



imec

6GSpecNet

Specialized Deterministic Connectivity for Demanding Markets

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Deterministic connectivity
bounded latency – reliable/safe - predictable

Need?

Today



Industrial automation

Network that supports requirements of industrial automation



Energy & power

Smooth functioning of energy production/distribution systems



Automotive

Safety-critical and real-time in-vehicle systems



Audio & video

Real-time, low latency distribution of audio and video



Transportation

Continuous train and trackside communication



Oil & gas

Timely communication for process and control networks



Aerospace

Precise time-stamped data acquisition and real-time traffic



Tomorrow

Tactile Internet



End-to-end (E2E)
latencies < 5ms

Industrial automation



20us to 10ms latencies
for M2M
Ultra-reliable

Social roboverse / Collaborative robotics



Multi-sensory input
to remote decision-
making < 10-100ms

Holographic-type communications



E2E latencies < 20ms
Gbps rates

6G

A network patch panel with numbered ports and connected cables. The panel is light-colored with dark ports. The ports are numbered in a grid: 057, 058, 059, 060, 061, 062, 063, 064, 065, 066, 067, 068, 069, 070, 071, 072, 073, 074, 075, 076, 077, 078, 079, 080, 081, 082, 083, 084, 085, 086, 087, 088, 089, 090, 091, 092, 093, 094, 095, 096, 097, 098, 099, 100. Several white cables are plugged into the ports. The text "Deterministic connectivity in the wired world" is overlaid in the center.

Deterministic connectivity
in the wired world

Time synchronization

All devices in the network have the same sense of time with sub-microsecond accuracy

Resource management

Configuration and management of resources to meet the requirements of TS streams

Time-sensitive networking (TSN)

TS traffic streams are delivered within a specified time via scheduling and shaping

Bounded low latency

TS traffic is protected against bandwidth violations and redundancy is provided

Ultra reliability

Set of IEEE 802.1 standards for deterministic transmission over Ethernet



AUTOMOTIVE

INDUSTRIAL

PROAV/MILAN

WIRELESS TSN

Avnu Alliance

The future is a converged network that guarantees real-time applications will just work.

[Learn More](#)

Avnu interoperable ecosystem of low-latency, time-synchronized, highly reliable networking devices using the IEEE open standard

AUTOMOTIVE

INDUSTRIAL

PROAV/MILAN

WIRELESS TSN

Set of TSN specifications

ProAV/Milan

Defines implementation details for media-integrated LAN

Milan specification is based on the following IEEE standards:

- IEEE 802.1BA-2011 [Audio Video Bridging \(AVB\)](#) Systems - consists of usage-specific profiles for device interoperability;
- [IEEE 802.1Q](#)-2011 Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks - defines methods for traffic shaping (Forwarding and Queuing for Time-Sensitive Streams) and bandwidth reservation (Stream Reservation Protocol) in [network bridges](#) and [VLANs](#);
- [IEEE 802.1AS](#)-2011 Timing and Synchronization for Time-Sensitive Applications - defines the Generalized [Precision Time Protocol \(gPTP\)](#);
- IEEE 1722-2016 Layer 2 Transport Protocol for Time Sensitive Applications - defines (AV Transport Protocol, AVTP) and payload formats;
- IEEE 1722.1-2013 Device Discovery, Enumeration, Connection Management and Control Protocol (AVDECC).

WAN tech

Licensed spectrum

Public and private

5G

LAN tech

Unlicensed spectrum

Indoor (80% of data consumed indoor)

WiFi 6™

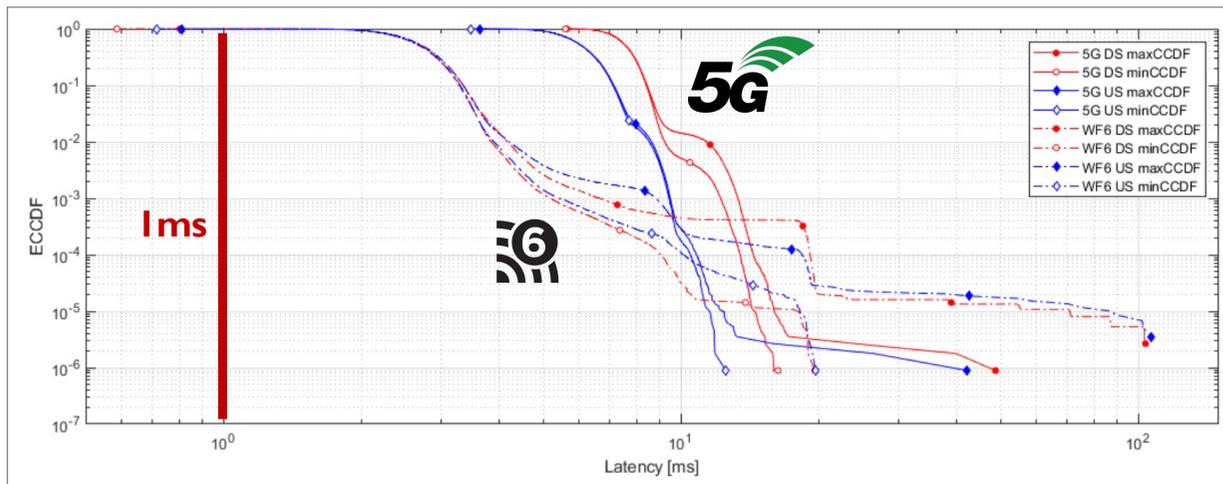


FIGURE 4. Latency distribution for 5G and Wi-Fi 6: ECCDF envelopes for both upstream (US) and downstream (DS).

Based on: Zhibo Pang, "Functional Safety Communication over Deterministic Wireless Networks", NIST Industry Meeting on Advanced Technologies and Use Cases for High-performance Industrial Wireless Systems, Sep. 12 2024

5G in production

Does 5G technology the hen-egg-probiemi

5G is the first mobile communications standard ever to be tailored to the specific needs of industry. A broader range of hardware suitable for industrial use is on the horizon - if a sufficient number of users join in.

Source: ke Next 01 2023



Latency & Reliability for Ultra-Reliable Low-Latency Communication (URLLC)

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. This permits reliable transmission of small data packets (with a size of only a few bytes) over the air within a specified time limit, as required for closed-loop control applications, for example. Low-latency communication is enabled by the introduction of short transmission slots, allowing faster uplink and downlink transmissions. By reducing the transmission duration and interval by flexible adjustments, both the time over the air and the delay introduced at the transmitter while waiting for the next transmission opportunity are reduced.



5G-ACIA White Paper

5G for Connected Industries and Automation
(Second Edition)

5G Alliance for Connected Industries and Automation



eMBB

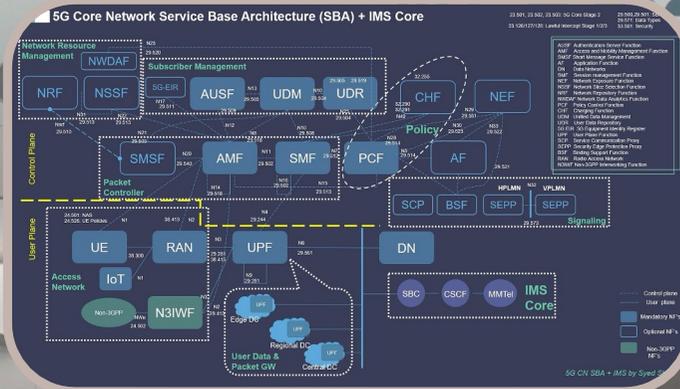
Increased data rates, high user density and very high traffic capacity



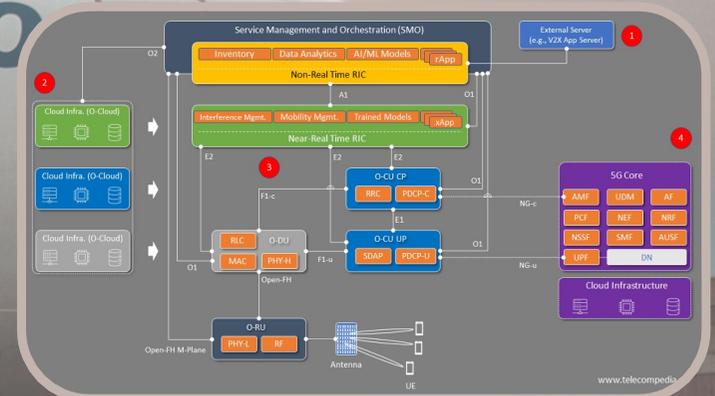
eMBB

Increased data rates, high user density and very high traffic capacity

Technology designed for a small number of extremely large national networks



Source: <https://sshazil.medium.com/5g-core-network-sba-ims-core-architecture-diagram-dcf0893d9bd9>



<https://telecompedia.net/open-ran-with-bullets-part-2/>

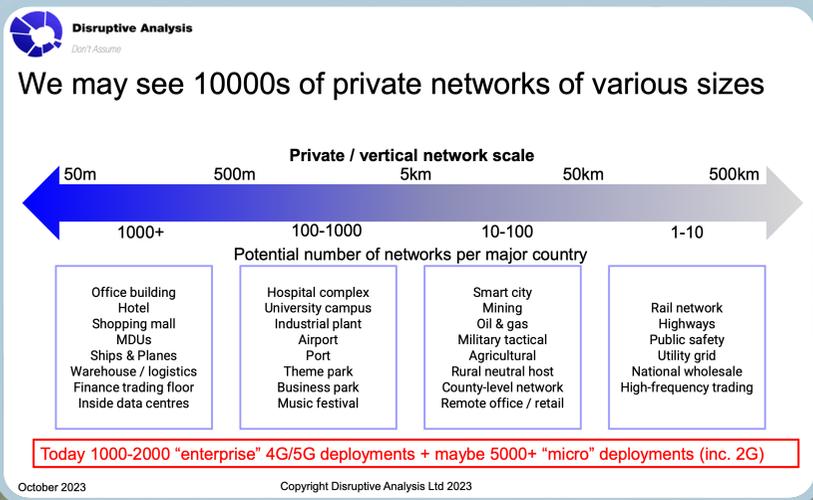
URLLC

Delivering strict latency and reliability



URLLC

Delivering strict latency and reliability



Features
(preemption of eMBB traffic flows, re-transmissions without waiting for feedback, mini-slots and self-contained slots, inter-UE prioritization, etc.)

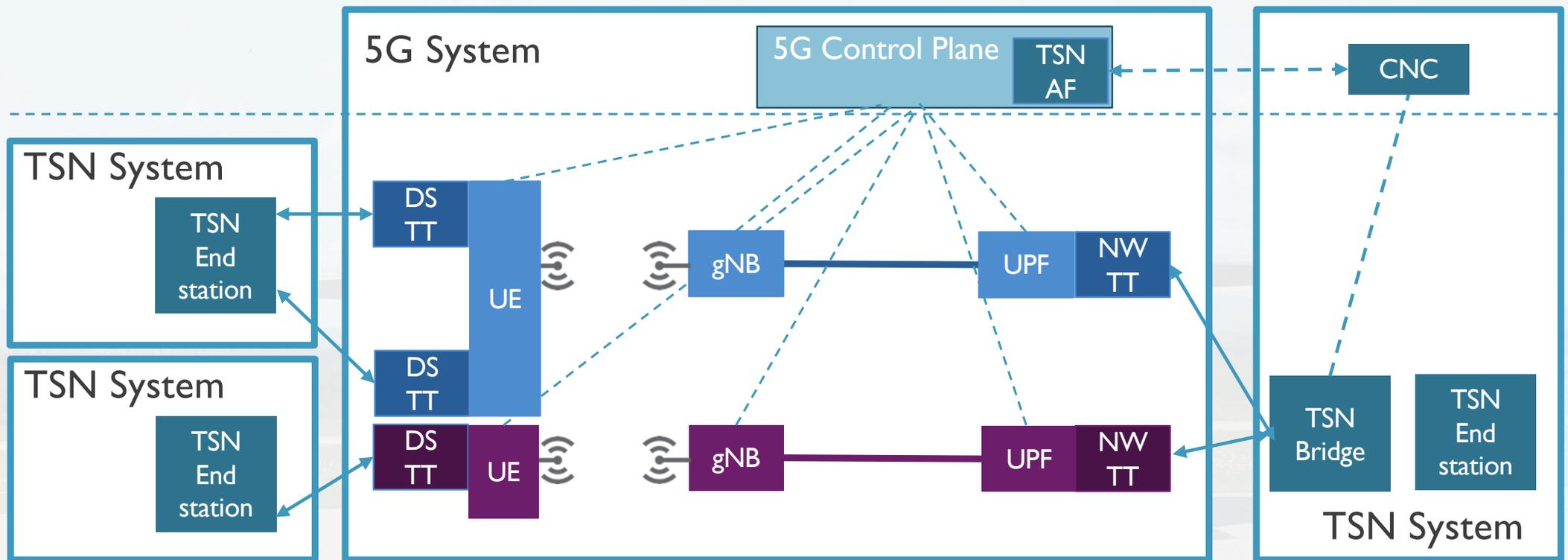
On top of a massively complex design that does not scale down well and that was driven by different needs*

Source: Dean Bublely, Disruptive Analysis, "5G: Evaluating Hype vs. Reality", ICASA 5G Forum, October 2023

* See also: Preston Marshall, "Evolving to 6G: the case for a new approach to 6G and beyond"

5G-TSN

5G = logical TSN bridge | translators & mappings



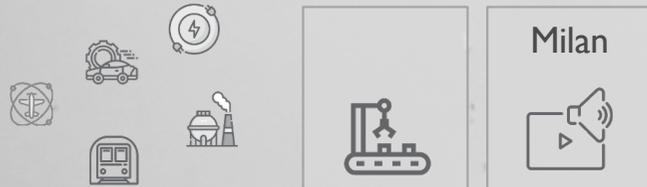
CNC – Central Network Controller | UPF – User Plane Function | AF – Application Function | DSTT – Device Side TSN Translator | NWTT – Network Side TSN Translator

A black and white photograph of a signpost with multiple directional signs against a cloudy sky. The signpost is a vertical pole with several horizontal signs of varying lengths and directions. The sky is filled with soft, horizontal cloud bands.

6GSpecNet

Specialized, fit for purpose networks

TSN



Resource management: centralized / distributed / hybrid, stream reservation protocol, etc.

Bounded latency: time-aware shaper, credit-based scheduling, cyclic queuing and forwarding, etc.

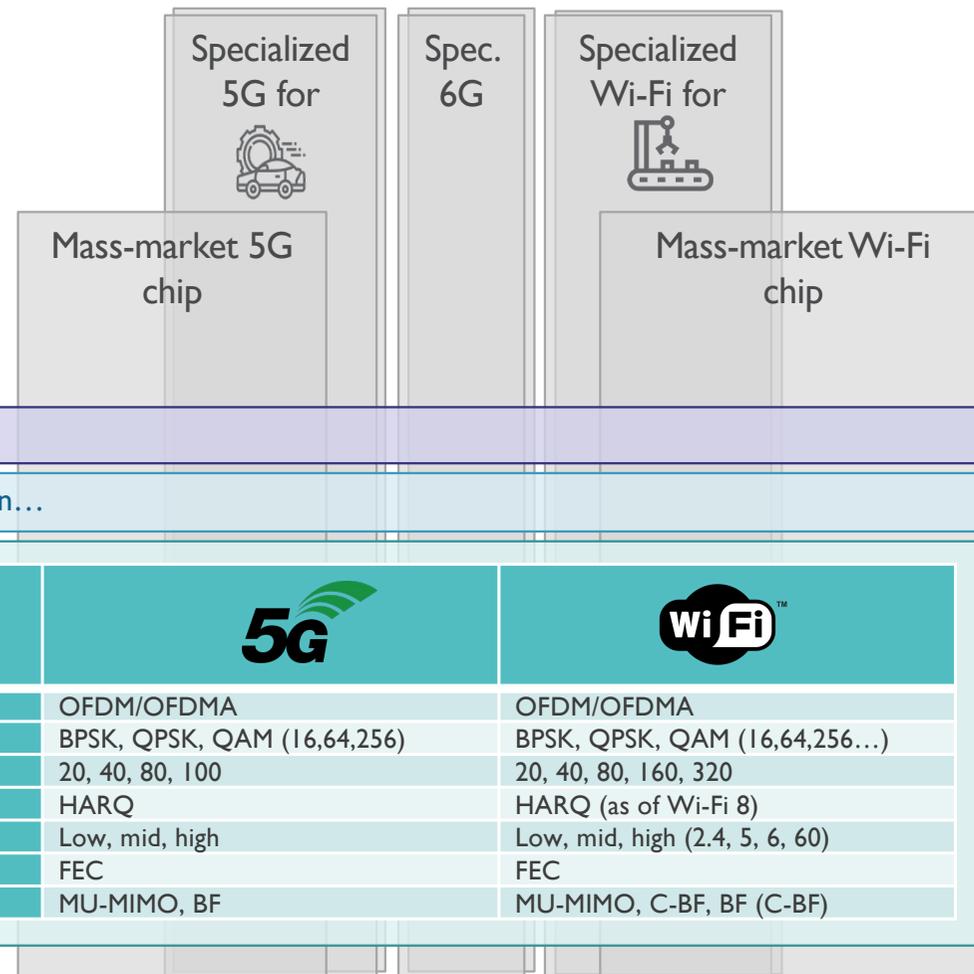
Reliability: frame replication and elimination, path control and reservation, reliability for time sync, etc.

Common baseline: Ethernet

6G



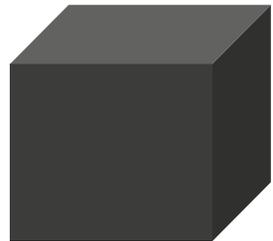
RAN specialization



+ customization capabilities

further tailoring to specific needs of TS use cases

evidence-based +
designs driven by proof



Application-network integration

Low-level reconfigurability

Greater level of control over radio capabilities

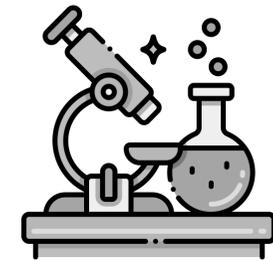
Programmable hardware (FPGA)

Low-level customization & dynamic reloading

```
aircr0 16384 0
mac80211 471040 0
cfg80211 253952 1 mac80211
ad9361_drv 114688 2
rmmod: ERROR: Module tx_intf is not currently loaded
+ insmod drv_and_fpga-7035/tx_intf.ko
tx_intf is loaded!
rmmod: ERROR: Module rx_intf is not currently loaded
+ insmod drv_and_fpga-7035/rx_intf.ko
rx_intf is loaded!
rmmod: ERROR: Module openofdm_tx is not currently loaded
+ insmod drv_and_fpga-7035/openofdm_tx.ko
openofdm_tx is loaded!
rmmod: ERROR: Module openofdm_rx is not currently loaded
+ insmod drv_and_fpga-7035/openofdm_rx.ko
openofdm_rx is loaded!
rmmod: ERROR: Module xpu is not currently loaded
+ insmod drv_and_fpga-7035/xpu.ko
xpu is loaded!
rmmod: ERROR: Module sdr is not currently loaded
+ insmod drv_and_fpga-7035/sdr.ko test_mode=0
sdr is loaded!
+ test -f /sys/kernel/debug/110/110:device0/direct_req
+ test -f /sys/kernel/debug/110/110:device1/direct_req
+ device_path=/sys/kernel/debug/110/110:device1
+ set *
the end
root@ana1og:~/openriffs# ./wgd.sh drv_and_fpga-7035
```

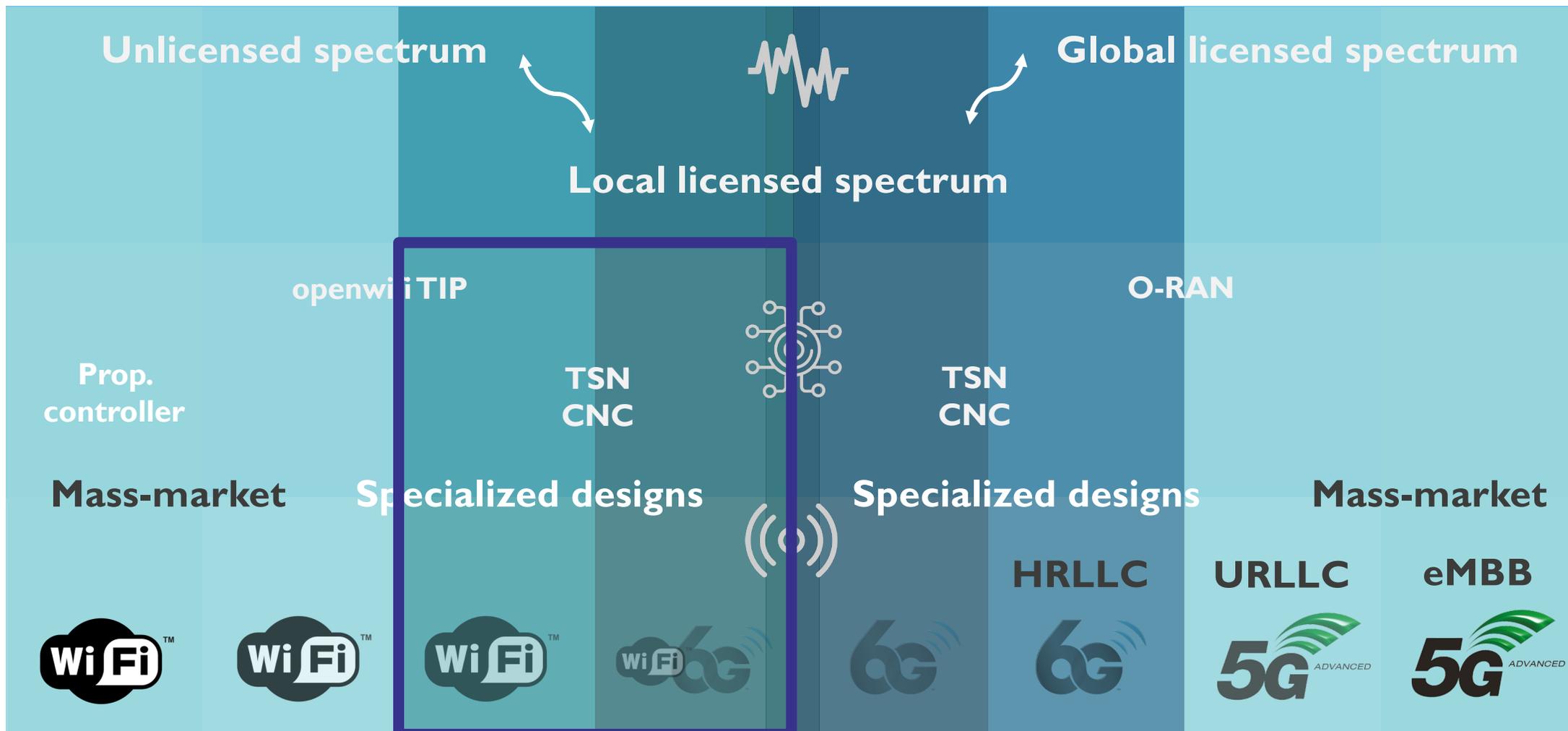


**HW
&
SW**



OPEN SOURCE

Bigger picture – specialized flavours of varying complexity



6GSpecNet

 Openwifi

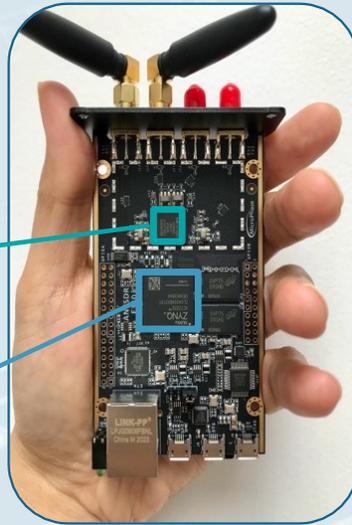
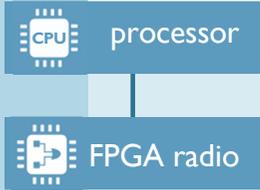


Today



System-on-Chip

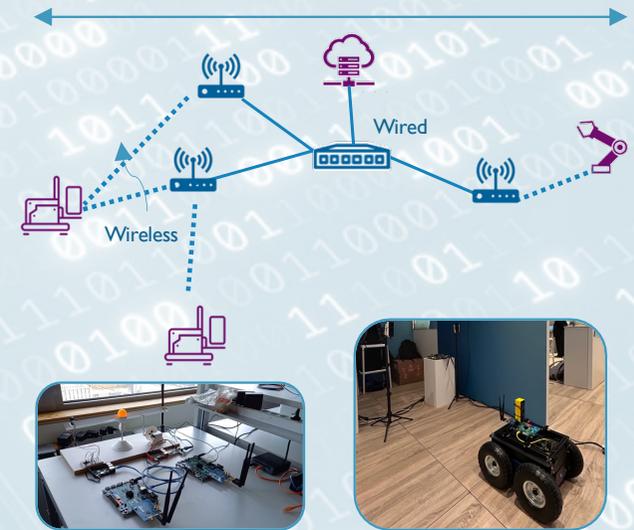
High
MAC
PHY +
low
MAC



W-TSN features

- Time synchronization
- Gating mechanism
- Bootstrapping
- Deterministic handover
- In-band telemetry
- Time-trigger low-level reconf.
- ...

Wireless-wired end-to-end guarantees



Key Wi-Fi features relevant for W-TSN

Tomorrow

Advanced platforms
(↑ BW, rate, range)



Local licensed spectrum



<< μs accuracy



Selected next-gen Wi-Fi features



Controller capabilities

TSN CNC



Over-engineering
(and complexity)



Specialization
(and simplification or focused complexity)



Openwifi TSN

For serving various demanding markets



embracing a better life

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