Running out of time

Jeroen Hoebeke,
Ingrid Moerman

4th Visions of Future Communications Summit
Nov. 7-8, Lisbon

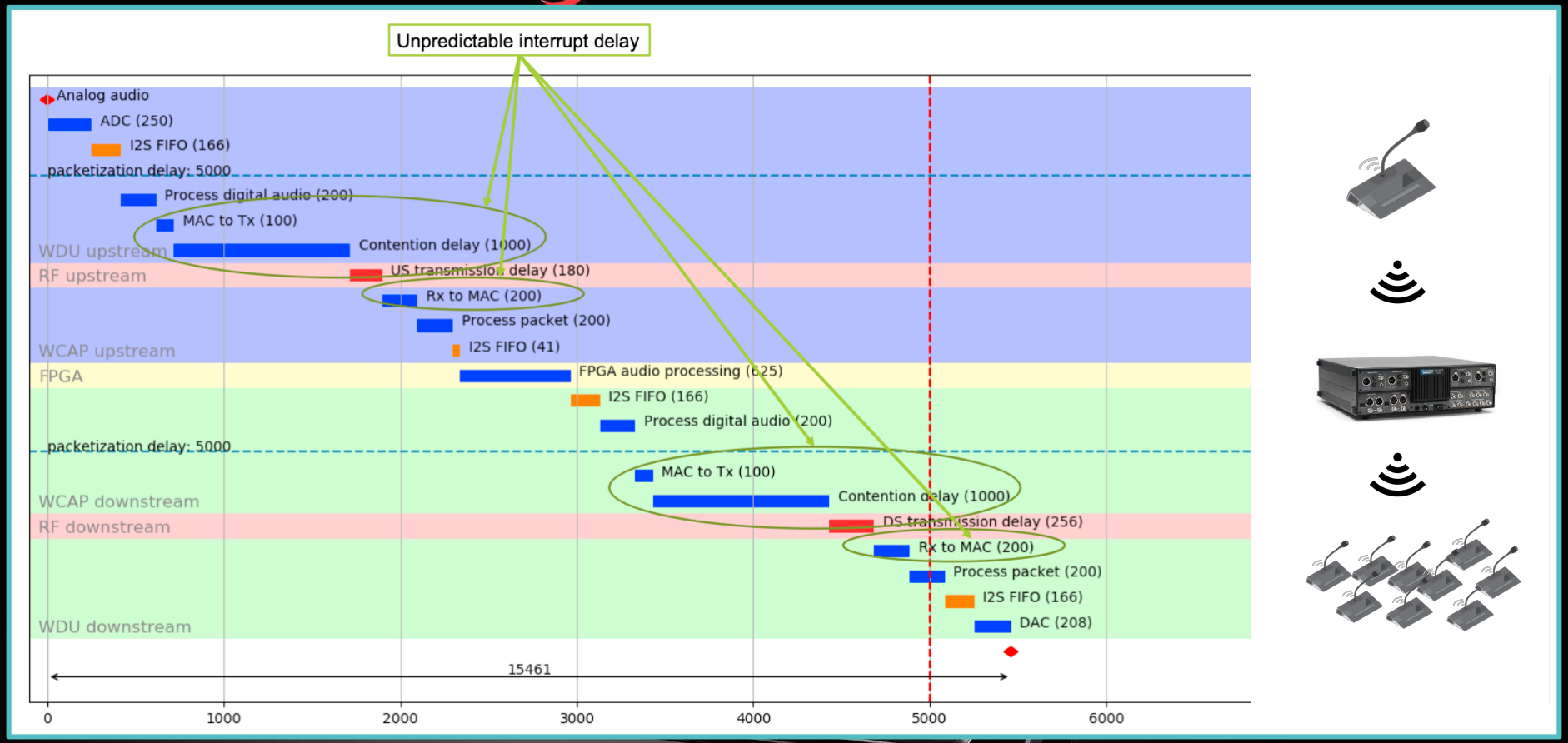
IDLAB, IMEC RESEARCH GROUP AT GHENT UNIVERSITY AND ANTWERP UNIVERSITY

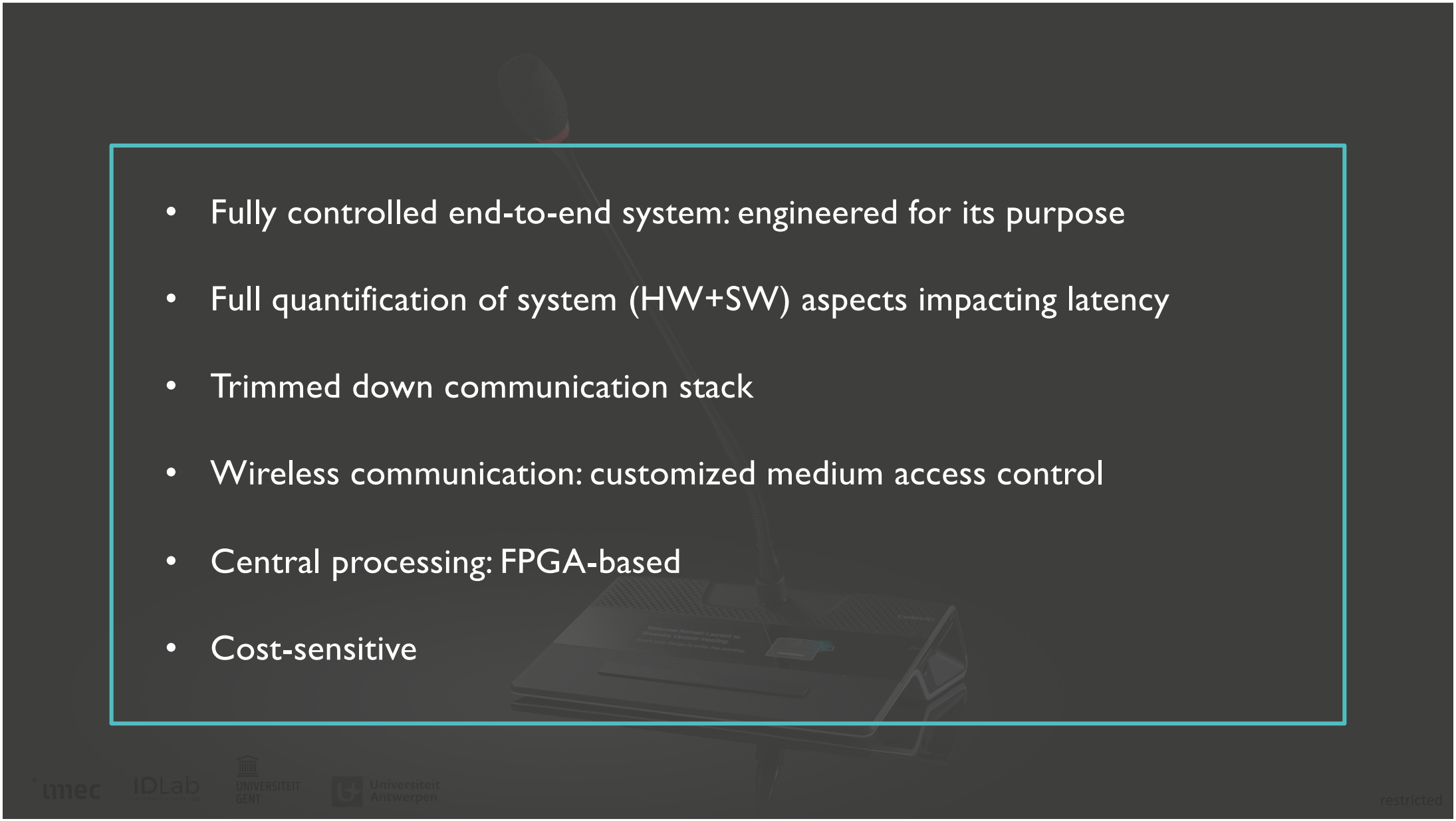

Deterministic communication systems
time-sensitive — reliable/safe - predictable

televic

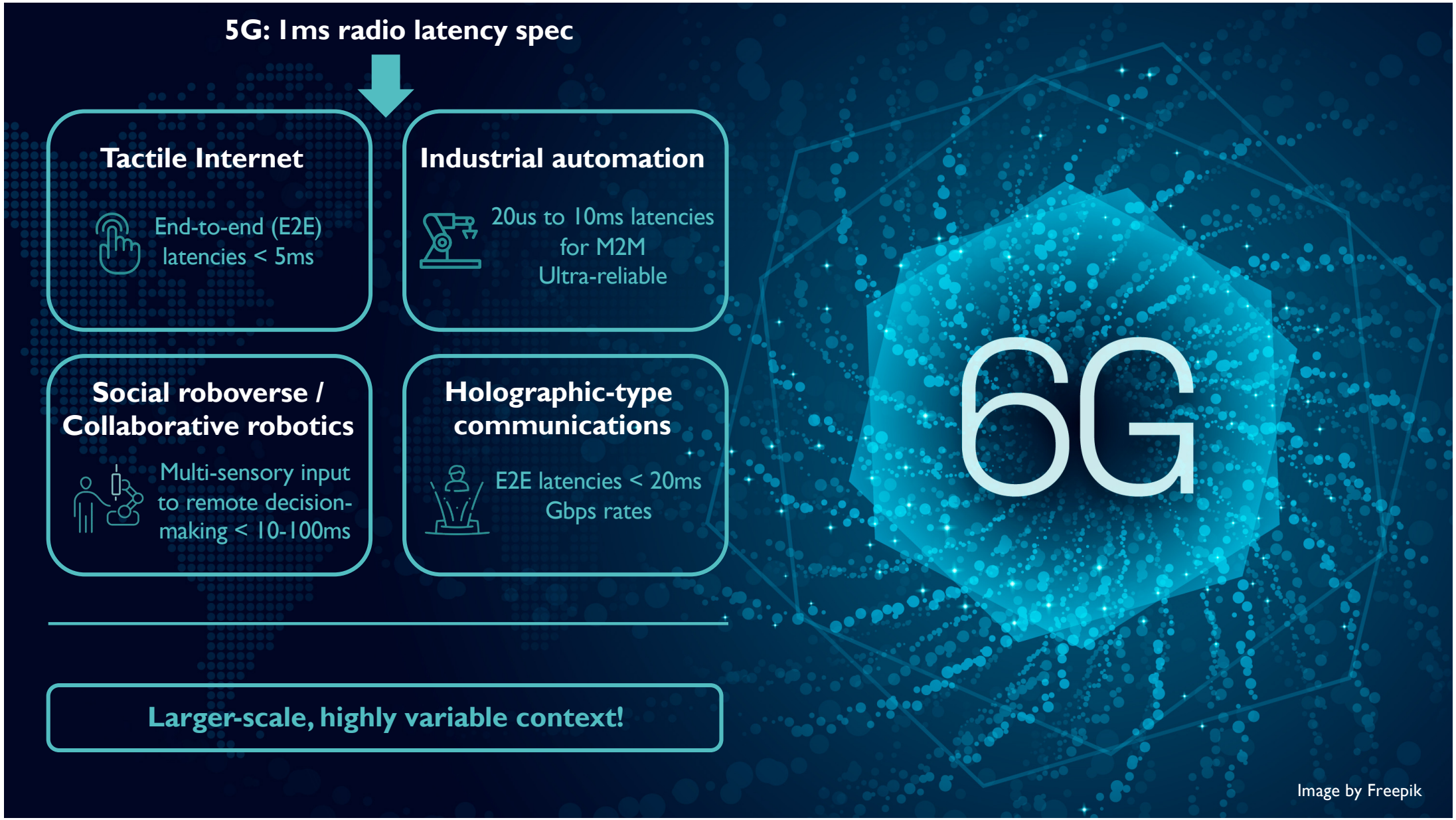

Welcome Romain Laurent to
Biweekly: Update meeting.
Insert your Badge to enter the meeting.
televic

Audio processing and transmission time schedule



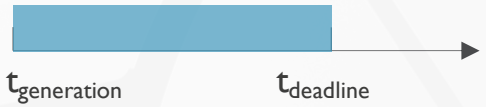


- Fully controlled end-to-end system: engineered for its purpose
- Full quantification of system (HW+SW) aspects impacting latency
- Trimmed down communication stack
- Wireless communication: customized medium access control
- Central processing: FPGA-based
- Cost-sensitive

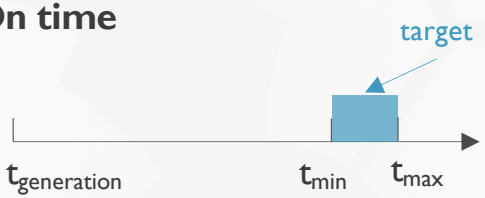

5G: 1ms radio latency spec
Tactile Internet
End-to-end (E2E) latencies < 5ms
Industrial automation
20us to 10ms latencies for M2M Ultra-reliable
Social roboverse / Collaborative robotics
Multi-sensory input to remote decision-making < 10-100ms
Holographic-type communications
E2E latencies < 20ms Gbps rates
Larger-scale, highly variable context!
6G
Image by Freepik

Mastering every aspect of time

In time

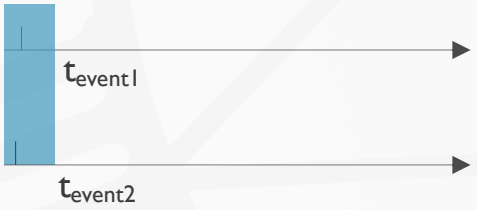


On time

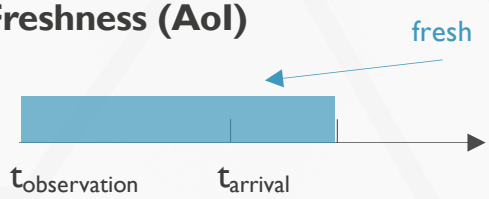


Granularity / clock types

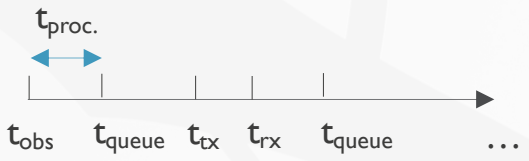
Simultaneity / causality



Freshness (AoI)



Latency breakdown



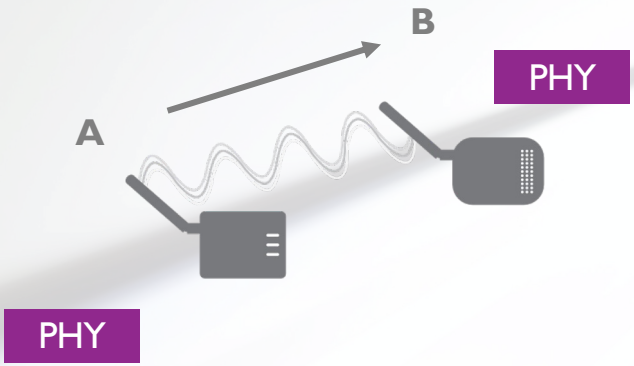
-
-
-

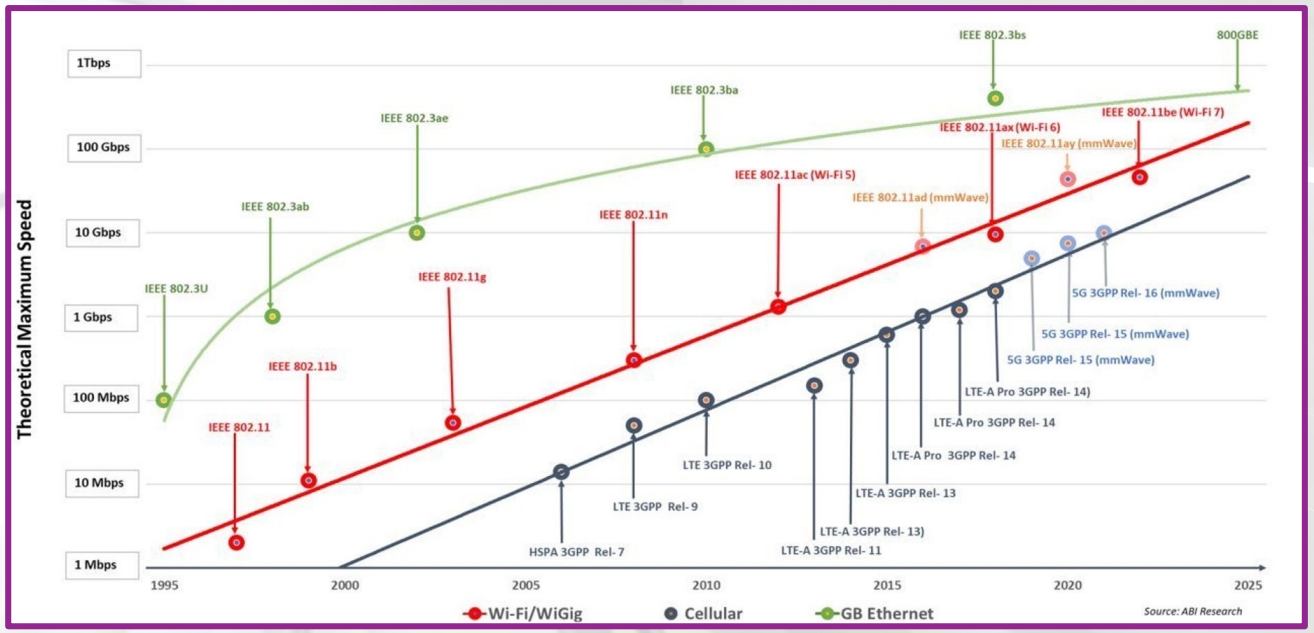
imec IDLab INTERNET & DATA LAB UNIVERSITEIT GENT Universiteit Antwerpen


Are we on track?

The wireless link

Continuous increase in peak data rates → low Tx latencies





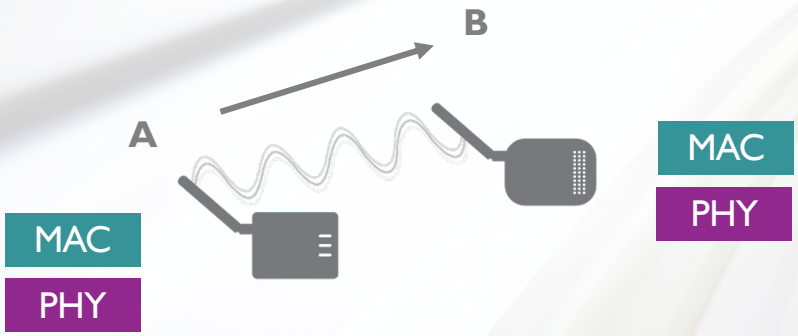
More to come: massive MIMO, THz wireless, RIS/IRS, JC&S…

The wireless link

Continuous increase in peak data rates → latency reduction?

Peak data rates only exist in a perfect (PHY) world.

Signalling overhead, rate versus distance, MAC complexity, coordination & joint processing, guaranteed latency (considering reliability), efficiency, protocol overhead / packetization, scheduling granularity, propagation characteristics of the environment, etc.



BRIDGE PHY-MAC GAP

- Benefits at PHY might come with complexities at MAC
- Co-design to properly understand latency trade-offs

TIME-AWARE KPIs

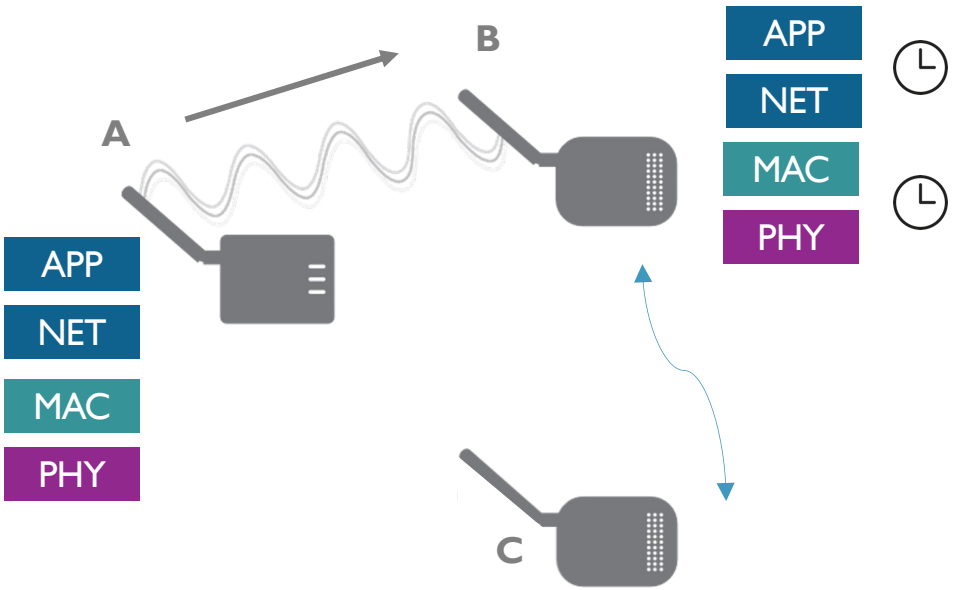
- Beyond PHY data rate
- Considering broader context
- Breakdown

BENCHMARKS

Quantify latency gains of new technologies

- Under realistic conditions
- Against 'legacy' systems

Wireless end device(s)



Deterministic application behavior (generation time, processing)

Aligned with network timings (per device, across devices)

Support for (intra/inter)flow differentiation and simultaneity

Limits of COTS (mass-market) HW, APIs and stacks

NOTION OF TIME

- Down to devices: accurate time synchronization as a network service
- Understanding of deterministic network capabilities (net → app)

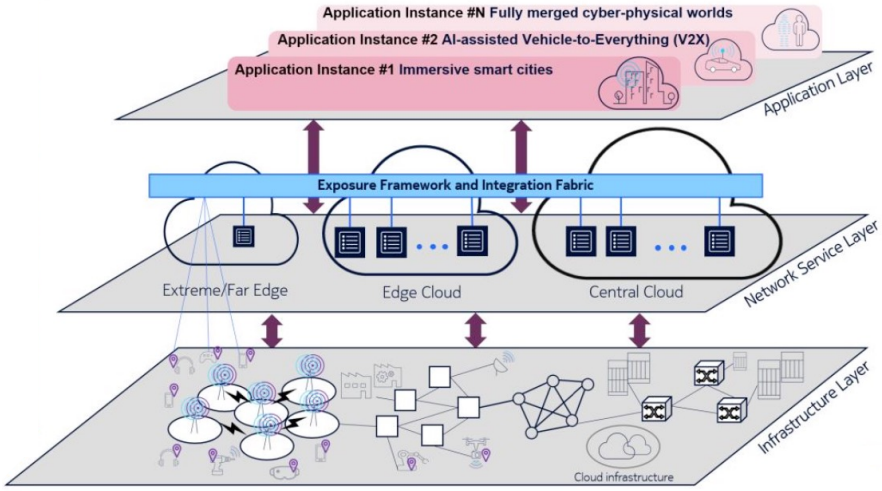
APP & PROTOCOL DESIGN

- Predictable behavior
- Versatile packetization
- Adaptable to NW constraints (app → net)
- Lightweight

SYSTEM DESIGN

- More open chip design
- Co-design: HW-SW, processing + communication
- Interplay TS / non-TS components
- Skilled engineers

The end-to-end system



Source: Hexa-X D1.3 – Initial E2E architecture

- Cloud-native, softwarization and service-based architecture
  Guaranteed execution times?
- Generalized, multi-purpose architecture
  Unnecessary complexity (and latency)?
- Traversal of different networks, possibly intermediate processing
  Protocol translations, how to oversee timings?

NOTION OF TIME

- Network of timelands: interconnected networks having same notion of time
- Support for various flavours of time: in-time, on-time, simultaneity, etc.

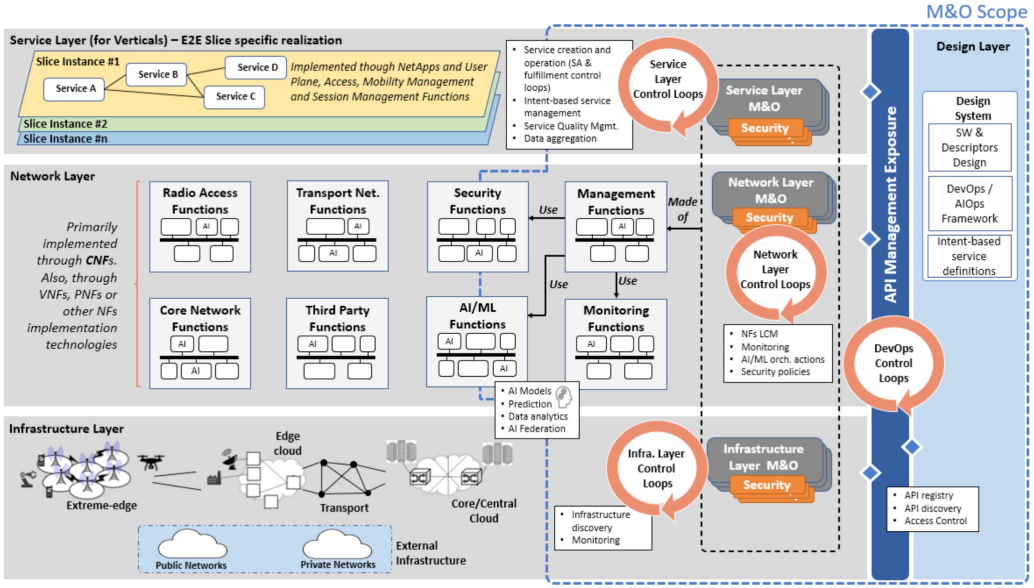
DETERMINISTIC END-TO-END

- Deterministic computing: bounded execution time of communication and computing services
- Hardware accelleration / HW programmability

5GRedCap → xGRedNet/SpecNet

- Lean, lightweight architecture
- Trimmed down architectural & protocol complexity
- Fit-for-purpose

The management



Source: Hexa-X D6.2 – Management and orchestration system – Structural view

- Cloud-native, softwarization and service-based architecture
  Determinism in control plane decisions?
- AI/ML-based network management
  Avoid unwanted side-effects on deterministic flows?
- Monitoring
  Continuous verification of timing requirements?

VERIFICATION

- Pre: predict packet forwarding latencies
- During: actual flow treatment (in-band)
- Post: expose analytics
- Using end-to-end notion of time

DETERMINISTIC CONTROL PLANE

- QoM: prioritization of management decisions
- Bounded execution time of mgmt
- Timescale = timescale data plane, or proactive

FLAWLESS AI/ML

- Guarantee any undesired side effects on deterministic flows
- Explainability
- No training in operational network: Digital Twin Network

The standardization, innovation and adoption

- Mass market first
  High-end low volume markets?

- Ever-increasing feature sets / implementation complexity / backwards compatibility
  Large telco network ≠ private network / hampers entrance new market players / overshooting / cost

- At market time: closed commercial products
  Black box not having right features/level of control

FIT-FOR-PURPOSE

- Downsize number of features: master complexity, whilst fit for the job
- Flavours: baseline + selected features (cfr. profiles)

EARLY PROOF

- Early prototyping and system validation against requirements
- Cfr. IETF: consensus + running code

CUSTOMIZATION & INNOVATION

- No black box: richer APIs/control, programmability (SDR)
- Open source / reference implementations


7 Guiding principles for
future deterministic communication systems

END-TO-END NOTION OF TIME

CO-DESIGN PHY/MAC, SW/HW, APP/NET, COMM./PROC., E2E

DETERMINISTIC CONTROL PLANE & FLAWLESS AI/ML

xGRedNet/ SpecNet: LEAN, FIT-FOR-PURPOSE SOLUTIONS

TIME-AWARE KPIs & BENCHMARKS

EARLY PROOF & VERIFICATION

OPEN INNOVATION, MORE WHITE-BOX DESIGNS

embracing a better life

imec IDLab INTERNET & DATA LAB UNIVERSITEIT GENT Universiteit Antwerpen