

KEYNOTE

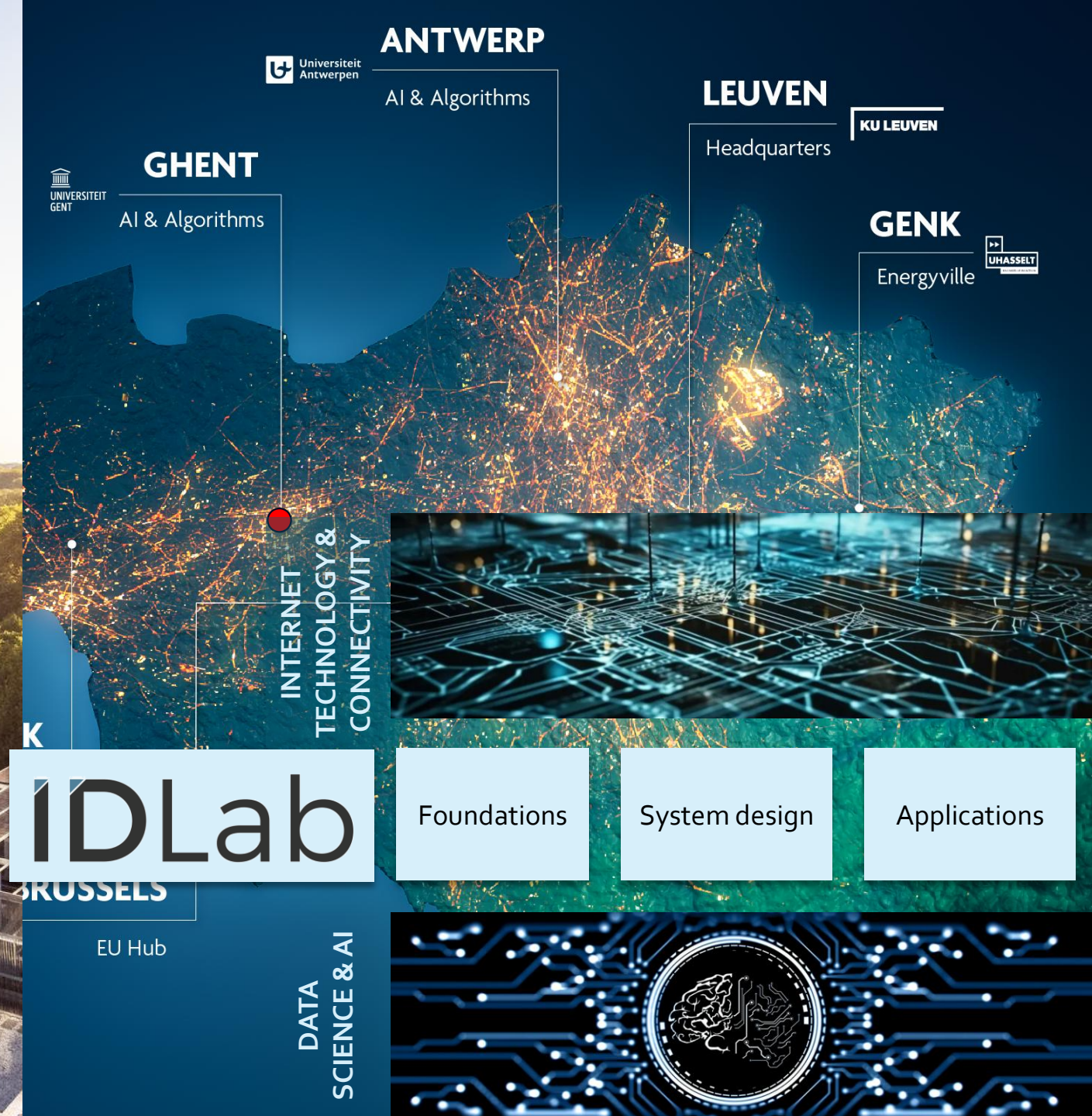
How Europe is Shaping the Future of Wireless Innovation

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 imec


GHENT
UNIVERSITY

 IDLab



Deterministic Connected Systems

Research program @ imec

Mass-market
connectivity



Specialized
connectivity

Deterministic
end-to-end communication



LESSONS LEARNED
Innovation based on mass-market
infrastructure and chipsets is hard!

DETERMINISM = guaranteed and predictable END-to-END connectivity (infrastructure AND end-devices)

- ***Beyond traditional metrics*** such as speed and capacity
- Delivering ***firm, verifiable guarantees*** (beyond promises) on bounded latency, reliability, mobility, uniform coverage, scalability, security, resilience, ad-hoc deployment...
- Also in ***complex, dynamic, and mobile environments***
- Meeting needs from (real-world) challenging applications in ***high-end professional use cases***



Industrial automation



Social roboverse / Collaborative robotics



Automotive



Energy & power



Professional audio & video



Aerospace



Oil & gas



Holographic-type communications



Mission-critical communication



Tactile Internet



Transportation



Defence

Why is innovation based on mass-market connectivity infrastructure and chipsets so hard?

Standardisation landscape vs specialized connectivity needs

			Specialized E2E connectivity needs
Ecosystem	One-size-fits-all complexity Many generations, releases, and new features with unknown mutual impact...		Solid baseline + specialization Simplification or focused complexity

Specifications rising
from 5000 pages (2G, GSM)
to 200K pages (5G-advanced, Rel-18)
From 0.5 m to 20 m printed pages
[20 meter = about 6-story building]



← Specifications
Actual deployment →



Simplifying radio connectivity

Standardisation landscape vs specialized connectivity needs

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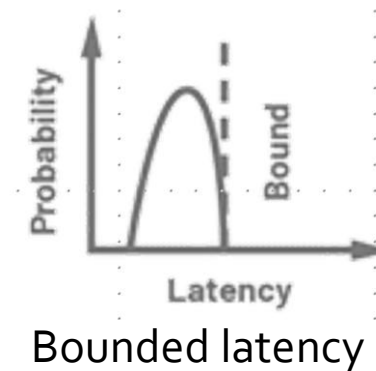


Standardisation landscape vs specialized connectivity needs

	WiFi	5G	Specialized E2E connectivity needs
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Features (limited by support in chipsets)	Driven by the market (revenue) High-speed, high-capacity, low-power... Mandatory features defined by certification		Driven by high-performance Bounded latency, reliability, coverage, etc., e.g., OFDMA, MLO, AP coordination



Economies of scale



Standardisation landscape vs specialized connectivity needs

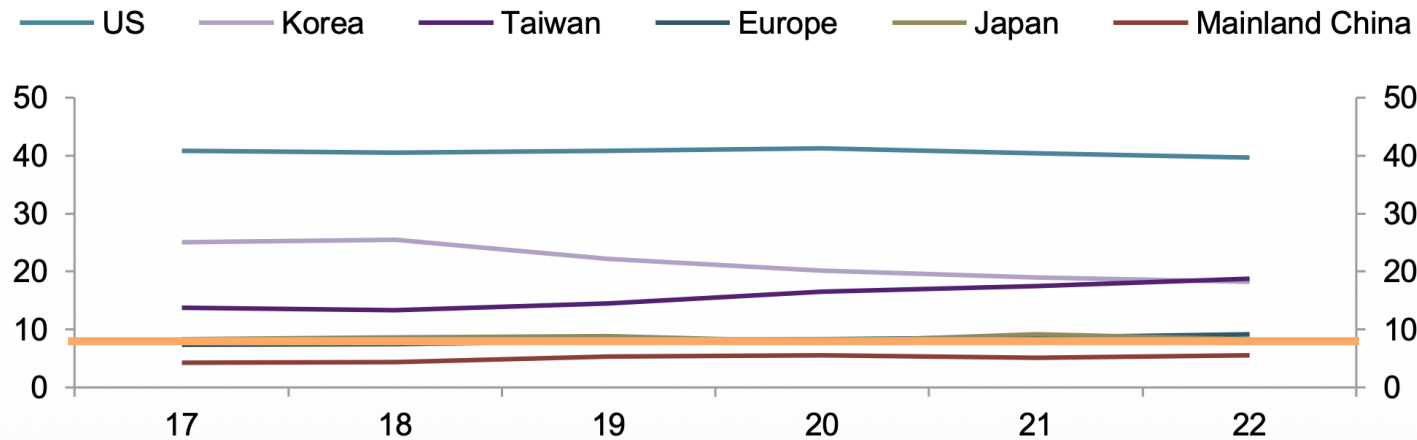
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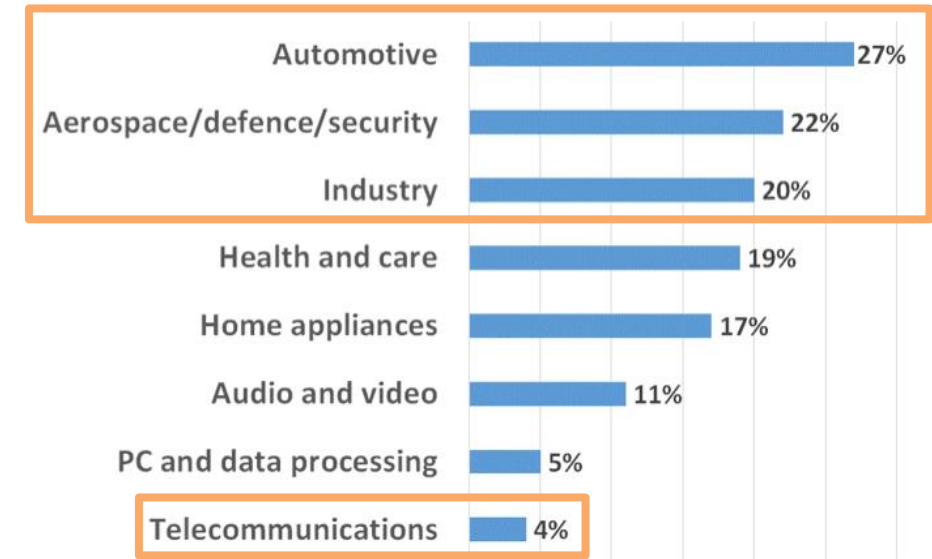
Global semiconductor manufacturing and value-chain landscape

Some observations (1)

- Europe's share in global fabrication capacity is below 10%, and in chip design below 2%
- Very low share of fabrication for telecommunications



Global market share of the semiconductors' supply chain
(design & foundries)

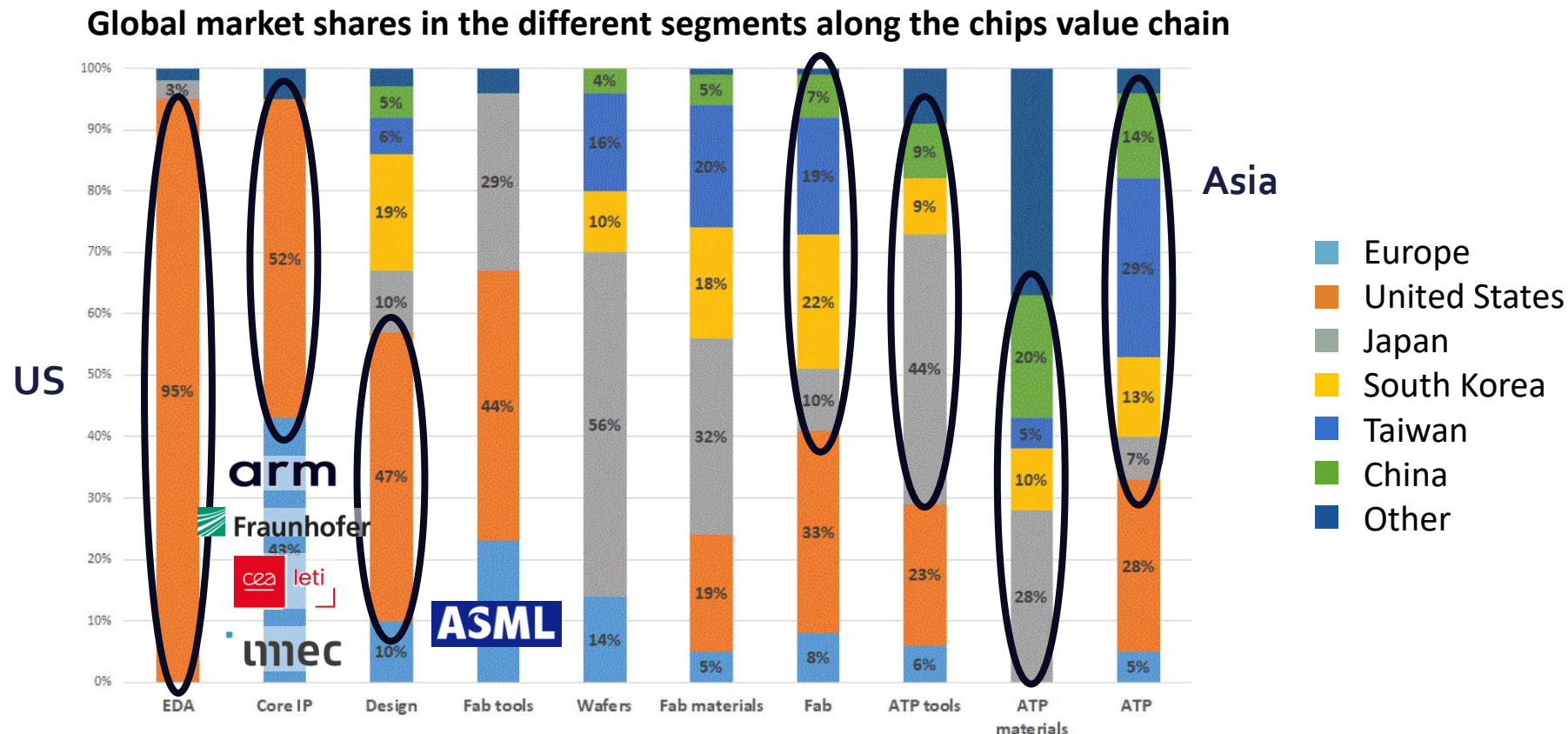


Europe's market shares in chips production for different sectors

Global semiconductor manufacturing and value-chain landscape

Some observations (2)

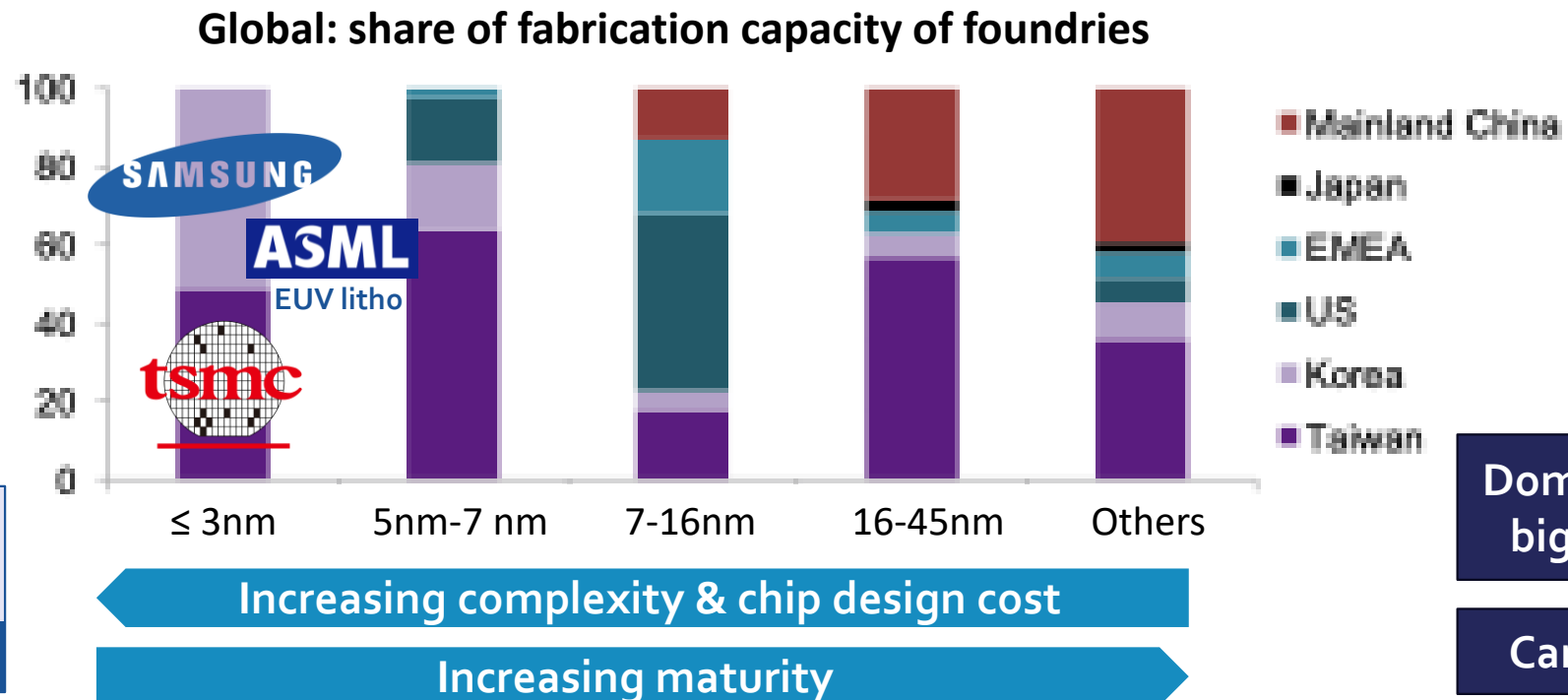
- Heavy reliance on the US for design and on Asia for manufacturing!
- EU is strong in the provision of fabrication tools and core IP blocks, but lags in many other segments



Global semiconductor manufacturing and value-chain landscape

Some observations (3)

- For advanced technologies (the 7- and 5-nm nodes), 100 % of global capacity is based in East Asia (Taiwan and South Korea).
- Only TSMC (Taiwan) and Samsung (South Korea) can manufacture chips at 5nm, and the global economy relies on Taiwan for 92 % of the production of these chips.



Dominance by a few big global players

Can EU compete?

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No interest from big global players to open up black box for small volumes!



Black box

VS



White box

Time to move away from 'economies of scale' law to realize focused complexity

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Coverage	Indoor (80-90% traffic)	Outdoor (10-20% traffic)	Indoor & outdoor (multi-RAT, multi-segment)

Why ignoring Wi-Fi –based research and innovation in EU, while more and more traffic is carried by Wi-Fi?

Coverage (and reliability) is limited by spectrum/regulation, not by technology

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Deployment	Global interoperability Endless backward compatibility		Local private networks Greenfield deployment, customization (fit for purpose)

Endless backward compatibility is blocking innovation and not a prime concern in private deployments

Have we reached a dead end for
wireless innovation in Europe?

Today's research & Innovation in Europe today

■ Shaped by global players in Europe

- [*Fabrication tools*: ASML (EU Chips Act and Chips-JU)]
- *Wireless connectivity*: Nokia, Ericsson (SNS-JU, CELTIC-NEXT...)
 - Focus on infrastructure and software: cloudification, virtualisation, disaggregation, decoupling...
 - Limited focus on low-level wireless technology enablers and end devices: no EU global players

Blocking factor for guaranteeing End-to-End connectivity performance!

■ Focus on large volumes

- [*Fabrication tools*: focus on data centers for AI & optical interconnect]
- *Wireless connectivity*: main focus on eMBB infrastructure, no progress with URLLC

Complex one-size-fits-all ecosystem cannot meet specialized connectivity needs

"Chicken-and-egg" problem: not investing too far ahead of demand

<https://www.politico.eu/article/europeans-missing-out-5g-data-shows-smartphone-internet-innovation/>

5G deployments are only affordable for larger enterprises, not for 99.8% of small and medium-sized enterprises in EU, employing about 2/3 of the active population

https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Structural_business_statistics_overview:

Or is this an opportunity to reshape the future?

Reshaping the future for wireless research & innovation

Yes, we can!

- We must recognize that
 - **Requirements** of professional environments are not (always) the same as consumer ones.
 - **Local operation** is more important than endless backwards compatibility: all we need is a **limited set of relevant features** promoting predictable and stable behaviour
 - There is no innovation without **transparency**: no black-box behaviour, but white-box behaviour, enabling fine-grained control and customisation
 - Small, medium, and mid-size enterprises need **affordable** connectivity solutions
 - We cannot ignore **Wi-Fi** as a complementary technology for 5G
- No more prejudices
 - There is playground for **specialized communication solutions and chips**
 - **Move away from 'economies of scale'** thinking and invest in **sovereign solutions** that can be designed and produced in smaller volumes in Europe
 - We have, besides cloud, software and AI, also **chip design and system-level competences** in Europe to build end-to-end connectivity solutions

Small-scale innovation today can have a global impact on a large scale in future



Wi-Fi innovation platform
for End-to-End specialized connectivity



UNDERSTAND



Usage and management of new features is left open.

Complex to assess real-life impact at design time.



INNOVATE



TSN Time Sensitive Networking
Powered by IEEE 802

A viable candidate for wireless TSN

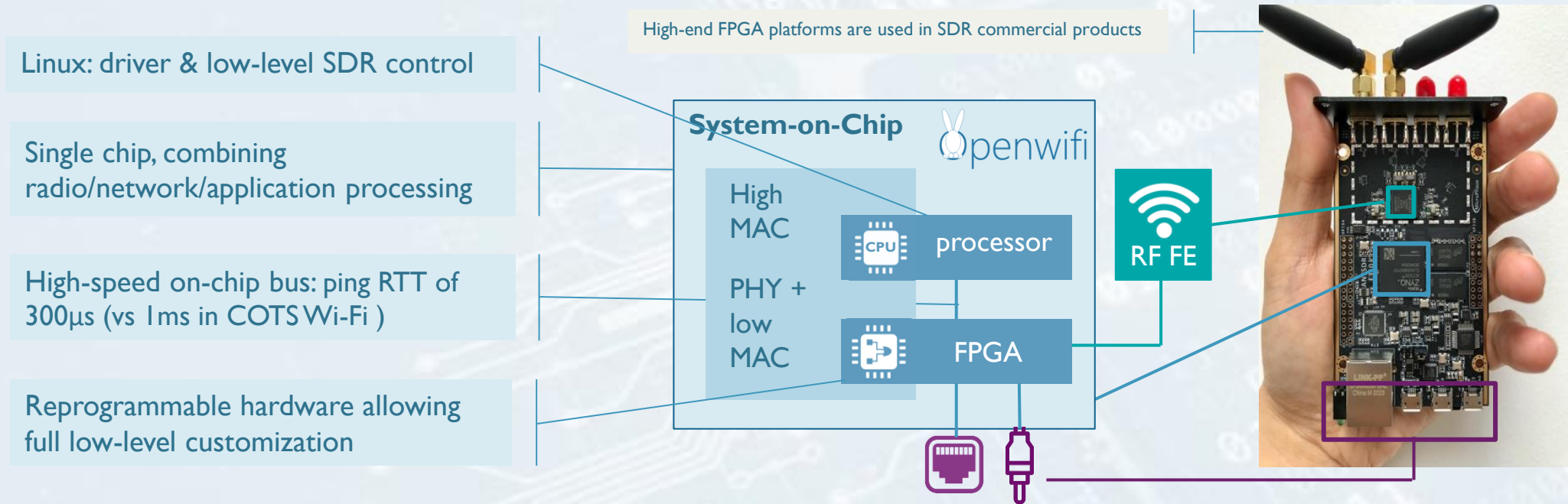
- High data rate for fast Tx
- Natural extension of IEEE 802.1 TSN
- New features addressing TSN needs
- Cost-effective, lightweight architecture
- No indoor environment without Wi-Fi
- Can run in local licensed spectrum



New capabilities beyond communication such as localization & sensing.

Customizable Wi-Fi running on system-on-chip FPGA platforms

White-box full-stack design: from digital baseband to linux driver

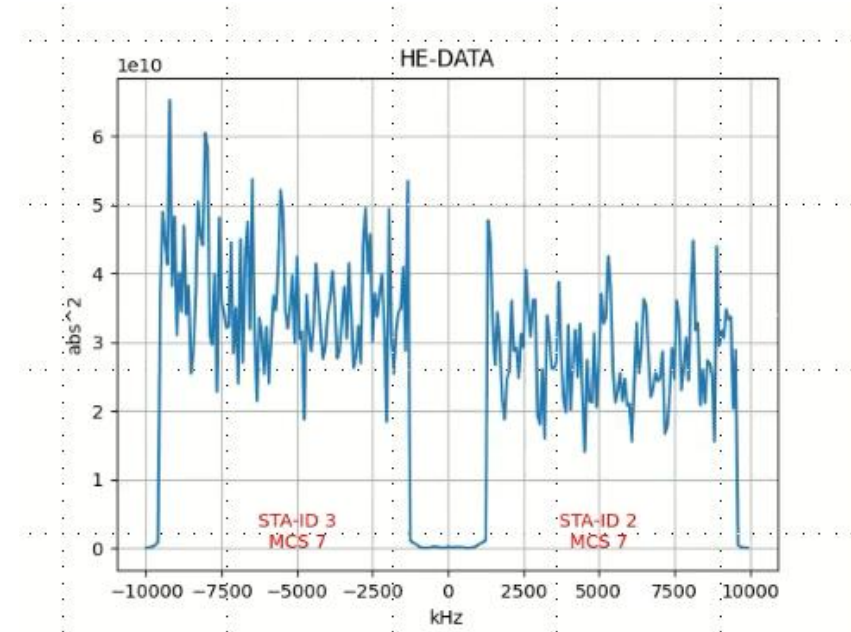
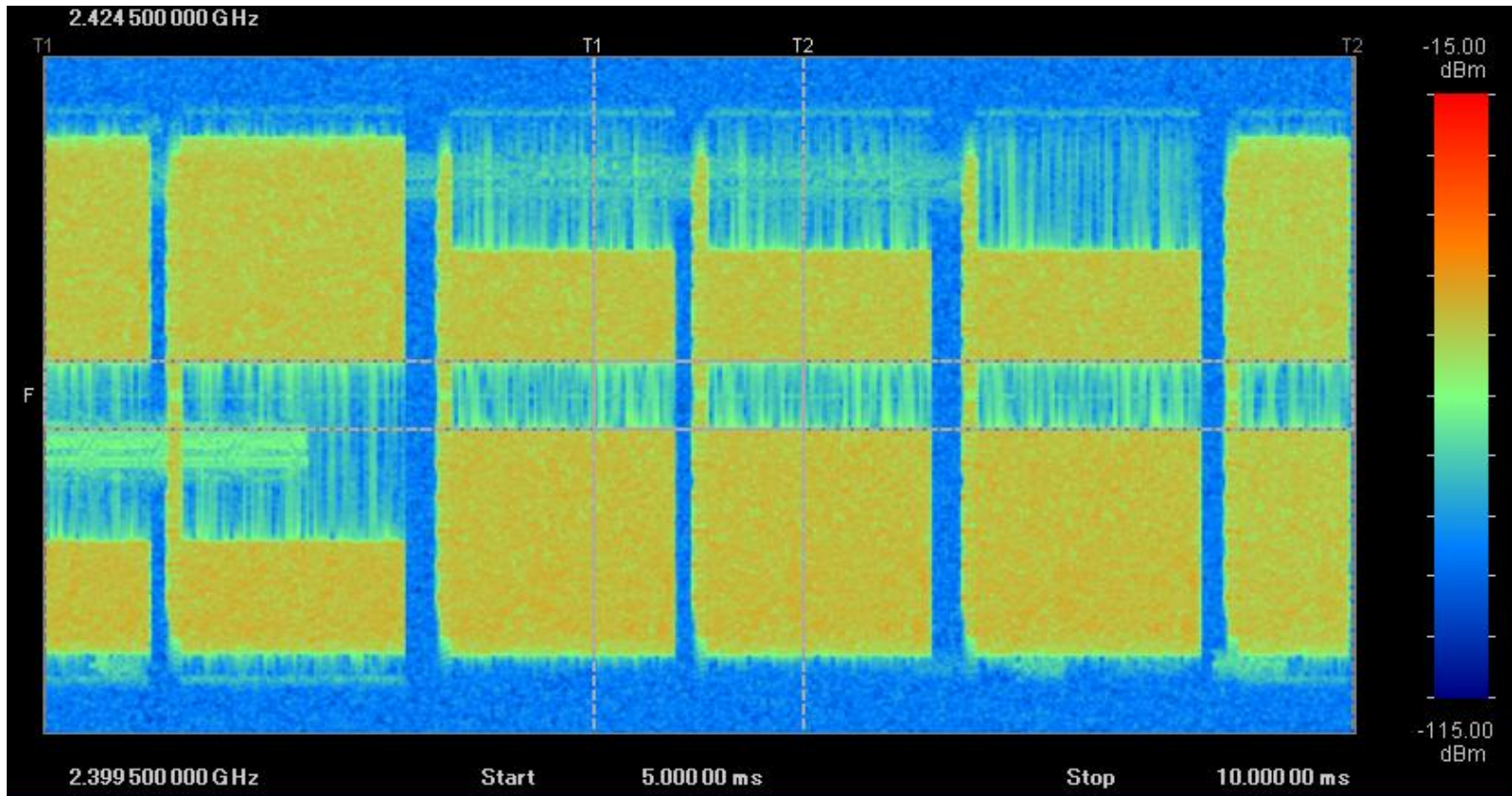


Baseline openwifi implementation: subset of Wi-Fi features available under AGPLv3 (<https://github.com/open-sdr/openwifi>)

Selected standard-compliant + advanced pre/non-standard (TSN) features: available via subscription model (<https://openwifi.tech>) & bilateral collaborations

Multi-User OFDMA - Flexible control beyond black-box COTS

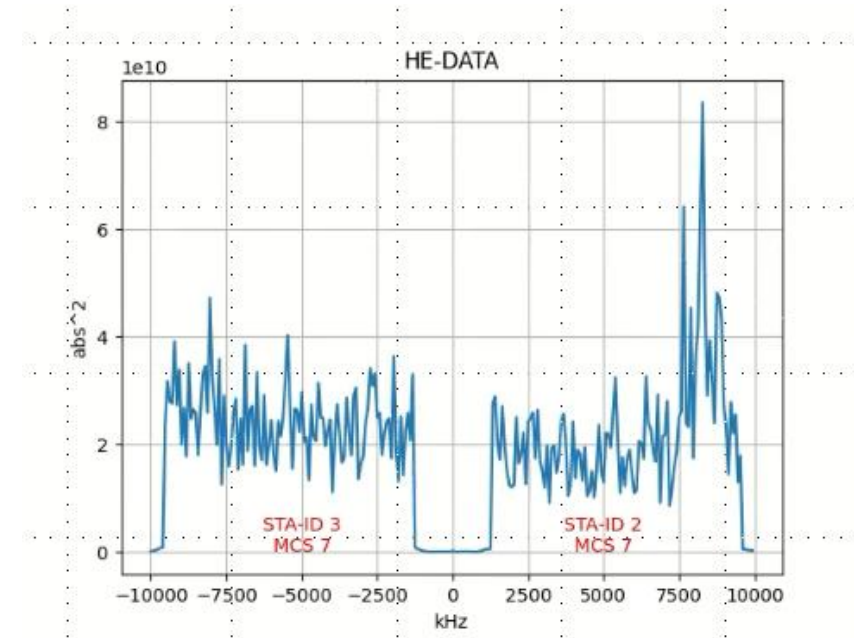
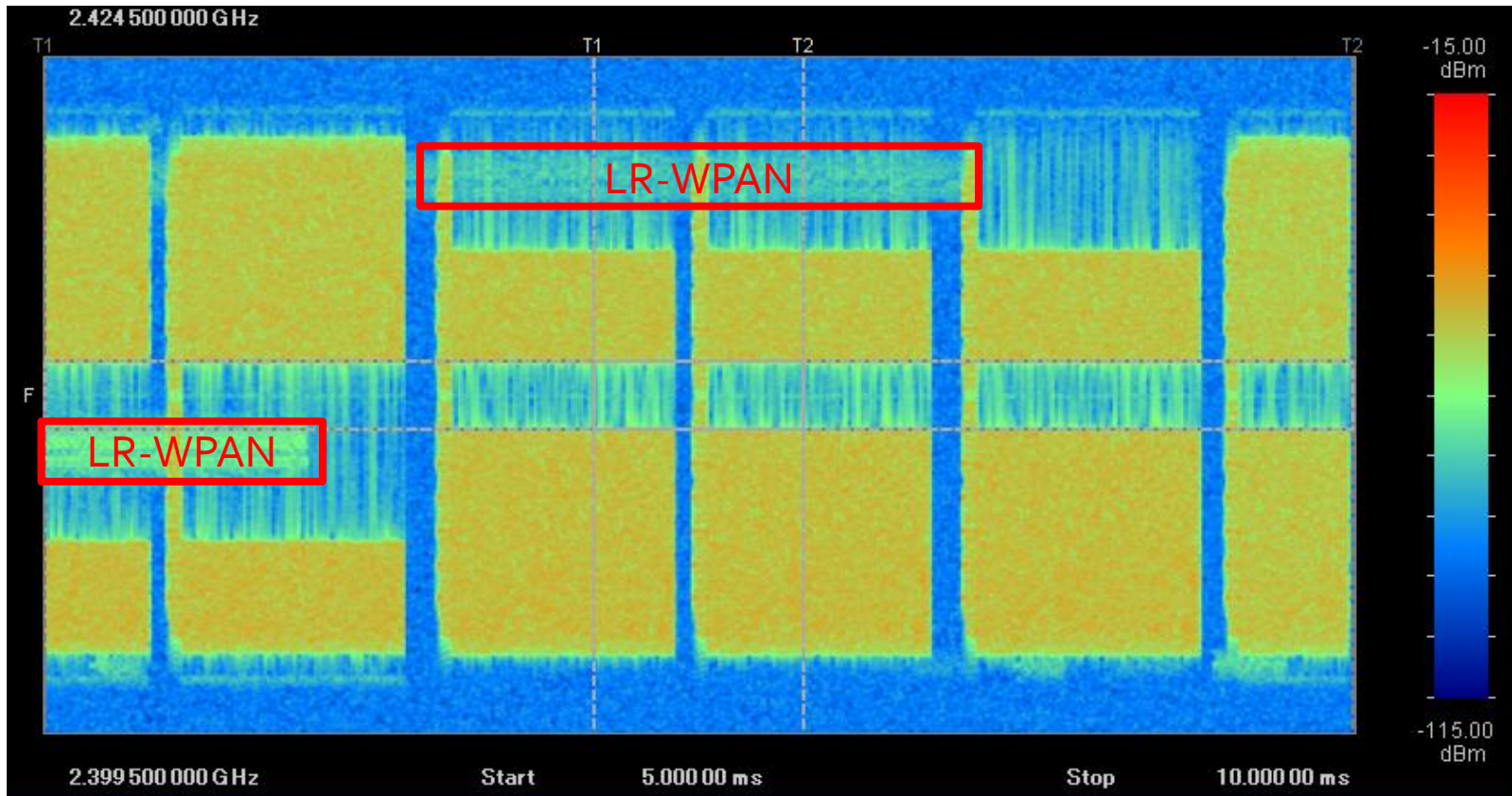
Cross-Technology Interference Awareness



No interference: 4 Wi-Fi users

Multi-User OFDMA - Flexible control beyond black-box COTS

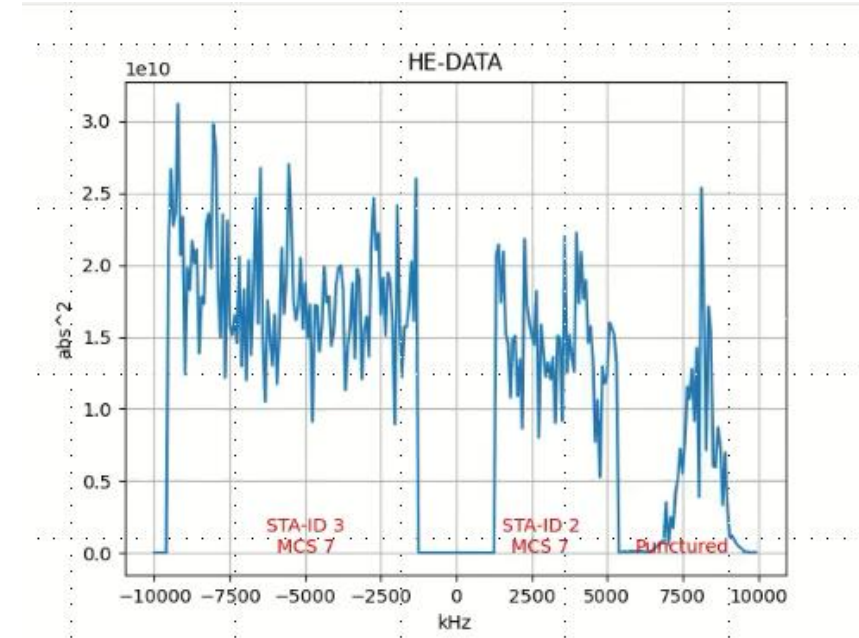
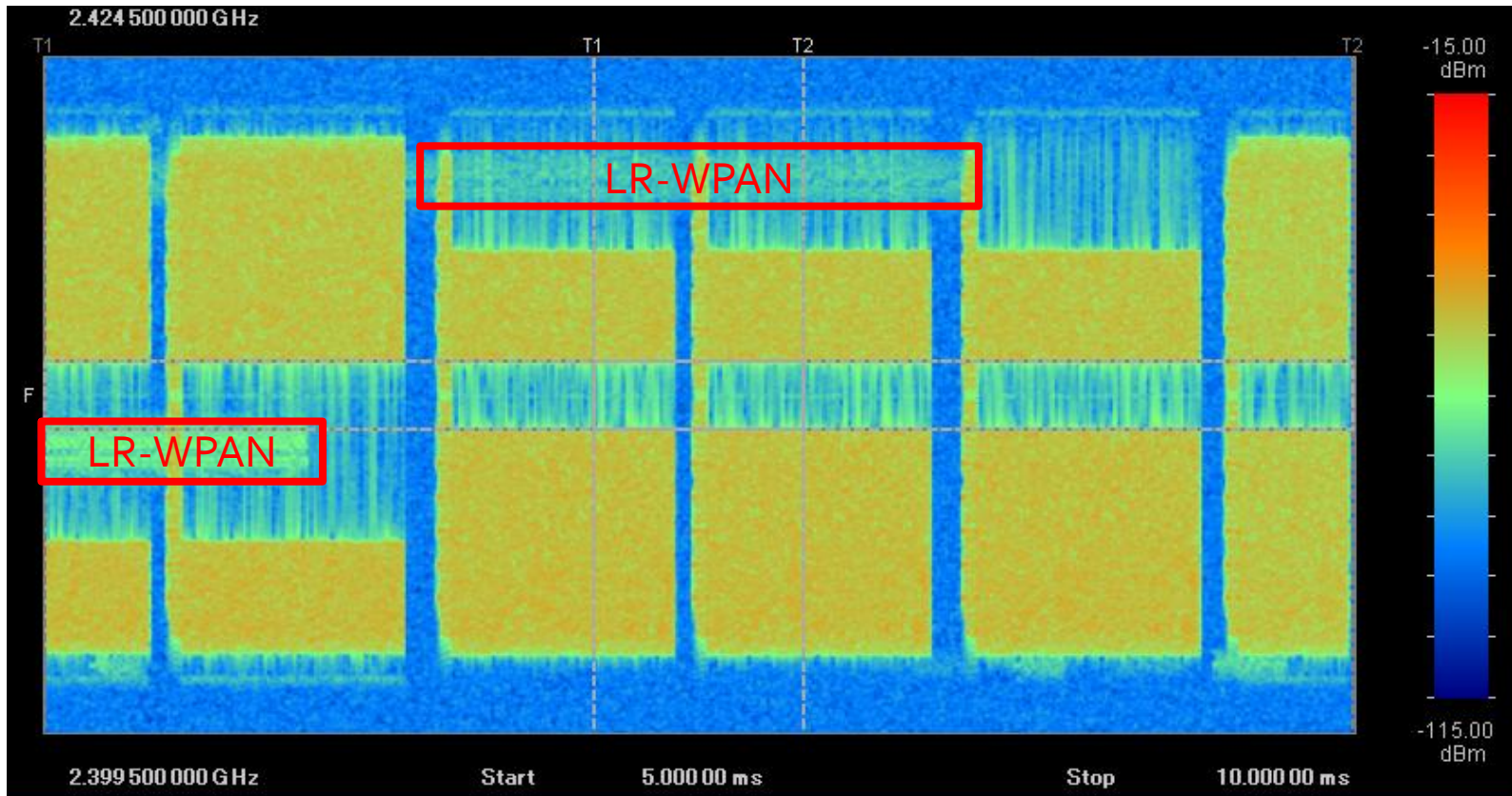
Cross-Technology Interference Awareness



Detection of narrowband interference

Multi-User OFDMA - Flexible control beyond black-box COTS

Cross-Technology Interference Awareness for improved coexistence



Mitigation of interference by
RU puncturing and RU re-allocation

Wireless Time-Sensitive Networking (TSN)

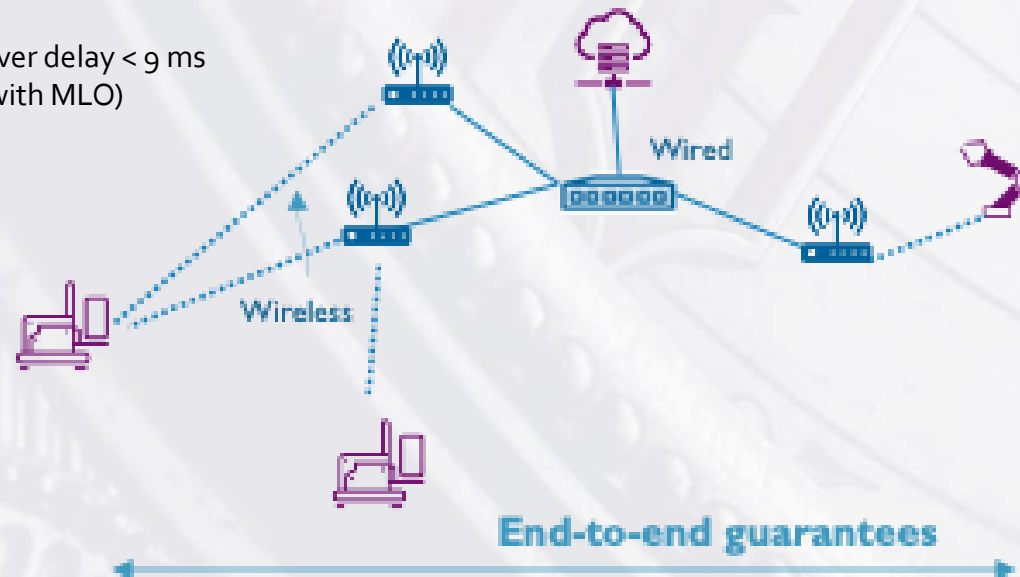
Advanced non/pre-standard features



► Bounded E2E latency < 3.25 ms



► Handover delay < 9 ms
(0 ms with MLO)



Controller



-  Time synchronization with < 1.5 μ s accuracy
-  Flexible gating & over-the-air scheduling
-  Low-level (time-aware) configurability
-  Impactless bootstrapping
-  Seamless mobility (< 10ms) with determinism
-  In-band telemetry
-  Micro-services-based network controller (management, monitoring,...)
-  User interface

Driver/SW



FPGA¹



openwifi

Patent

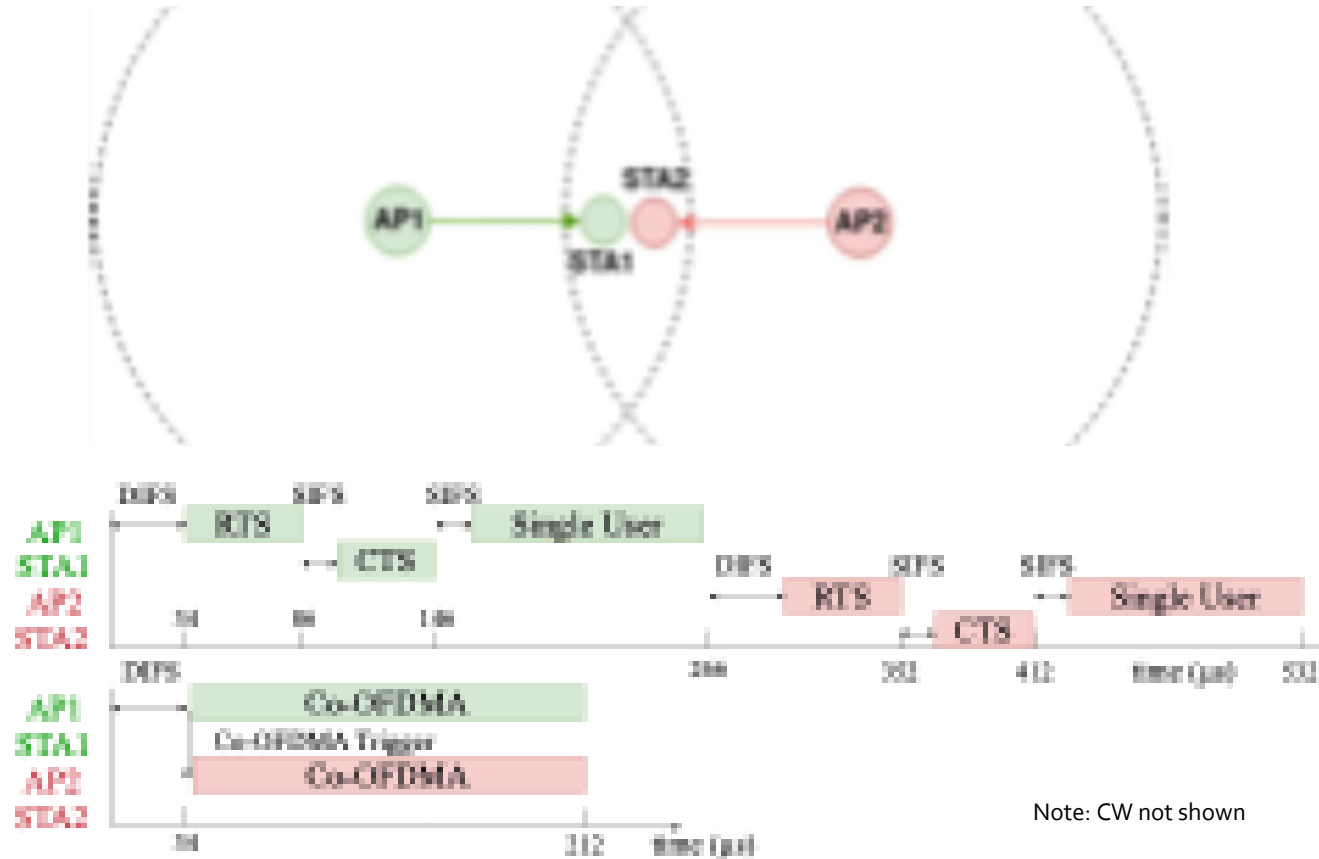
1. Communication hardware virtualization (EP4026384)

Filed patents

1. Device and Method for clock synchronisation in a wireless network
2. Impactless association in a wireless time-sensitive network
3. Impactless hand-over in a wireless time-sensitive network

Coordinated OFDMA (Wi-Fi 9)

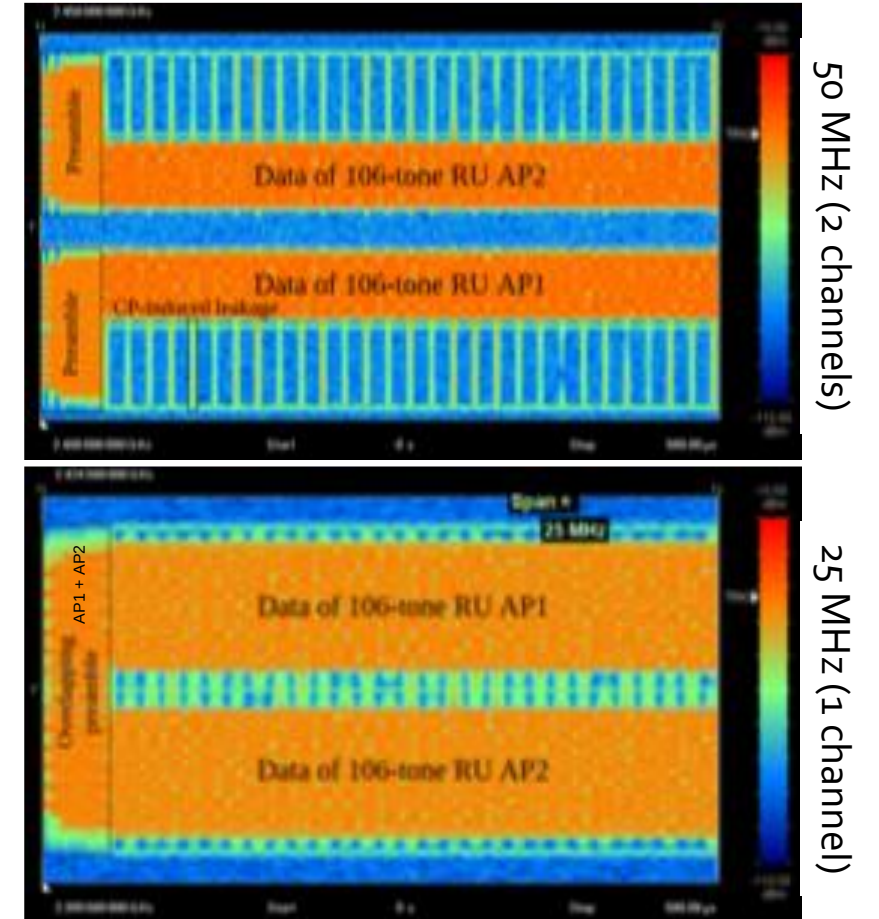
Anticipating new standards: enabled by TSN



Note: CW not shown

Thijs Havinga, Xianjun Jiao, Wei Liu, Baiheng Chen, Robbe Gaeremynck, Ingrid Moerman, WiNTECH '25, Proceedings of the ACM Workshop on Wireless Network Testbeds, Experimental evaluation & Characterization, pp 41-48, **Best paper award**

OFDMA



co-OFDMA

< 50 ns synchronisation accuracy across APs

Start small, think big - Let's build EU sovereign wireless technology & End-to-End systems!

Many remaining challenges for high-performance wireless connectivity

- Specialized front-end design
- Chip architectures promoting flexible design (e.g. chiplets)
- Software – hardware co-design
- Time-Sensitive Networking
- Resilience
- Trustworthy (edge) AI
- Hardware-supported security
- End-to-end, system-level PoC validation in realistic environments
- ...



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