5G-ACIA Annual Internal Planning Workshop 2023

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5G for industrial control systems: a critical reflection

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Our business areas

Electrification

Motion

Process Automation

Robotics & Discrete Automation

Outline

Needs and opportunities

Promises and Expectations

Experimental results from COTS 5G products and gaps

Reflections and recommendations

Needs and opportunities

5G enables mobility and flexibility

Large height

Rural areas

Mobile machines

Mobile operation

Moving parts

Harsh or corrosive

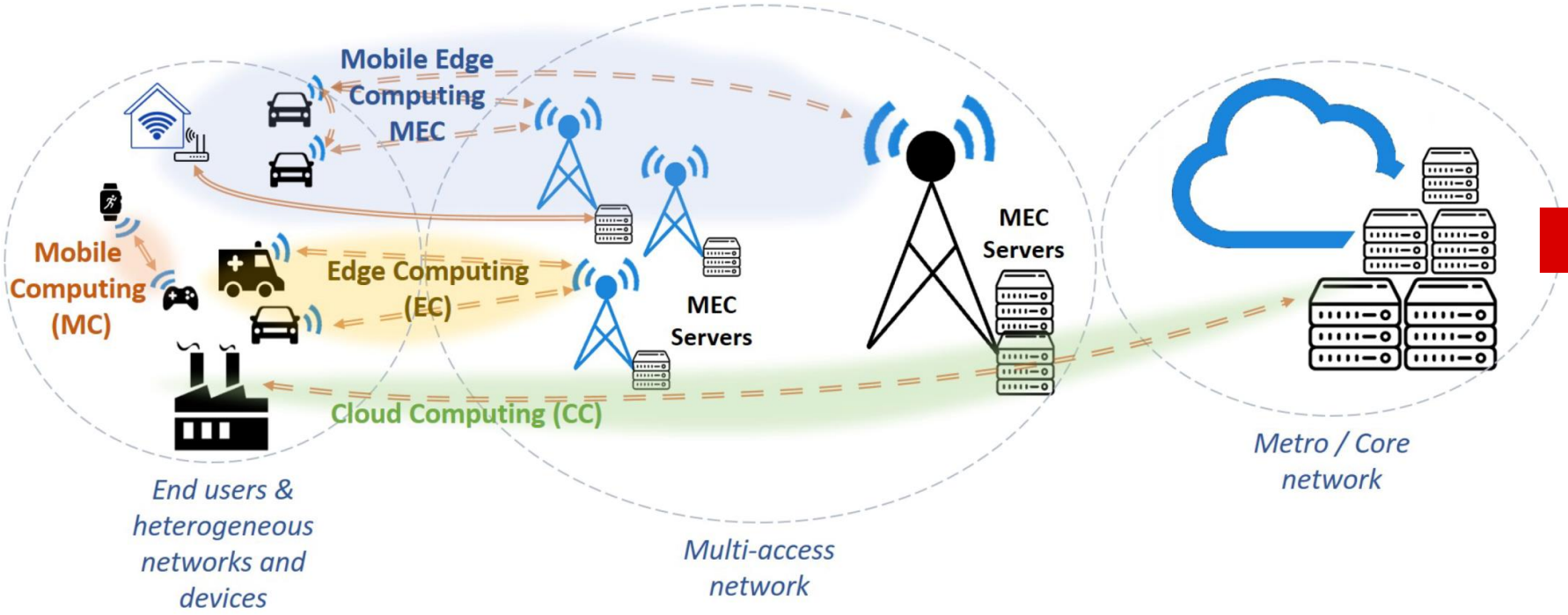
Access forbidden

Cabling forbidden

Temporary deployment

Needs and opportunities

5G brings computation to mobile edge



- Data ownership
- Security and privacy
- New BM, e.g., XaaS

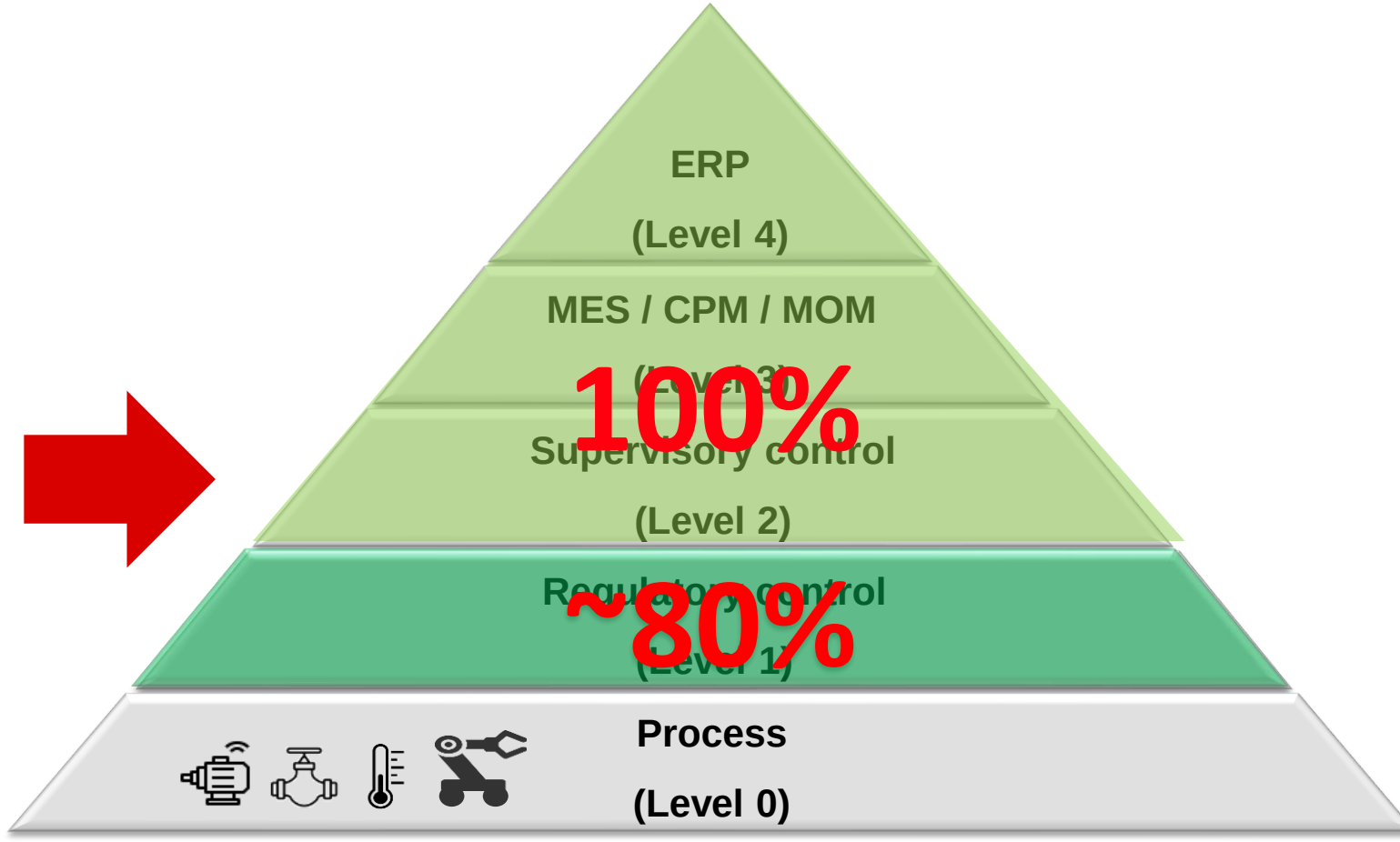
ETSI, “Mobile Edge Computing A key technology towards 5G”, 2015, link
McClellan, M.; Cervelló-Pastor, C.; Sallent, S. Deep Learning at the Mobile Edge: Opportunities for 5G Networks. *Appl. Sci.* **2020**, *10*, 4735. https://doi.org/10.3390/app10144735

Promises and Expectations

5G ACIA
5G Alliance for Connected Industries and Automation

"For URLLC, the first release of **5G (Release 15)** already has the capability to achieve a latency of **1 ms** with a reliability of **99.999%** over the 5G radio interface."

-- the flagship White Paper[1]

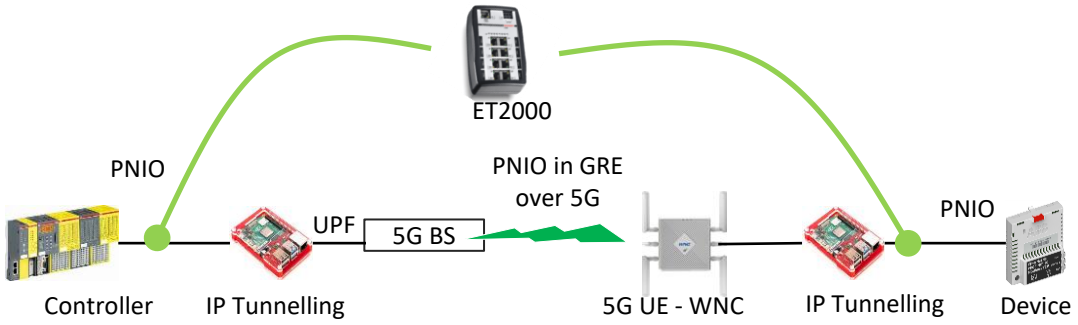


5G is expected to be generic communication infrastructure for "nearly all" industrial control systems

[1] 5G-ACIA White Paper 5G for Connected Industries and Automation, Second Edition, 28.02.2019. link

Experimental test of COTS 5G in Level-1 control loop

Mid-band, eMBB, NSA, line-of-sight, lab condition (tested in Feb 2022)



Unobtrusive to control loop

Insertion delay: <1us

Latency error: < 40ns

Verified reliability: < 10e-8

Verified protocols: PROFINET, PROFIsafe, Modbus TCP, EtherNet/IP, TCP, UDP, DDS, OPC UA

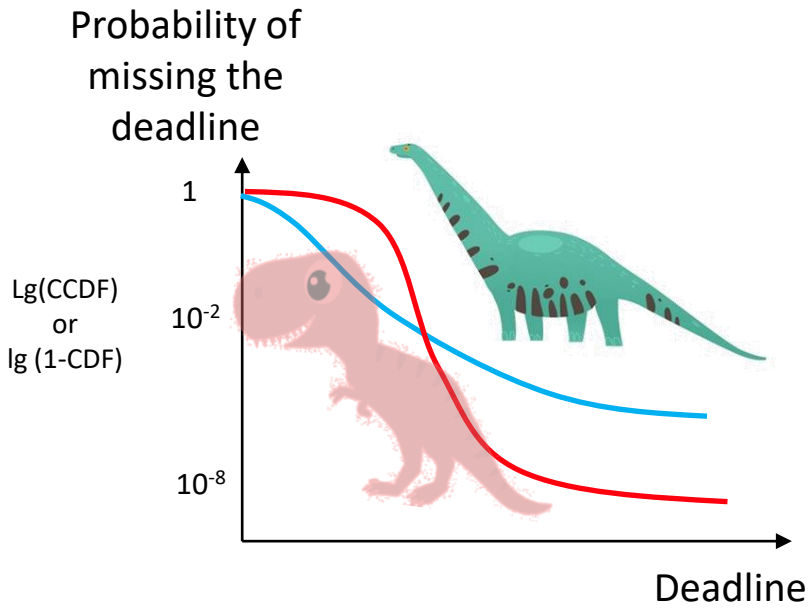
Limitation: Distance between probes: <100m (a)

Parameter	5G
Generation of standard	3GPP Release 15 (R15), eMBB profile
TC-IoT Controller	AC500 PLC
TC-IoT Device	ACS880 Drive
Deployment mode	Non-standalone (NSA)
TDD slot pattern	DDSU
User Equipment/ Access point	WNC SKM-5xE
Frequency band(s)	LTE: 1875-1880 MHz 5G: 3720-3800 MHz
Industrial Ethernet protocol	PROFINET RT
Distance of the wireless link	≤ 10m
QoS at network and user equipment levels	No
Network type	Private network in office building
Application cycle time	16ms
Packet rate	62.5 packets/sec in each direction (from Controller to Drive and vice versa)
Packet length	76 bytes
Timeout limit of packet matching	300ms
Experiment duration	112 hours
Other parameters	Line of sight (LoS) between UE and BS, radio resource pre-allocation enabled

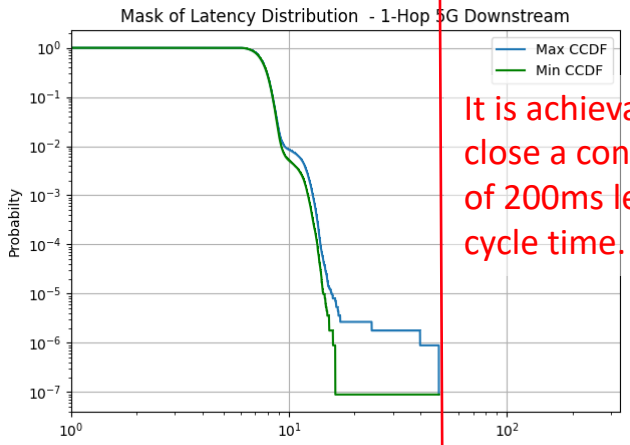
K. Bhimavarapu, Z. Pang*, O. Dobrijevic and P. Wiatr, "Unobtrusive, Accurate, and Live Measurements of Network Latency and Reliability for Time-Critical Internet of Things," in IEEE Internet of Things Magazine, vol. 5, no. 3, pp. 38-43, September 2022, doi: 10.1109/IOTM.001.2200068.

Latency and reliability of COTS 5G

The “Dinosaur Curve“ (tested in Feb 2022, settings in previous pages)

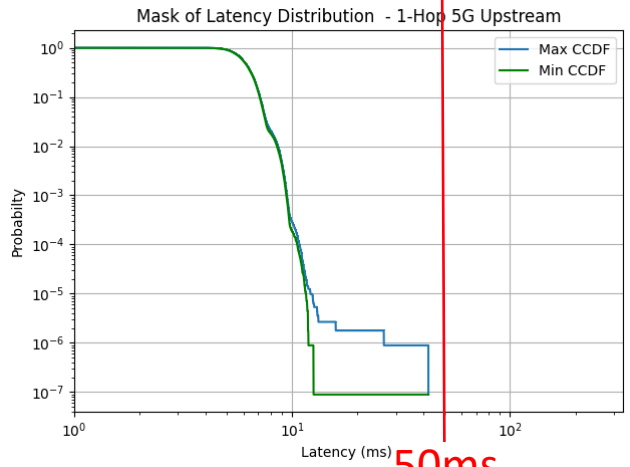


Downstream



It is achievable to close a control loop of 200ms level cycle time.

Upstream



50ms

- 5G has achieved a lot
- URLLC not there yet
- Lab results are encouraging, but field tests are necessary:
  - Field survivability
  - Scalability

Conditions: in lab, 1-hop 5G, 2m distance, no obstacle, no competing traffics, 16ms cycle time, 60B Ethernet frame (PNIO in GRE in Eth), when 5G system is stable, tested for 3 days, statistic window is 5-hour

Known functional gaps of COTS 5G

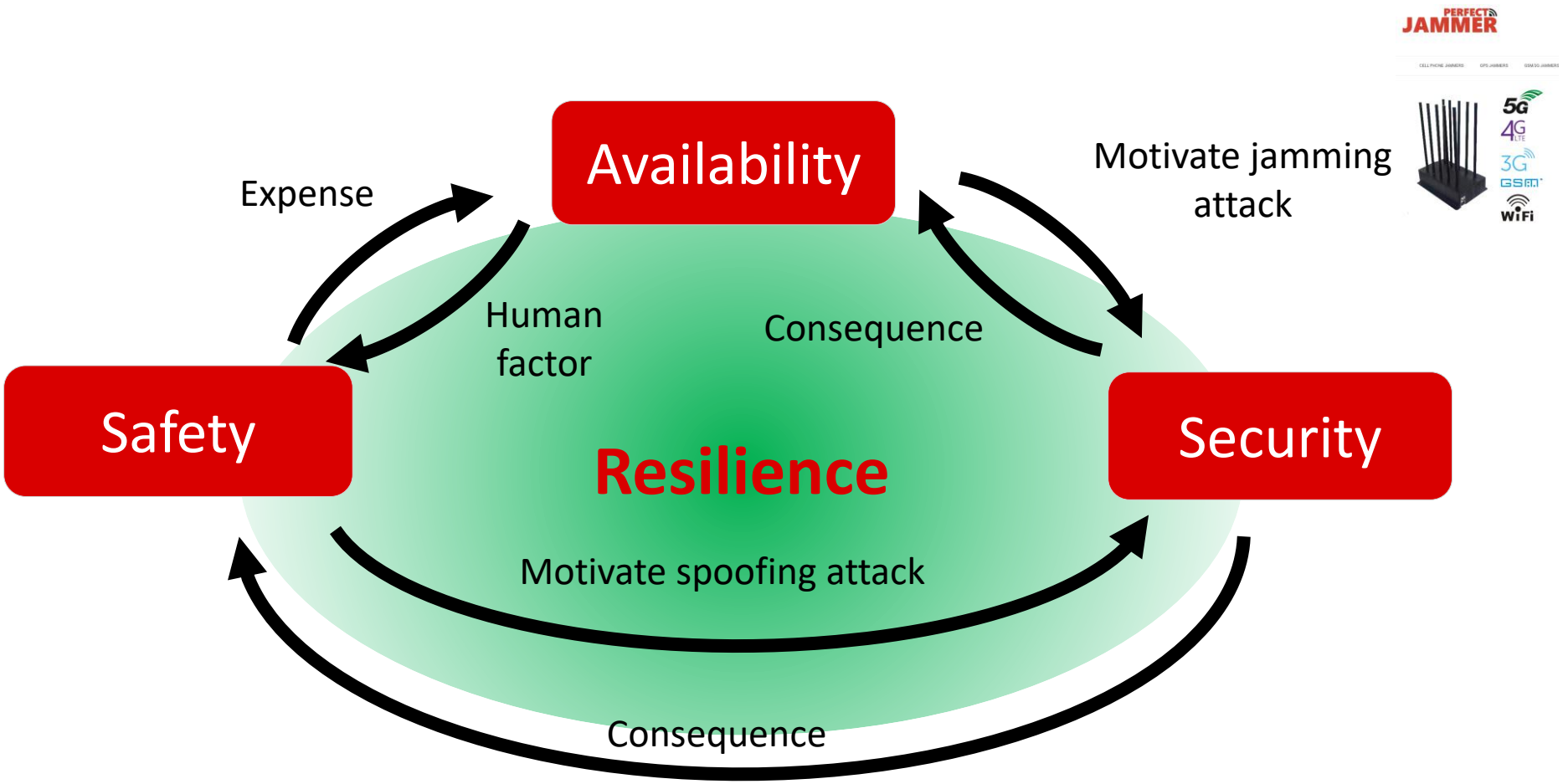
to integrate 5G in Level 1 control network (tested in Feb 2022, settings in previous pages)

It lacks support to layer2 Ethernet PDU	→	Cannot fully support layer2 industrial ethernet e.g., PROFINET
It lacks time synchronization signaling for user devices	→	Difficult or infeasible to realize time-critical application
It lacks support to IP/UDP multicast	→	Difficult or infeasible to realize time-critical PubSub e.g., DDS, OPC UA PubSub

Ethernet PDU (protocol data unit) is the layer 2 Ethernet packet which is commonly used in main-stream industrial ethernet protocols.
UDP: user defined protocol, a common way of realizing industrial communication protocols on top of IP (internet protocol).

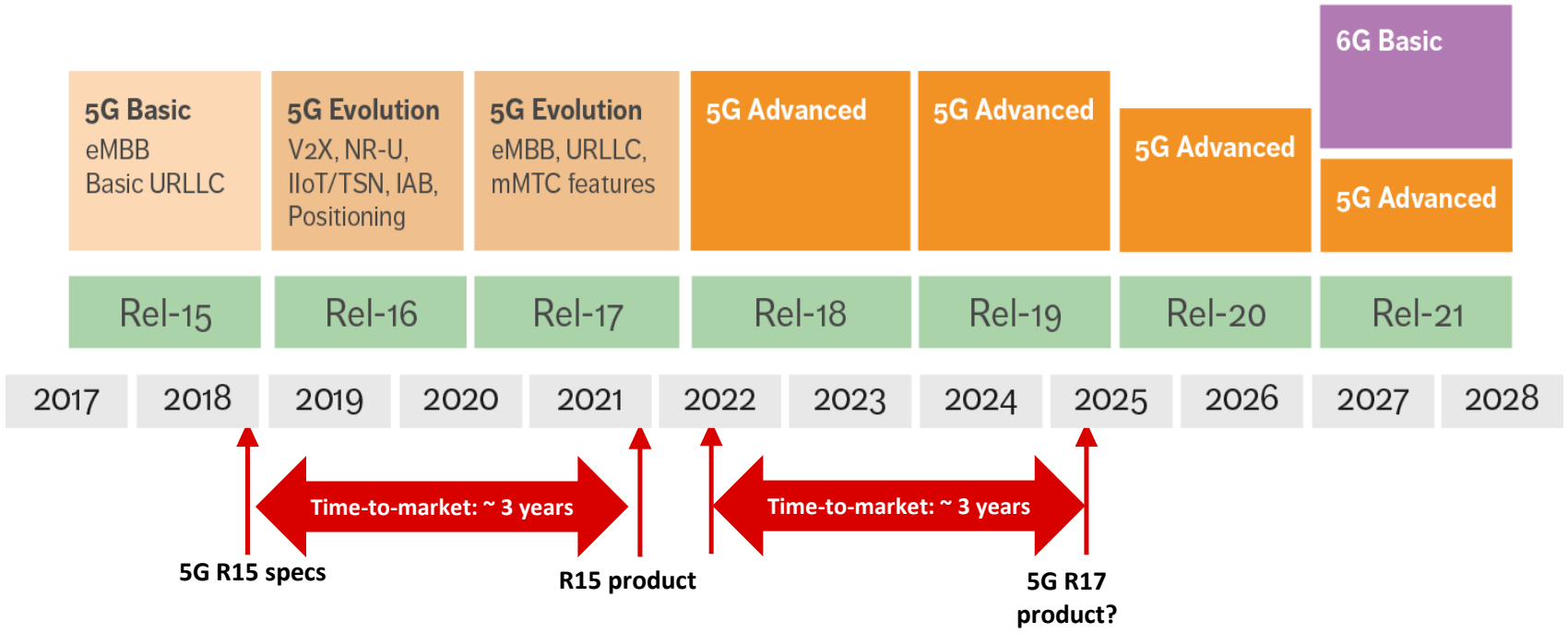
Other challenges for your attention

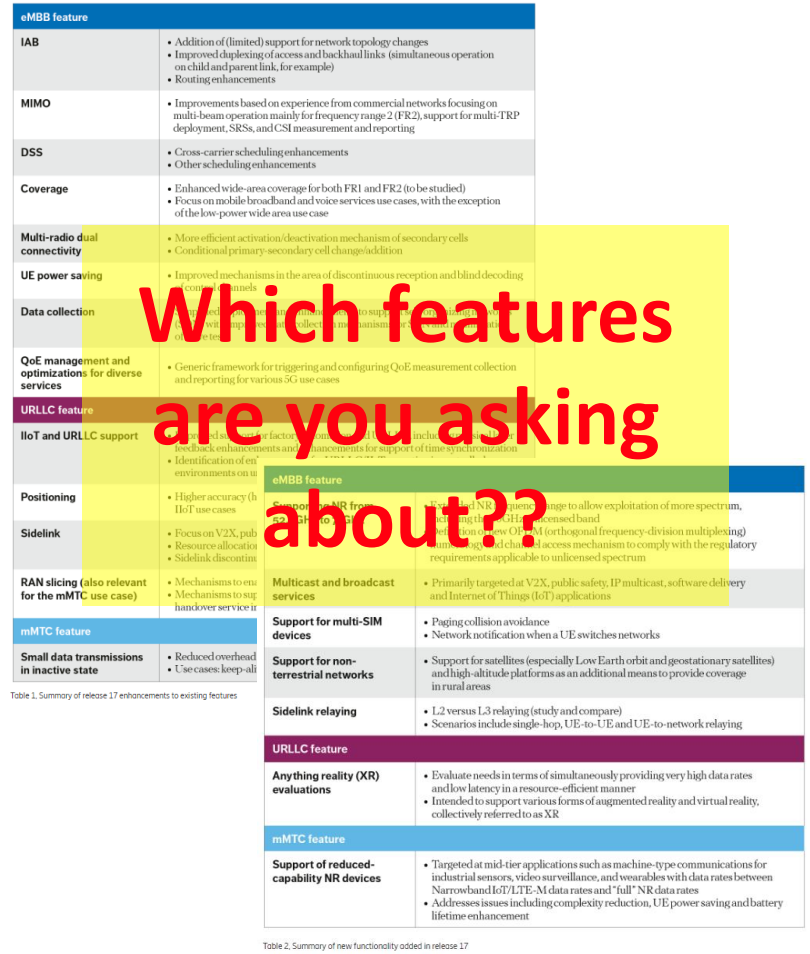
Relations between the 3 major concerns



Reflections and recommendations

Use “production timeline” in IT-OT collaboration and planning





eMBB feature	
IAB	• Addition of (limited) support for network topology changes • Improved duplexing of access and backhaul links (simultaneous operation on child and parent link, for example) • Routing enhancements
MIMO	• Improvements based on experience from commercial networks focusing on multi-beam operation mainly for frequency range 2 (FR2), support for multi-TRP deployment, SRSs, and CSI measurement and reporting
DSS	• Cross-carrier scheduling enhancements • Other scheduling enhancements
Coverage	• Enhanced wide-area coverage for both FR1 and FR2 (to be studied) • Focus on mobile broadband and voice services use cases, with the exception of the low-power wide area use case
Multi-radio dual connectivity	• More efficient activation/deactivation mechanism of secondary cells • Conditional primary-secondary cell change/addition
UE power saving	• Improved mechanisms in the area of discontinuous reception and blind decoding
Data collection	
QoE management and optimizations for diverse services	• Generic framework for triggering and configuring QoE measurement collection and reporting for various 5G use cases
URLLC feature	
IIoT and URLLC support	
Positioning	• Higher accuracy (h IIoT use cases
Sidelink	• Focus on V2X, pub • Resource allocation • Sidelink discontin
RAN slicing (also relevant for the mMTC use case)	• Mechanisms to enu • Mechanisms to sup handover service i
mMTC feature	
Small data transmissions in inactive state	• Reduced overhead • Use cases: keep-ali

Table 1. Summary of release 17 enhancements to existing features

eMBB feature	
Multicast and broadcast services	• Primarily targeted at V2X, public safety, IP multicast, software delivery and Internet of Things (IoT) applications
Support for multi-SIM devices	• Paging collision avoidance • Network notification when a UE switches networks
Support for non-terrestrial networks	• Support for satellites (especially Low Earth orbit and geostationary satellites) and high-altitude platforms as an additional means to provide coverage in rural areas
Sidelink relaying	• L2 versus L3 relaying (study and compare) • Scenarios include single-hop, UE-to-UE and UE-to-network relaying
URLLC feature	
Anything reality (XR) evaluations	• Evaluate needs in terms of simultaneously providing very high data rates and low latency in a resource-efficient manner • Intended to support various forms of augmented reality and virtual reality, collectively referred to as XR
mMTC feature	
Support of reduced-capability NR devices	• Targeted at mid-tier applications such as machine-type communications for industrial sensors, video surveillance, and wearables with data rates between Narrowband IoT/LTE-M data rates and “full” NR data rates • Addresses issues including complexity reduction, UE power saving and battery lifetime enhancement

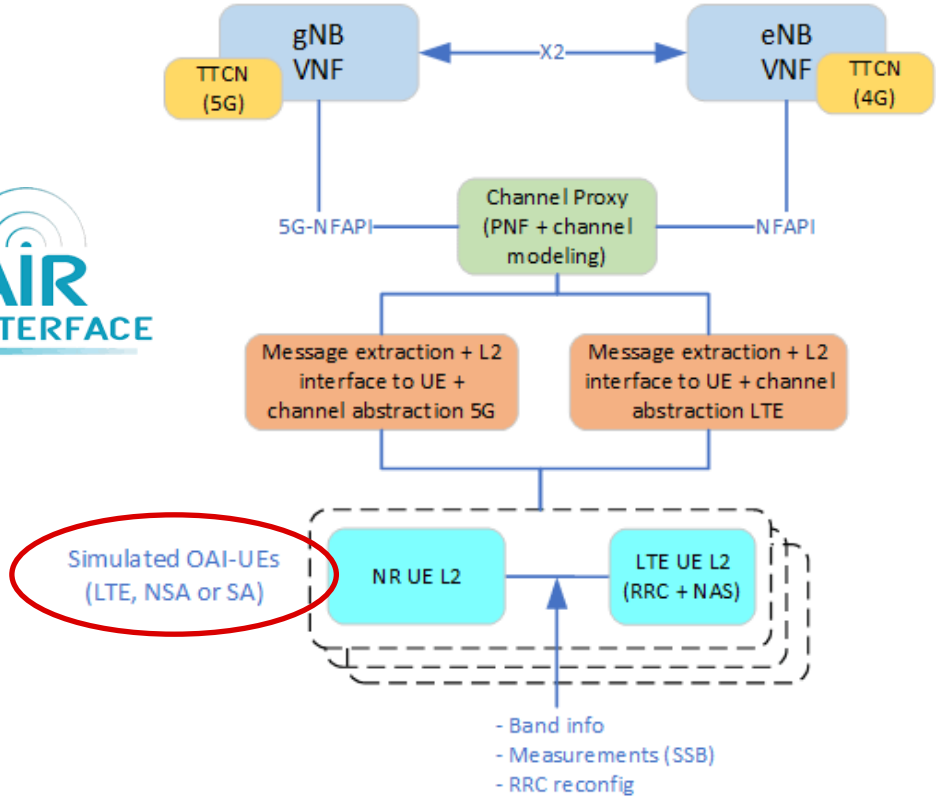
Table 2. Summary of new functionality added in release 17

Which features are you asking about??

Toward 5G Advanced: overview of 3GPP releases 17 & 18 – Ericsson
3GPP releases 16 & 17 overview – 5G NR evolution - Ericsson

Reflections and recommendations

Pay more attention to UE, e.g., “OpenUE”, learn from OT open standards



OAI 5G RAN

OT market is value-sensitive rather than cost-sensitive

Reflections and recommendations

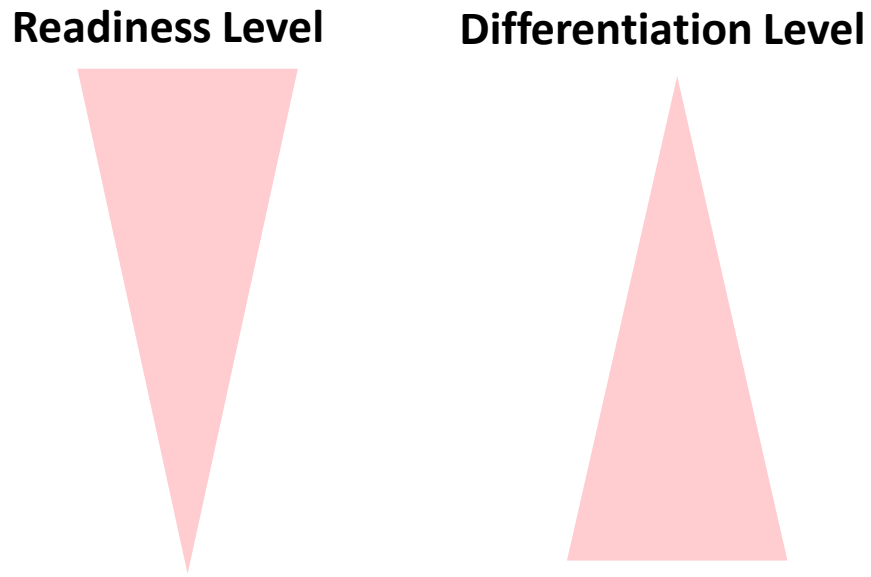
Revisit the 5G use cases and gaps before rush into 6G

Victor K. L. Huang; Zhibo Pang; Cheng-Jen Allen Chen; Kim Fung Tsang "New Trends in the Practical Deployment of Industrial Wireless: From Noncritical to Critical Use Cases", *IEEE Industrial Electronics Magazine*, Volume: 12, Issue 2, 2018, Pages: 50 – 58, 2018.


ABB

“Killer applications” or “iPhone moment” of 5G/6G for OT?

- Wide area, long distance, flexibility
- Mobility of operator and machine
- Machine Intelligence (AI, vision)
- Automation/Control-as-a-Service



Not new, but they are still the strongest candidates. Don’t expect the “iPhone moment” in OT.