5G NR Overview

2020年5月19日（火）
Rohde Schwarz Japan
江森　浩司

ROHDE&SCHWARZ
Make ideas real

From a two-man laboratory to a global group of companies with various fields of business

86 years
of success

12.100
employees

300
new products

Test and Measurement

Networks and Cybersecurity

Aerospace & Defense

Broadcast and Media

Security

Make ideas real

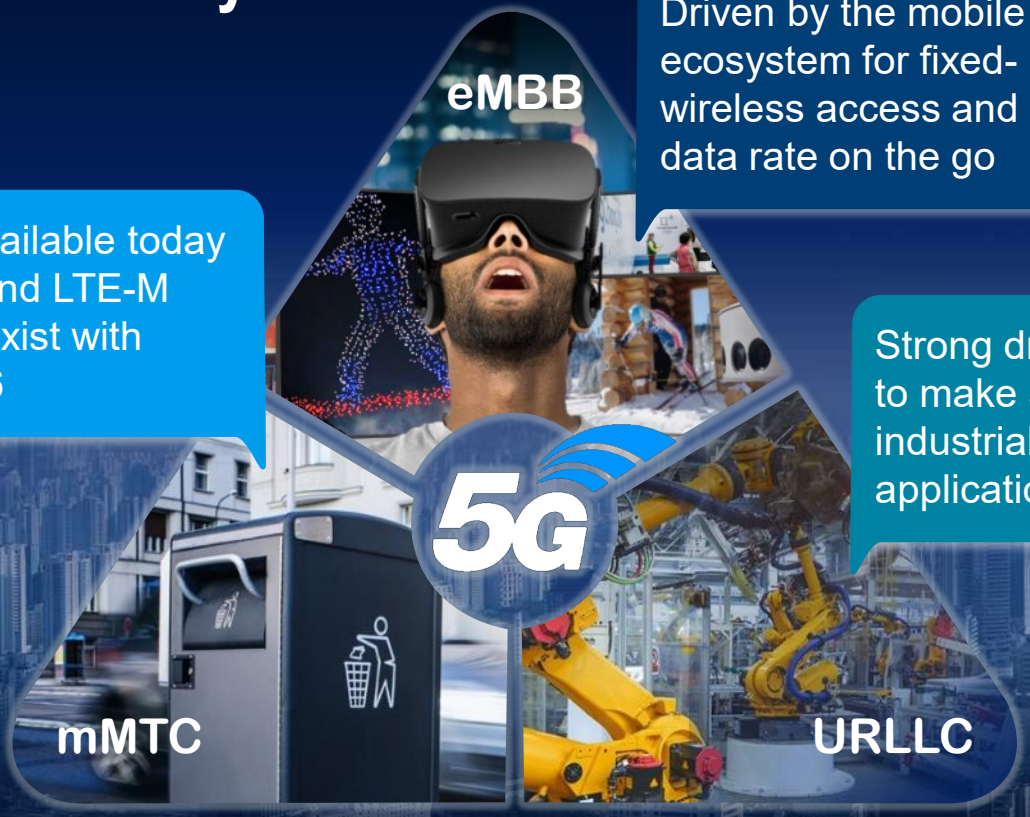
A story about mobile evolution over four decades

5G becomes reality

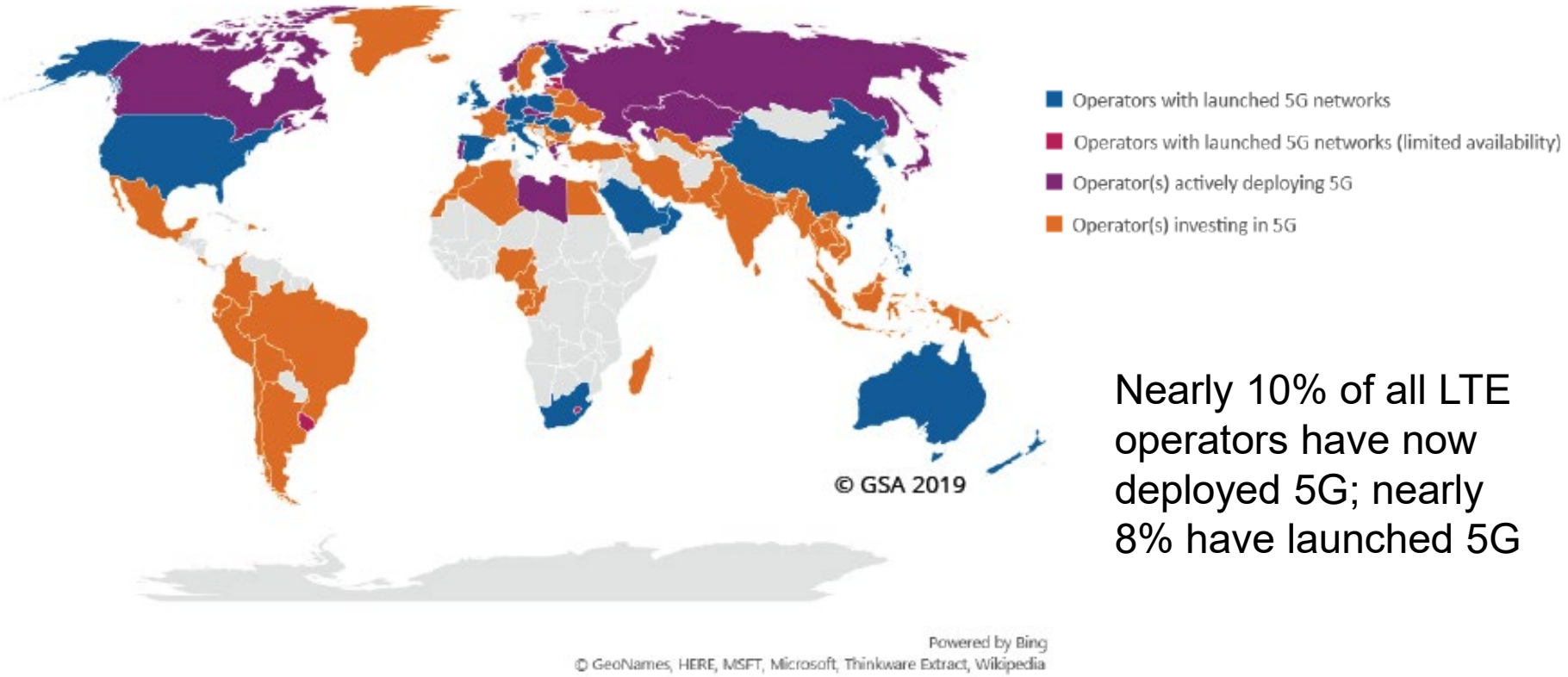
Driven by the mobile ecosystem for fixed-wireless access and high data rate on the go

Essentially available today with NB-IoT and LTE-M which will coexist with 5G NR Rel.16

Strong drive by verticals to make 5G ready for industrial and automotive applications

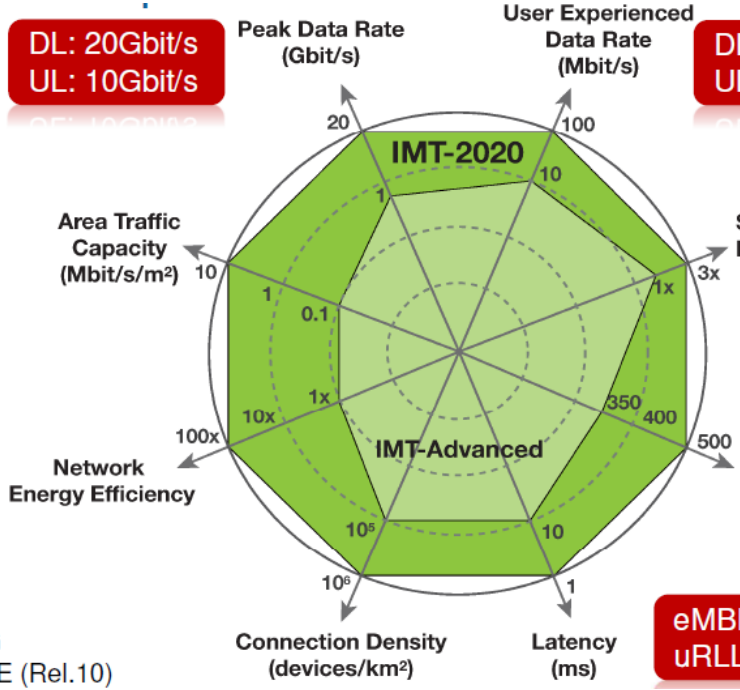


STATUS OF 5G BY COUNTRY, END OF 2019



Nearly 10% of all LTE operators have now deployed 5G; nearly 8% have launched 5G

IMT2020 REQUIREMENTS



DL: 20Gbit/s
UL: 10Gbit/s

DL: 100Mbit/s
UL: 50Mbit/s

DL: 30bit/s/Hz (8x8)
UL: 15bit/s/Hz (4x4)

with 0ms interruption
eMBB, uRLLC

eMBB: 4ms
uRLLC: 1ms

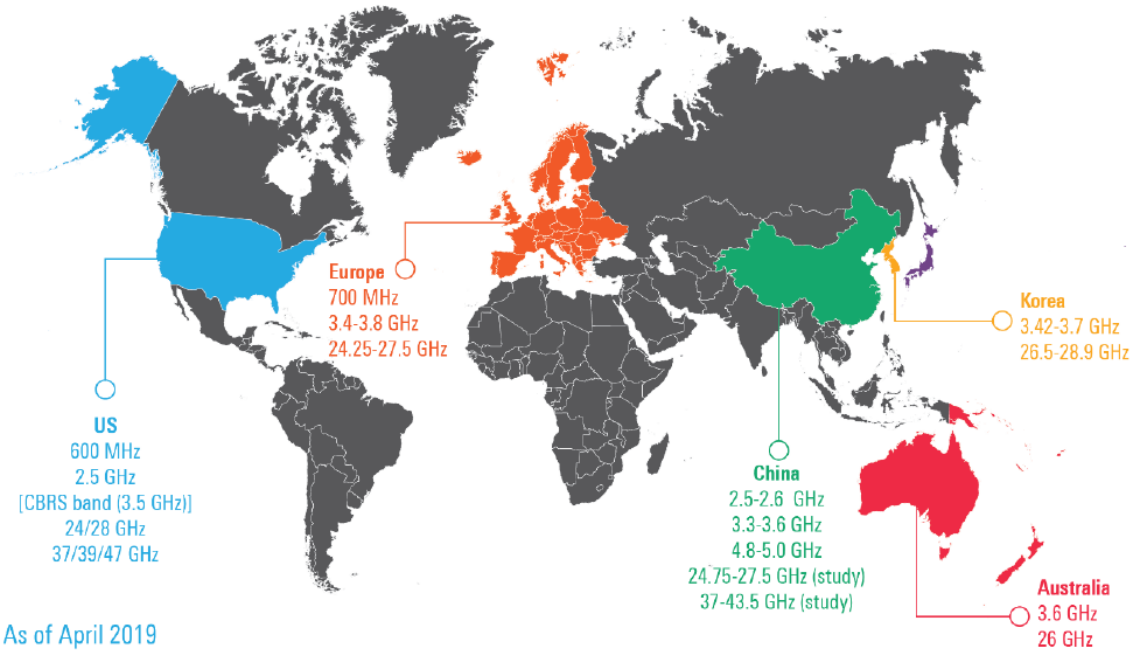
Control Plane: 20ms
10ms “encouraged”

IMT-2020 → 5G
IMT-Advanced → LTE (Rel.10)

FREQUENCY ALLOCATION

NR frequency range 2 Reserved numbers 257-512		
	Downlink	Uplink
n257	26.5 – 29.5 GHz	26.5 – 29.5 GHz
n258	24.25 – 27.5 GHz	24.25 – 27.5 GHz
n259	n/a	n/a
n260	37 – 40 GHz	37 – 40 GHz

NR frequency range 1 reserved numbers 65-256		
	Downlink	Uplink
…	…	…
n77	3.3 – 4.2 GHz	3.3 – 4.2 GHz
n78	3.3 – 3.8 GHz	3.3 – 3.8 GHz
n79	4.4 – 5.0 GHz	4.4 – 5.0 GHz
…	…	…



FREQUENCY ALLOCATION

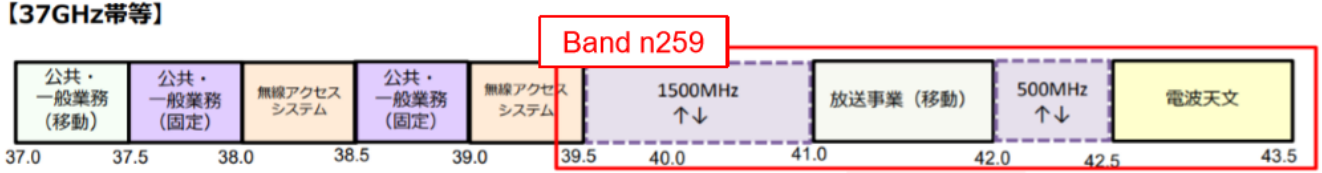
2．1　40GHz帯の技術的条件(案)について

✓ 40GHz帯(39.5-41GHz及び42-43.5GHz)について、以下の方針で、5G NRの技術的条件を策定する。

– 下記3GPPバンド規定を反映

周波数帯	NR Band	備考
39.5-43.5GHz	n259	技術的条件として策定するのは39.5-41GHz及び42-43.5GHzとする

【37GHz帯等】



– FPUとの共用に課題がある**41-42GHz**については**技術的条件として策定しない。**

– 2019年5月の3GPP RAN4会合において、39.5-43.5GHzをBand n259として定義することについて3GPP内で合意。現在技術的条件を**議論中**（2019年11月に完了予定）

– 本日の技術的条件(案)は、既に標準化が完了しているBand n260(37-40GHz)の規定を基に作成（3GPP内の議論に応じて**変更の可能性あり**）

– 技術的条件の答申を受けてから、技術基準として省令に定めるまでの間に、3GPPにおける規定値が一部変更される可能性があり、その場合は省令改正等のタイミングで国内への技術基準に反映することが望ましいことから、昨年度答申の「第5世代移動通信システム（５G)の技術的条件」と同様に、技術的条件のなかに**「本技術的条件の一部の規定については暫定値であり、3GPPの議論が確定した後、適正な値を検討することが望ましい。」**と記載することとする

5G NR Radio communication tester

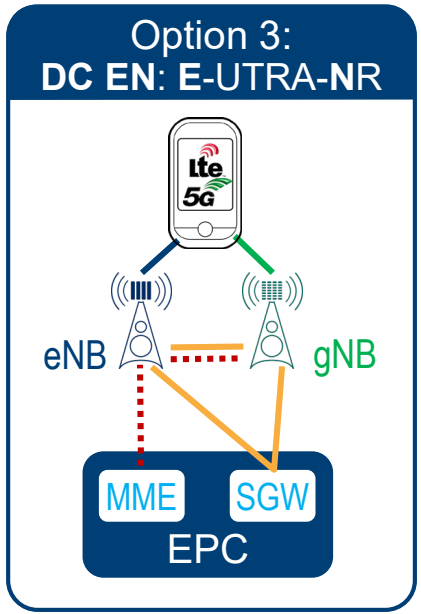
CMX500 5G NR Signaling Tester

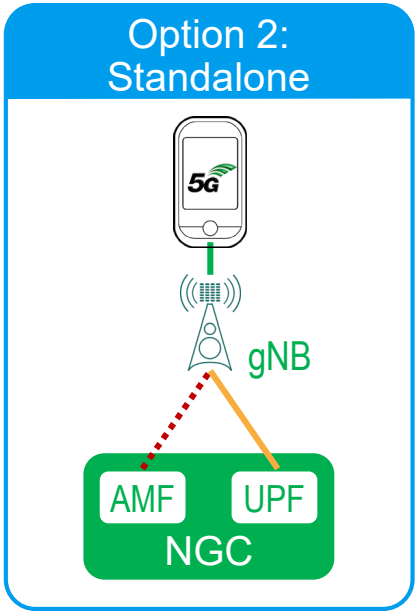
- Future proof 5G NR signaling test platform
- Independent Operating System (Linux)
- Modular and scalable HW-Architecture
- 20 Gbps+ End-to-End IP Data Performance capability
- FR2 Multiband Remote Radio Support (24 – 43.5GHz)
- Single Web-based GUI for RF, Protocol and App Tests
- LTE Anchor support for up to 8CC LTE, 8x4 DL MIMO and 1024QAM (with CMW500)

ARCHITECTURE OPTIONS

OPTION 3 IS PRIORITY 1 IN 3GPP, FOLLOWED BY OPTION 2

eNB is the Master Node

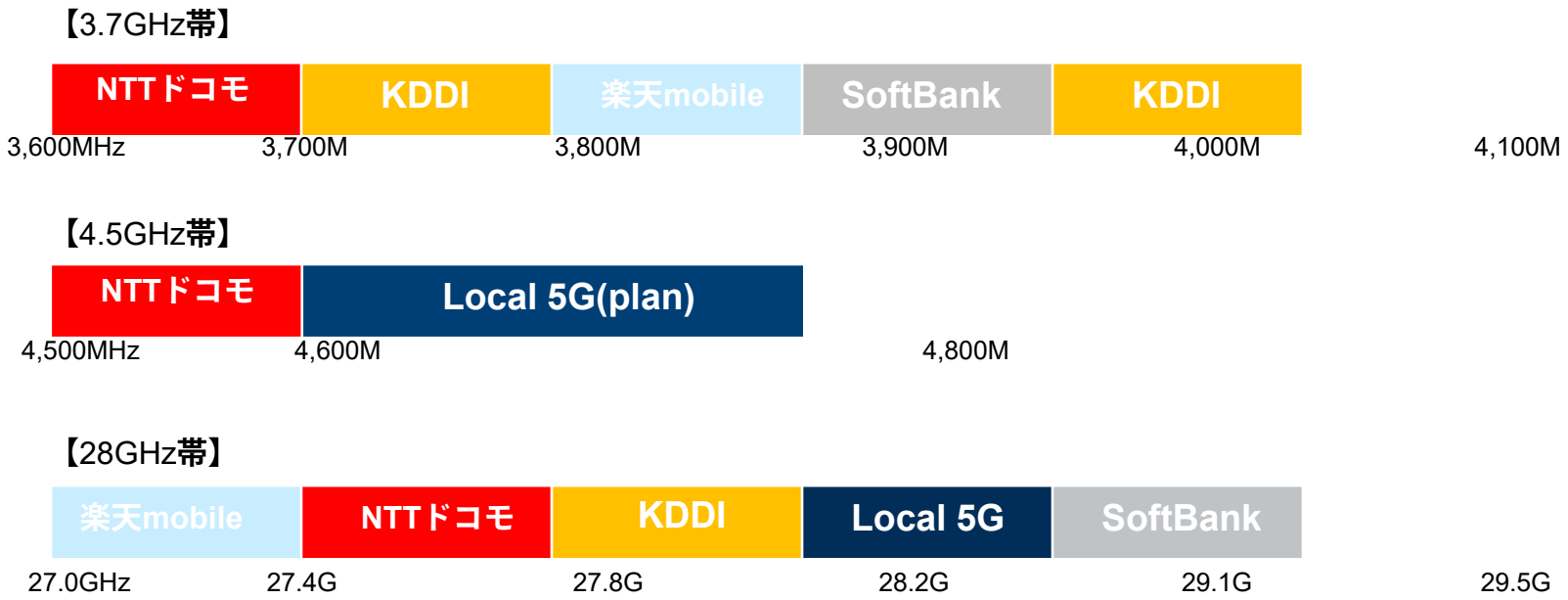




Data

Control

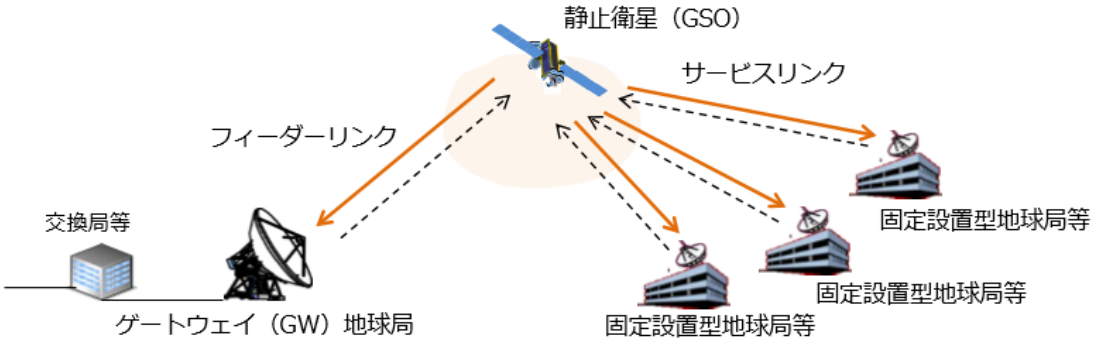
FREQUENCY ALLOCATION JAPAN



FREQUENCY ALLOCATION JAPAN

他の無線システムの概要

■ Cバンド固定衛星業務（↓：宇宙から地球）



図：Cバンド固定衛星業務（ダウンリンク）の利用イメージ

周波数帯	利用/計画状況（概要）
3.4-4.2GHz	● 国内通信（サービスリンクとして離島向け通信や各種情報配信、移動衛星通信サービスのためのフィーダーリンク）、国際通信（直接通信、中継サービス）、衛星管制・監視等に利用。 ● 国内免許の地球局は56局（※常設ではなく将来にわたり不定期に短期間開設される可能性がある地球局5局、計画中の地球局12局を含む）。その他、国内外の免許による固定衛星や、海外衛星放送配信を受信する受信専用設備も存在（※本資料では、地球局と受信専用設備を合わせて、地球局等と表現）

WHO USES 5G IN FUTURE AND HOW?

- New **classes** of users in 5G
  - **Humans** (smartphone use case)

more interactive eMBB applications

  - **Automotive** (connected, autonomous driving, Vehicle-to-X)
  - **Industry 4.0** (Smart Manufacturing, private 5G networks)
  - **IoT, mMTC** (Smart City, Connected Energy,...)

Really low latencies require standalone 5G

- **Each user class generates individual traffic patterns and has individual network requirements!**
- **A network optimized for human users may not deliver best performance for cars or industry**

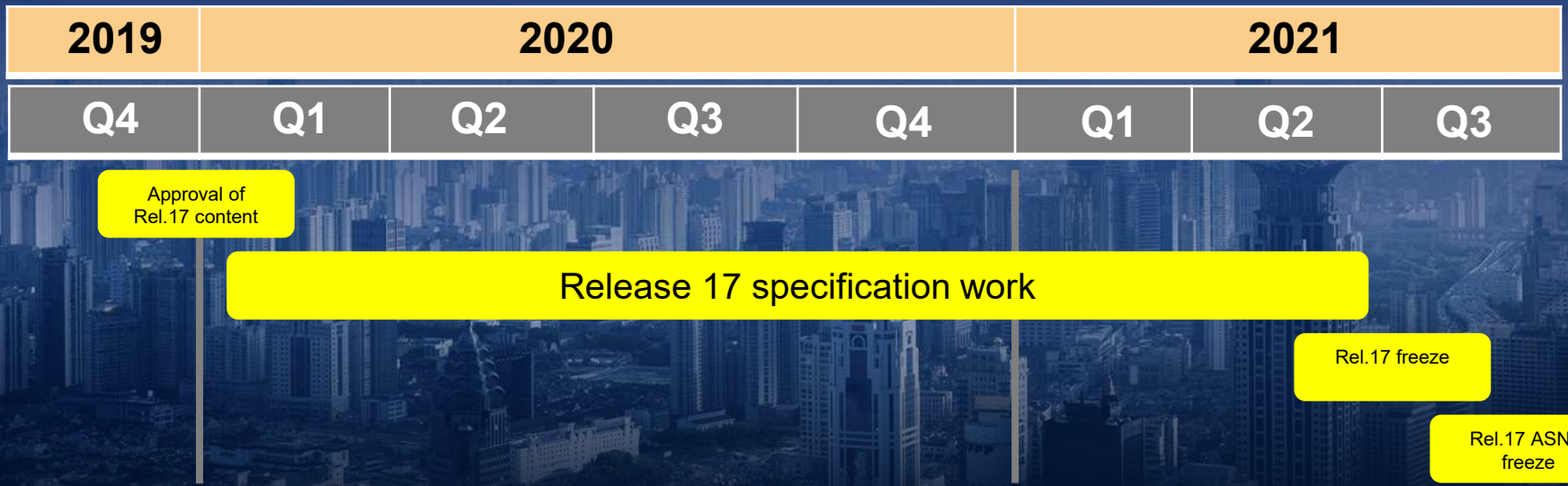
The magic triangle of communication is smart factories

- Security is a must!
- Reliability is essential, but on different levels
- Strongest latency requirements apply for specific applications (e.g. AGV)

5G roadmap and ecosystem expansion

5G NR Release 17 Key Milestone

- RAN#84 (June/2019): One full day was set aside for initial presentations on Rel-17 proposals
  - Consolidation of multi-company proposals into Work Areas, start email discussion on these
- RAN#85 (September/2019): Review of email discussion progress on Work Areas, adjust where necessary
- RAN#86 (December/2019): Approval of Release 17 content



5G NR Release 17 Content Approval

- NR Light
  - Optimal operation for mid-teir NR devices (e.g. wearable, MTC) incl. power saving aspects.
- Small data transfer optimization
  - Small data and inactive data transmission (Uplink and Downlink both)
- Sidelink enhancements
  - Includes V2X, Commercial, Critical Communications
  - Includes FR2 aspects
  - Achieve maximum commonality between commercial, V2X and Critical Communication usage of sidelink
- NR above 52.6GHz (incl. 60GHz unlicensed)
  - Preparing for waveform decision for >52.6G
- Multi SIM operation
  - Identify the RAN impact of target use cases for multi SIM operation, identify specification impacts
- NR multicast broadcast
  - Main drivers : V2X and Public Safety

5G NR Release 17 Content Approval

- Coverage enhancement
  - Clarify requirements for relevant scenarios focusing of extreme coverage
  - Data rate target FFS.
  - Includes both indoor as well as wide area
- NB-IoT and eMTC enhancement
  - Enhancements motivated by current commercial deployment
- IIoT and URLLC enhancement
  - Header compression aspects and other Rel.16 leftovers
- MIMO enhancements
  - Enhancements motivated by current commercial deployment
  - E.g.: Support for cases with high speed mobility, better support for FDD
- NR for Non Terrestrial Networks
- Integrated Access and Backhaul Enhancements
  - E.g.: mobile IAB (Interactive Advertising Bureau)

5G NR Release 17 Content Approval

- Generic enhancements to NR-U
  - Generic unlicensed operation enhancements not covered by any other items
- Power saving enhancement
  - Enhancements for power saving of smartphones
  - Network power saving aspects
- RAN data correction enhancement
  - Includes SON and MDT enhancement
  - Data correction to enable AI
- Positioning enhancements
  - Factory/campus positioning , IoT, V2X positioning , 3D positioning , cm level accuracy, incl. latency and reliability improvements

BEYOND 5G

Rohde and Schwarz is already working on the next Gen Communication Technologies

R&S Co-operates with leading Research Institutes and engages in certification bodies

R&S partners with early adopters from the Industry

How will 5G evolve towards 6G

2020 2025 2030

Verticals drive 5G evolution

5GAA Automotive Association

5GACIA 5G Alliance for Connected Industries and Automation

1st 5G eMBB deployments

6G research starts now

Super massive MIMO

subTeraHertz waves

AI/ML optimized networks

Security: Quantum Key Distribution (QKD)

…. and more to come

Lte

5G

6G

Munich/Berlin/Freiburg / 06-Nov-2019

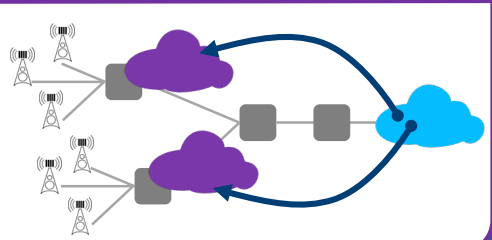
Rohde & Schwarz together with Fraunhofer Institutes HHI and IAF join forces in researching 6G at THz frequencies

While the new 5G technology is at the first stages of rollout, Rohde & Schwarz, the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI and the Fraunhofer Institute for Applied Solid State Physics IAF are taking a step further with demonstrations in the terahertz (THz) frequency band, related to the 6th generation wireless mobile communication (6G). The collaboration has resulted in a wireless transmit and receive system operating between 270 and 320 GHz, with further frequency extensions for potential 6G bands already in preparation.

https://www.rohde-schwarz.com/uk/about/news-press/all-news/rohde-schwarz-together-with-fraunhofer-institutes-hhi-and-iaf-join-forces-in-researching-6g-at-thz-frequencies-press-release-detailpage_229356-714688.html

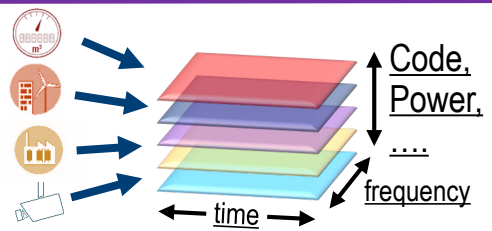
5G NR technology cornerstones to meet latency requirements of URLLC applications (Rel 16)

Mobile edge computing



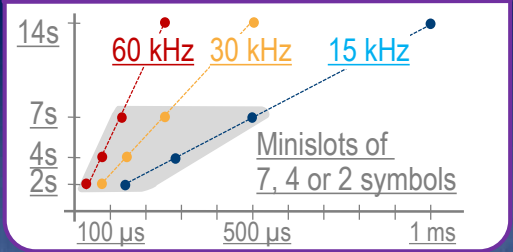
- bring cloud to edge of network
- controlled private environment in NPN (non-public networks)

Grant free access



NOMA: power/code domain multiplexing

Minislots – short symbols



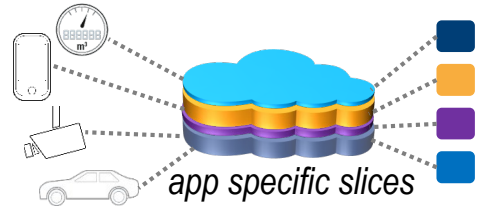
- new 5G NR numerology and TTI for lower latency
- basic URLLC in Rel 15 with TTI structures for low latency (AR/VR entertainment)
- flexible slot structure for different SCS: mini-slot 35µs

NOMA: non-orthogonal multiple access

SCS: 5G NR subcarrier spacing

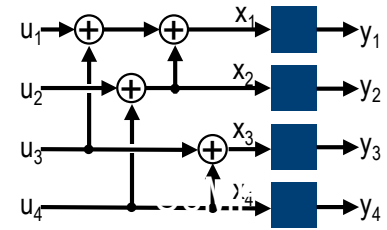
5G NR technology cornerstones to meet reliability requirements of URLLC applications (Rel 16)

Network Virtualization



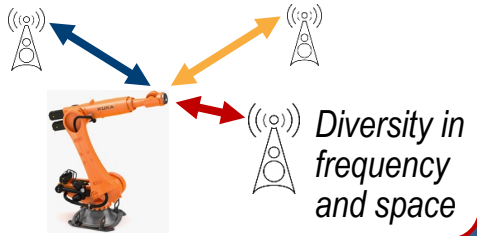
- ensure QoS
- network slicing tailored to applications

Robust coding



- Robust coding in Rel 15
- Rel 16: Data duplication and multi-connectivity enhancements

Multipoint connectivity

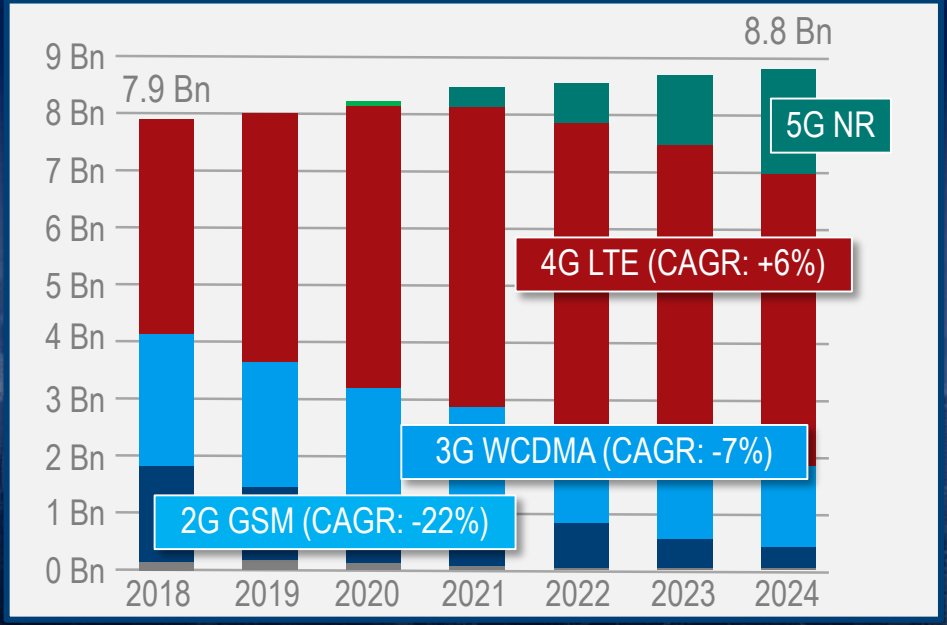


- CoMP: spatial diversity for reliability, capacity (interference reduction)
- frequency diversity: reliability against rouge devices trying to access

CoMP: coordinated multipoint transmission and reception

The state of the mobile network

Mobile subscription forecast (excl. IoT subs)



Source: Ericsson Mobility Report, June 2019

# of 4G LTE subscriptions continues to grow to reach 4.9 Bn by e2024

By the end of 2024 1.9 Bn 5G subscriptions are projected

High diversity of 5G applications in smart factories, ….

mMTC

- Sensors
- Door looks
- Screwdrivers
- ……

eMBB

- VR/AR human-machine i/f
- Handhelds
- Surveillance CAMs

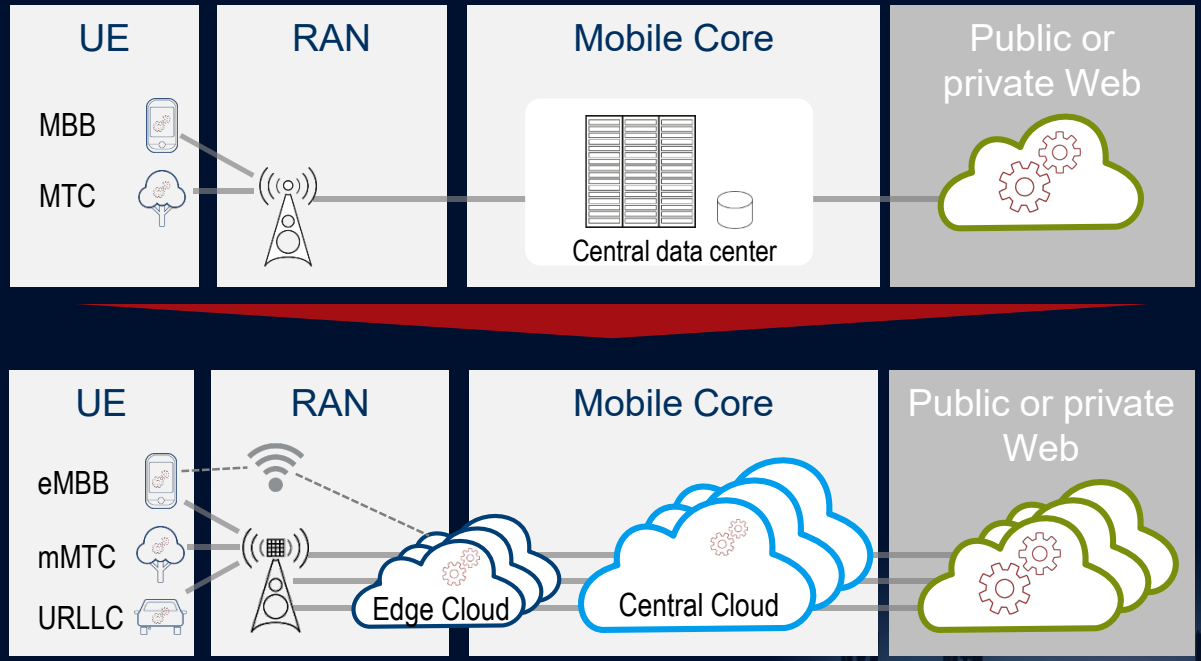
uRLLC

- Robots
- Automated guided vehicles (AVG)

…. which require safe, reliable and secure operation 24/7/365

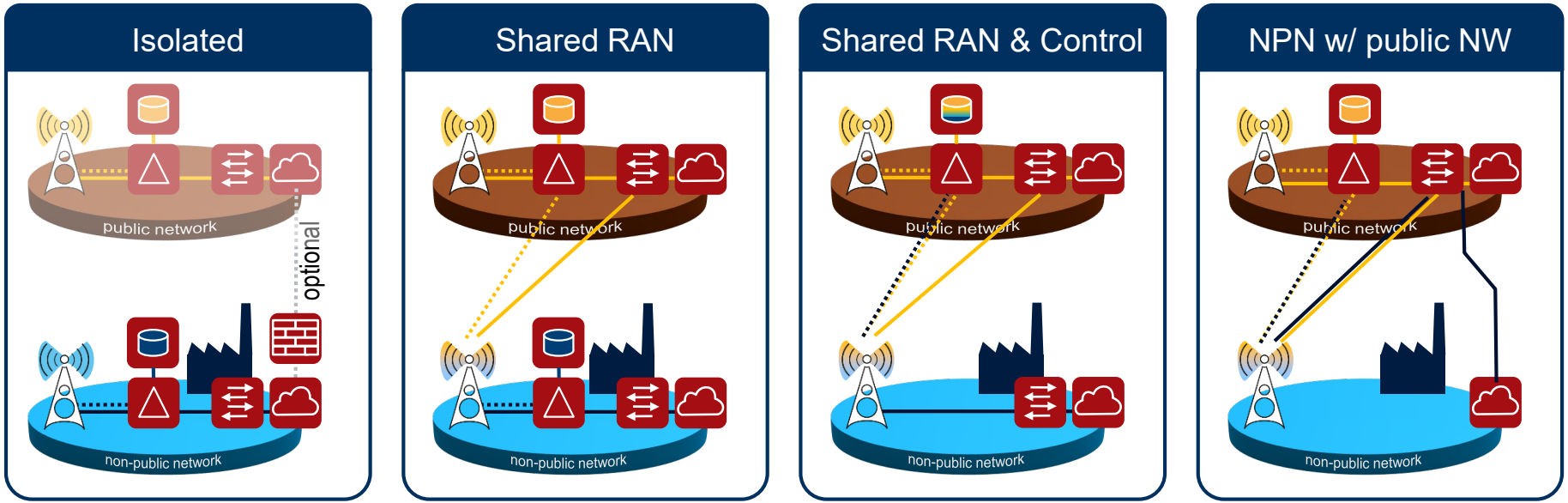
5G is just another mobile communication standard, but some aspects make security a hot topic in 5G

- New network architecture incl. virtualization, cloud and edge computing makes 5G more complex and vulnerable
- New services and deployment models (e.g. non-public) make 5G network more attractive for attackers
- Significantly more network endpoints creating more ‘opportunities’ for cyber criminals



INDUSTRY 4.0 SPECIFIC DEPLOYMENT SCENARIOS

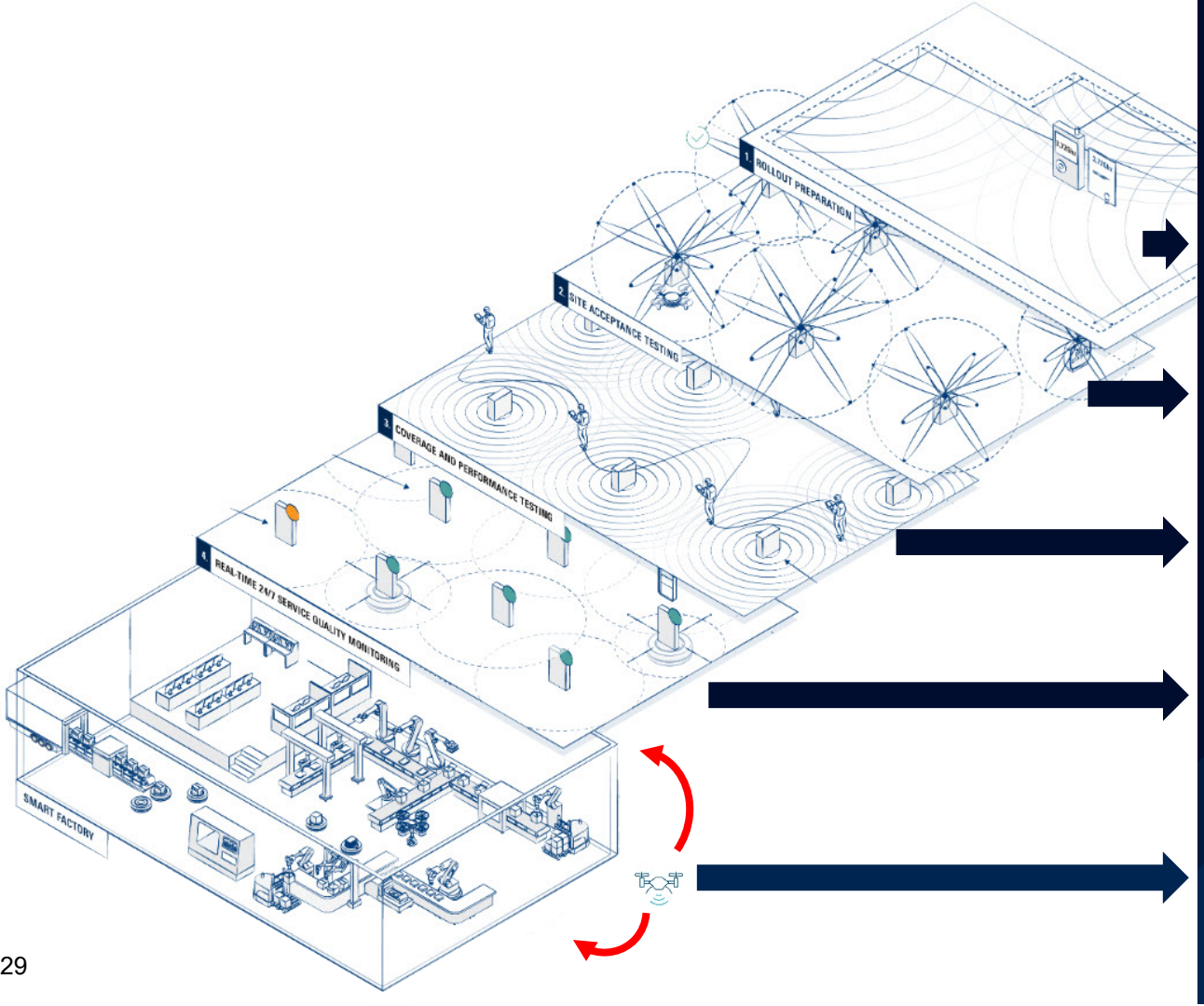
5G-ACIA WP: 5G NON-PUBLIC NETWORKS (NPN) FOR INDUSTRIAL SCENARIOS



- WP provides a description of the four industrial deployment scenarios for 3GPP-defined 5G non-public networks (NPN)
- NPN provides 5G network services to a clearly defined user organization or group of organizations
- NPN deployed on the organization's defined premises, such as a campus or a factory

R&S FACTORIES WILL DEPLOY 5G PRIVATE NETWORKS

- Big manufacturers will deploy own, private 5G networks (sometimes in dedicated spectrum)
- 5G deployed in private spectrum opens the door for high efficiency and more flexibility
- Strong need for Network Performance Testing and Security solutions



DIFFERENT PHASES OF TEST

1) Rollout preparation / spectrum clearance
2) gNb installation / site acceptance testing (redundant coverage, CoMP)
3) Coverage and performance testing (once / regularly / continuously)
4) Service Quality Monitoring / Service Level Agreement verification
5) Regulatory obligations: spurious emissions from campus ne

TEST PHASES

1) Rollout preparation / spectrum clearance
2) gNb installation / site acceptance testing (redundant coverage, CoMP)
3) Coverage and performance testing (once / regularly / continuously) incl. interference hunting
4) Service Quality Monitoring / SLA verification
5) Regulatory obligations: spurious emissions from campus network

RELIABLE CAMPUS NETWORKS REQUIRE:

- Before deployment: Is the spectrum free?
- Low noise floor?
- If not: Interference hunting inside / outside the factory!

- Functional test + Site Testing incl. demodulation
- Sufficient coverage / number of gNb signals everywhere for CoMP?

- Sufficient coverage (RSRP) and signal quality (SINR)?
- QoE: Application / throughput / interactivity tests
- Trouble shooting in case of non-optimal performance

- Measure the campus network quality and performance
  - Manual tests regularly
  - Automatic tests continuously (fixed RF/QoE probes)
- Analytics + Machine Learning: identify risks pro-actively

- Check signal leakage outside campus area
- Walk test or “fly” test (drones) around campus

TEST SOLUTION OPTIONS

1) Rollout preparation / spectrum clearance
2) gNb installation / site acceptance testing (redundant coverage, CoMP)
3) Coverage and performance testing (once / regularly / continuously) incl. interference hunting
4) Service Quality Monitoring / SLA verification
5) Regulatory obligations: spurious emissions from campus network

Scanner: TSMA6

Spectrum Analyzer

QualiPoc Android

Spec. Analyzer FPH

5G Site Testing Solution

?

RF probes

QualiPoc Probe

RF probes

SmartMonitor/Analytics ML

?

TSMA6

R&S TEST SOLUTIONS TO DEPLOY MOBILE NETWORKS

Field Services, Interference Hunting



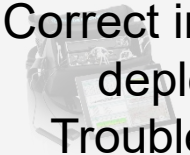
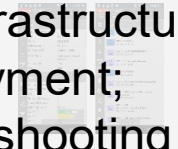
R&S®TSMA6 R&S®FPH 31GHz R&S®FSH

Clean spectrum


R&S®MNT100/PR100 R&S®MobileLocator

Site Acceptance

Correct infrastructure deployment;
Trouble shooting

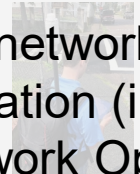



R&S®TSMA6 QualiPoc Android

5G NR network measurement solution

Passive measurements

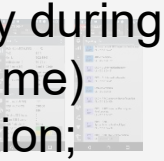

R&S®TSME6 R&S®TSMA6

Shoulder bag Backpack for mmwave

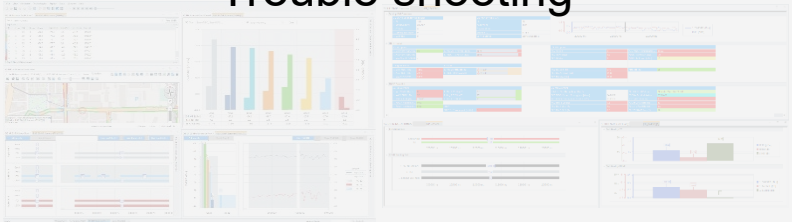
Active measurements

Smartphones Mobile Test Platform



QualiPoc Android

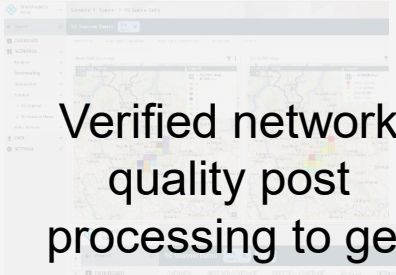
Verified network quality during operation (in real-time)
Network Optimization;
Trouble shooting



R&S®ROMES4: 5G NR Software for network engineering, analysis and optimization

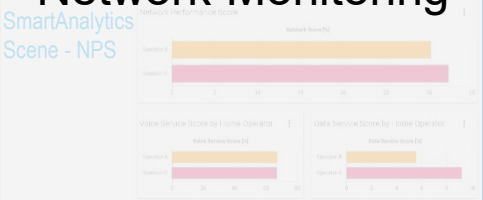
Data Analytics

SmartAnalytics Scene



Verified network quality post processing to get deep insights;
Quality Benchmarking;
Network Monitoring

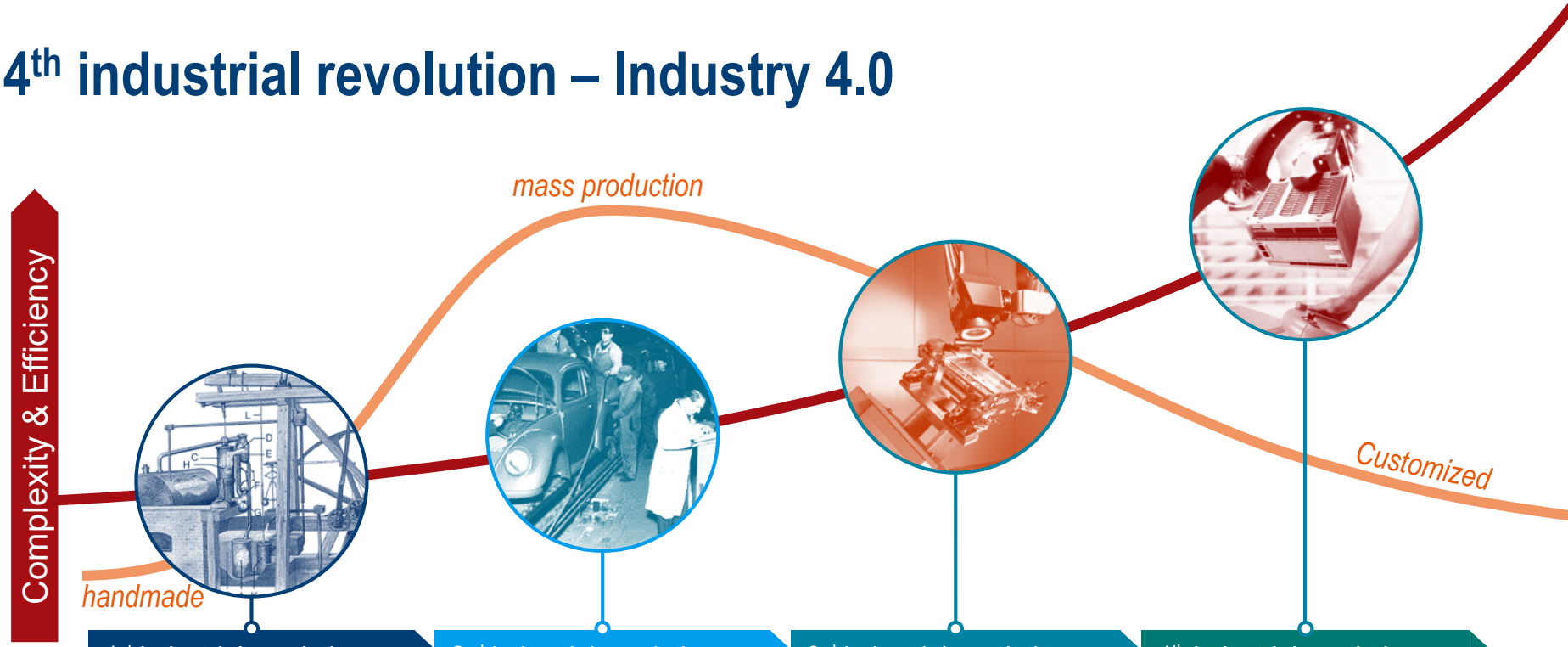
SmartAnalytics Scene - NPS



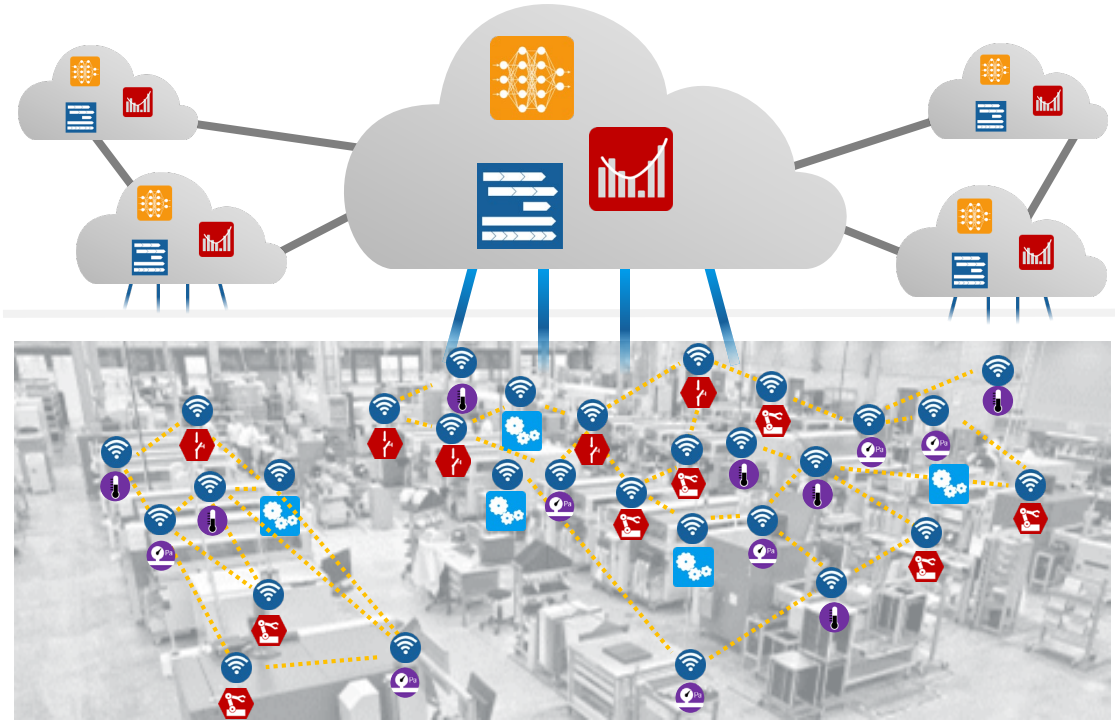
ROHDE & SCHWARZ T&M PERSPECTIVE

- Comprehensive coverage for 5G NR lab and field testing solutions
- Focus remains on efficient OTA test solutions for chipset, device and BS verification
- Development towards cloud testing, smart analytics and mobile network testing services

4th industrial revolution – Industry 4.0



Industrial Internet of Things – Smart Factories

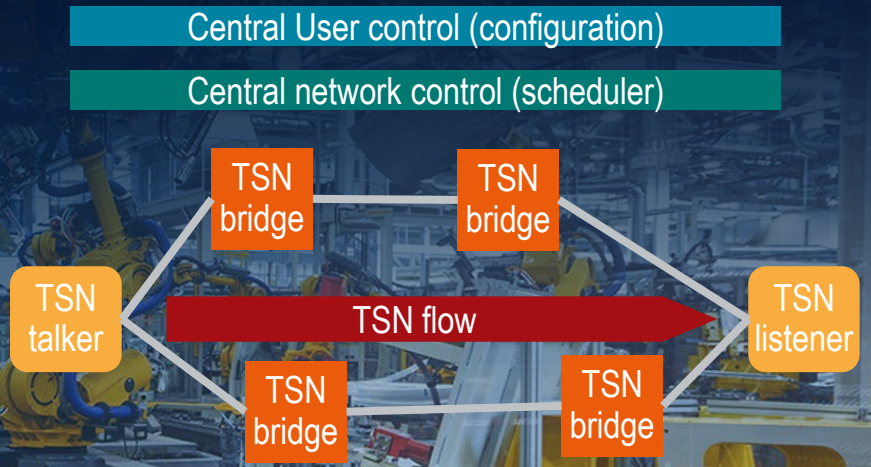


- Deep Learning
- Data Analytics
- Process control
- Real-time processing
- Connectivity
- Actuators
- Real-Time Sensing

Time-Sensitive Networks: Deterministic communication with a common sense of time implemented on Layer 2

IEEE standardization for TSN

Time Synchronization IEEE 802.1AS	**Ultra Reliability** IEEE 802.1CB /Qci /Qca
Bounded Low Latency IEEE 802.1Qav /Qbv /Qbu /Qch /Qcr	**Resource Management** IEEE 802.1Qcc /Qcp / Qcw / CBcv



IIOT CONNECTIVITY LANDSCAPE TODAY

≈ 50%

Industrial Ethernet

PROFINET
Modbus TCP
sercos the automation bus
ETHERNET POWERLINK
EtherCAT
EtherNet/IP

≈ 40%

Fieldbus

PROFIBUS
Modbus
Fieldbus Foundation
DeviceNet

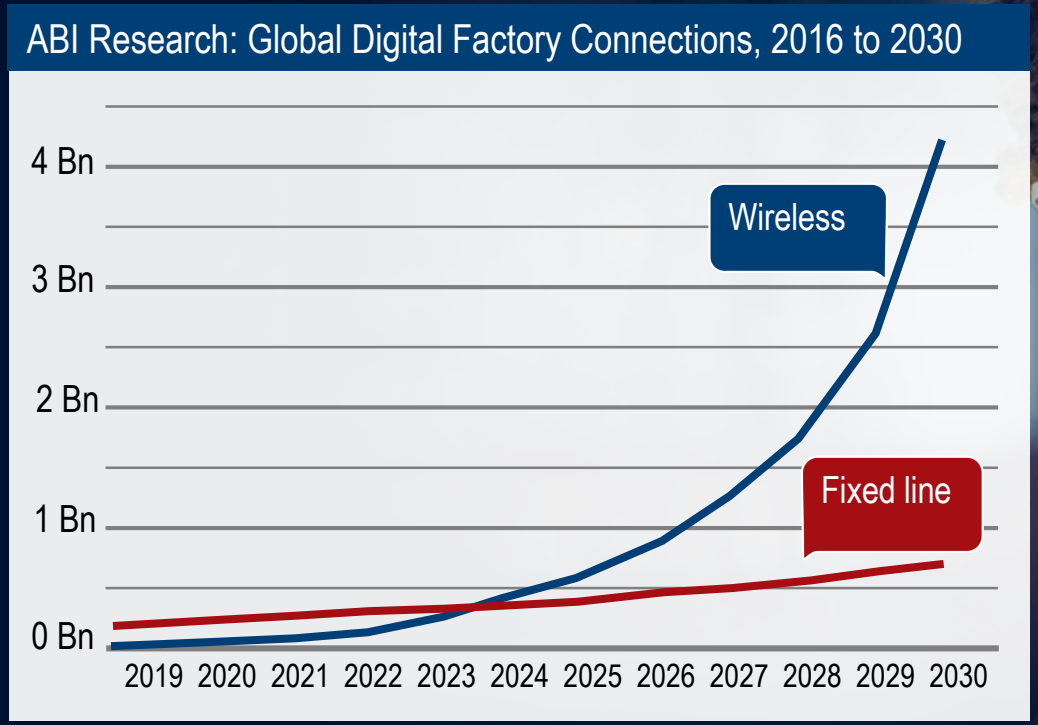
< 10%

Wireless

Wi Fi
Bluetooth
RFID
ISA100 WIRELESS COMPLIANCE INSTITUTE
WirelessHART
Lte

Dominated by industrial Ethernet connection supporting also TSN for industry automation

SMART FACTORIES GOING WIRELESS!



ABI Research forecasts that the smart manufacturing market will grow to US$1 trillion with **4.3 billion** wireless connections by 2030.
Majority (3.8 Bn) will be for asset tracking using LPWAN (NB-IoT/LTE-M)

Wireless technologies IN SMART factories

We see a high diversity of attractive 5G factory applications

mMTC

- Sensors
- Door locks
- Screwdrivers
- ……

eMBB

- VR/AR human-machine i/f
- Handhelds
- Surveillance CAMs

uRLLC

- Robots
- Automated guided vehicles (AGV)

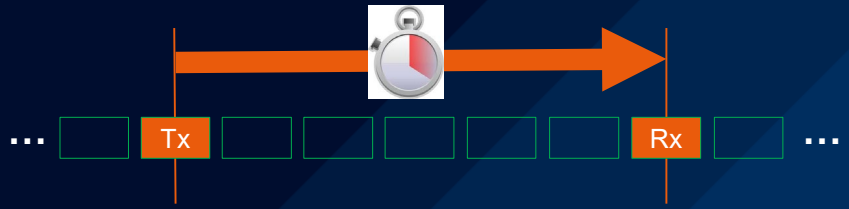
…. which require safe, reliable and secure operation 24/7/365

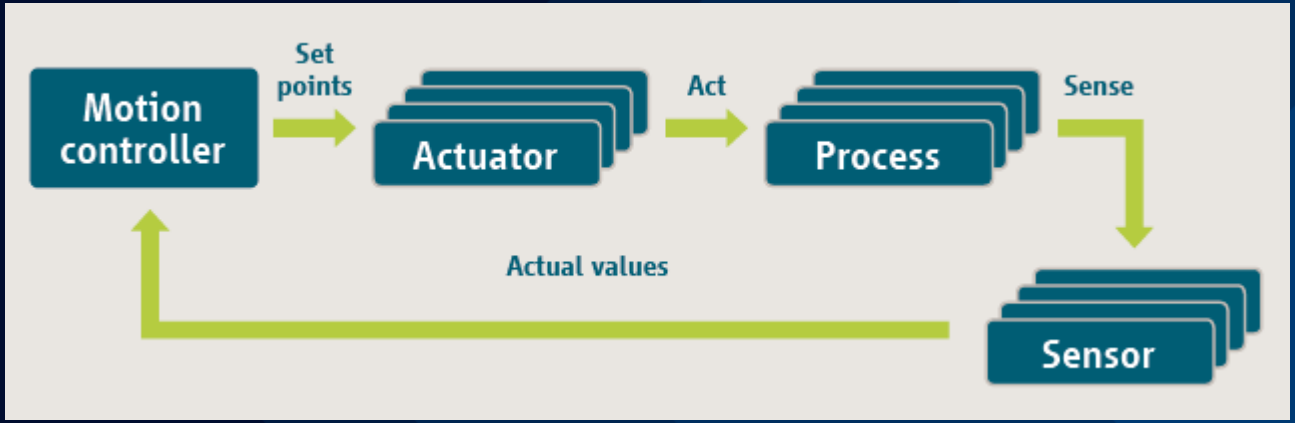
The magic triangle of communication in smart factories

- Security is a must!
- Reliability is essential, but on different levels
- Strongest latency requirements apply for specific applications (e.g. AGV)

LATENCY
MOTION CONTROL IS THE MOST DEMANDING USE CASE

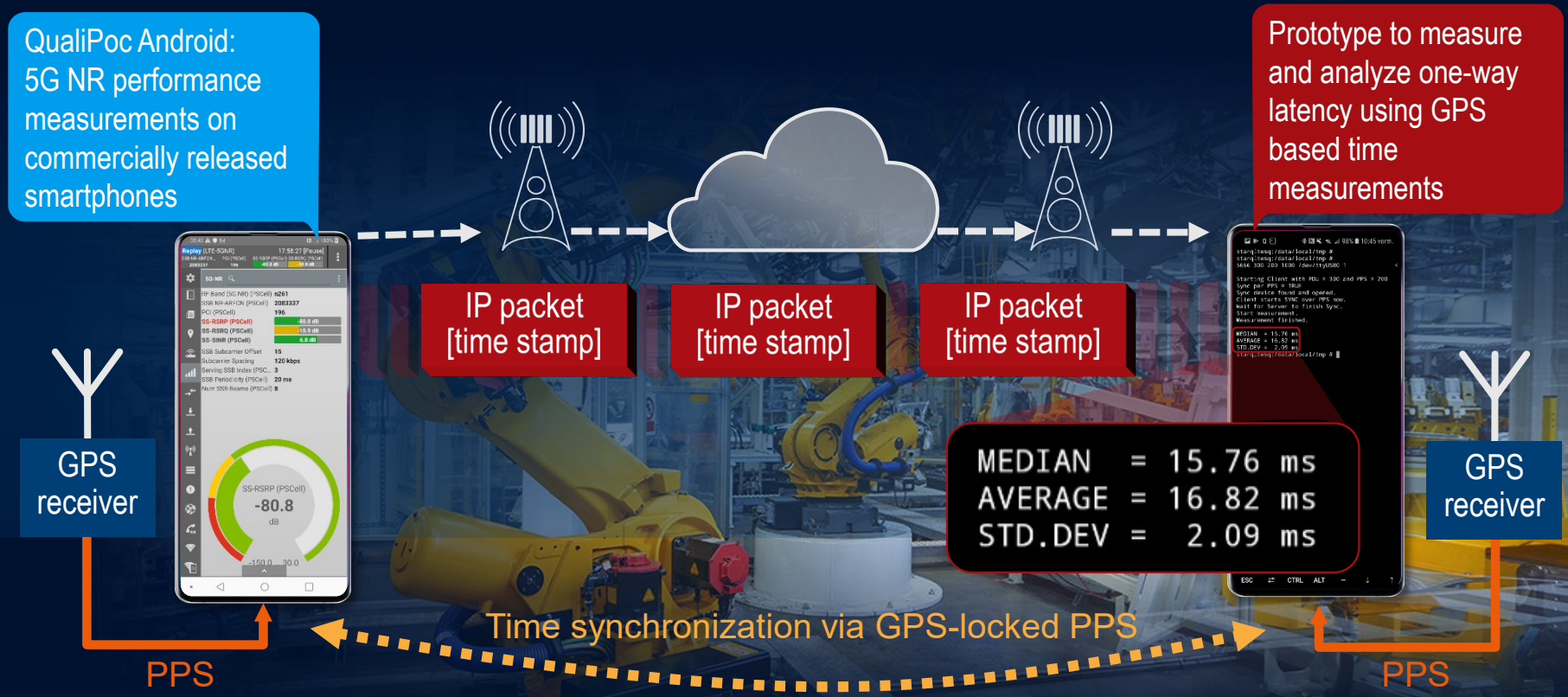
► Schematic of a motion control system



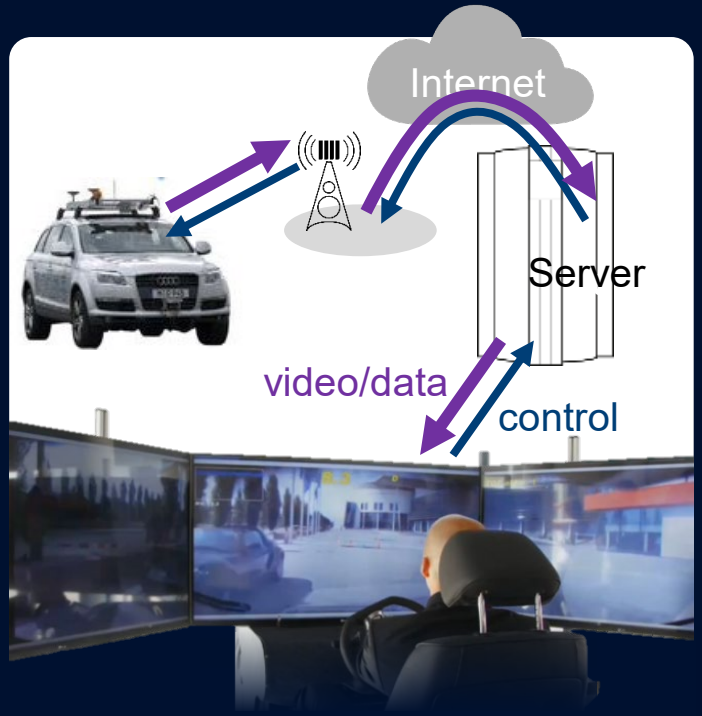


Source: 5G-ACIA White Paper „5G for Au

Need for accurate one-way latency measurement



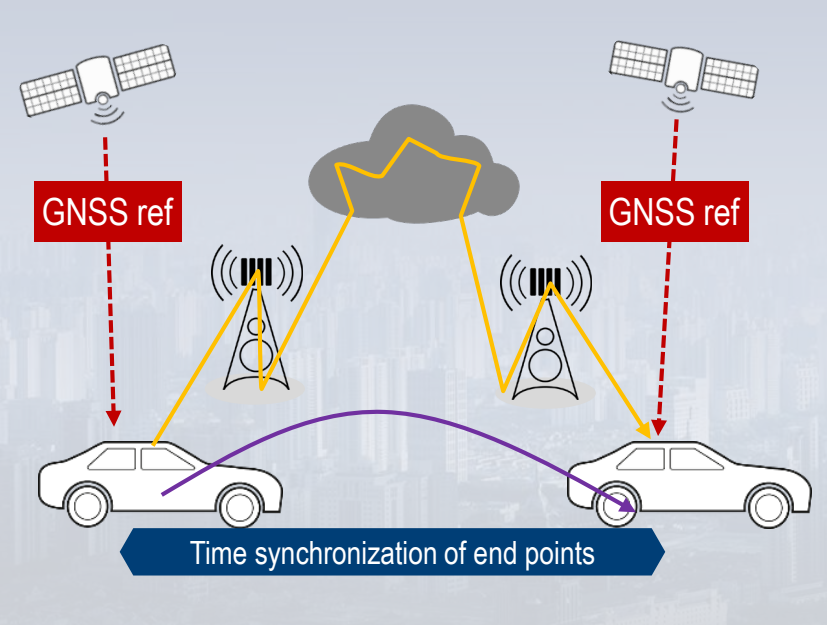
Demand for testing the complete communication stack: TUM FTM research project: Tele-operated driving



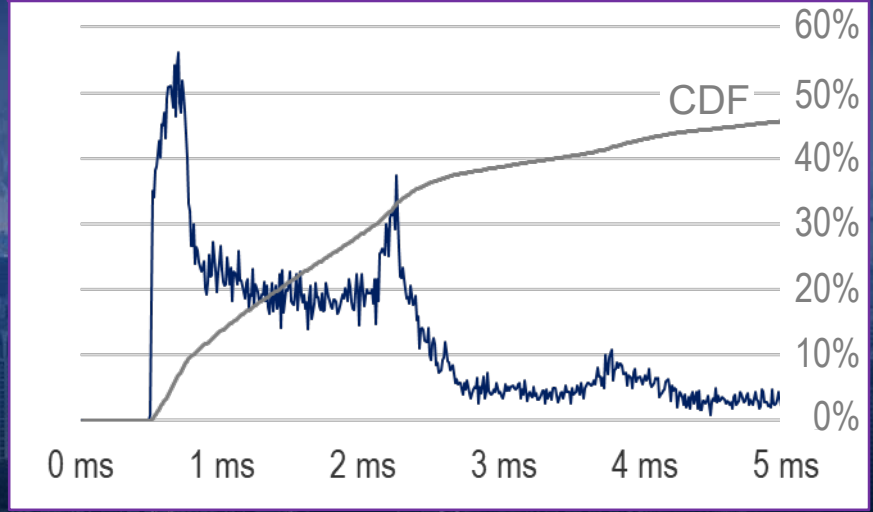
Lehrstuhl für Fahrzeugtechnik
Fakultät für Maschinenwesen
Technische Universität München

http://www.ftm.mw.tum.de/forschungsfelder/fahrerassistenz-und-sicherheit/teleoperiertes-fahren/

Verification of low-latency communication in dynamic environments requires one-way latency measurement (us precision)

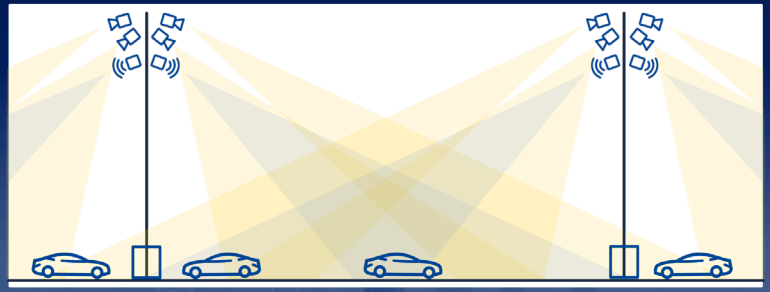


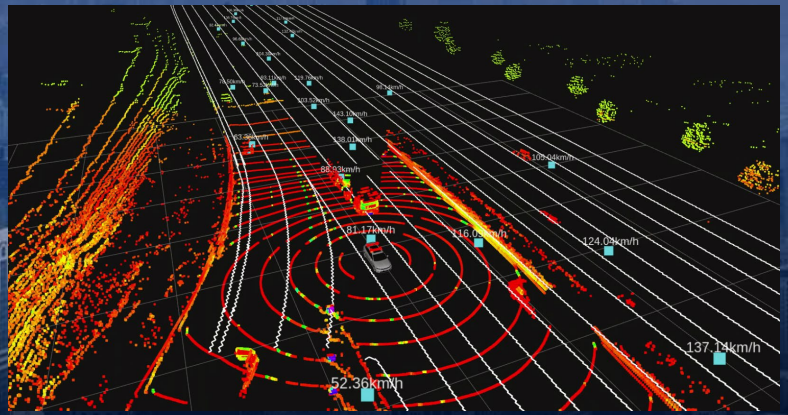
Designed for less than 1 ms latency, but implementation shows some issues



Providentia
Digitalization of roads and highways

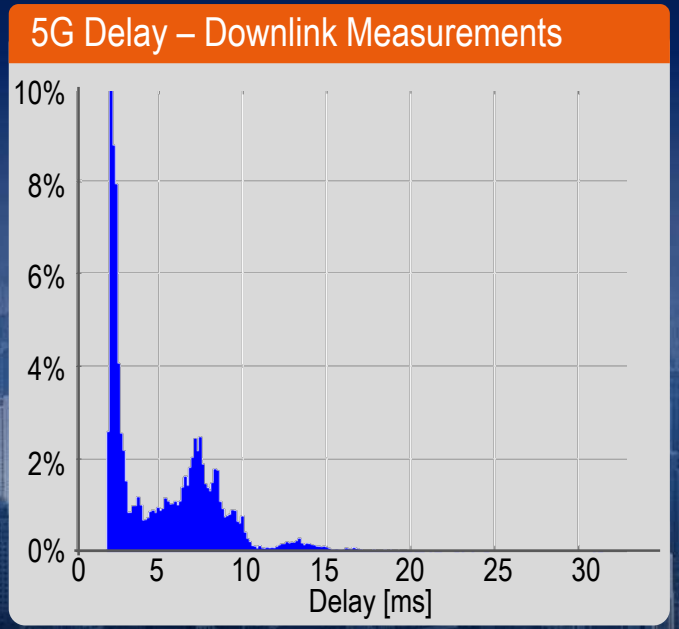
- Providentia sets focus on future digital highways
- Investigates specific senor infrastructure to extend view of automotive onboard sensors
- 5G mobile communications network to transmit object data provided by a digital twin
- R&S supports partners to
  - Establish 5G infrastructure
  - Investigate deployed 2G, 3G and 4G networks for new automotive use cases
  - Verify whole system performance

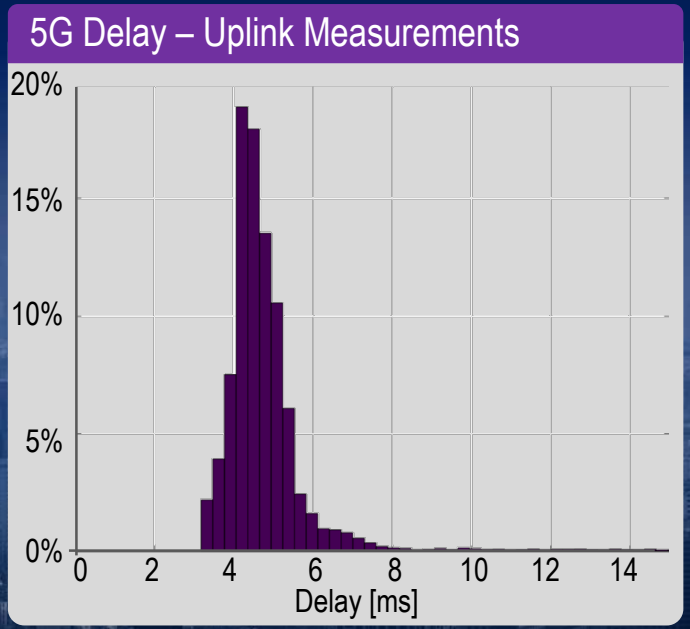




Providentia: Setup of infrastructure

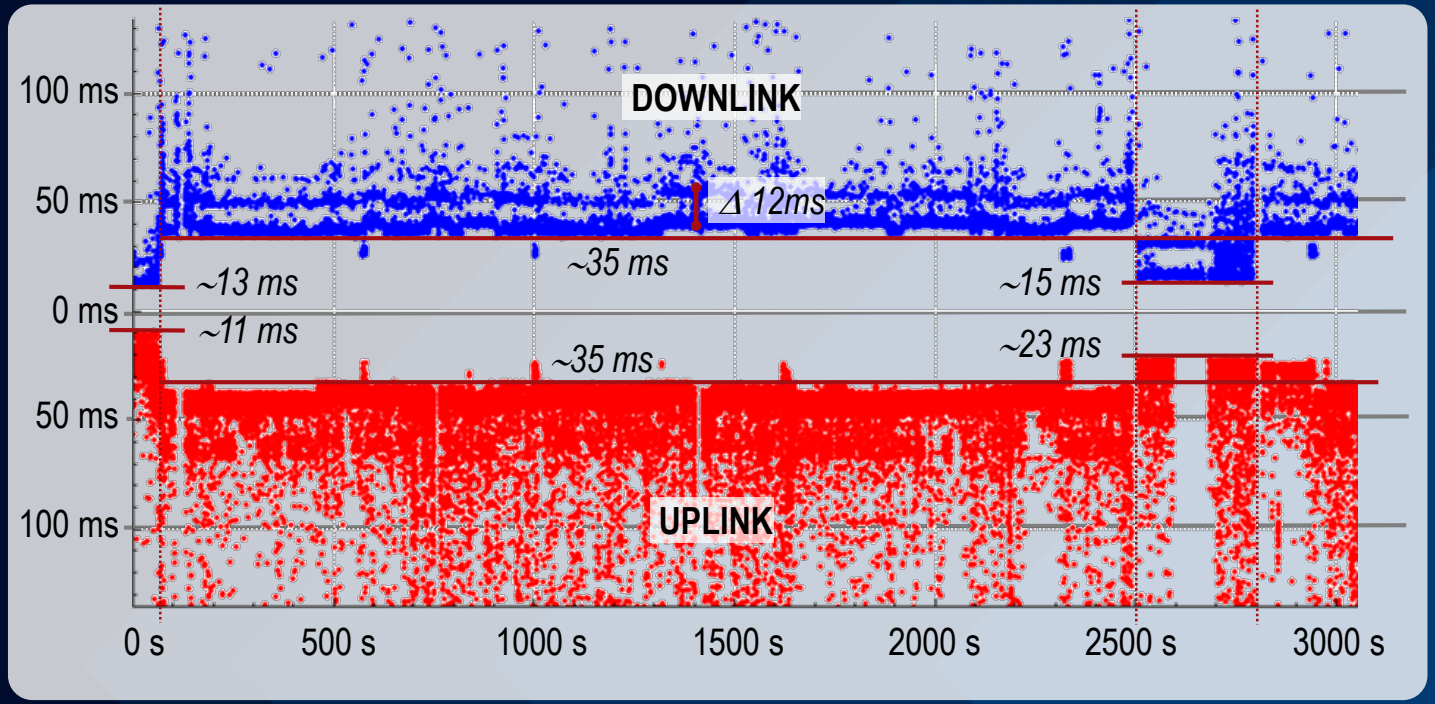
Providentia: 5G NR V2X latency measurements (July 2019) distance up to 1km from BTS





Delay measurement in V2X scenario (LTE, UMTS, GSM) from English garden via providentia test track to R&S HQ

Test Track



5G in R&S factories

Development of private campus networks with high IT security in the plants

Worker guidance & robotics as pilot use cases in Teisnach and Memmingen

Use of private test licenses 3.7-3.8 GHz possible since Sep 2019

5G

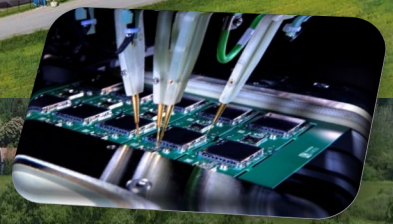
Elaboration & Evaluation of Pilot use cases

Planning & Decision on Infrastructure

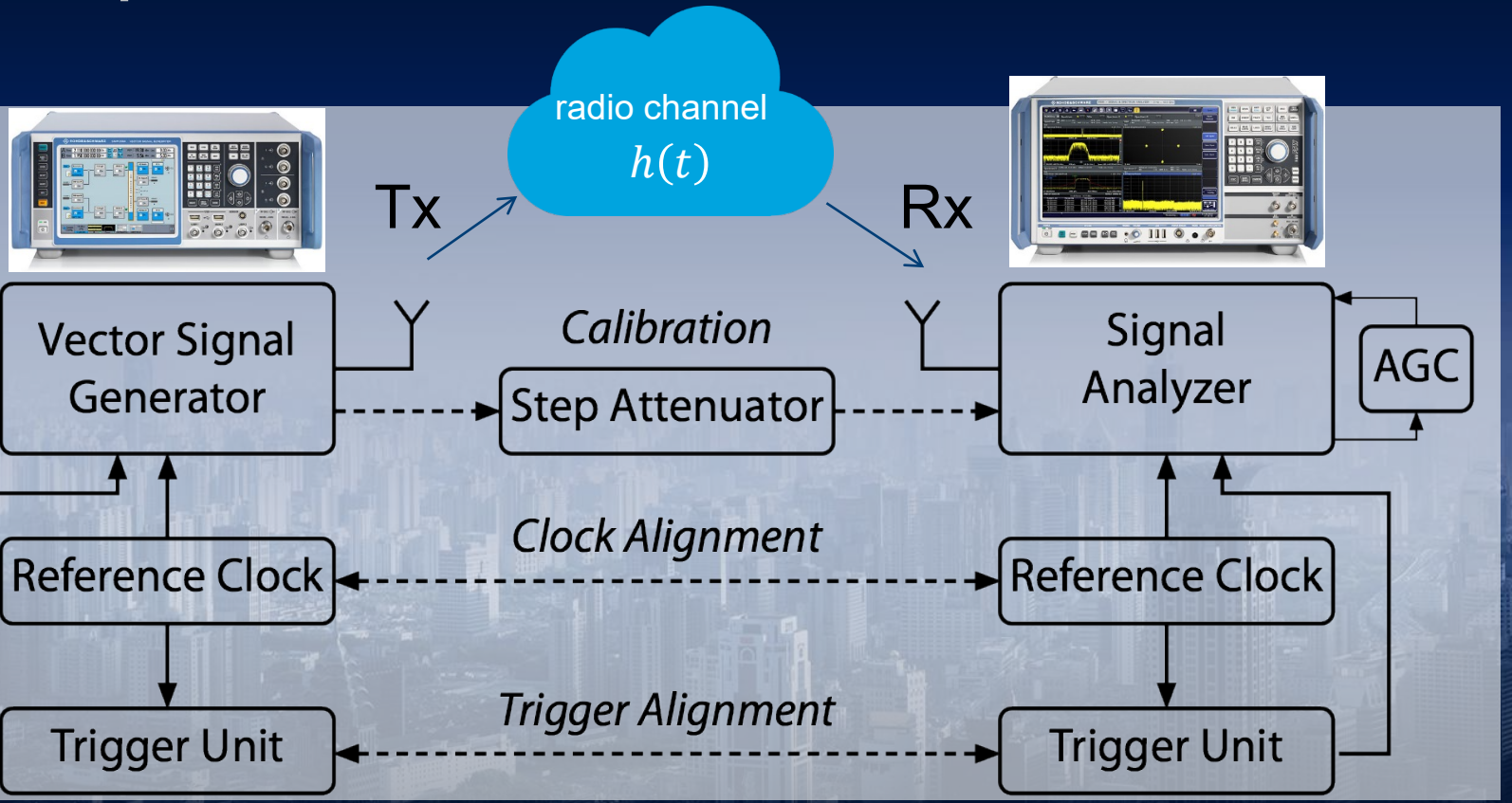
Implementation of Infrastructure & Pilot use cases

R&S USER PERSPECTIVE

- Digitalization enables significant potential for process optimization
- 5G deployed in private spectrum opens the door for high efficiency and more flexibility
- Smooth integration into existing deployments is a key requirement

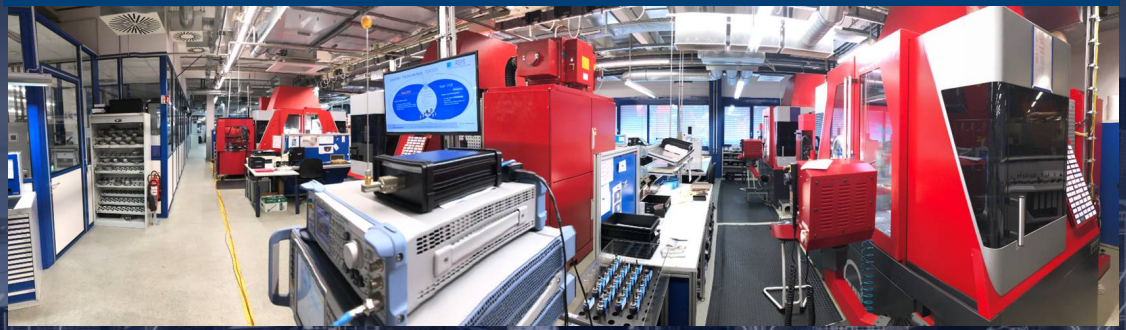


Basic Setup for Channel measurements

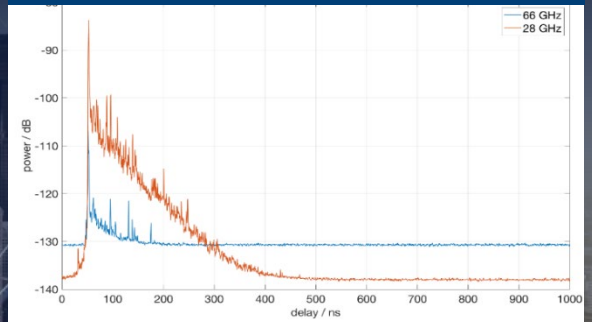


Measurement campaigns at 28 GHz (3.7 GHz, 67 GHz) in our factories in Memmingen and Teisnach performed together with NTT DOCOMO and Fraunhofer HHI

- Measurement Campaign at 3.7 GHz, 28 GHz and 67 GHz

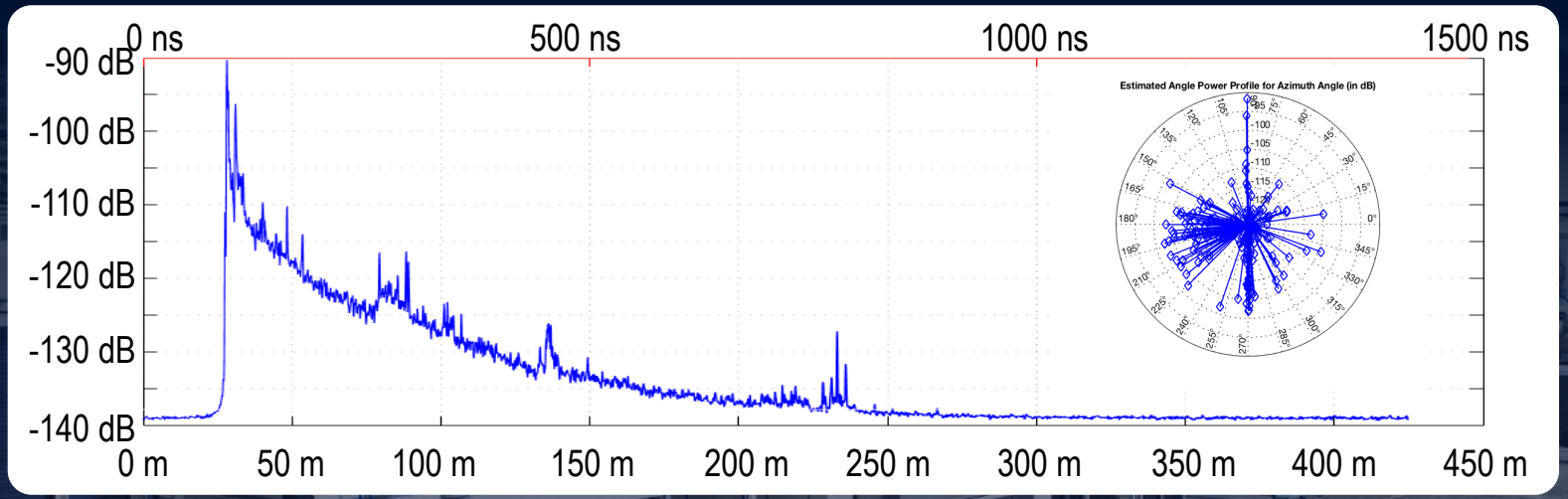


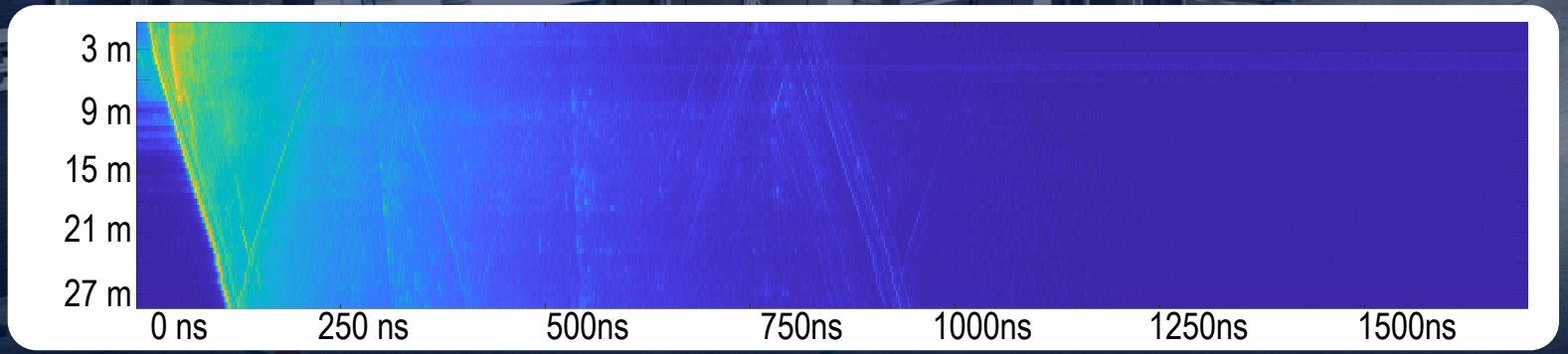
Power Delay Profile



Contribution to the 3GPP study item (Rel.16: FS_IIIOT_CM) on channel modeling for indoor industrial scenarios up to 100 GHz, EuCAP 2020 paper

Averaged Power Delay Profile (28 GHz Line-of-Sight)

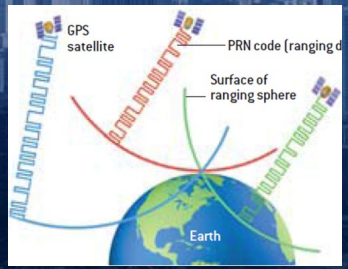




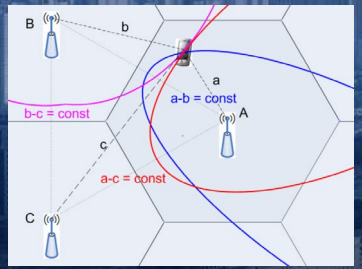
Positioning technologies: 3GPP Rel-16 5G NR positioning and sensor fusion (GNSS, motion sensors, barometer for vertical)

Outdoor

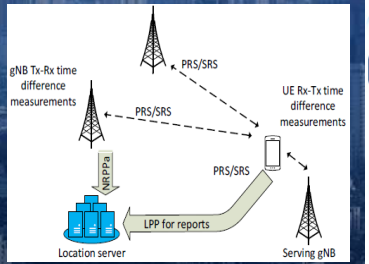
- GNSS (time delay, TOF)
- GNSS enhancement for ultra-precise positioning (phase): RTK



- OTDOA observed time difference of arrival



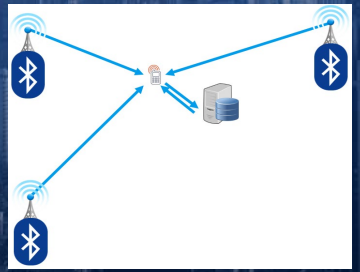
5G NR positioning:
- new positioning reference signals



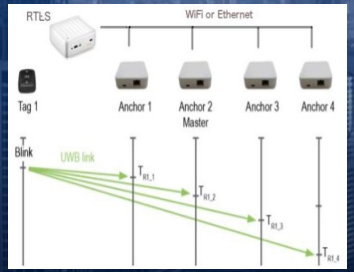
TOF: time-of-flight
RTK: real-time kinetic

Indoor

- Bluetooth LE
- WiFi (Beacons RSSI, AoA)



- ultra-wideband UWB (TOF relative to at least 3 anchor positions, precision 10-30cm)

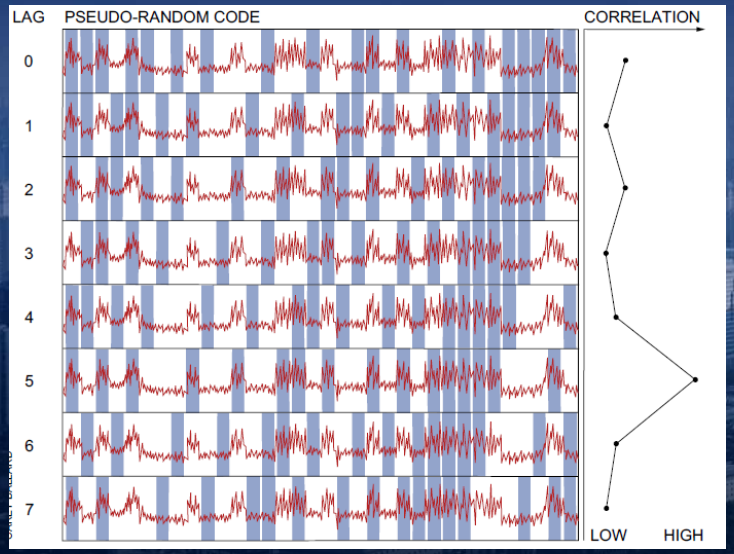


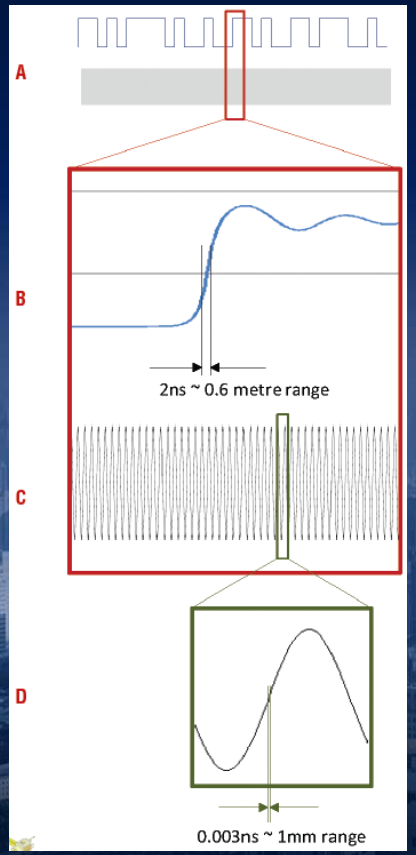
RSSI: Received signal strength indicator
AoA: Angle-of-Arrival

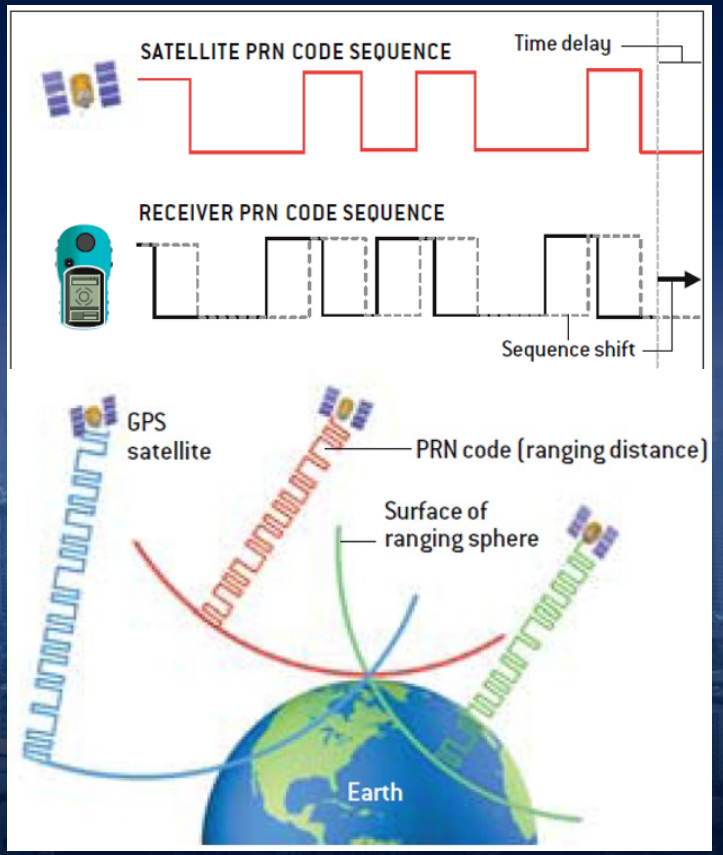
Correlation for time delay measurement (RTK)

Analogy to GPS (each satellite distinctive PRN “song”)

Velocity = Distance / Time



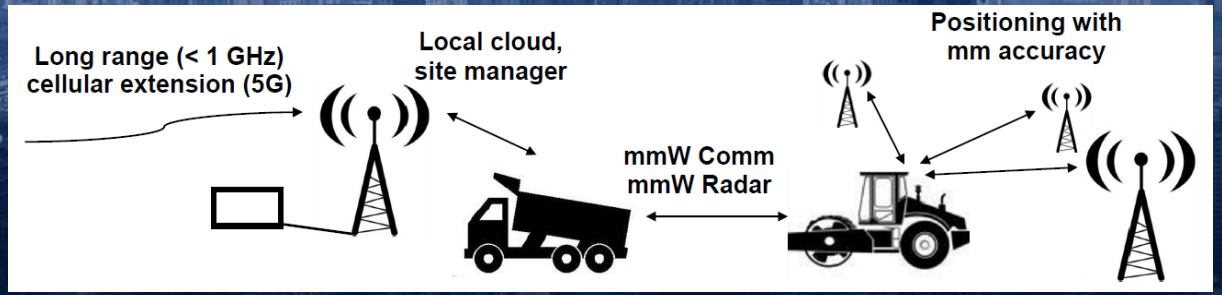




AMMCOA: Autonomous Mobile Machine Communication for Off-Road Applications (mmWave positioning)

Objective: development of PLMN-embeddable infrastructure-less wireless 5G networking solution for agricultural and construction vehicles for supporting novel cooperative autonomous driving functions

- Communication & autonomization solution for vehicle-centric applications in agriculture and road construction
- Partner: Fraunhofer HHI, Infineon, John Deere, TU Kaiserslautern, Robot Makers GmbH, etc., T&M equipment: R&S
- Meshed mmW point-to-point communication links
- mmW-based point-to-point positioning
- Cellular / Sub GHz / long range air interface



AMMCOA: Measurement setup

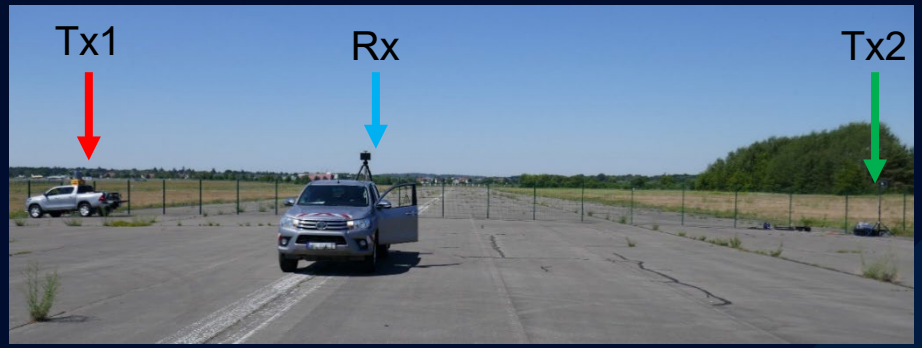
Transmitter Tx1

Transmitter Tx2

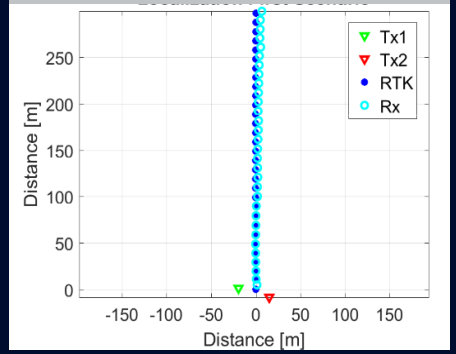
Receiver Rx

- The used measurement setup consists of two transmitters (fixed reference points) and one receiver with the aim of performing a spatially resolved simultaneous multi-transmitter channel measurement that allows a receiver localization based on angle of arrival (AoA) and time of arrival (ToA) information
- The measurement has been performed at a carrier frequency of 28.5GHz with a used bandwidth of 2GHz
- For verification of the calculated receiver positions a RTK GPS reference has been used

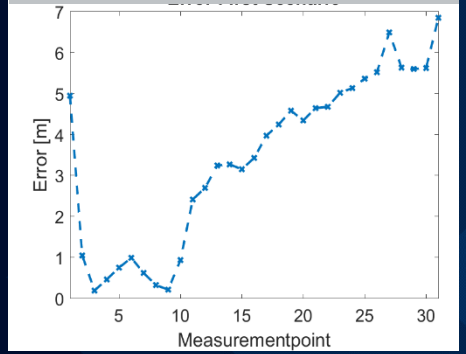
AMMCOA: Measurement results (Berlin, Gatow, former airport)



Localization (1st scenario)

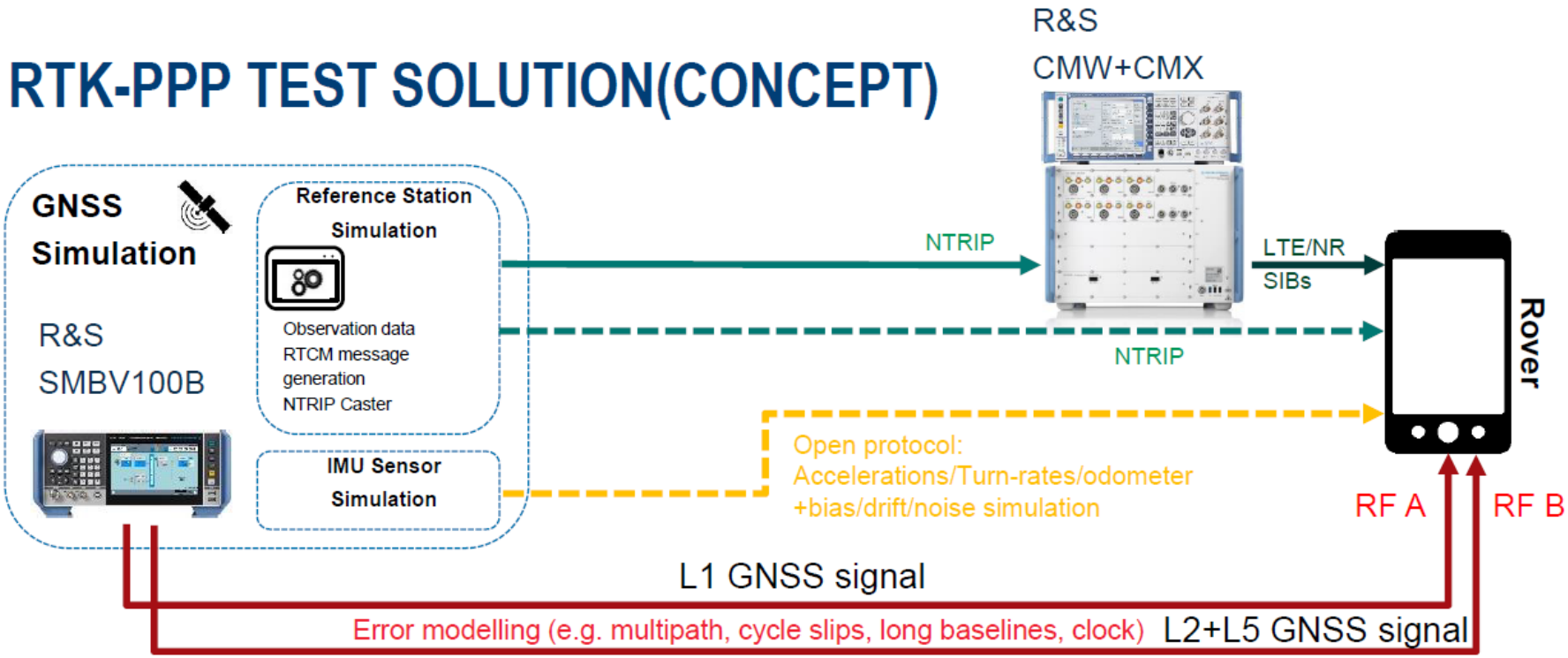


Error (1st scenario)



- A total # of 31 measurement points have been recorded
- Every 10 m a measurement has been performed (distance over 300 m)
- The transmitters distance is approx. 40m
- The determined receiver positions have been calculated from ToA and AoA information that originate from a fully synchronized measurement setup and the Fraunhofer HHI VUCA (Virtual Uniform Circular Array)
- Overall an accuracy of 18cm to 7m has been achieved

RTK-PPP TEST SOLUTION(CONCEPT)



ROHDE&SCHWARZ

Make ideas real