D(i) is the individual delay of one packet and D(min) is the minimum individual delay of all packets in the measurement interval.

PDV values can be zero or positive, and quantiles of the PDV distribution are direct indications of delay variation.

This vector is used to calculate the:
- PDV 50th percentile (median)
- PDV 99.9th percentile (approx. maximum)

4.1.3 Packet error rate

The packet error rate is derived from the number of packets that were not available to the hypothetical application at the time needed. This includes:
- Packets that could not leave the client device due to uplink congestion
- Packets that were lost on the way
- Packets that were too slow and arrived after the given packet delay budget; they are discarded and count as lost
- Packets where the payload is corrupted 1)

$$\textit{Packet error rate} = \frac{\textit{packets not sent} + \textit{packets lost} + \textit{packets corrupted}}{\textit{packets scheduled}}$$

4.1.4 Channel QoS 3GPP

The 3GPP TS 23 501 "System Architecture for the 5G System" specification (and the former document for 4G/LTE) includes a list of standardized QoS characteristics, for example services. Each set of characteristics is identified by a 5QI value. For instance, it specifies a packet delay budget (PDB) and a maximum packet error rate.

3GPP defines the resource types' guaranteed bit rate (GBR), non-GBR and delay critical GBR. In this classification, only packets of the last class that arrive after the PDB is exceeded are counted as lost (5QI values 82 to 85).

In the case of real-time gaming (5QI = 3), the one-way packet delay budget is 50 ms and the packet error rate is 1:1000 packets. These values must be doubled for two-way measurements. Although real-time gaming is defined as resource type GBR, packets with a delay of more than the PDB are considered lost since this test case is aimed at true real-time games with strong requirements for a low latency connection. In a real-time application, delayed packets are not usable and have no benefit for the user and are therefore considered to be lost information.

If the measured packet error rate (which includes the packets that exceeded the PDB) is below the maximum allowable packet error rate, the channel QoS can be said to be high enough for a good real-time eGaming experience.

Fig. 5: Detail of the 3GPP standard TS23.501 "System Architecture for the 5G System"

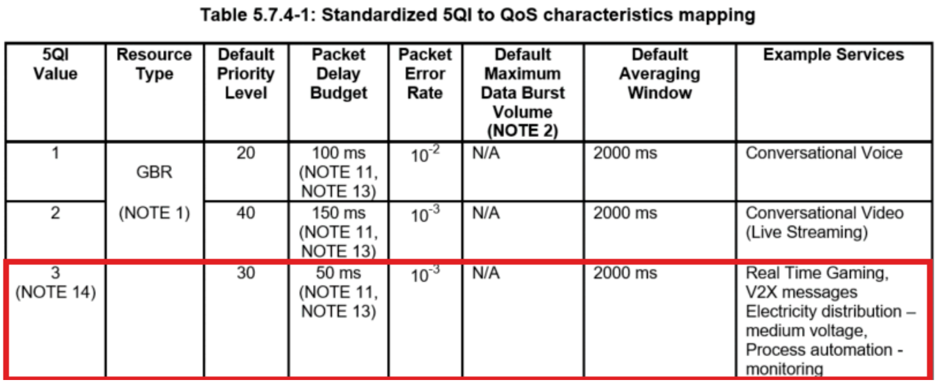


Table 5.7.4-1: Standardized 5QI to QoS characteristics mapping

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume (NOTE 2)	Default Averaging Window	Example Services
1	GBR (NOTE 1)	20	100 ms (NOTE 11, NOTE 13)	10^{-2}	N/A	2000 ms	Conversational Voice
2		40	150 ms (NOTE 11, NOTE 13)	10^{-3}	N/A	2000 ms	Conversational Video (Live Streaming)
3 (NOTE 14)		30	50 ms (NOTE 11, NOTE 13)	10^{-3}	N/A	2000 ms	Real Time Gaming, V2X messages Electricity distribution – medium voltage, Process automation - monitoring

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1) Planned, not implemented in the current release of the interactivity test.

A measure for the channel QoS is derived from this 3GPP based definition. It is a single value expressing the percentage of valid packets that have arrived in time compared to the maximum allowable packet error rate (PER) for a given application. It has the value 100 % if the requirement is fulfilled and 0 % if no packet arrived at the destination in time.

$$\mathit{Channel\ QoS} = 100\,\%\ \text{if}\ PER_{meas} < PER_{max}$$

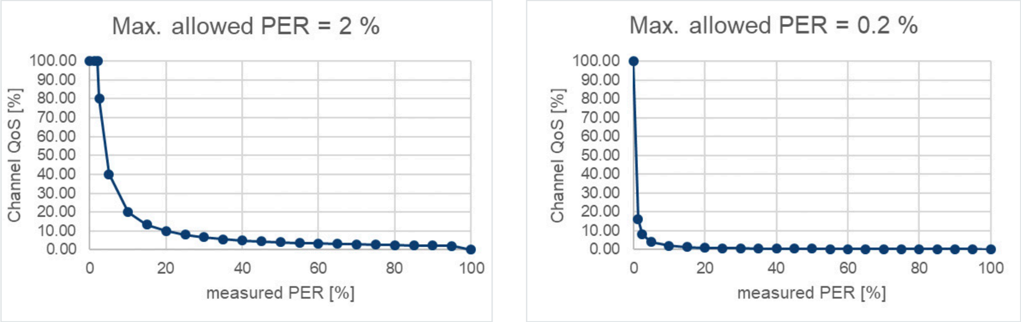
$$\mathit{Channel\ QoS} = 0\,\%\ \text{if}\ PER_{meas} = 100\,\%$$

$$\mathit{Channel\ QoS} = \frac{PER_{max}}{PER_{meas}} \times 100\,\%\ \text{else}$$

The steepness of the decay of the channel QoS depends on the maximum allowable PER, and the function has discontinuities at

$PER = PER_{max}$ and $PER = 100\,\%$.

Fig. 6: Channel QoS versus measured and maximum allowed packet error rate

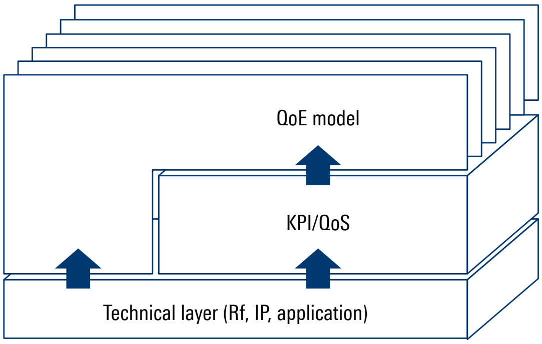


Since the maximum allowable PER is application dependent and is defined in the 5G QoS classes, the channel QoS can be used to describe how well the network channel fulfills the QoS requirements for the given application.

4.2 QoE model – interactivity score

To emulate real applications, a generic QoE model is used per application class. Each QoE model creates a "synthetic" MOS based on the QoS and technical KPIs. These technical measurements are the same for all types of applications, except for the underlying traffic pattern. This is the most efficient way to cope with the huge number of different applications.

Fig. 7: Generic QoE models based on the same set of KPIs and QoS parameters



This type of generic QoE model is fully scalable and based on a common set of parameters.

4.2.1 First implemented QoE model: real-time eGaming

The first step is to provide a QoE model that is based on latency, packet delay variation and packet loss rate and targets today's real-time eGaming applications.

$$Interactivity\ score = Score_{LATENCY} \times Score_{PDV} \times Score_{PL} \times 100\ \%$$

The first term of the score is an s-shaped logistic function that maps the individual round trip time measurements per packet to a pseudo perceptive scale, see left-hand graph in Fig. 8.

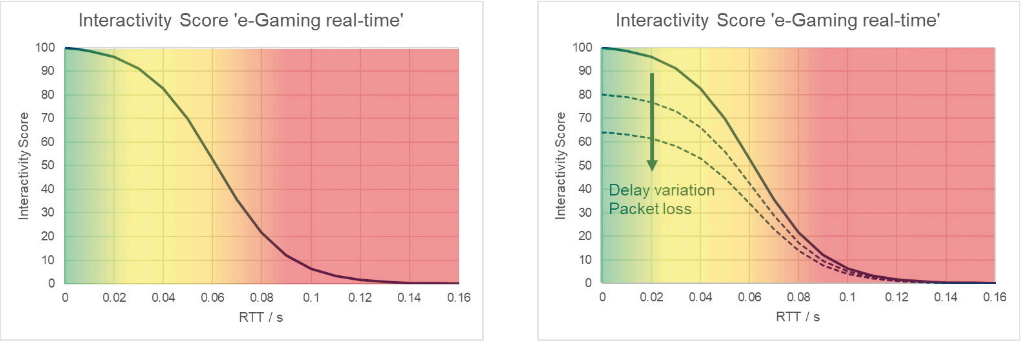
$$Score_{LATENCY} = \frac{1}{N}\sum_{i}\left[\frac{1 - \dfrac{0.005}{0.005 + 0.09\ \exp^{-70 \times (RTT_i - 0.02)}}}{0.9865}\right] \in [0,1]$$

The remaining two terms depend on packet delay variation and packet loss rate, whereby higher values lead to a downward shift of the s-curve (right-hand graph in Fig. 8).

$$Score_{PDV} = \max\left(0, 1 - \frac{200 \times median(PDV)}{70}\right) \in [0,1]$$

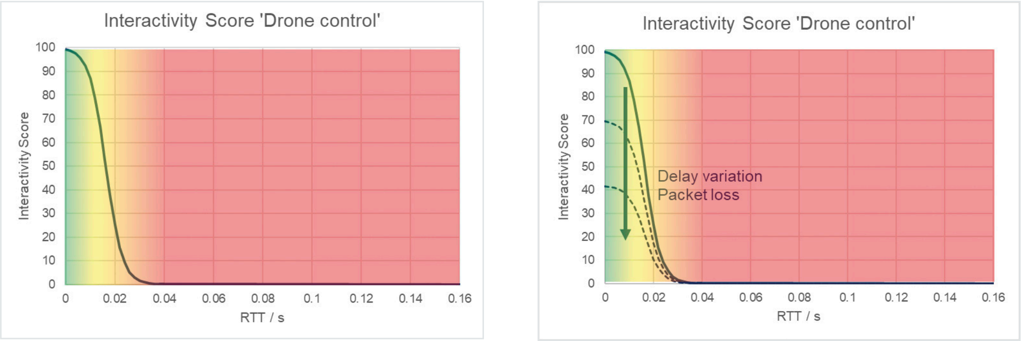
$$Score_{PL} = \max\left(0, 1 - \frac{300 \times PL}{70}\right) \in [0,1]$$

Fig. 8: Realization of an interactivity score for eGaming



The model can be easily adapted for the different requirements and expectations for application types other than eGaming. For example, the s-shaped model for the latency value in the interactivity score for drone control will be much steeper:

Fig. 9: Using the interactivity score concept for drone control



5 MEASUREMENT SCENARIOS

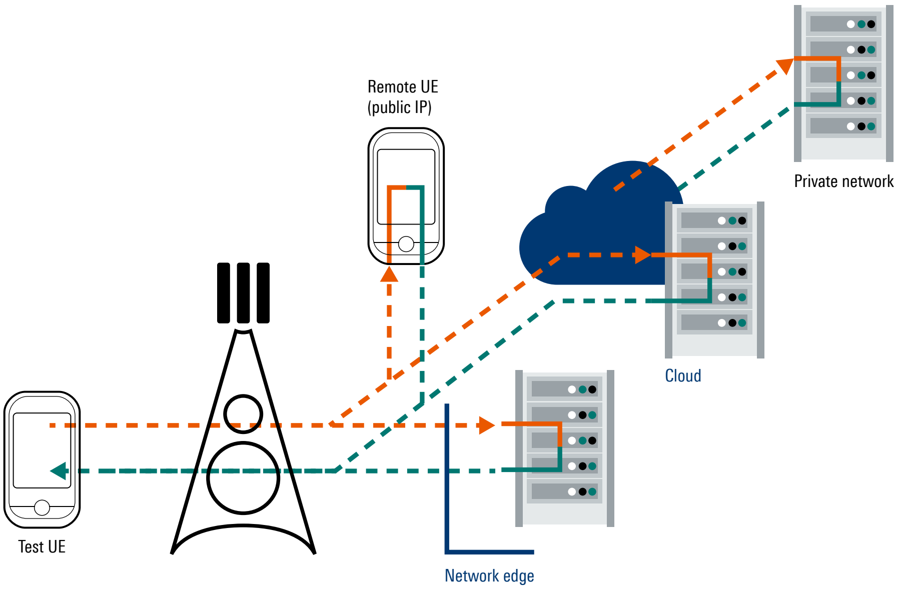
When defining the measurement scenario and setup, it is important to decide what the goal of the measurement is. Specifically, the location of the server/reflector is important because the further it is from the network edge, the more the interactivity measurement is dominated by the content delivery network and its technical means, how it is connected, and less by the mobile network.

For an interactivity measurement of the mobile link, it is important to place the server as close as possible to the network edge. This is facilitated by the use of the TWAMP protocol, which is supported by selected infrastructure equipment.

If the measurement target is a realistic emulation e.g. of a real-time eGaming experience, it is better to place the server in the cloud or in a private network where eGaming service providers are usually located.

To give full flexibility to customers and users, mobile network testing products from Rohde & Schwarz offer a lightweight Linux VM installation that can be installed on servers preferred by the user and reflects the targeted test situation.

Fig. 10: Positioning of the responder based use case to be modelled



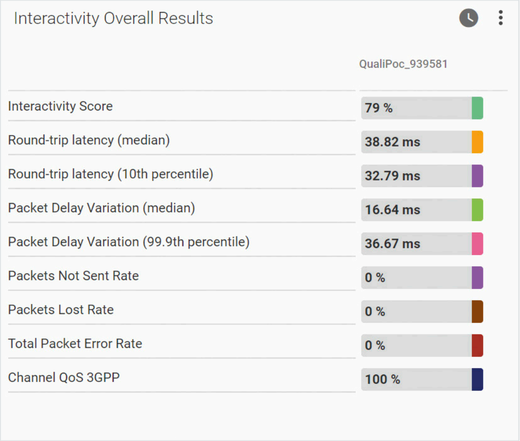
The remote server installation can also be placed on a remote smartphone. An Android version is also available from Rohde & Schwarz. However, the remote device needs a public IP address for direct communication.

6 INTERACTIVITY TEST IN THE FIELD

6.1 Real-time eGaming emulation in 4G/LTE – good coverage

In 4G LTE, with the remote packet responder positioned in a cloud in the same country, we see median round trip latencies of approx. 40 ms to 25 ms. Under good network conditions, no packet is lost or delayed beyond the packet delay budget of 2 × 50 ms and the channel QoS is therefore 100 %. The interactivity score is between 65 % and 80 % due to a rather long RTT for real-time applications, so a reasonable to good real-time eGaming experience can be expected.

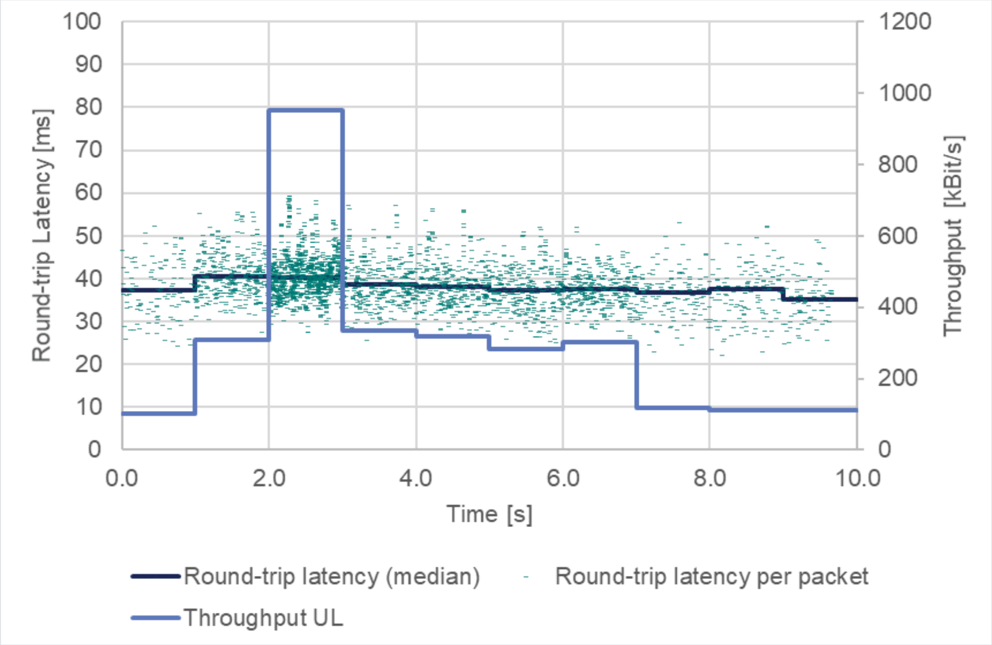
Fig. 11: Example 1: interactivity test results in 4G



Interactivity Overall Results

	QualiPoc_939581
Interactivity Score	79 %
Round-trip latency (median)	38.82 ms
Round-trip latency (10th percentile)	32.79 ms
Packet Delay Variation (median)	16.64 ms
Packet Delay Variation (99.9th percentile)	36.67 ms
Packets Not Sent Rate	0 %
Packets Lost Rate	0 %
Total Packet Error Rate	0 %
Channel QoS 3GPP	100 %

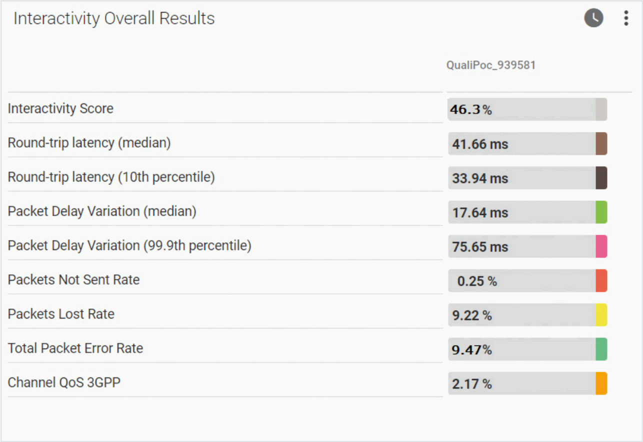
Fig. 12: Example 1: distribution of the per-packet round-trip latencies in 4G



6.2 Real-time eGaming emulation in 4G/LTE – handover

In the following example, a 4G intra-RAT handover takes place during the measurement after the quality of the radio signal has decreased substantially. This leads to temporarily high packet delays and lost packets, which are marked as red intervals. For a short time period, we see an increased median round trip latency. The overall channel QoS drops to below 10 % because 40 times more packets were lost than allowed. However, the overall interactivity score remains at a fair level since the integrated QoE is not degraded very much by a short-term impairment of the network interactivity.

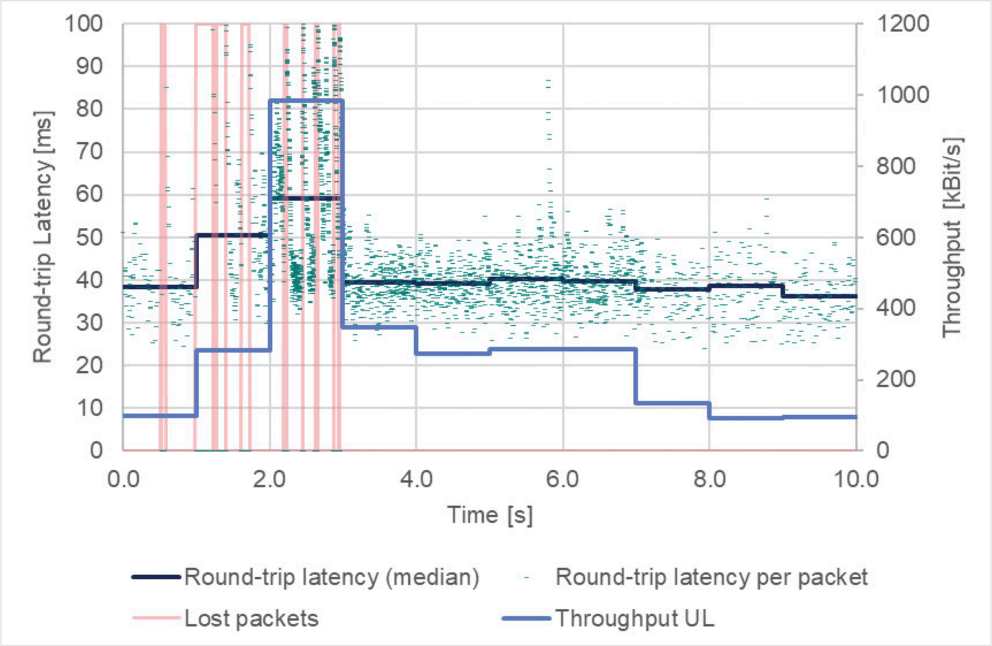
Fig. 13: Example 2: interactivity test results in 4G with cell handover



Interactivity Overall Results

	QualiPoc_939581
Interactivity Score	46.3 %
Round-trip latency (median)	41.66 ms
Round-trip latency (10th percentile)	33.94 ms
Packet Delay Variation (median)	17.64 ms
Packet Delay Variation (99.9th percentile)	75.65 ms
Packets Not Sent Rate	0.25 %
Packets Lost Rate	9.22 %
Total Packet Error Rate	9.47%
Channel QoS 3GPP	2.17 %

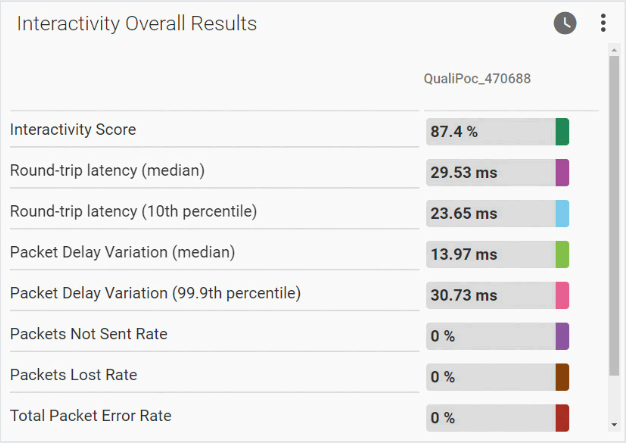
Fig. 14: Example 2: distribution of the per-packet round-trip latencies in 4G with cell handover



6.3 Real-time eGaming emulation in 5G EN-DC/NR

First measurements in 5G EN-DC mode with dual connectivity show that the latency is a bit lower than in 4G networks. Experience has shown that the RTT median drops to around 30 ms down to 20 ms in some network configurations. In addition, the packet delay variation is also a few milliseconds less compared to LTE. The interactivity score is in the range of 85 % to 90 %, which indicates a good to very good real-time eGaming experience.

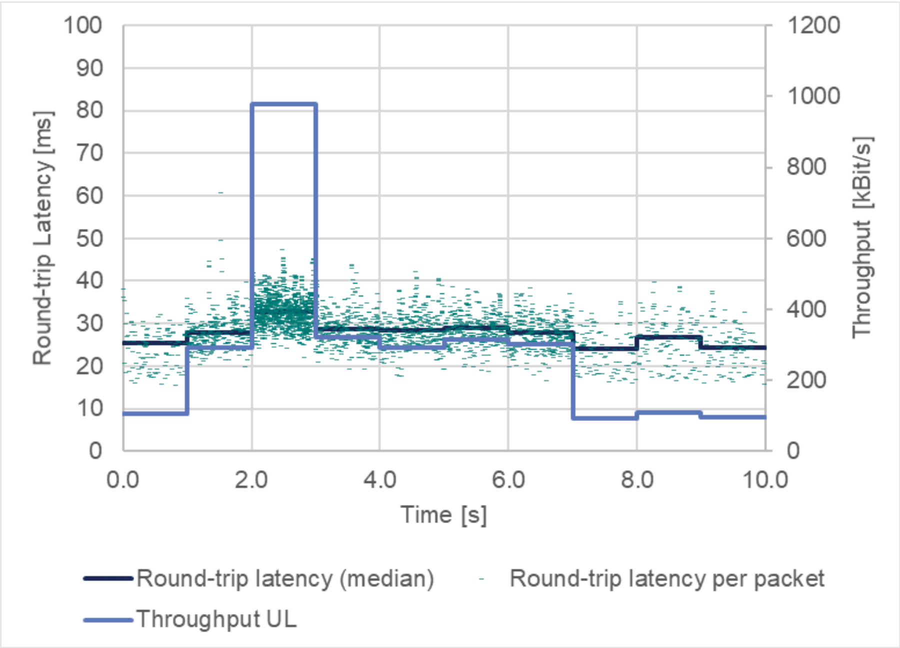
Fig. 15: Example 3: interactivity test results in 5G



Interactivity Overall Results

	QualiPoc_470688
Interactivity Score	87.4 %
Round-trip latency (median)	29.53 ms
Round-trip latency (10th percentile)	23.65 ms
Packet Delay Variation (median)	13.97 ms
Packet Delay Variation (99.9th percentile)	30.73 ms
Packets Not Sent Rate	0 %
Packets Lost Rate	0 %
Total Packet Error Rate	0 %

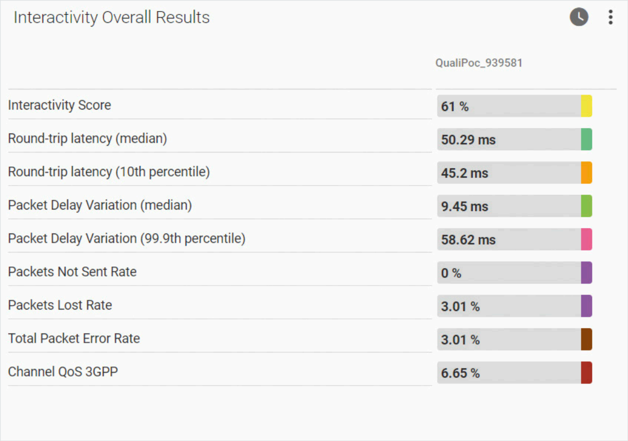
Fig. 16: Example 3: distribution of the per-packet round-trip latencies in 5G



6.4 Real-time eGaming emulation in 3G/UMTS

In UMTS, the median measured round trip latency for the eGaming pattern is in the range of 50 ms to 70 ms. In theory, this is fast enough for a fair to good eGaming experience. However, the channel is easily overloaded, which leads to delays and packet loss. Only about 10% of our tests in UMTS have a channel QoS of 100%, the majority have phases of high packet loss, especially in the test phase with high bit rate. Below is a typical example.

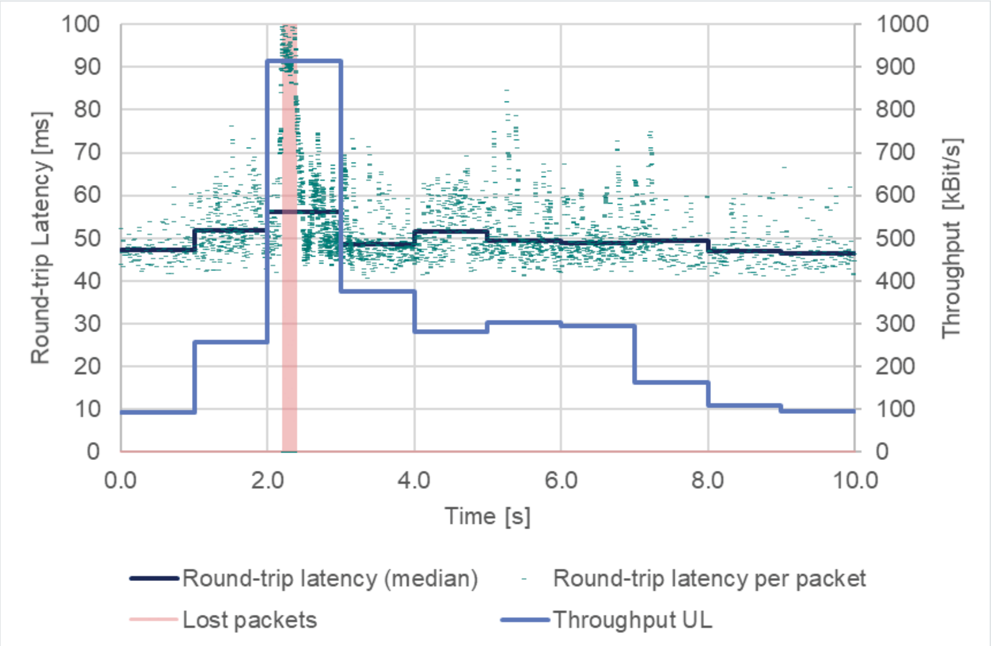
Fig. 17: Example 4: interactivity test results in 3G



Interactivity Overall Results

	QualiPoc_939581
Interactivity Score	61 %
Round-trip latency (median)	50.29 ms
Round-trip latency (10th percentile)	45.2 ms
Packet Delay Variation (median)	9.45 ms
Packet Delay Variation (99.9th percentile)	58.62 ms
Packets Not Sent Rate	0 %
Packets Lost Rate	3.01 %
Total Packet Error Rate	3.01 %
Channel QoS 3GPP	6.65 %

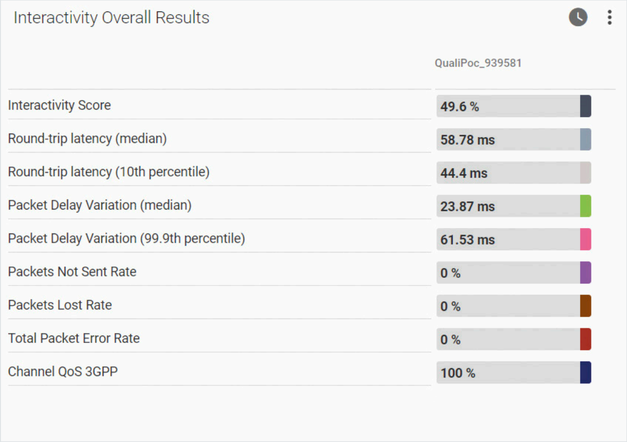
Fig. 18: Example 4: distribution of the per-packet round trip latencies in 3G



6.5 Constant traffic measurement in 4G/LTE

With the constant traffic patterns, it is possible to measure network interactivity very quickly under a given target bandwidth. The high bandwidth pattern has a target bandwidth of over 15 Mbps in both the uplink and downlink, which is quite demanding for an LTE network. The example below shows how the round trip latency increases and decreases over time, with a maximum latency of 100 ms.

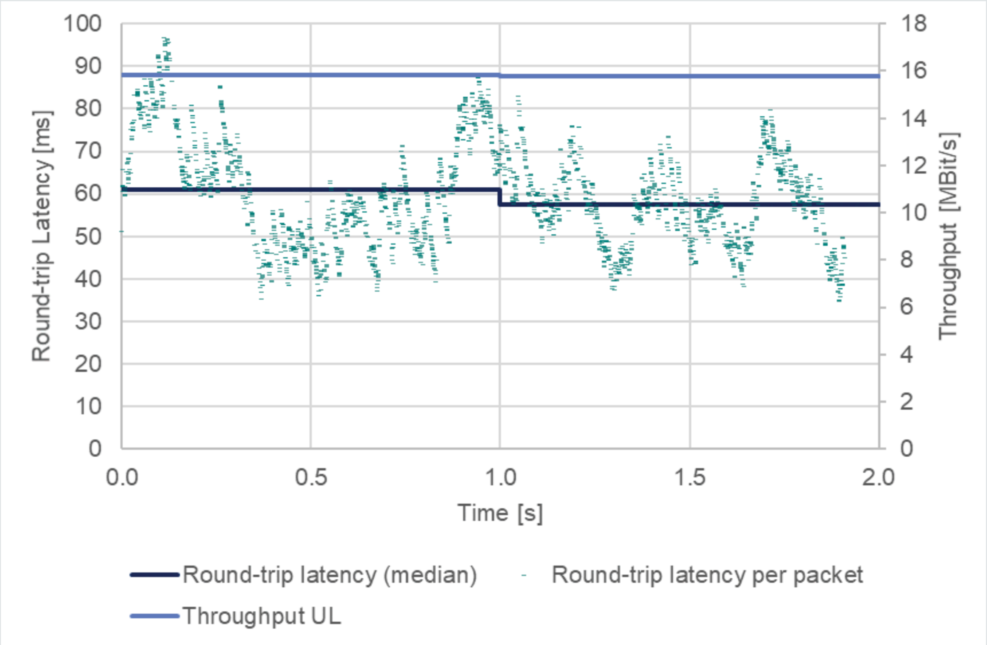
Fig. 19: Example 5: interactivity test results in 4G with constant traffic



Interactivity Overall Results

	QualiPoc_939581
Interactivity Score	49.6 %
Round-trip latency (median)	58.78 ms
Round-trip latency (10th percentile)	44.4 ms
Packet Delay Variation (median)	23.87 ms
Packet Delay Variation (99.9th percentile)	61.53 ms
Packets Not Sent Rate	0 %
Packets Lost Rate	0 %
Total Packet Error Rate	0 %
Channel QoS 3GPP	100 %

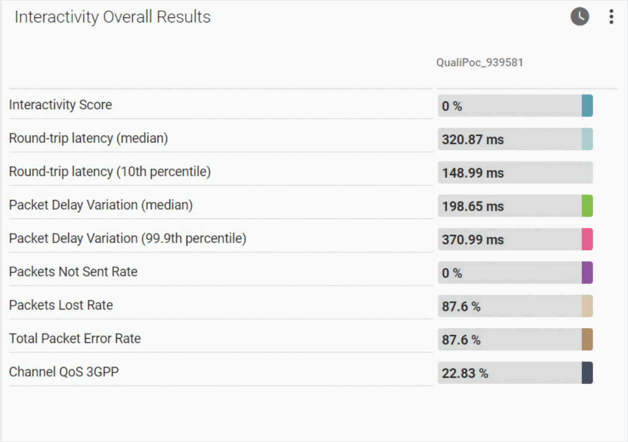
Fig. 20: Example 5: distribution of the per-packet round trip latencies in 4G with constant traffic



6.6 Constant traffic measurement in 2G/GSM

In GSM, the average round trip latency is much higher compared to the other technologies. When using the eGaming pattern with its packet delay budget of 100 ms for the round trip time, no packets are able to reach the client in time. With a constant traffic pattern and the much higher packet delay budget of 500 ms, some packets can stay below the threshold. Nevertheless, even for the constant low traffic pattern, the channel usually gets overloaded very quickly. A typical example is shown below (note the different axis range for the round trip time). The packet round trip time increases rapidly over time until the threshold is reached. After that, all packets are lost and the packet stream cannot be recovered.

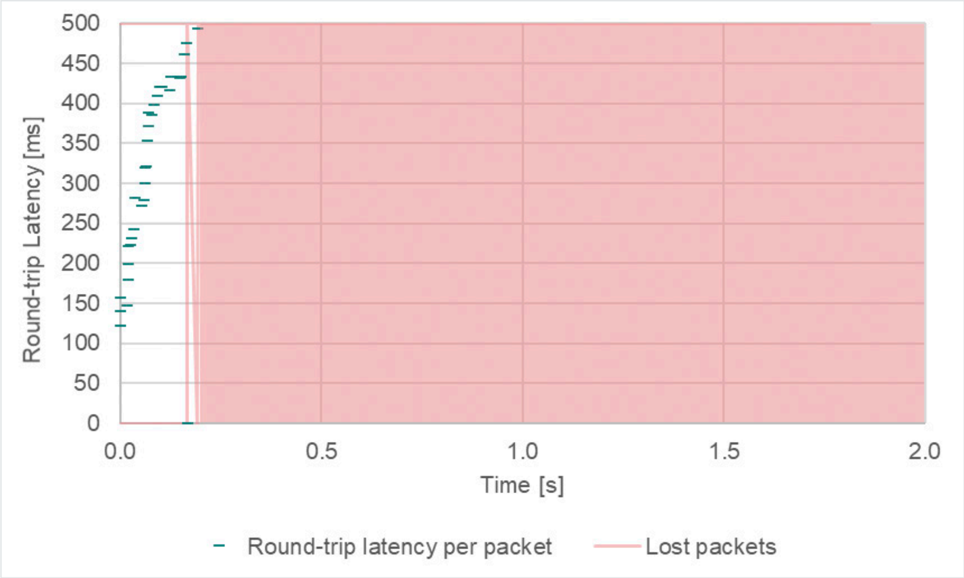
Fig. 21: Example 6: interactivity test results in 2G with constant traffic



Interactivity Overall Results

	QualiPoc_939581
Interactivity Score	0 %
Round-trip latency (median)	320.87 ms
Round-trip latency (10th percentile)	148.99 ms
Packet Delay Variation (median)	198.65 ms
Packet Delay Variation (99.9th percentile)	370.99 ms
Packets Not Sent Rate	0 %
Packets Lost Rate	87.6 %
Total Packet Error Rate	87.6 %
Channel QoS 3GPP	22.83 %

Fig. 22: Example 6: distribution of the per-packet round trip latencies in 2G with constant traffic



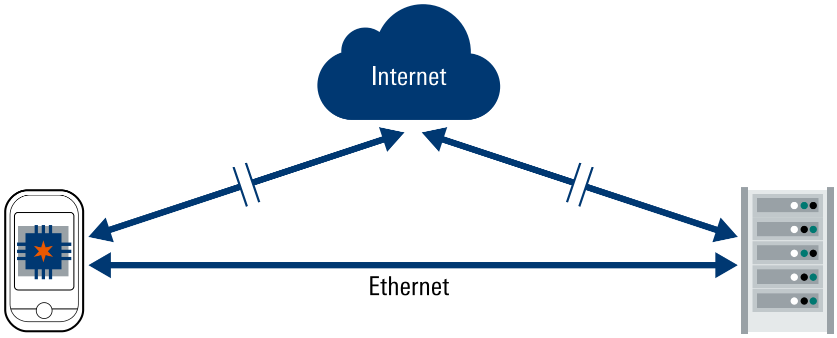
7 MEASUREMENT ACCURACY

The interactivity test is specifically designed to measure very short latencies, including in URLLC conditions on realistically shaped network traffic.

In order to evaluate the measurement accuracy that can be achieved in an ideal network channel, we have created a reference setup with extremely low latency.

The smartphone with the interactivity test running on a QualiPoc handheld was connected directly via Ethernet (over a USB interface) to a Linux server where the session reflector was located. The whole setup was standalone and not connected to the internet, so no background data could interfere with the test.

Fig. 23: Reference setup for accuracy analysis

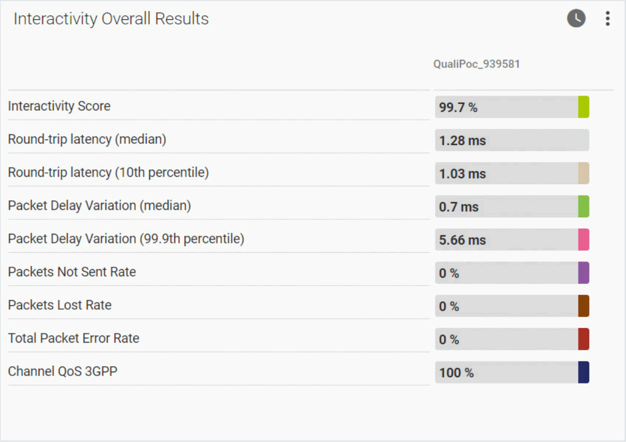


In this reference setup, we conducted more than 1000 tests with the real-time eGaming pattern and achieved very low latencies, packet delay variation and a high interactivity score. Specifically, we measured an average two-way latency of 1.26 ms ± 0.01 ms. The analysis of the outlier ratios shows that only 1:5000 packets arrive more than 10 ms later than the median RTT. The full set of performance data is listed in the table below.

KPI	Value
Average (RTT median)	1.26 ms
Standard deviation (RTT median)	0.01 ms
Outlier ratio RTTi > RTT median + 5 ms	0.17 %
Outlier ratio RTTi > RTT median + 10 ms	0.02 %
Average (PDV median)	0.78 ms
Standard deviation (PDV median)	0.04 ms
Average (interactivity score)	99.6 %

An example measurement with the real-time eGaming pattern in the reference setup is shown below.

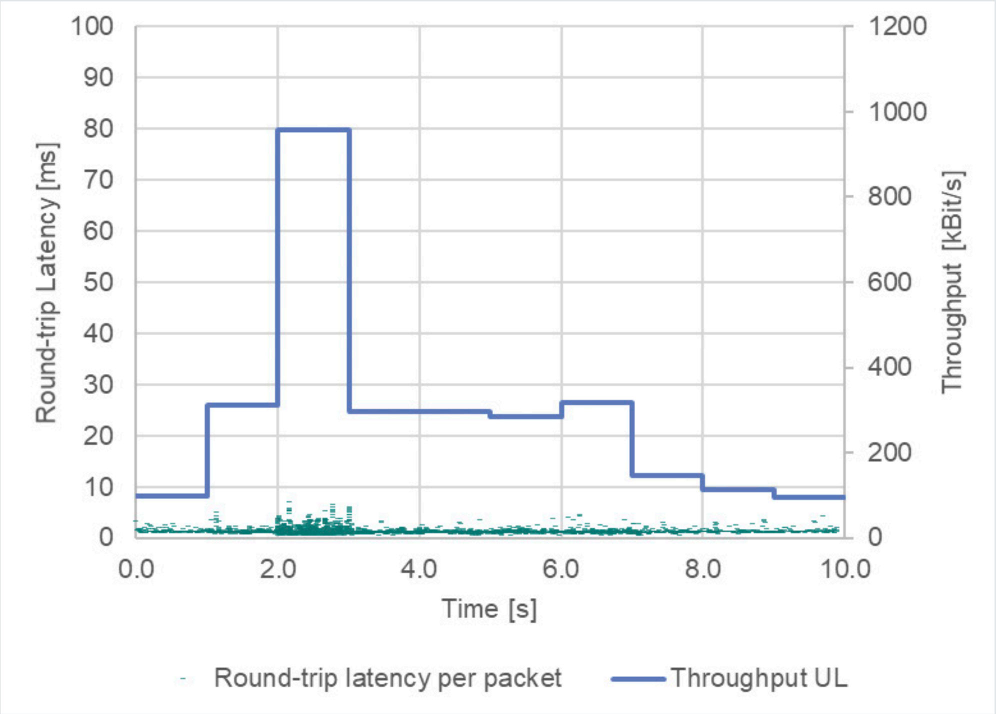
Fig. 24: Example 7: interactivity test results in the ultra-low latency reference system



Interactivity Overall Results

	QualiPoc_939581
Interactivity Score	99.7 %
Round-trip latency (median)	1.28 ms
Round-trip latency (10th percentile)	1.03 ms
Packet Delay Variation (median)	0.7 ms
Packet Delay Variation (99.9th percentile)	5.66 ms
Packets Not Sent Rate	0 %
Packets Lost Rate	0 %
Total Packet Error Rate	0 %
Channel QoS 3GPP	100 %

Fig. 25: Example 7: distribution of the per-packet round trip latencies in the ultra-low latency reference system.



There is a clear baseline between 1 ms and 2 ms, and no packet has a round trip latency longer than 10 ms.

8 CONCLUSION

5G will enable a new set of services, not only for human users, but also for industrial and automotive purposes. Key factors for acceptance and use are the ultra high reliability and the ability for real-time interaction. For these future applications, it is key to measure and rate the interactivity of a network and to efficiently identify bottlenecks in the transmission.

- The interactivity test combines testing round trip latency, packet delay variation, packet error rate and proofing bit rate in one single test
- It can measure very short latencies with high accuracy and is URLLC-ready
- The configuration based on realistic traffic patterns is very flexible and scalable and can easily be extended to a large range of application types
- It provides a full set of detailed results down to per-packet analysis
- The smart integrative scoring delivers a representative quality indication for a given use case such as eGaming
- The implementation based on the standardized TWAMP protocol ensures very flexible configuration of the session reflectors with existing components anywhere in the network

In light of the rise in industrial and automotive real-time applications in 5G, we should rethink the term QoE. QoE refers to experience that is based on expectation and therefore to a human rating or perception. At first glance, non-human use cases do not fall under this conventional QoE classification.

However, fundamental elements of QoE also apply to non-human use cases and also have associated expectations or limits to enable those applications to work properly. Similar to human use cases, it is not "works" versus "doesn't work" but rather a continuous score where the functionality becomes increasingly limited.

Consequently, there will also be QoE-like models for non-human use cases, producing a sort of "synthetic" MOS based on QoS and technical KPIs. These synthetic QoE scores can be used to describe how well the network channel fulfills the QoS requirements for a given application irrespective of human or non-human use cases.

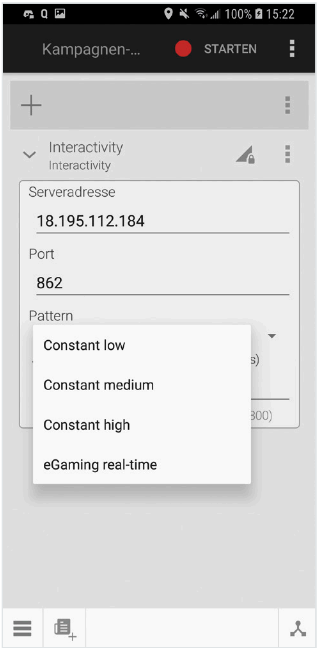
A APPENDIX

The interactivity test in the mobile network testing product line from Rohde & Schwarz

A.1 Data collection

With the given predefined traffic patterns, it is very simple to configure the test in the mobile network testing products for data collection from Rohde & Schwarz: SmartBenchmarker, SmartMonitor or QualiPoc. You simply define the host, port and traffic pattern and the test is ready to be executed.

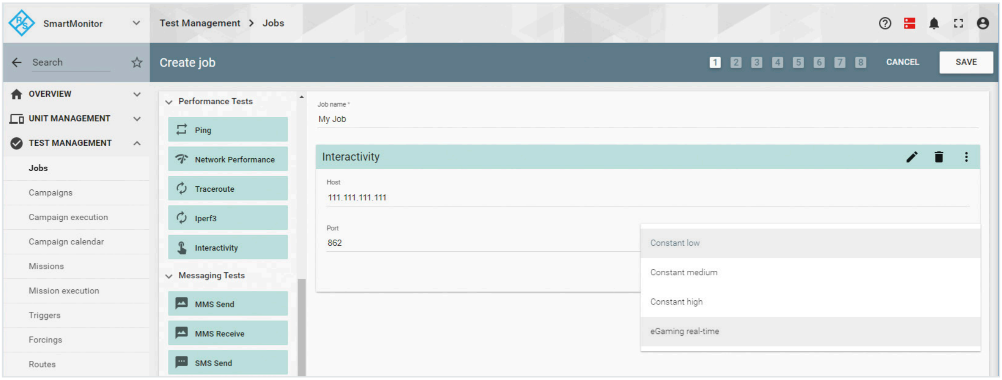
Fig. 26: Configuration of the interactivity test in QualiPoc



Serveradresse
18.195.112.184

Port
862

Fig. 27: Configuration of the interactivity test in SmartBenchmarker and SmartMonitor



Job name *
My Job

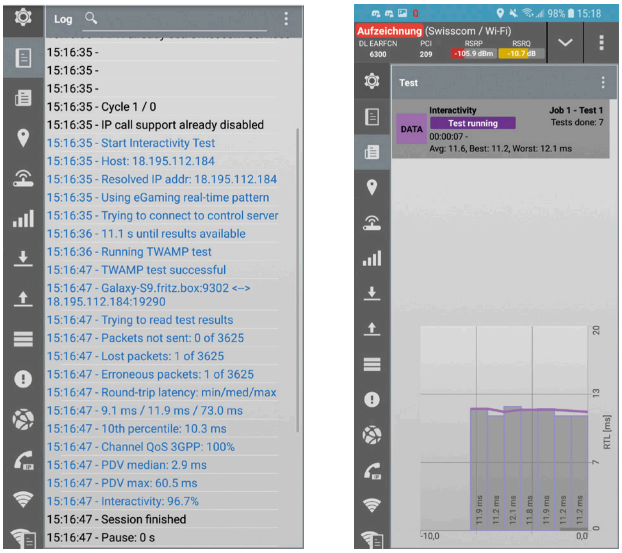
Host
111.111.111.111

Port
862

A.2 Monitoring

In QualiPoc, the test execution can be monitored on the test and log monitors.

Fig. 28: Monitoring of the interactivity test in QualiPoc



```
15:16:35 -
15:16:35 -
15:16:35 -
15:16:35 - Cycle 1 / 0
15:16:35 - IP call support already disabled
15:16:35 - Start Interactivity Test
15:16:35 - Host: 18.195.112.184
15:16:35 - Resolved IP addr: 18.195.112.184
15:16:35 - Using eGaming real-time pattern
15:16:35 - Trying to connect to control server
15:16:36 - 11.1 s until results available
15:16:36 - Running TWAMP test
15:16:47 - TWAMP test successful
15:16:47 - Galaxy-S9.fritz.box:9302 <-->
18.195.112.184:19290
15:16:47 - Trying to read test results
15:16:47 - Packets not sent: 0 of 3625
15:16:47 - Lost packets: 1 of 3625
15:16:47 - Erroneous packets: 1 of 3625
15:16:47 - Round-trip latency: min/med/max
15:16:47 - 9.1 ms / 11.9 ms / 73.0 ms
15:16:47 - 10th percentile: 10.3 ms
15:16:47 - Channel QoS 3GPP: 100%
15:16:47 - PDV median: 2.9 ms
15:16:47 - PDV max: 60.5 ms
15:16:47 - Interactivity: 96.7%
15:16:47 - Session finished
15:16:47 - Pause: 0 s
```

98% 15:18

Aufzeichnung (Swisscom / Wi-Fi)

DL EARFCN	PCI	RSRP	RSRQ
6300	209	-105.9 dBm	-10.7 dB

Interactivity — Job 1 - Test 1

Tests done: 7

00:00:07 -

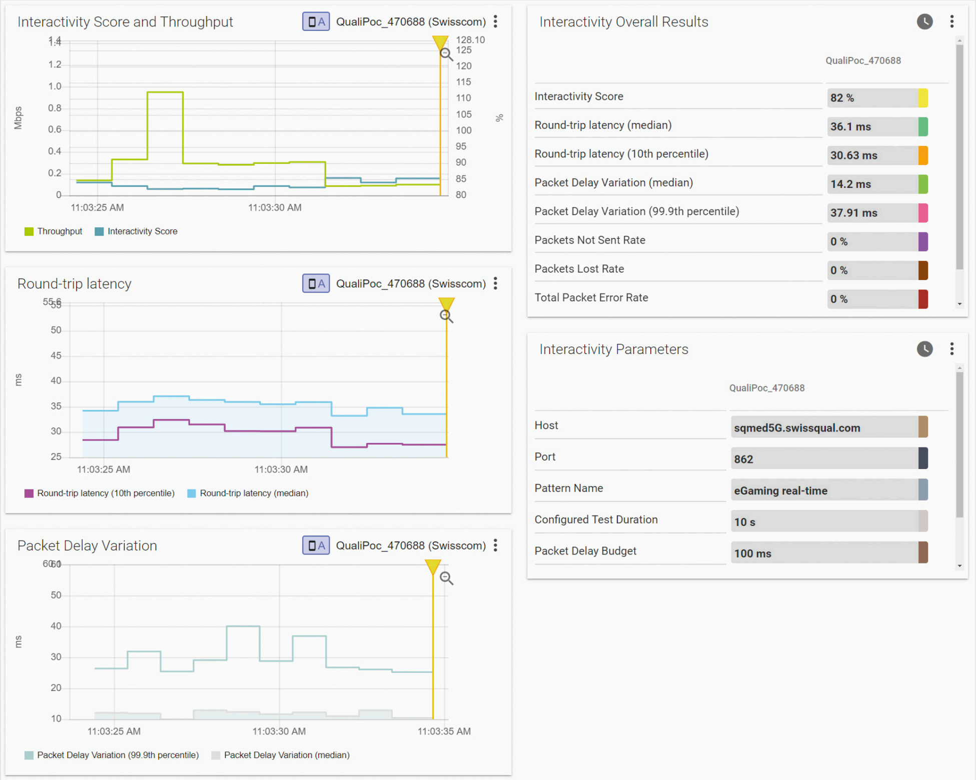
Avg: 11.6, Best: 11.2, Worst: 12.1 ms

In SmartBenchmarker and SmartMonitor, the test progress can also be followed on the test and log monitors.

A.3 SmartAnalytics scene

Scene supports the time-based presentation of the interactivity test's intermediate and overall results. The results of the individual tests can be listed in a table. After selecting a test, value lists display all test parameters and overall results, and intermediate results can be plotted in line charts.

Fig. 29: Analysis of the interactivity test results in SmartAnalytics scene



Interactivity Overall Results

	QualiPoc_470688
Interactivity Score	82 %
Round-trip latency (median)	36.1 ms
Round-trip latency (10th percentile)	30.63 ms
Packet Delay Variation (median)	14.2 ms
Packet Delay Variation (99.9th percentile)	37.91 ms
Packets Not Sent Rate	0 %
Packets Lost Rate	0 %
Total Packet Error Rate	0 %

Interactivity Parameters

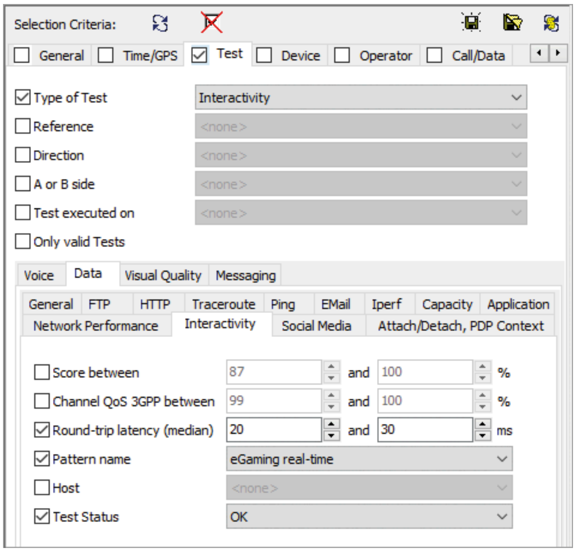
	QualiPoc_470688
Host	sqmed5G.swissqual.com
Port	862
Pattern Name	eGaming real-time
Configured Test Duration	10 s
Packet Delay Budget	100 ms

A.4 NQDI network quality data investigator

NQDI is a legacy tool for drilldown analysis. For the interactivity test, the information goes down to the per-packet level.

It provides filtering possibilities for the most important values such as round trip latency, interactivity score and pattern name.

Fig. 30: Filtering of the interactivity test results in NQDI

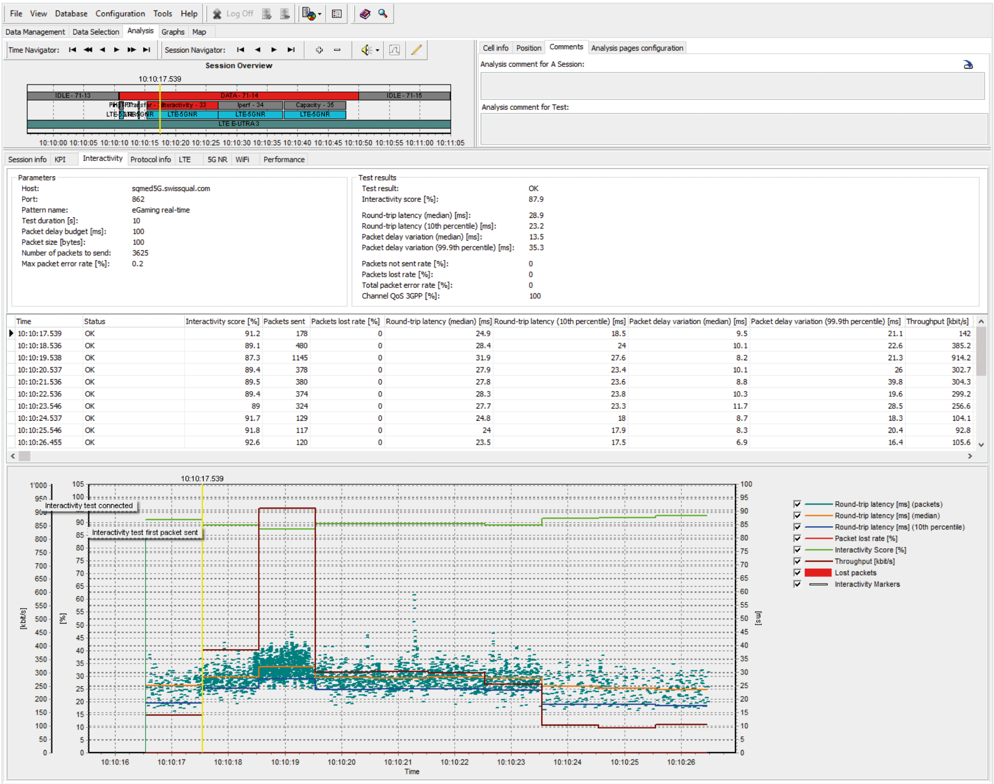


☑ Type of Test: Interactivity
☐ Reference: <none>
☐ Direction: <none>
☐ A or B side: <none>
☐ Test executed on: <none>
☐ Only valid Tests

☐ Score between 87 and 100 %
☐ Channel QoS 3GPP between 99 and 100 %
☑ Round-trip latency (median) 20 and 30 ms
☑ Pattern name: eGaming real-time
☐ Host: <none>
☑ Test Status: OK

The analysis tab shows the overall, intermediate and per-packet results.

Fig. 31: Analysis of the interactivity test results in NQDI



Parameters
Host: sqmed5G.swissqual.com
Port: 862
Pattern name: eGaming real-time
Test duration [s]: 10
Packet delay budget [ms]: 100
Packet size [bytes]: 100
Number of packets to send: 3625
Max packet error rate [%]: 0.2

Test results
Test result: OK
Interactivity score [%]: 87.9

Round-trip latency (median) [ms]: 28.9
Round-trip latency (10th percentile) [ms]: 23.2
Packet delay variation (median) [ms]: 13.5
Packet delay variation (99.9th percentile) [ms]: 35.3

Packets not sent rate [%]: 0
Packets lost rate [%]: 0
Total packet error rate [%]: 0
Channel QoS 3GPP [%]: 100

Time	Status	Interactivity score [%]	Packets sent	Packets lost rate [%]	Round-trip latency (median) [ms]	Round-trip latency (10th percentile) [ms]	Packet delay variation (median) [ms]	Packet delay variation (99.9th percentile) [ms]	Throughput [kbit/s]
10:10:17.539	OK	91.2	178	0	24.9	18.5	9.5	21.1	142
10:10:18.536	OK	89.1	480	0	28.4	24	10.1	22.6	385.2
10:10:19.538	OK	87.3	1145	0	31.9	27.6	8.2	21.3	914.2
10:10:20.537	OK	89.4	378	0	27.9	23.4	10.1	26	302.7
10:10:21.536	OK	89.5	380	0	27.8	23.6	8.8	39.8	304.3
10:10:22.536	OK	89.4	374	0	28.3	23.8	10.3	19.6	299.2
10:10:23.546	OK	89	324	0	27.7	23.3	11.7	28.5	256.6
10:10:24.537	OK	91.7	129	0	24.8	18	8.7	18.3	104.1
10:10:25.546	OK	91.8	117	0	24	17.9	8.3	20.4	92.8
10:10:26.455	OK	92.6	120	0	23.5	17.5	6.9	16.4	105.6

The results can also be found on the KPI tab, in the map plots, in the cockpit view and in the report generator.

Rohde & Schwarz
The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

www.rohde-schwarz.com

Rohde & Schwarz customer support
www.rohde-schwarz.com/support

Mobile network testing
The company's broad and diverse product portfolio for mobile network testing addresses every test scenario in the network lifecycle – from base station installation to network acceptance and network benchmarking, from optimization and troubleshooting to interference hunting and spectrum analysis, from IP application awareness to QoS and QoE of voice, data, video and app-based services.

www.rohde-schwarz.com/mnt

PD 3609.9492.52 | Version 01.00 | February 2020 (fi)
White paper | Interactivity test

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