Mobile Network Testing SMART FACTORIES 5 PHASES OF 5G NETWORK TESTING

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Make ideas real



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AGENDA

5G Smart Factory: 3GPP features and potential benefits (Rel15 and Rel16)

5G network test phases: From spectrum clearance to deployment, optimization and operation

Verify demanding QoS, in particular in terms of latency (round-trip vs. one way)



Learnings for successful Smart Factory operation

5G NR TECHNOLOGY EVOLUTION DRIVEN BY INDUSTRIAL AND AUTOMOTIVE USE CASES



eMBB: enhanced Mobile Broadband URLLC: Ultra-Reliable Low Latency Communication mMTC: massive Machine Type Communication

LATENCY ASPECTS 3GPP RELEASE 15 TECHNOLOGY COMPONENTS



K parameters specify the time gap between associated reception and transmission. Dependent on the processing speed of the UE and the type of UE, processing budget can be reduced to zero slots (K_0 , K_1 , $K_2 \ge 0$ slots)

'Grant-free' uplink transmission



Grant-free access realized by semi-persistent scheduling SPS type 2: Periodic resource availability activated by DCI SPS type 1: Continues reservation of a shared resource configured and activated by RRC signaling

RELIABILITY ASPECTS 3GPP RELEASE 15 TECHNOLOGY COMPONENTS

Modulation Target Code MCS Spectral Rate R x [1024] Index order Qm efficiency 2 30 0.0586 0 2 40 0.0781 0.0077 50 4.2129 19 28 6 772 4.5234

Robust RF link

Using low code rate and low modulation schemes to achieve block error rates of 10⁻⁵ as defied in the new MCS table for low SE QAM64 (see Table 5.1.3.1-3 of TS 38.214)



K repetitions can be sent with an optional feedback (ACK/NACK) at the end to improve reliability which is especially attractive in combination with mini-slots.

5G INTEGRATION INTO AN ETHERNET TSN ARCHITECTURE 3GPP RELEASE 16 TECHNOLOGY COMPONENTS

TSN Translator



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Time synchronization



5GS calculates and adds the measured residence time between the TTs into the Correction Field (CF) of the synchronization packets of the TSN working domain (TS 23.501 - chapter 5.27.1).

gNB may signal 5G system time reference information to the UE using unicast or broadcast RRC signaling with a granularity of 10ns

TSN traffic characteristic exchange



Knowledge of the TSN traffic pattern is useful for the gNB to allow it to more efficiently schedule periodic, deterministic traffic flows either via configured grants, semi-persistent scheduling or with dynamic grants.

R&S USER PERSPECTIVE

- Smooth and cost-efficient integration into existing deployments is key
- Industrial grade performance, reliability and security required
- Target to deploy 5G in private spectrum for high efficiency and flexibility
- Use Cases: Machine control, quality control using AR/VR, AGVs, flexible and efficient data distribution and collection...



INDUSTRIAL USE CASES CREATE ANOTHER 5G TRIANGLE



Secure Integration



Mobile Network Testing

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SMART FACTORY CRITERIA

- 5G connectivity allows flexible and adaptable production facilities
- Connected robots and AGV (Automated Guided Vehicles)
 – self driving
 → URLLC
- AR/VR support for operations
 → eMBB
- Numerous sensors, inventory control, supply chain management
 mMTC

TEST PHASE 1: ROLLOUT PREPARATION Result: Clean RF environment inside factory

Spectrum Clearance

Α





Interference Hunting

В Locate interferers Locate source of interfering signal



Webinar: Smart Factory

ROLLOUT PREPARA When? Before deployment Regularly during operation

TEST PHASE 2: SITE ACCEPTANCE TESTING Result: Correctly installed network infrastructure



В

Functional testing Measure download, upload and round-trip time performance from end user perspective.

OTA RF signal verification Visualize the transmitted signal to verify correct 5G transmission, incl. SSBs



Check EMF: (Electro-Magnetic Field strength) Sifte ACCET When? ► After deployment ► After deployment change

TEST PHASE 3: COVERAGE AND PERFORMANCE TESTING Result: Verified coverage and performance

A

Coverage and performance analysis



Test 5G connectivity incl. sufficient redundancy. Collect data using portable HW platform, then analyze with data analytics SW in control room.

B Network optimization

Optimization by modifying the network configuration, e.g. base station position, poweror beam-specific parameters.

S.

3D data collection Multi-level warehouses need to collect data in three dimensions. Data collection tool using a drone enables measurement at various levels.

Webinar: Smart Factory

When?

- After factory completed
- After factory modification
- Regularly

TEST PHASE 4: 24/7 REAL-TIME SERVICE QUALITY MONITORING Result: Continuous performance monitoring and awareness of issues





В

Real-time QoE monitoring

Ensure network performance is within defined thresholds. Deviations from the required QoE are visualized in a dashboard



Data analytics Machine learning algorithms are used to identify trends and detect anomalies.

С

Webinar: Smart Factory

When?
▶ Continuously and real-time
▶ 24 / 7 / 365

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TEST PHASE 5: REGULATORY COMPLIANCE Result: Network compliant to private network license terms

Periodic spectrum clearance Measure RF environment to ensure compliance with private network license terms, e.g. to keep transmission of leaked signals outside of the factory within specified limits

Walk test solutions or network test solutions mounted to a drone

When?

- ► After factory completed
- ► After factory modification
- ► Regularly

HOW TO MEASURE



Most network measurement solutions available already
 24/7 Service Quality Monitoring requires tailored RF modules

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Round-trip latency

One way latency

□ Redundancy

eMBB: Augmented Reality (AR / VR)

► Interactive / round-trip latency is key → Interactivity test!

URLLC:

 Often one-way latency is important (e.g. robot control, automated guided vehicles, remote controlled trolley, etc.)

Key performance Indicators for operating a Smart Factory

DIFFERENT USE CASES IN THE APPLICATION AR / VR

Application	Area	Use cases		
	Communications & Social Media	AR / VR immersive Calling		
		User generated AR / VR content		
		Stream my life in 360°		
	Gaming &	Outdoor Augmented Gaming		
	Entertainment	Immersive sport / music arenas		
	Sports & fitness	Augmented / virtual stats & maps		
		Augmented personal trainer		
AK / VK	Retail &	AR / VR retail shopping		
		Real Estate viewing		
		Product finder / in store		
	la ductria l	Assisted maintenance		
	industrial	Remote support		
	Llaghth	Remote patient care		
	Health	Assisted surgery		

- ► Underlying "Service" is UDP (or QUIC)
- Different "use cases" using the same AR / VR application
- Use cases have different performance requirements

•	5QI¶ Value¤	Resource- Type=	Default- Priority- Levels	Packet Delay Budget¶ (NOTE*3)=	Packet Error¶ Rate-s	Default- Maximum- Data-Burst- Volume¶ (NOTE'2)=	Default¶ Averaging- Window®	Example-Services*
•	80=	Non-GBR	68¤	10°ms¶	10 ⁻⁶ m	N/A#	N/A¤	Low-Latency-eMBB- applications- Augmented-Reality=
•	82#	Delay- Critical- GBR®	19=	10°ms +	10 ⁻⁴ ¤	255 bytesя	2000- <u>ms</u> #	Discrete-Automation- (see TS'22.261'[2])®
•	83¤	в	22¤	10°ms -	10 ⁻⁴ ¤	1354-bytes¶ (NOTE'3)¤	2000-ma ^a	Discrete Automation (see TS'22.26112));¶ V2X messages (UE RSU-Platooning, Advanced-Driving Cooperative Lane Change with low (JoA, See TS'22.186[111])#

according to 3GPP TS23.501

Individual QoE models for individual use cases required

QUIC: Quick UDP Internet Connections 5QI: 5G QoS Identifier

THE NEW INTERACTIVITY TEST – eMBB IS ROUND-TRIP

- 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)



Control parameters (on technical level) are:



Results:

INTERACTIVITY SCORE – THE QOE MODEL

- ► For emulating 'real' applications we will apply a generic QoE model
- ► The QoE model produces a 'synthetic' MOS (Mean Opinion Score) based on QoS and techn. KPIs

Interactivity Score









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

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INTERACTIVITY TEST – a scalable concept for round-trip latency measurements

scalable

This sort of generic QoE model is fully scalable



 The parametrization of the Interactivity Test and Score is individual for each application class
 e.g. AR / VR Remote Support in Smart Factory

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DEMO: INTERACTIVITY TEST ROUND-TRIP LATENCY MEASUREMENT



Measure and analyze round-trip latency on QualiPoc Android using TWAMP reflector (any TWAMP capable Internet node)

Interactivity Test is commercially available in our QualiPoc Android solution offering

PROTOTYPE SOLUTION ONE WAY LATENCY MEASUREMENT

((1111))

IP packet

[time stamp]

Measure and analyze one-way latency using GPS based time measurements on a dedicated server

Time synchronization via GPS-locked PPS

IP packet

[time stamp]

Network under test

(4G, 5G, WiFi, ..)

PROTOTYPE SOLUTION: <u>ONE</u> WAY LATENCY MEASUREMENT EXAMPLE RESULTS FOR OUR SPECIFIC SCENARIO (MUNICH)

- Direction server to client (includes LTE DL) or client to server (includes LTE UL) is important. E.g. 18ms (UL) and 6ms (DL) for a medium data rate connection (1Mbps) in our example measurement
- WLAN latency shows more symmetrical behavior
- Generally increased latency with increased data rates
- More investigations are planned, in particular in real 5G based industrial deployments



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3GPP Rel. 16 driven by Industrial and Automotive Use Cases Smart Factories require eMBB and URLLC use cases

5 phases of 5G (LTE) network testing in Smart Factories require a complete portfolio of network testing solutions

Service Quality Monitoring (24/7) in combination with Machine Learning recommended to pro-actively ensure high reliability

Interactivity Test combines testing round-trip latency, packet delay variation and packet error rate in a single test and a single score

Prototype test solution for one way latency measurements based on QualiPoc Android: one way latency ≠ round-trip latency / 2

Rohde & Schwarz is the one-stop shop for network testing solutions required in Smart Factories

DETAILS DO MATTER

www.rohde-schwarz.com/mnt/smart-factory

