Differentiated Connectivity and Dependable Communication

Enablers in future Mobile Networks

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Driving mobile networks for new waves of innovation

1,000,000×
Data speed increase in 30 years

1G Local voice calls — 1980

2G Global voice calls and SMS — 1990

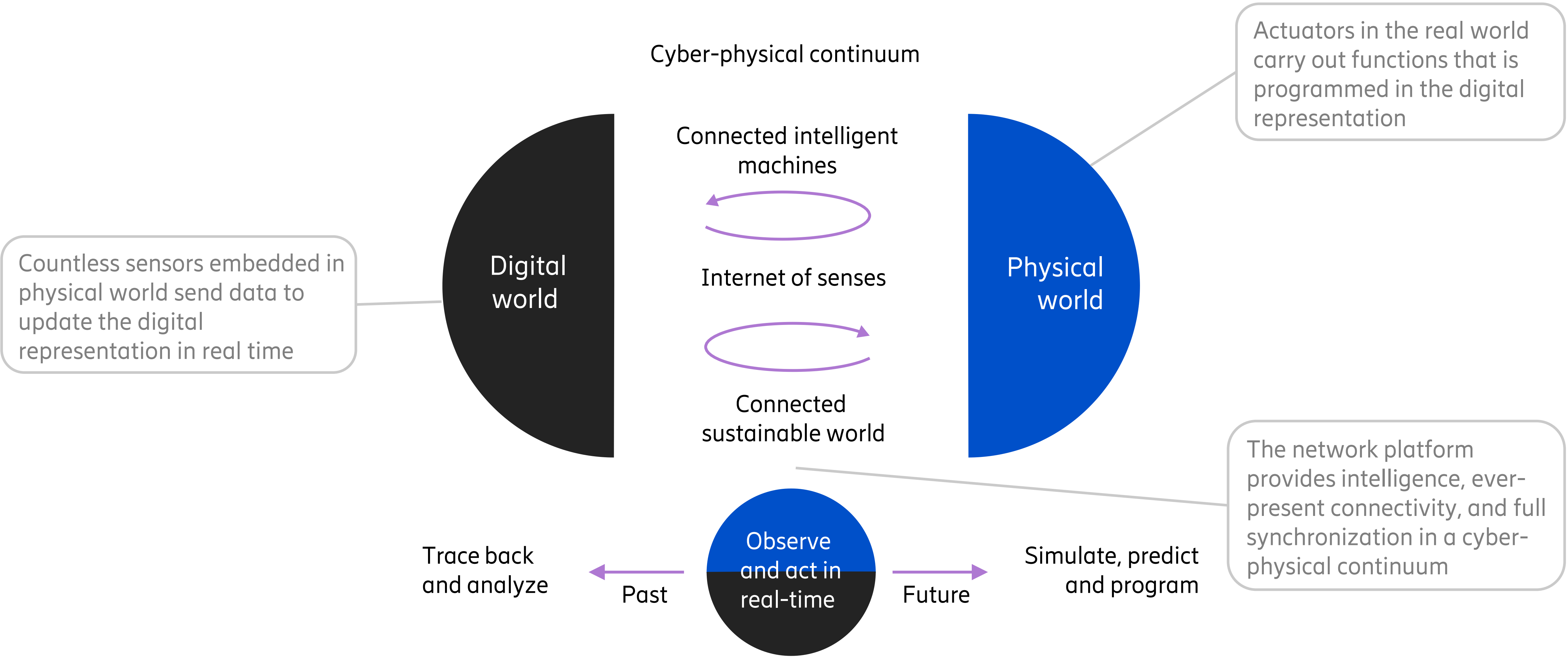
3G Mobile broadband — 2000

4G App economy — 2010

5G Digitalization of societies and industries — 2020

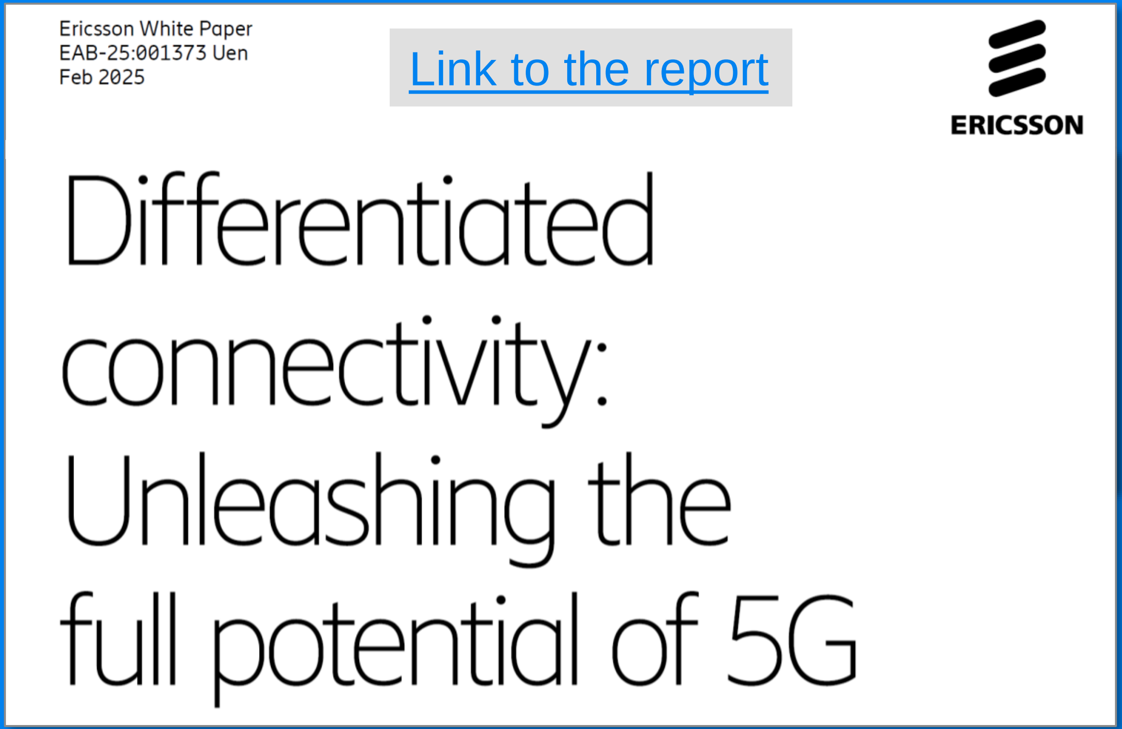
6G Cyber-physical interaction — 2030

Connecting a cyber-physical world



Read more in: [Ericsson 6G whitepaper (2024)]

Differentiated Connectivity


Ericsson White Paper
EAB-25:001373 Uen
Feb 2025

Link to the report

ERICSSON

Differentiated connectivity: Unleashing the full potential of 5G

Review of mobile networks status

- Mobile networks – a platform for innovation
  - Data rates have increased by a factor of 1.000.000 over 30 years

- Increasing dependence of society and enterprises on availability of mobile network connectivity
  - Immersive interactions, real-time digital twinning, mission-critical operations, …

- Mobile connectivity is, in essence, still a best-effort mobile broadband (MBB) service
  → limits innovation in applications

Review of mobile networks status

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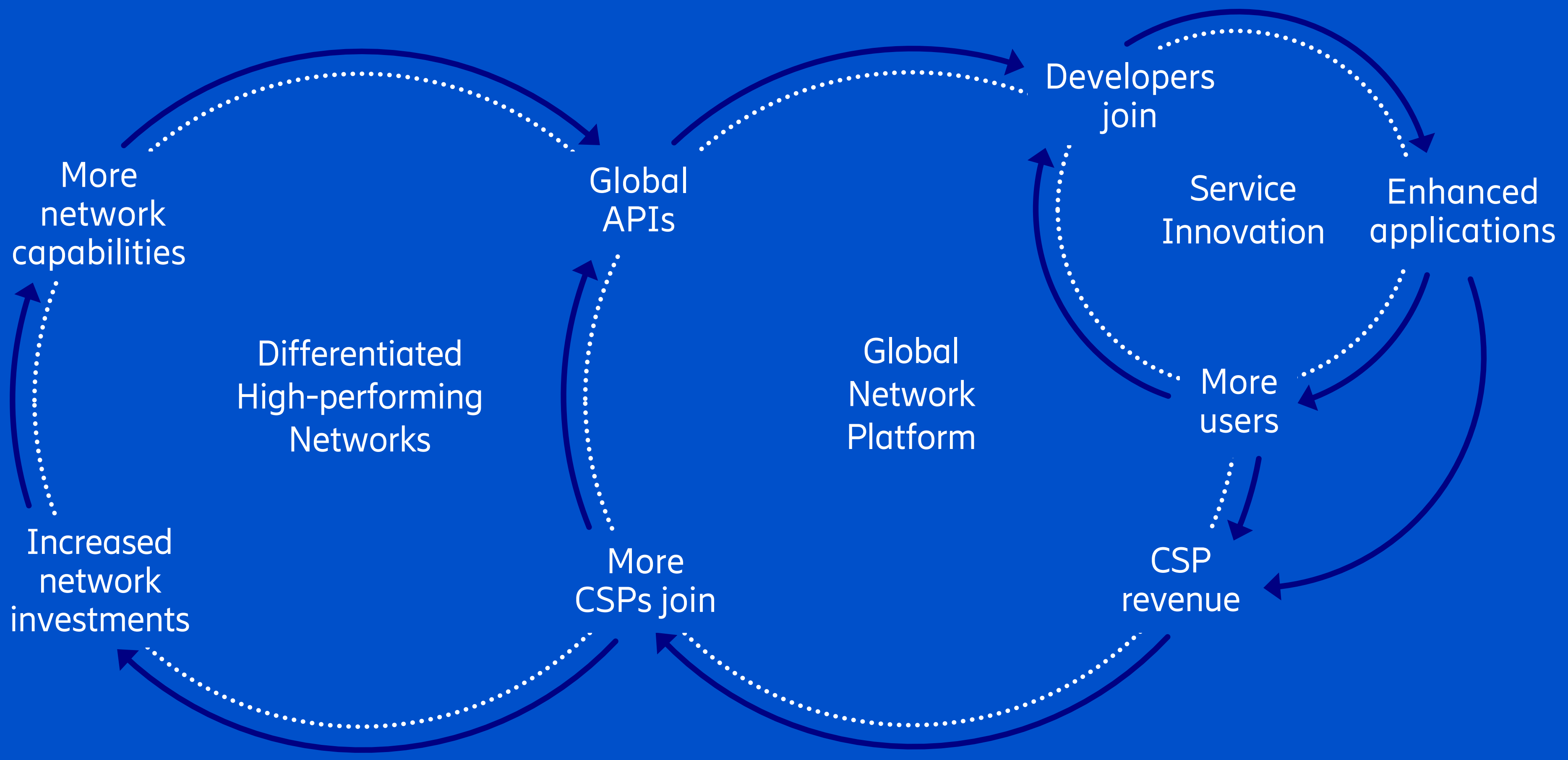
Programmable Networks: enable applications to utilize network capabilities and create application value

Ericsson industry vision - A network effect to accelerate industry growth



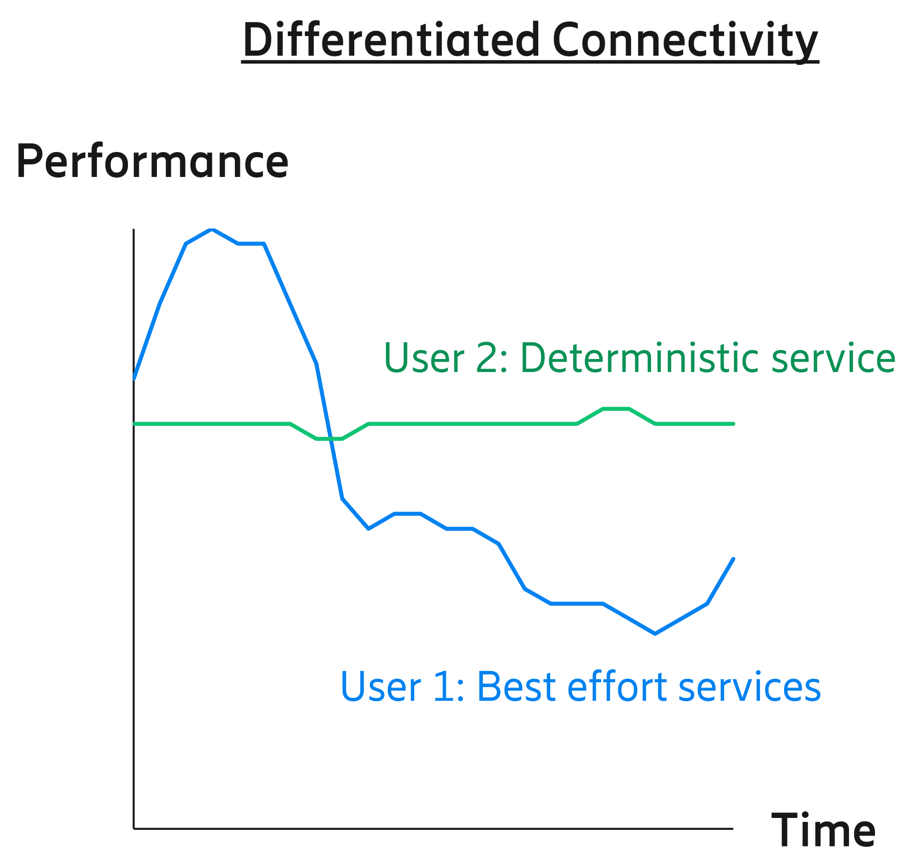
The need for performance

- Digitalization, electrification, and automation increase society’s dependence on high-performance mobile connectivity.
- For example, network capabilities such as Quality of Service (QoS), consistent throughput and bounded latency are required for
  - real-time cloud interactions,
    - from gaming
    - to real-time digital twinning
    - and extended reality (XR)

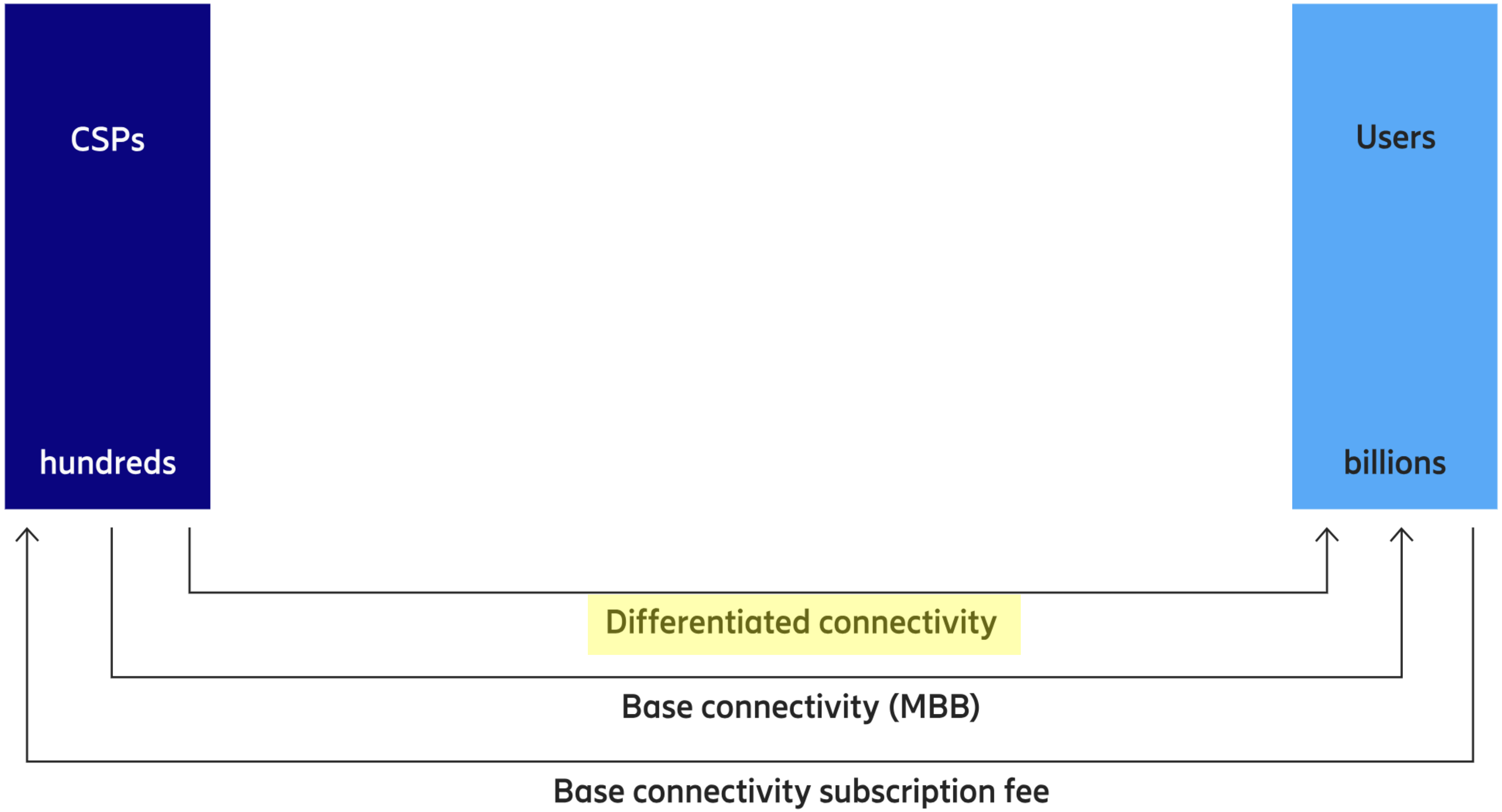
Differentiated Connectivity

- Network traffic with variety of traffic streams
  - Unique characteristics and requirements

- Differentiated connectivity: being able to meet the needs of different applications



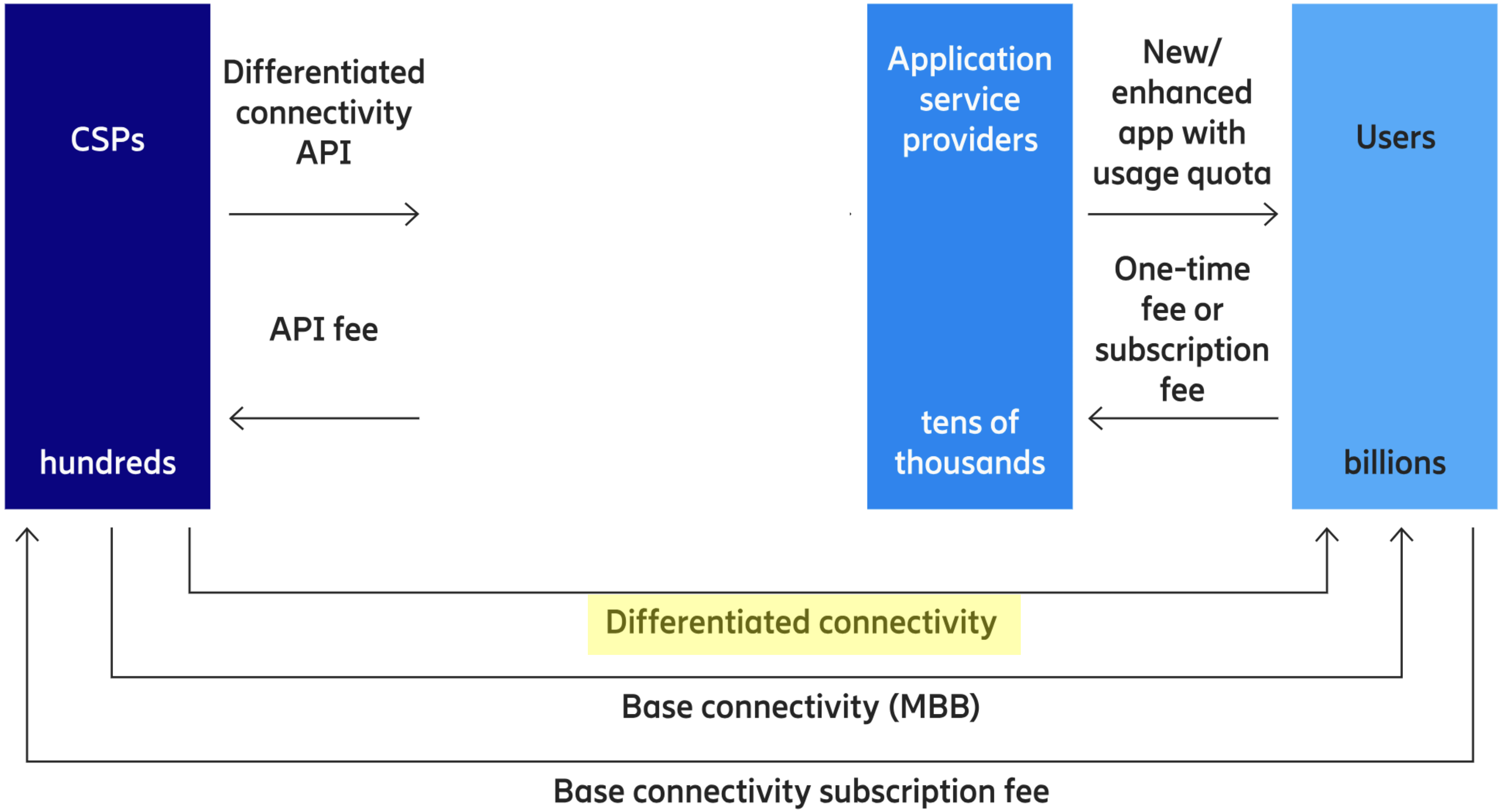
Differentiated connectivity: the business models



CSP - communication service provider

Differentiated connectivity: the business models

- Direct: from CSPs to
  - consumers
  - enterprises
  - E.g. via in-app purchase or subscription
- Indirect: from CSP to
  - App developer (with in-app or app subscription premium)



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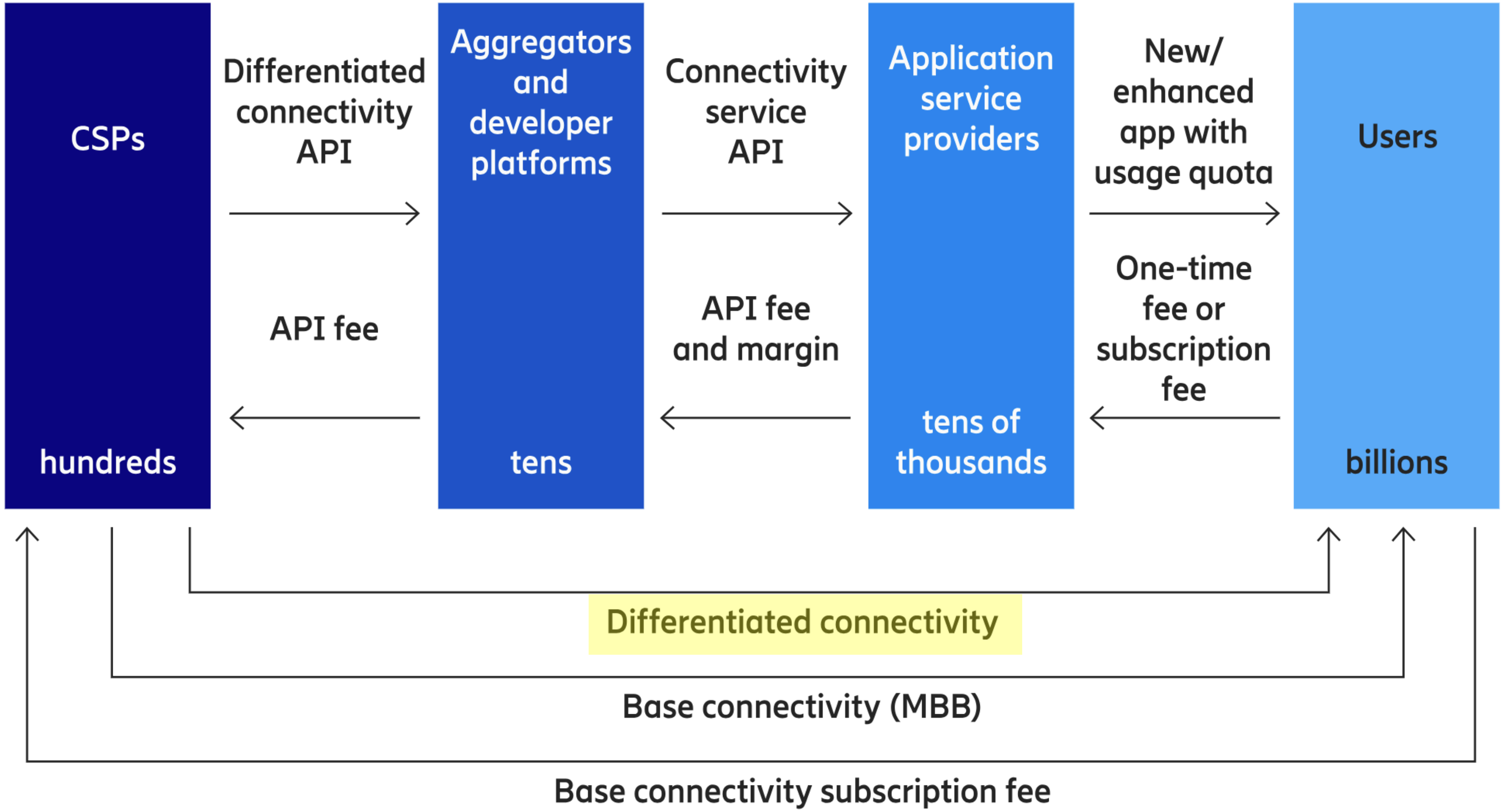
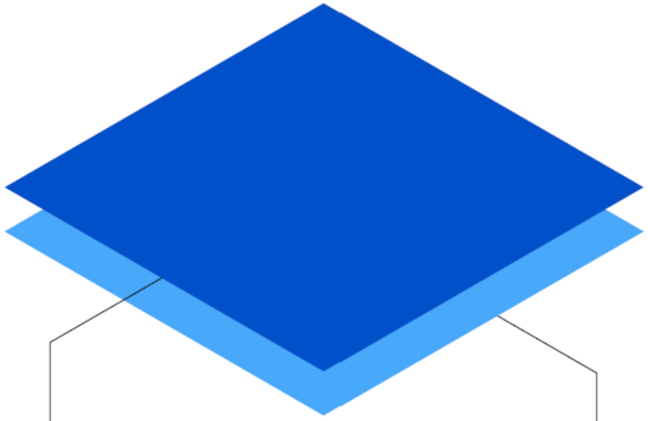
- Indirect: from CSP to
  - App developer (with in-app or app subscription premium)
  - → aggregators to reach end users scalable, and easy to use



CSP - communication service provider

Connectivity services with different performance levels

- Connectivity services for specific KPIs performance levels
- Useable by different applications via Network-Initiated QoS or UE route selection policy
- Transparency of delivered performance to applications



Performance Level 2.0
- Data rate downlink (DL): 510 Mbps
- Data rate uplink (UL): 0.52 Mbps
- Latency per burst UL and DL: Max 20ms (99th percentile)

Performance Level 1.0
- Data rate downlink (DL): 26 Mbps
- Data rate uplink (UL): 0.56 Mbps
- Latency per burst UL and DL: Max 60ms (99th percentile)

Applications

Business communications | High-end AR gaming | Remote vehicle operator video communication

Aggregator/developer platforms

Packaging of connectivity from multiple CSPs into global APIs where applicable

CSP connectivity service offerings

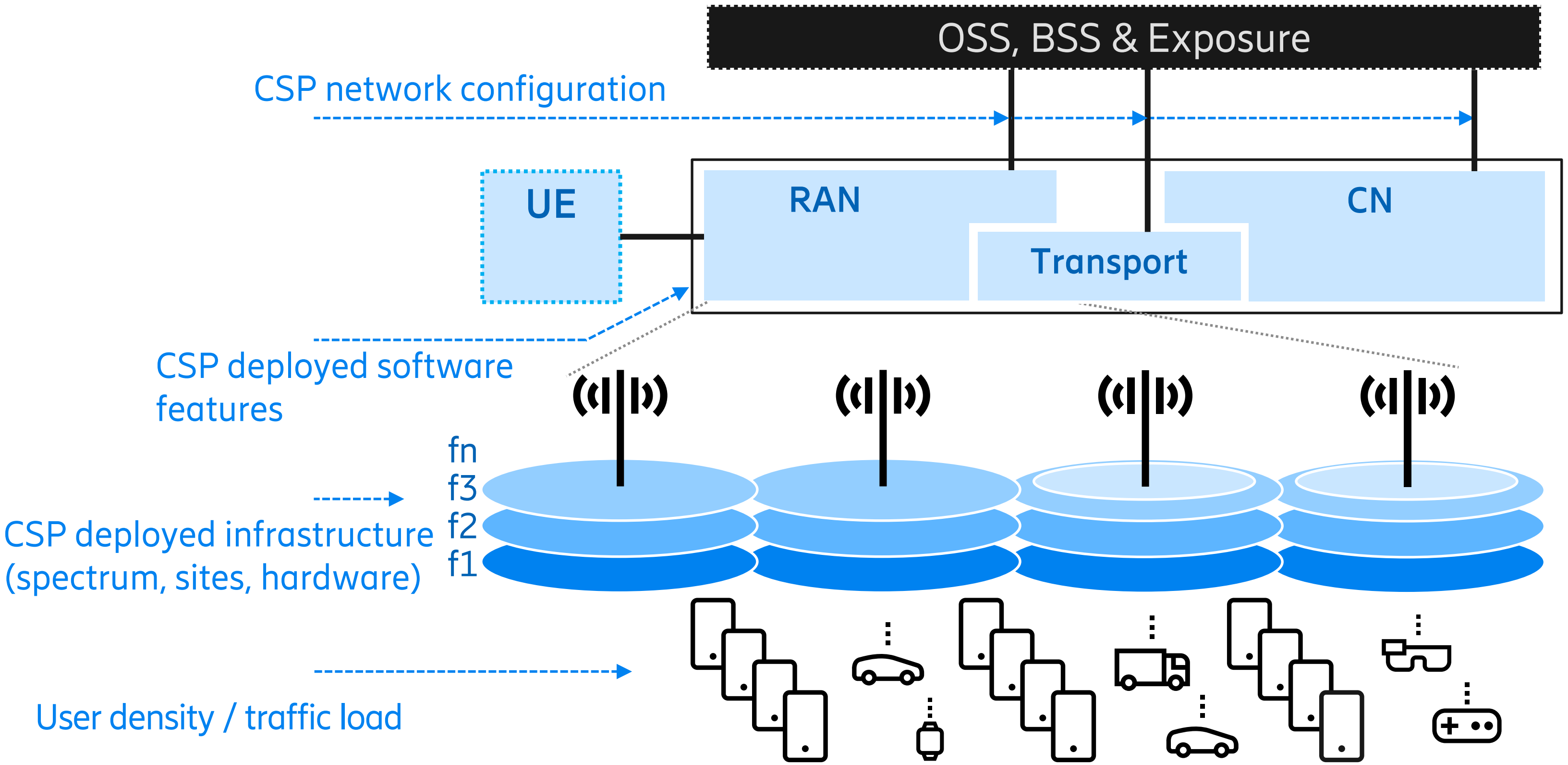
Performance Level 1.0
Business customers
- Device type: User managed devices
- Revenue model: Volume licensing monthly fee
- Coverage: In full network
- Price: $

Performance Level 2.0
Smartphone consumers
- Device type: Platform devices
- Revenue model: In-app purchase
- Coverage: Selected urban areas
- Price: $$

Performance Level 1.0
Driverless fleet operators
- Device type: Full stack system
- Revenue model: Subscription
- Coverage: Along specified highways
- Price: $$$

Realizing differentiated connectivity – 7 steps

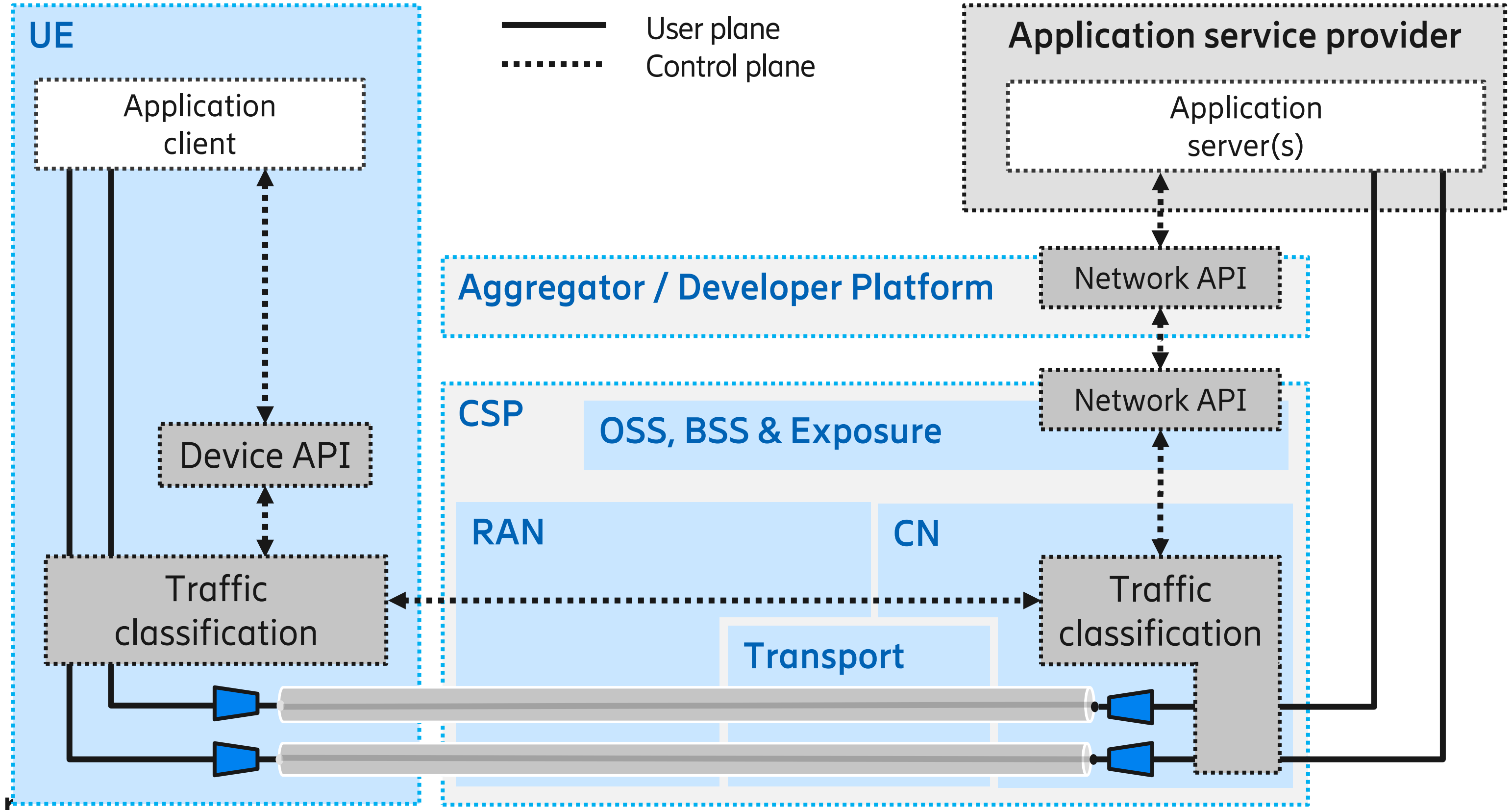
1. CSP develops a service offering
   – What and where for whom?
2. Network design/provisioning
   – Network deployment, network capabilities
   – Business support for purchase and instantiation of differentiated services
   – Network management to support differentiated connectivity services (e.g. via intent-based automation)
3. Commercial service offering



OSS – operation support system
BSS – business support system
CSP - communication service provider

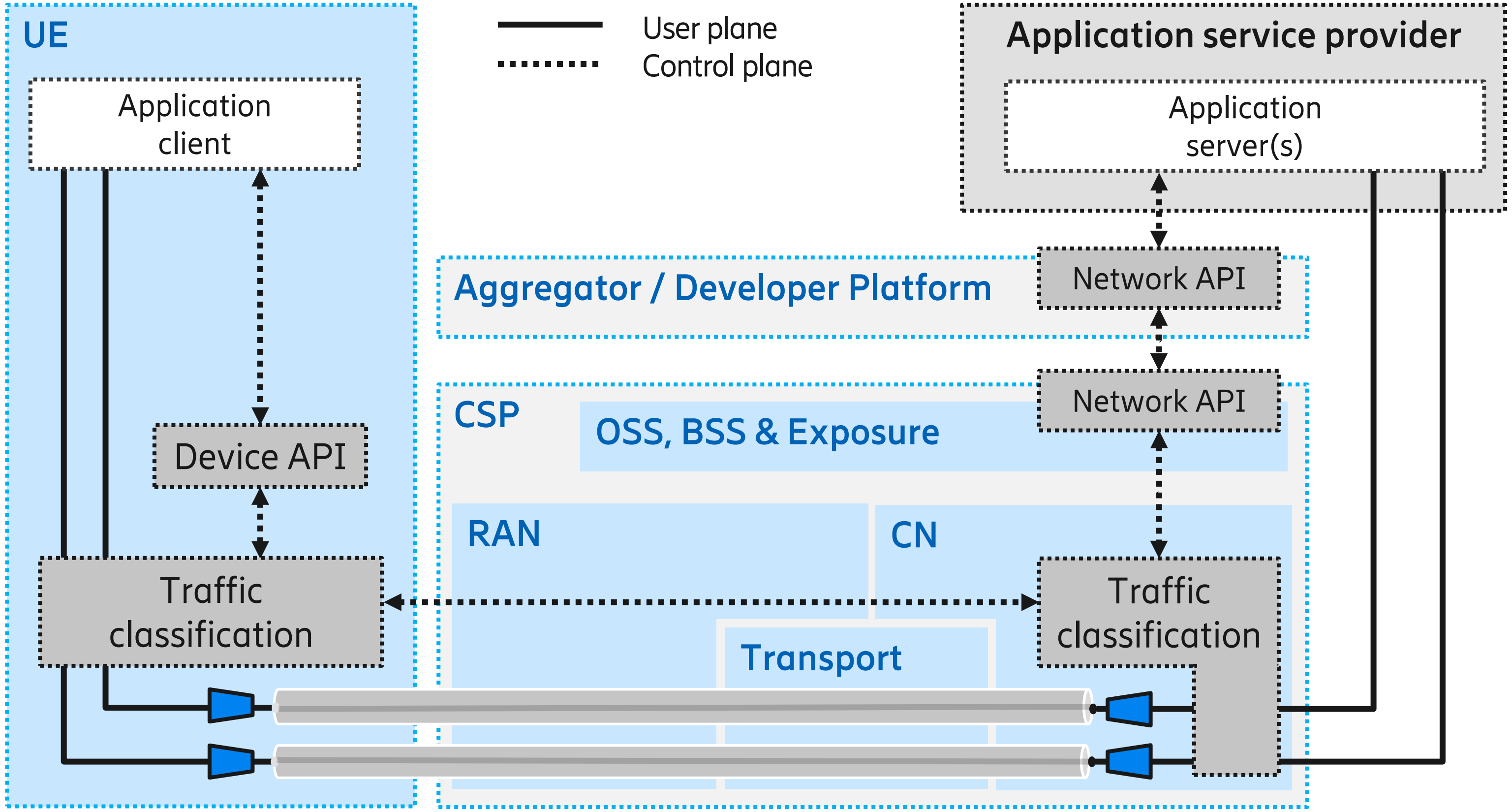
Realizing differentiated connectivity – 7 steps

4. Application preparedness
   – Discover differentiated connectivity offerings and value for application
   – Develop application for using differentiated connectivity
5. Commercial "sign-up", e.g. via subscription
6. Session runtime initiation
   – Instantiate service via network API request
   – Can be generalized via aggregator over multiple CSP networks



Realizing differentiated connectivity – 7 steps

7. Network service assurance to deliver the performance level



Differentiated Connectivity – Take aways

- Need of transformation of telecom industry to realize the value of wireless connectivity.
  – Enable performance based business models
  – Turn connectivity into a platform: support application service providers in innovations (e.g. in combination with other innovation enablers, like AI and cloud computing)
- (Indutry-aligned) Exposure of wireless connection characteristics to applications / application developers.
- APIs for network programmability

Differentiated Connectivity – Industry actions and alignment

- Communication Service Providers (CSPs)
  → prepare commercial packaging for connectivity with different performance levels
  → early engagements with application service providers
- Application Service Providers (ASPs)
  → Explore / experiment with application innovation leveraging differentiated connectivity
- Device & device platform vendors
  → Ensure devices support differentiated connectivity, e.g. APIs to map traffic to differentiated connectivity
- Telecommunication vendors
  → Coordinate and push industry alignment and enable network support for differentiated connectivity
- Cross-industry
  → Advance standardized APIs (e.g. in GSMA, CAMARA) and understand role of aggregators and developer platforms to reach billions of users with 10.000's apps in 100's of CSP networks

Dependable Communication for Critical Applications

“What is a critical application ?”

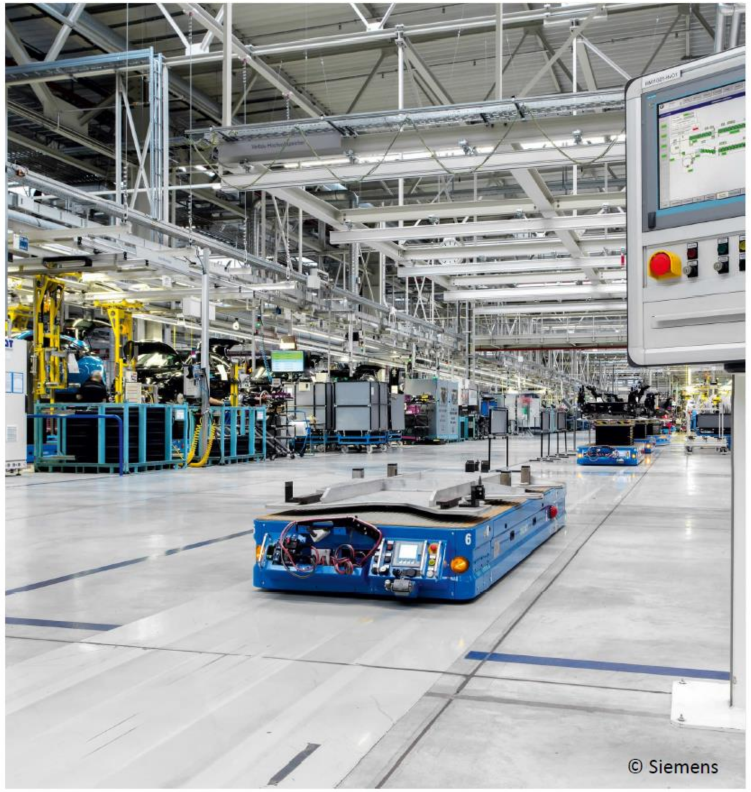
The Industrial view (Industrial IoT)

Industrial 5G/6G Use Cases

Industrial 5G use cases are also applicable for 6G

From 3GPP 6G workshop March 10-11, 2025, 6GWS-250214

5GACIA



Flexible Modular Assembly Area

Communication of mobile assets (AGVs, mobile robots, ...)

Industrial Automation

Wireless communication between PLCs and devices

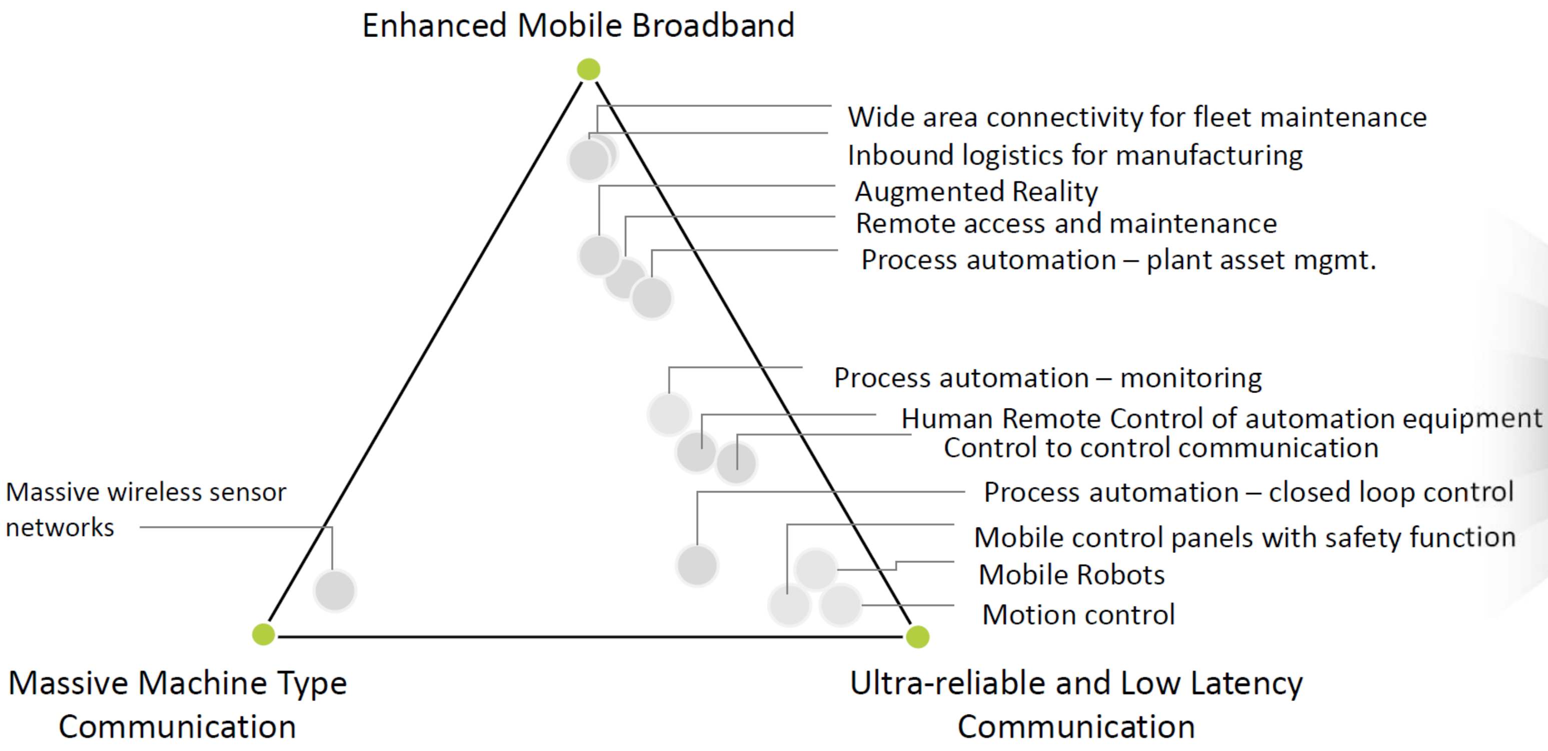
Industry 4.0: Flexible Manufacturing

Dynamically configured production processes, mobility

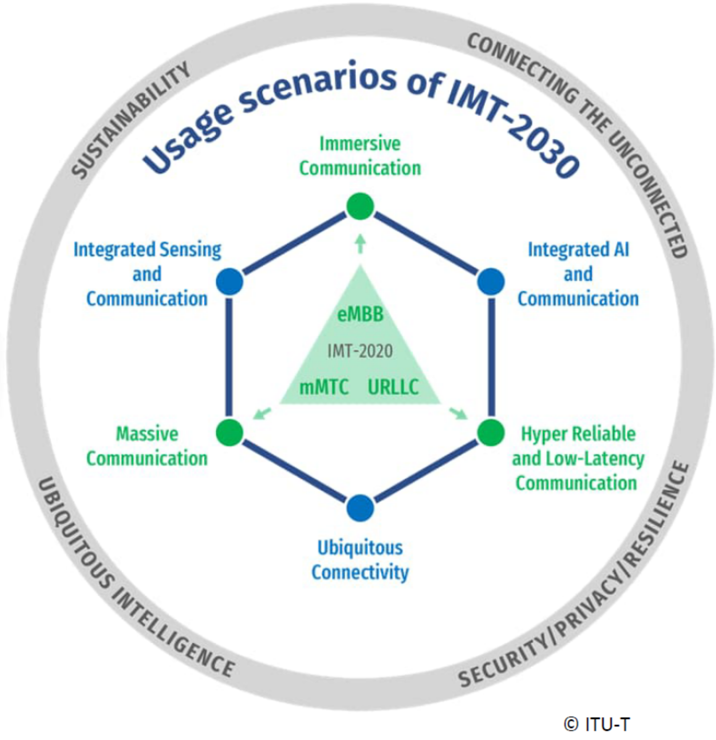
The Industrial view (Industrial IoT)

Industrial use cases – what is the next step?

From 3GPP 6G workshop March 10-11, 2025, [6GWS-250214]



5G Era



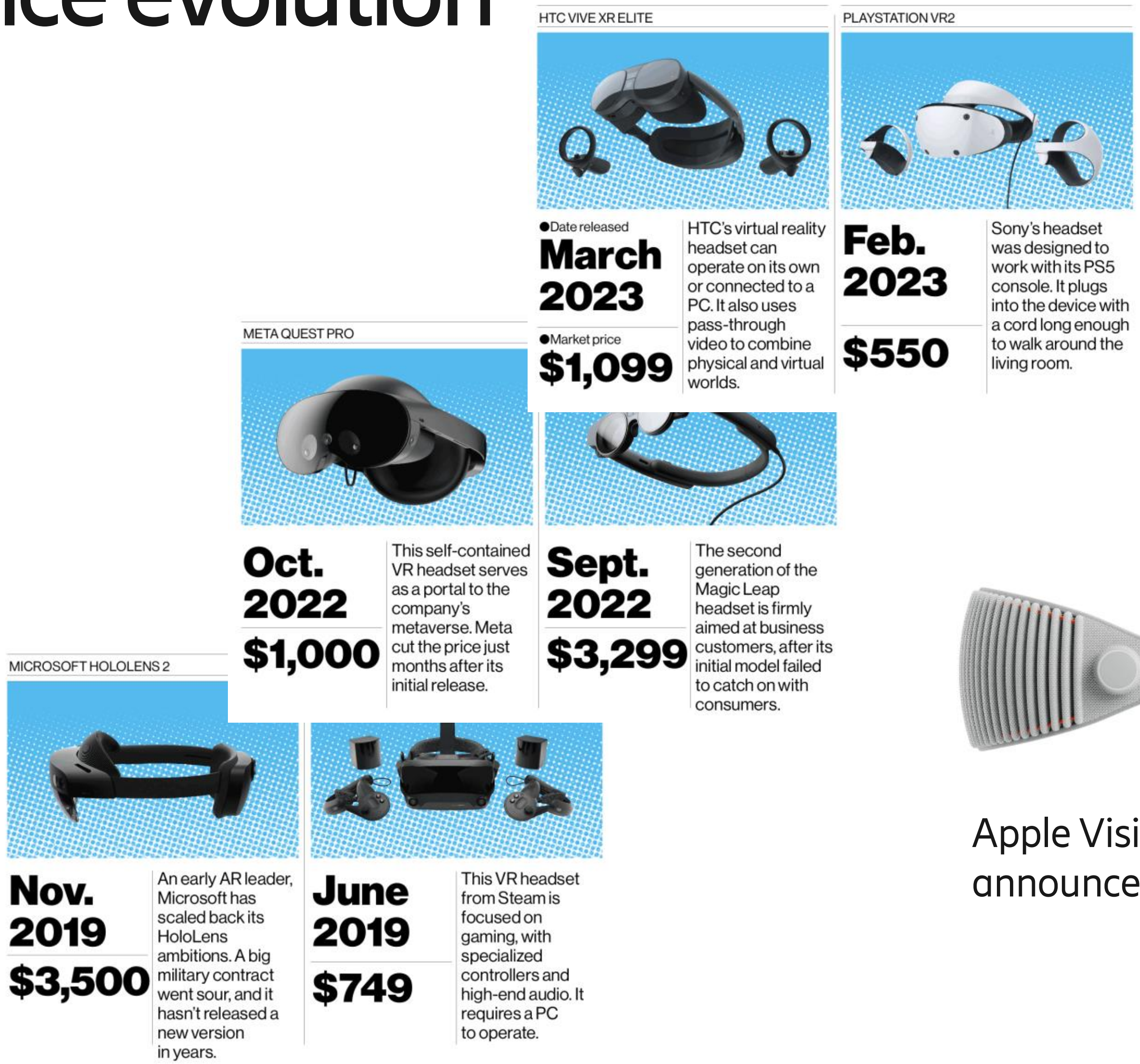
6G Era

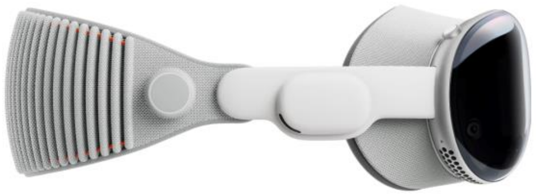

Coffee House
2m
Sushi Kaze
5m
Café Time
10m
St James Pub
15m
Echo Vino
20m
Burrito Barn
20m
Event meeting point
150m
Restroom
10m
Home 2 - 1 Away
39:52
Ball possession
Home 70%
Away 30%
Shots on goal
Home 13
Away 10
42
15

XR device evolution

The first VR Head Mounted Display: Telesphere Mask (patented 1960)

...





Apple Vision Pro: announced on June 5, 2023

...

?

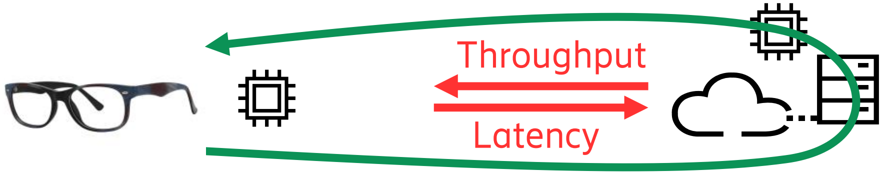
Stylish Glasses maybe in 2026(?)

Slim devices with integrated 5G/6G modems

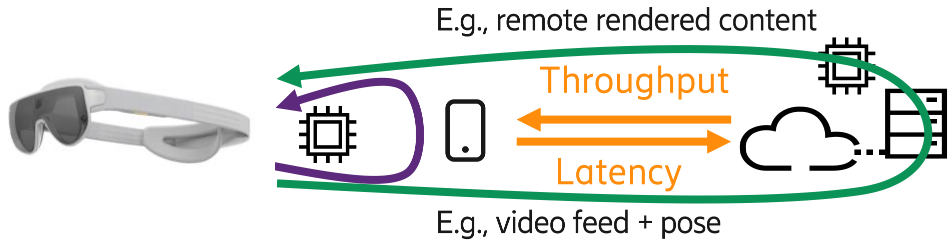
Time

XR compute offload enables an evolution towards slim glasses for everyday use

Radio modem and some processing in device + most processing in edge cloud



Processing in device + companion + edge cloud



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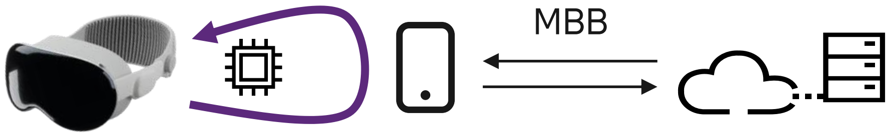


Cloud-based spatial compute[1] & rendering

Device-based spatial compute[1] & rendering

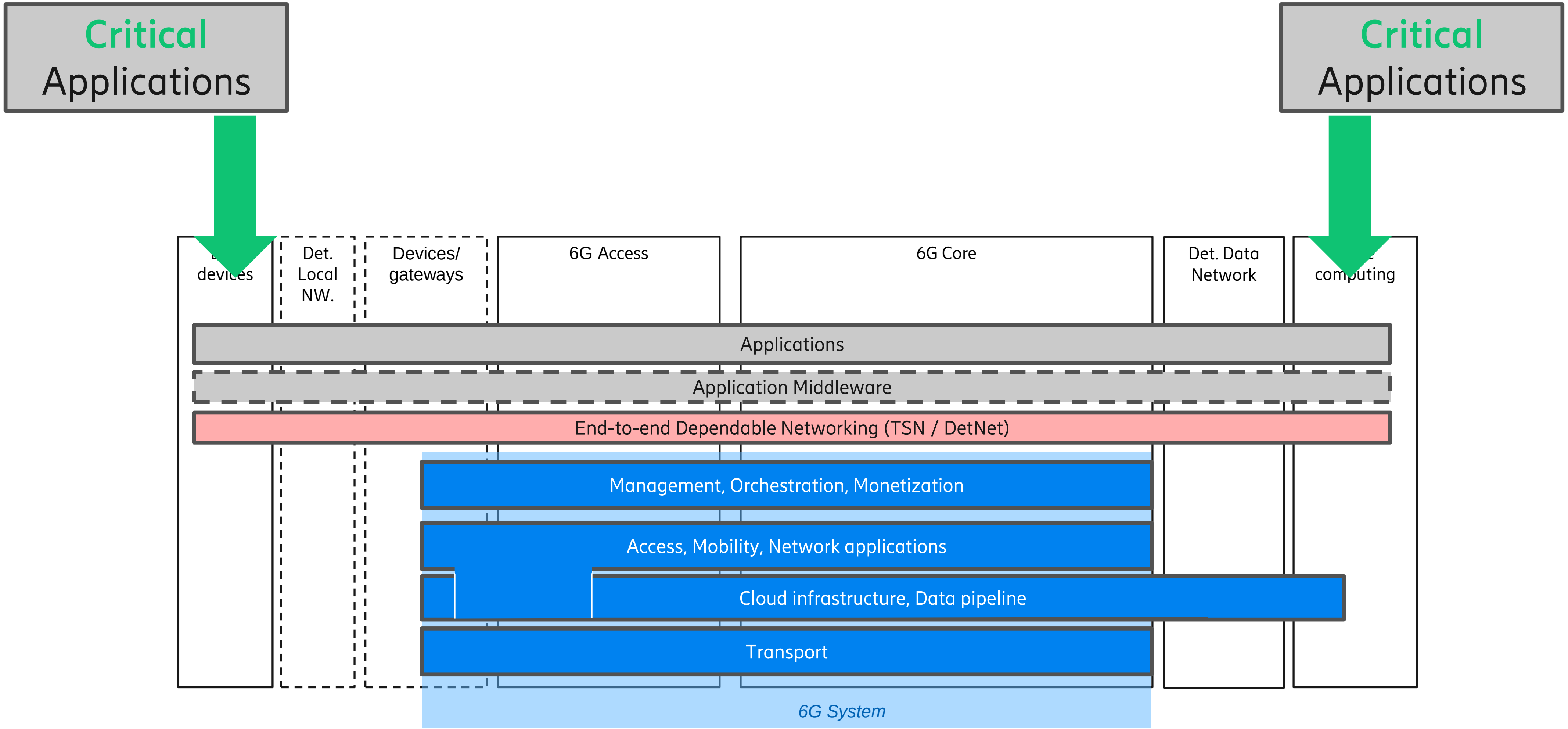
1. Localization, mapping, object detection

Other critical application areas

- Industrial IoT (manufacturing, process automation, mining, ...)
- Immersive Interactions like XR
- Electrical power generation and distribution / smart grid
- Automated mobility and Future Railway Mobile Communication System (FRMCS)
- Mission-critical services (e.g. public safety)
- …
- …
- Cyber-physical systems for XYZ

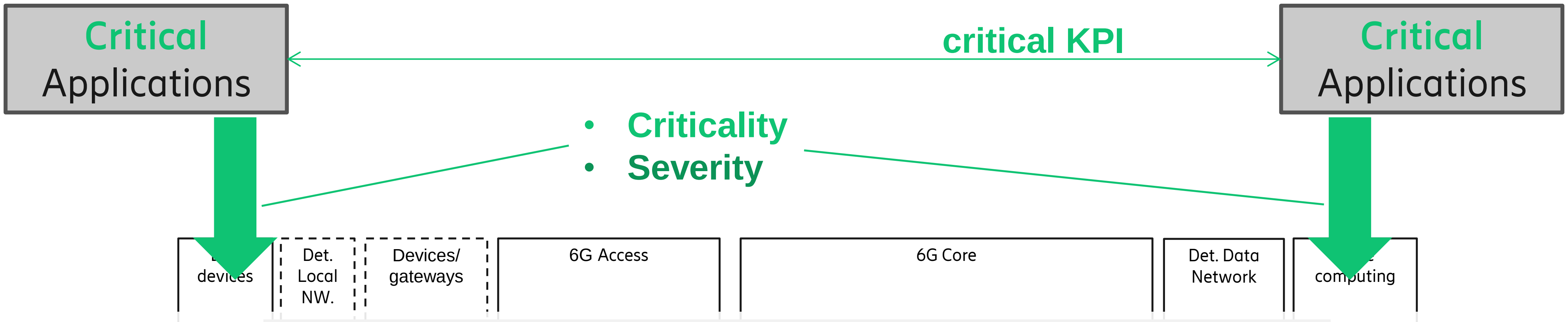
Dependable Networks are needed for critical applications

What is a critical application?



[D1.4] DETERMINISTIC6G, Deliverable 1.4, "First report on DETERMINISTIC6G architecture," April. 2024, https://deterministic6g.eu/index.php/library-m/deliverables

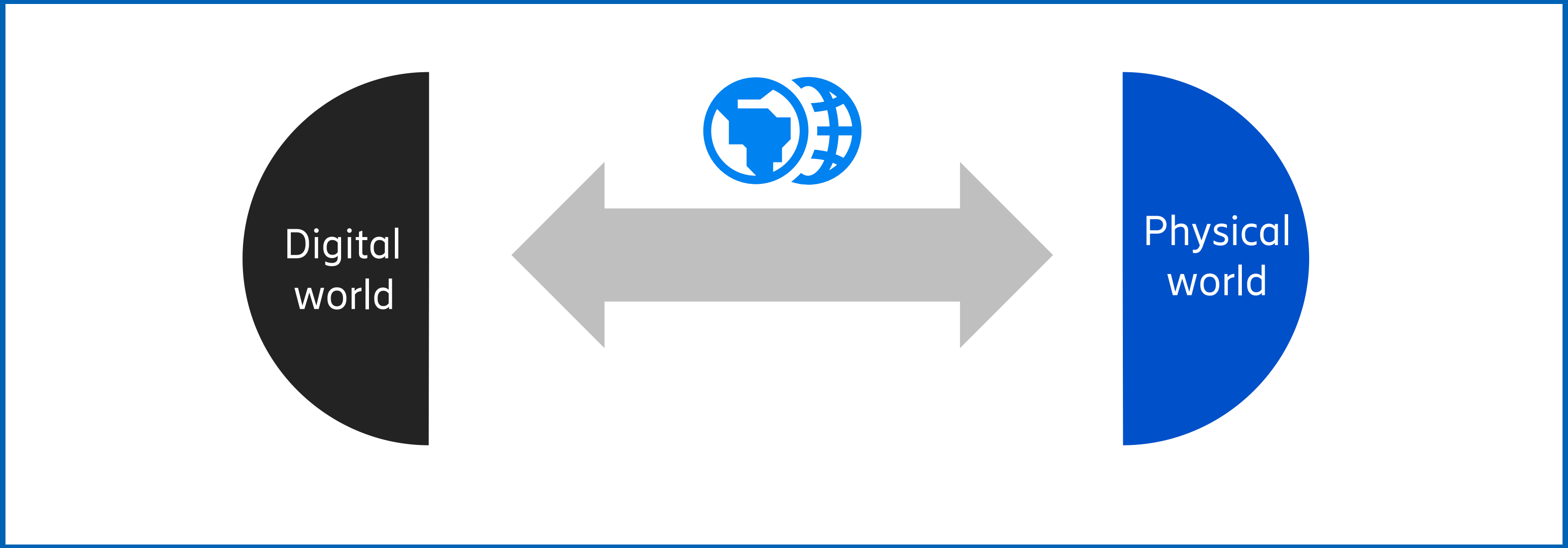
What is a **critical application**?



Criticality: The application has some **critical** requirement for which best-effort service delivery is unacceptable **(critical KPI with minimum performance)**

Severity: A failure of meeting the minimum performance results in some loss (e.g. an emergency stop is triggered, a safety risk appears, a high-value action fails incurring a financial loss).

Dependable communication with 6G



DETERMINISTIC6G

Dependable E2E communication with 6G

Project coordination: Ericsson, Technical coordination: KTH, Project start: January 2023, Project duration: 30 months, Contact: coordinator@deterministic6g.eu, deterministic6g.eu

E2E dependable system architecture

6G challenges and vision

System aspects for dependable E2E communication

- 6G use cases requiring dependable communication
- Dependable service definition (KPI/KVI)
- Security analysis

Dependable communication technology enablers

- Dependable 6G wireless transmission design
- Data driven characterization for 6G wireless system
- E2E time synchronization

- Deterministic communication standards (TSN, DetNet) Evolution
- Edge computing solution for dependable communication
- Situational awareness via digital twins
- Security countermeasures

Validation framework

- System level modelling
- Data driven model evaluation and validation
- System level simulations

Beyond DETERMINISTIC6G

DETERMINISTIC6G has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under grant agreement No.101096504. The SNS JU receives support from the European Union's Horizon Europe research and innovation programme

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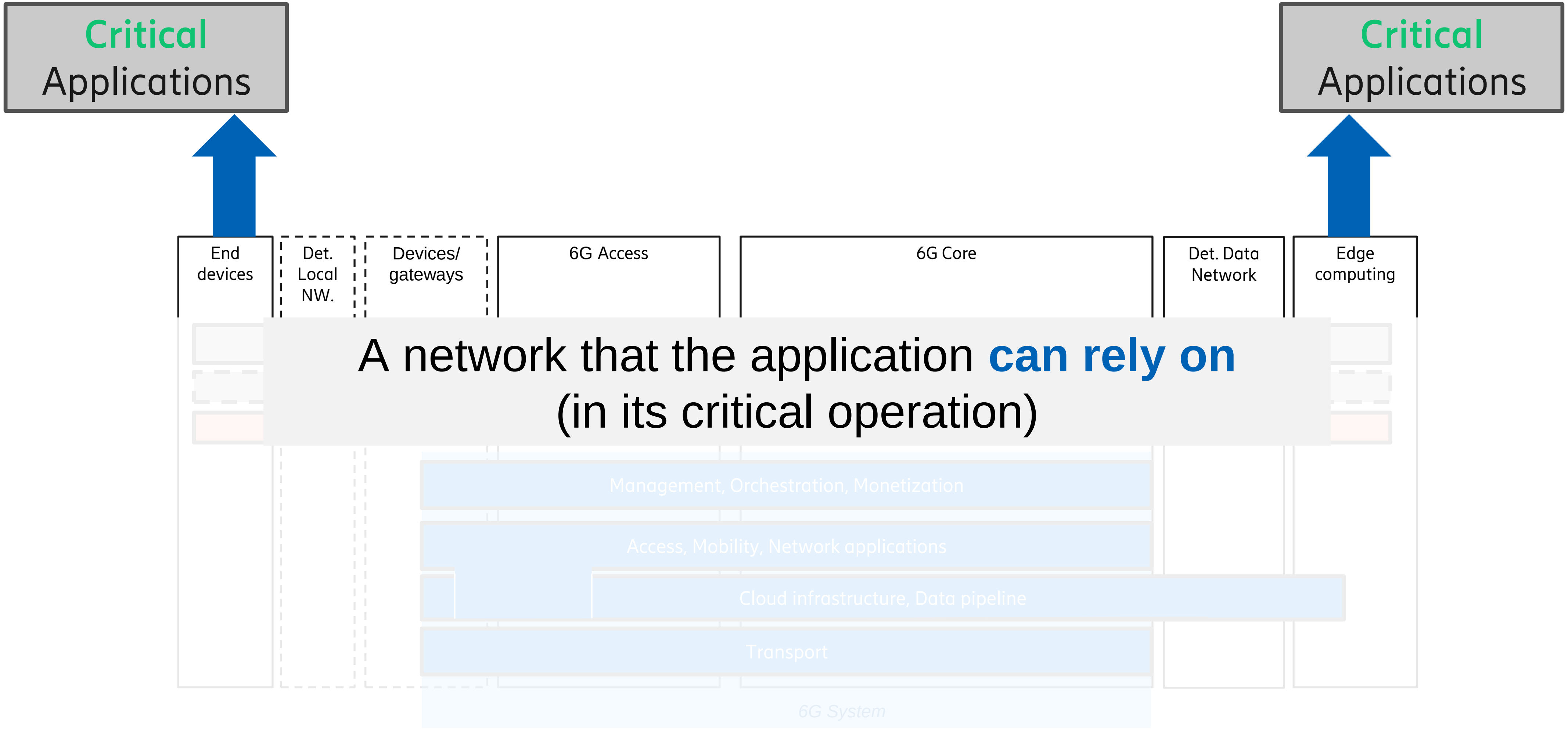
What is a **dependable network**?



A network that the application **can rely on**
(in its critical operation)

Dependable (Mobile) Networks [a technical definition]

*A **dependable network** can quantitatively ascertain that it will deliver the required service performance for the network services according to the performance level(s) that were agreed upon.*

[D1.3] DETERMINISTIC6G, Deliverable 1.3, "Report on dependable service design," Dec. 2024, https://deterministic6g.eu/index.php/library-m/deliverables

Dependable (Mobile) Networks [a technical definition]

2 1

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3 4

1. Time-critical and resilient communication
2. Observability and Predictability
3. Programmability
4. Adaptability

[D1.3] DETERMINISTIC6G, Deliverable 1.3, "Report on dependable service design," Dec. 2024, https://deterministic6g.eu/index.php/library-m/deliverables

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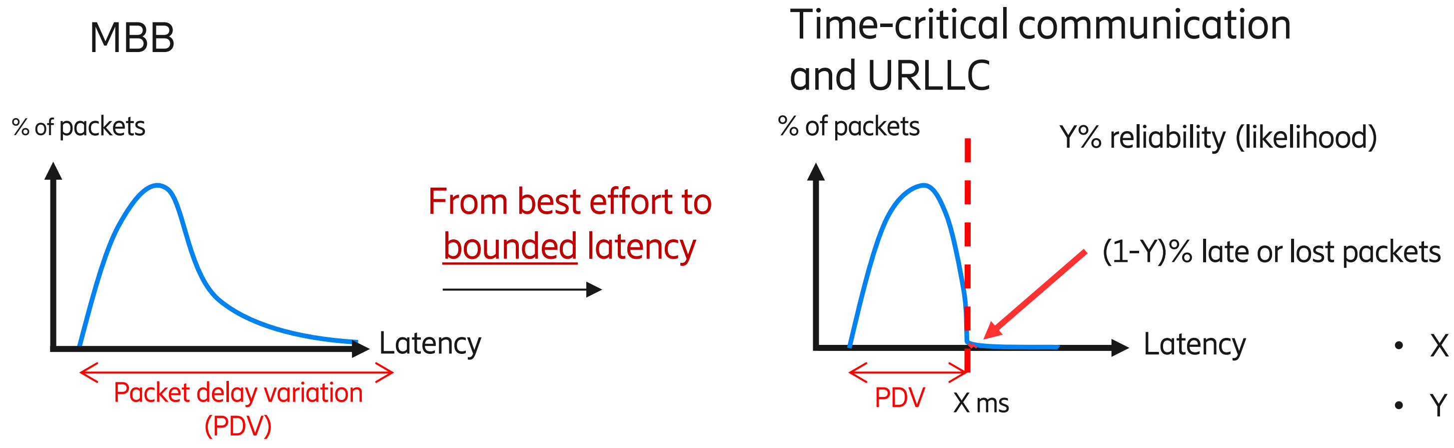
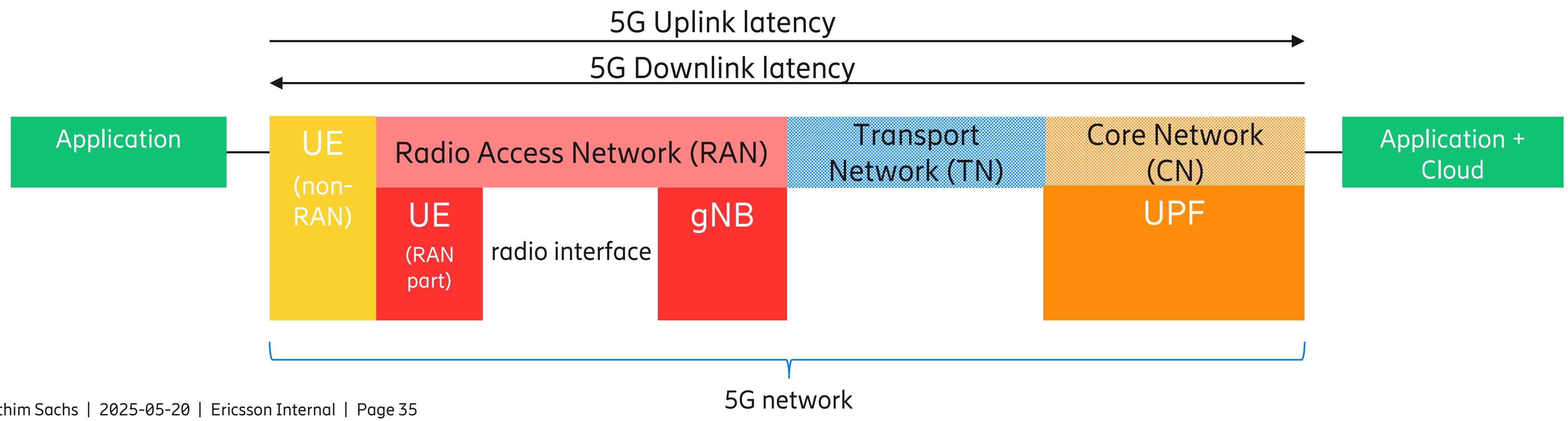
[D1.3] DETERMINISTIC6G, Deliverable 1.3, "Report on dependable service design," Dec. 2024, https://deterministic6g.eu/index.php/library-m/deliverables

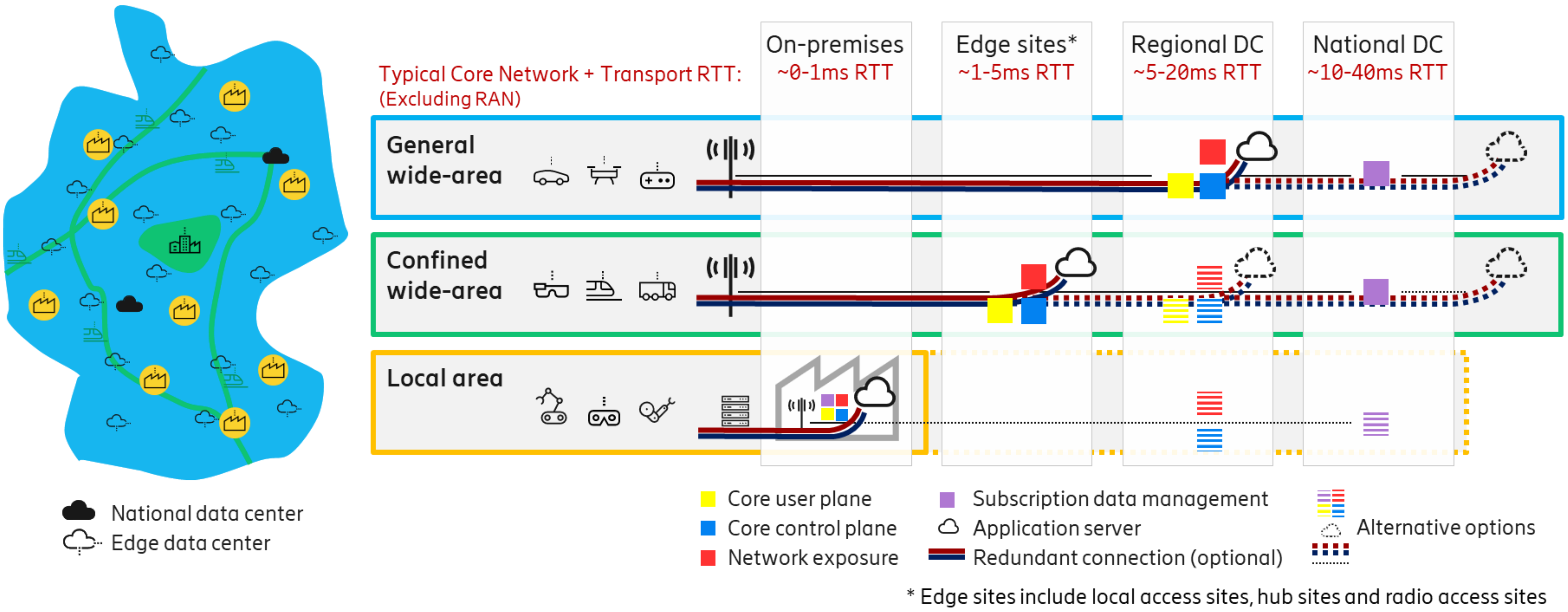
Time-critical communication



- X ranges from tens of ms to 1ms latency
- Y ranges from 99% to 99,999% reliability

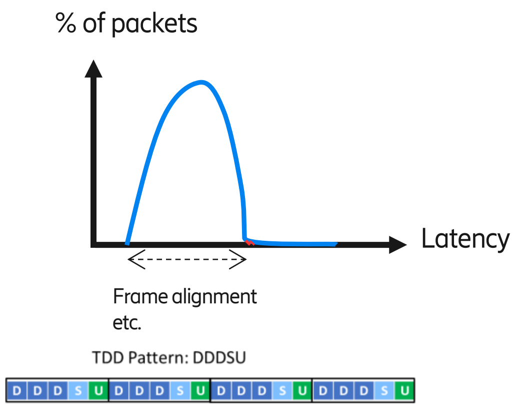


Latency induced by distance



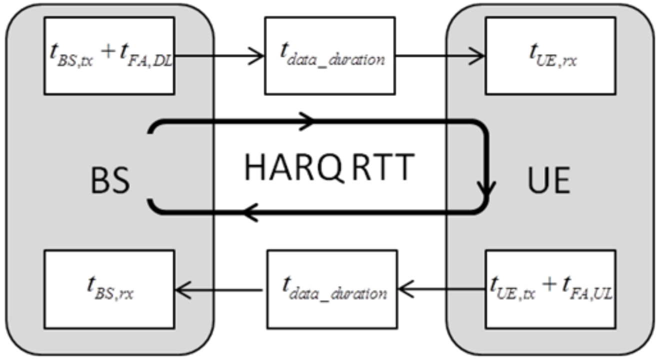
F. Alriksson, L. Boström, J. Sachs, Y. . -P. E. Wang and A. Zaidi, "Critical IoT connectivity Ideal for Time-Critical Communications," in Ericsson Technology Review, vol. 2020, no. 6, pp. 2-13, June 2020, doi: 10.23919/ETR.2020.9905508

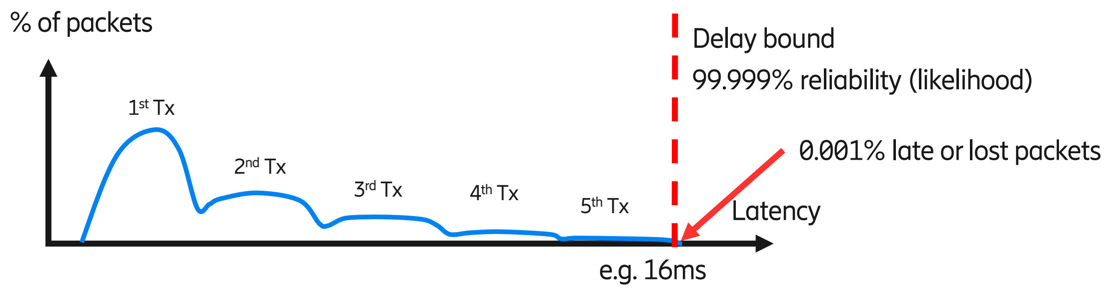
RAN Latency and Reliability (1)



DETERMINISTIC6G, Deliverable 2.1, “First report on 6G centric enablers,” Dec. 2023, https://deterministic6g.eu/index.php/library-m/deliverables

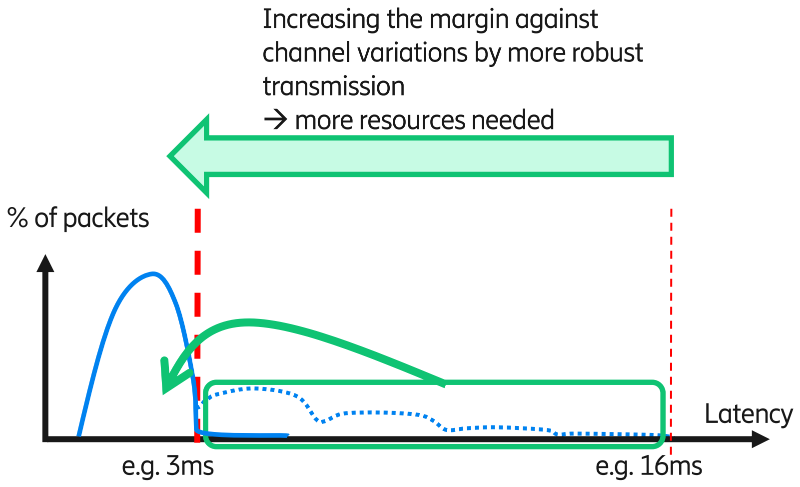
RAN Latency and Reliability (2)

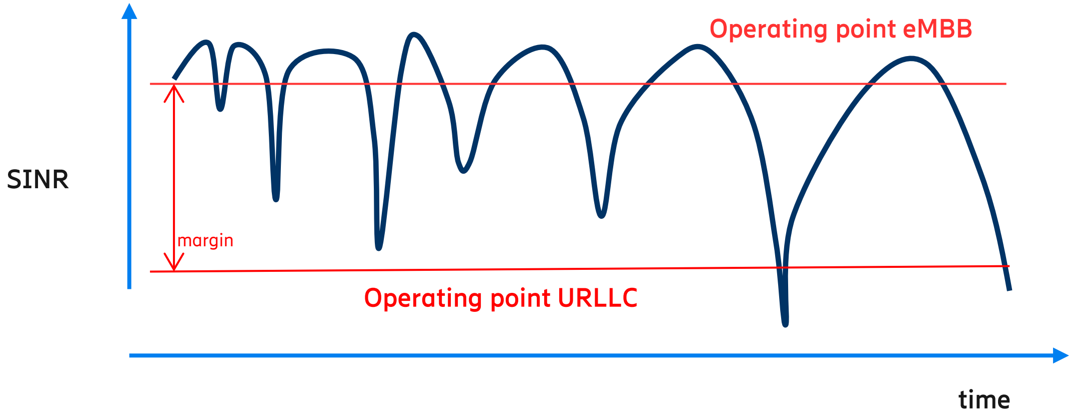




DETERMINISTIC6G, Deliverable 2.1, “First report on 6G centric enablers,” Dec. 2023, https://deterministic6g.eu/index.php/library-m/deliverables

Latency & Reliability and Spectral Efficiency



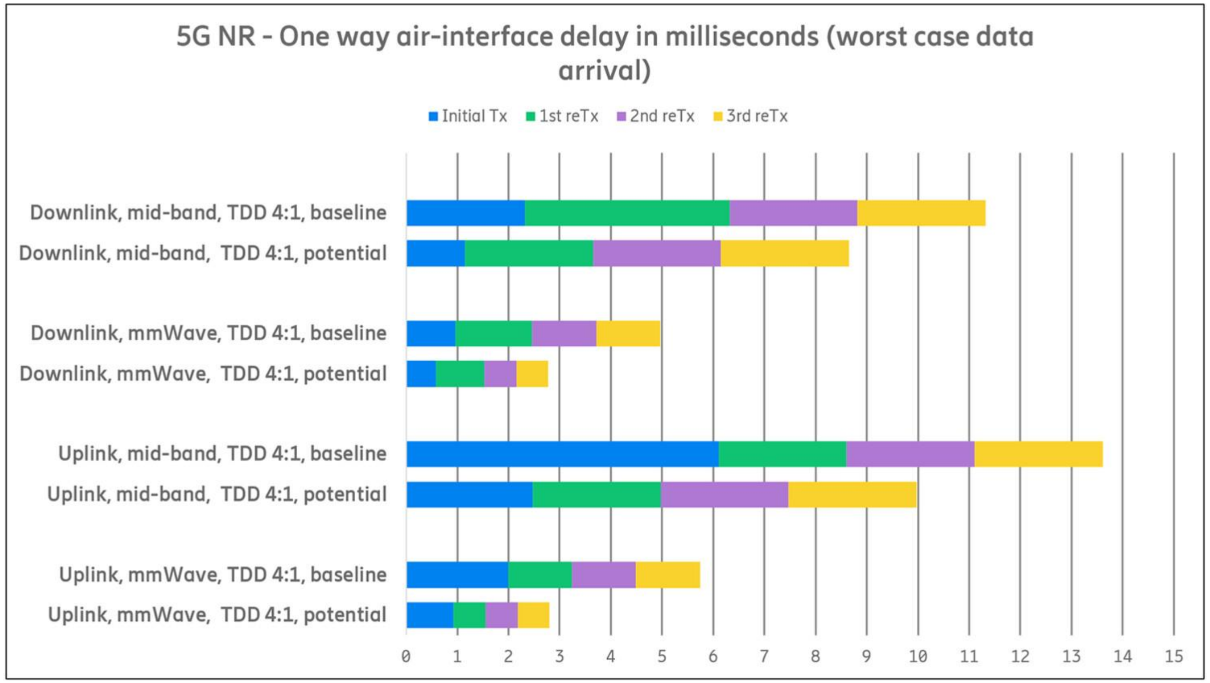


DETERMINISTIC6G, Deliverable 2.1, "First report on 6G centric enablers," Dec. 2023, https://deterministic6g.eu/index.php/library-m/deliverables

A toolbox for time-critical communication

URLLC toolbox

- Pre-scheduling and configured grant
- Mini-slots and flexible numerology
- Fast HARQ
- Preemptive transmission
- Robust control and data channels
- Redundant connectivity
- Multi-antenna diversity



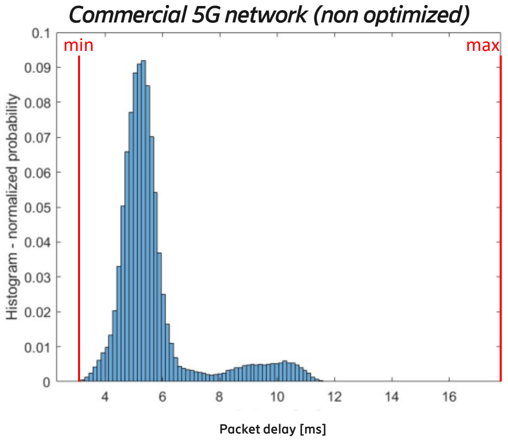
5G-SMART deliverable D1.5, "Evaluation of radio network deployment options", Dec. 2021, https://5gsmart.eu/deliverables/

- J. Sachs, L. A. A. Andersson, J. Araújo, C. Curescu, J. Lundsjö, G. Rune, E. Steinbach, G. Wikström, "Adaptive 5G Low-Latency Communication for Tactile Internet Services," in Proceedings of the IEEE, vol. 107, no. 2, pp. 325-349, February 2019. *http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8454733&isnumber=8626773*
- O. Liberg, M. Sundberg, Y.-P. E. Wang, J. Bergman, J. Sachs, G. Wikström, *Cellular Internet of Things - From Massive Deployments to Critical 5G Applications*, Academic Press, second edition, ISBN: 9780081029022, October 2019.

- 5G-SMART deliverable D1.5, "Evaluation of radio network deployment options", Dec. 2021, https://5gsmart.eu/deliverables/

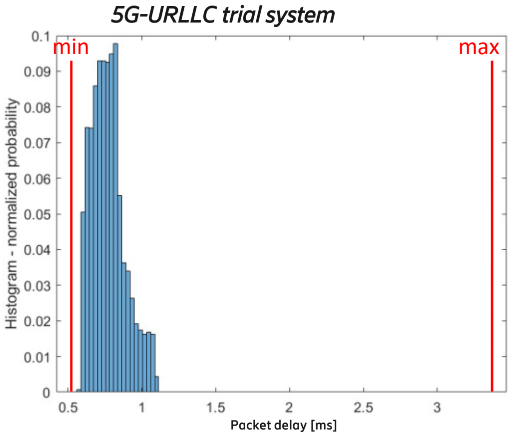
5G Networks: From Trials to Reality

- 5G networks show comparatively large packet delay variation (PDV), even with URLLC



(a)

Ansari et al. Electronics 2022



(b)

Ansari et al., TSNA 2022
Kehl et al. Electronics 2022

[1] J. Ansari, C. Andersson, P. de Bruin, J. Farkas, L. Grosjean, J. Sachs, J. Torsner, B. Varga, D. Harutyunyan, N. König, R. H. Schmitt, "Performance of 5G Trials for Industrial Automation. Electronics", 2022; 11(3):412. https://doi.org/10.3390/electronics11030412

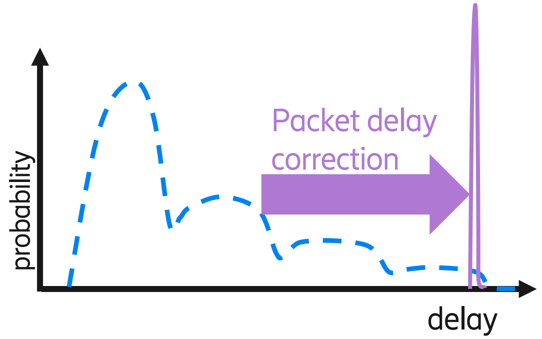
[2] P. Kehl, J. Ansari, M. H. Jafari, P. Becker, J. Sachs, N. König, A. Göppert, R. H. Schmitt, "A Prototype of 5G Integrated with TSN for Edge-Controlled Mobile Robotics" Electronics 11, no. 11: 1666, 2022. https://doi.org/10.3390/electronics11111666

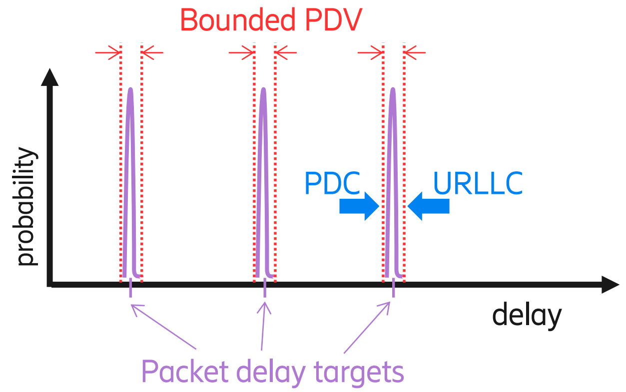
[3] DETERMINISTIC6G, "Digest on First DetCom Simulator Framework Release", deliverable D4.1, Dec. 2023, https://deterministic6g.eu/index.php/library-m/deliverables

[4] DETERMINISTIC6G, "Report on 6G convergence enablers towards deterministic communication standards", deliverable D3.1, Dec. 2023, https://deterministic6g.eu/index.php/library-m/deliverables

Packet Delay Variation (PDV) & Deterministic communication

- Time-sensitive / deterministic transmission
  - Receiving the right packet at the right time
  - Packet-delay variation creates uncertainty on packet arrivals
- Can be problematic for e.g. Time-Sensitive Networking (TSN) time-scheduled transmission [D3.1] [EDV+25]
  - Correction of PDV via packet delay correction (PDC) in 6G can remove uncertainty of packet delays [D2.1]





[D2.1] DETERMINISTIC6G, Deliverable 2.1, "First report on 6G centric enablers," Dec. 2023, https://deterministic6g.eu/index.php/library-m/deliverables

[D3.1] DETERMINISTIC6G, Deliverable 3.1, "Report on 6G convergence enablers towards deterministic communication standards," Dec. 2023, https://deterministic6g.eu/index.php/library-m/deliverables

[EDV+25] S. Egger, F. Dürr, B. Varga, M. De Andrade, G.P. Sharma, J. Sachs, J. Harmatos, J. Gross, "Wireless-aware TSN Engineering: Implications for 5G and Upcoming 6G Networks," IEEE Network, vol. 39, no. 3, May 2025, https://ieeexplore.ieee.org/document/10945893

Dependable (Mobile) Networks [a technical definition]

2 1

*A **dependable network** can quantitatively ascertain that it will deliver the required service performance for the network services according to the performance level(s) that were agreed upon.*

3 4

1 Time-critical and resilient communication

2 **Observability and Predictability**

3 Programmability

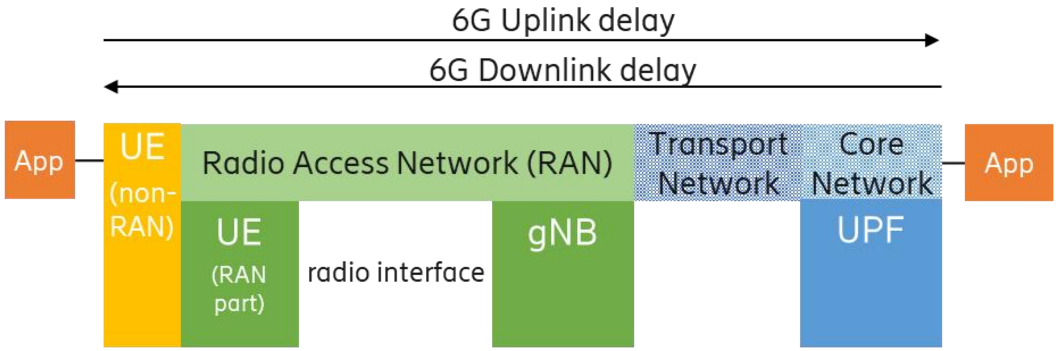
4 Adaptability

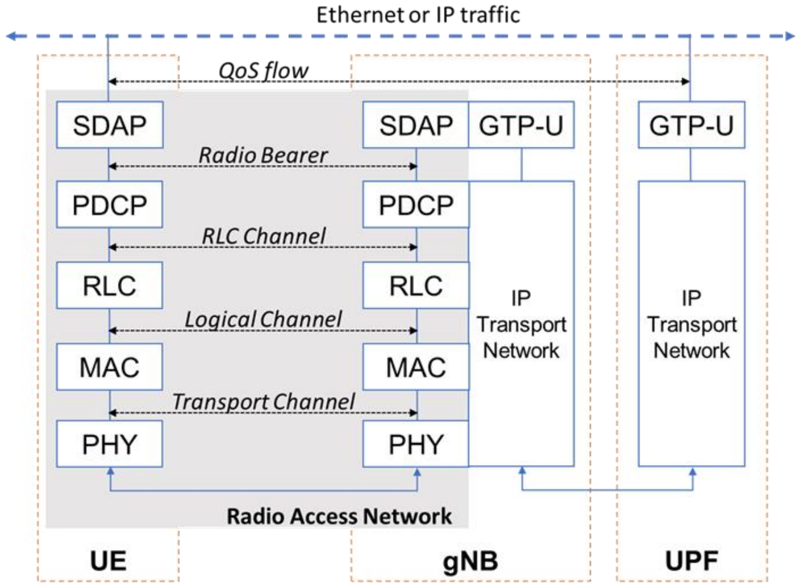
[D1.3] DETERMINISTIC6G, Deliverable 1.3, "Report on dependable service design," Dec. 2024, https://deterministic6g.eu/index.php/library-m/deliverables

Performance Observability of *critical KPIs*

- Performance guarantees & service level agreements require the capability to assess the service performance

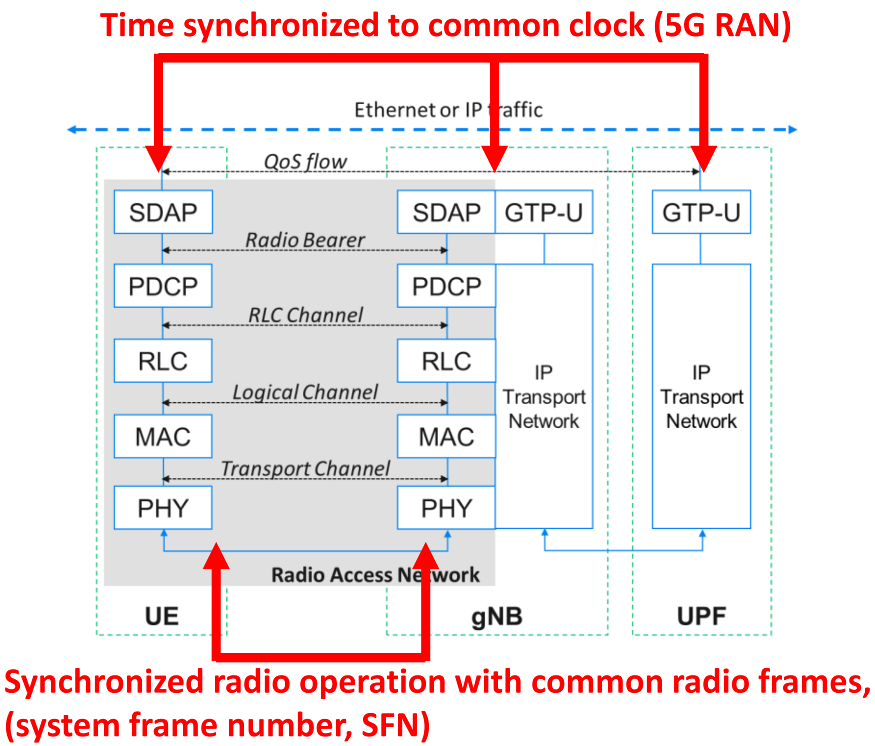
- Performance typically dominated by RAN





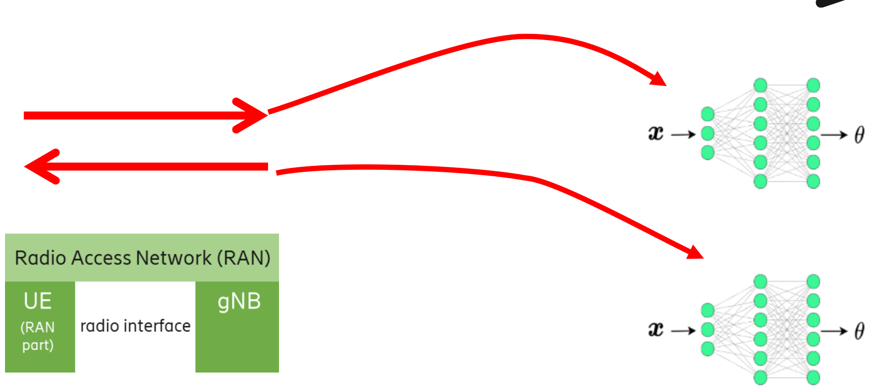
Delay observability

- Delay observability requires two observation points (ingress, egress)
  - Requires common notion of time



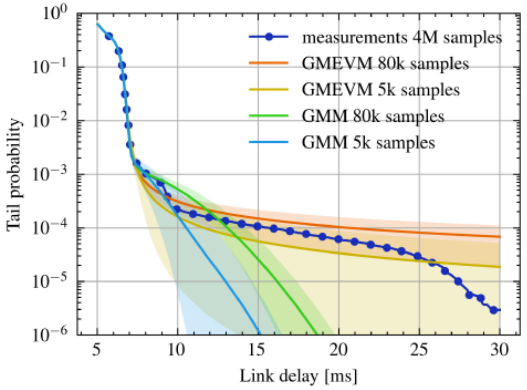
- DETERMINISTIC6G, “Second report on 6G-centric enablers”, deliverable D2.3, April. 2025.
- I. Godor et al. “A Look Inside 5G Standards to Support Time Synchronization for Smart Manufacturing,” IEEE Communications Standards Magazine, Sep. 2023. https://ieeexplore.ieee.org/document/9204594
- A. Mahmood et al. “Time Synchronization in 5G Wireless Edge: Requirements and Solutions for Critical-MTC,” IEEE Communications Magazine Dec. 2019, https://ieeexplore.ieee.org/document/8930825

Performance prediction



- Performance prediction allows to estimate the amount of guarantee that can be provided for a certain performance by the network

- Data-driven approaches are promising
  – Tail-behaviour relevant for performance guarantees



- S. Mostafavi, G. P. Sharma and J. Gross, "Latency Probability Prediction for Wireless Networks: Focusing on Tail Probabilities," in *IEEE Globecom 2023*, 2023.
- [DET23-D21] DETERMINISTIC6G, “First Report on 6G-centric enablers”, deliverable D2.1, Dec. 2023,
- [DET24-D12] DETERMINISTIC6G,“First report on DETERMINISTIC6G architecture”, deliverable D1.2, April. 2024, https://deterministic6g.eu/index.php/library-m/deliverables
- [DET25-D23] DETERMINISTIC6G, “Second report on 6G-centric enablers”, deliverable D2.3, April. 2025,
- G. P. Sharma, D. Patel, J. Sachs, M. De Andrade, J. Farkas, J. Harmatos, B. Varga, H. -P., Bernhard, R. Muzaffar, M. Ahmed, F. Duerr, D. Bruckner, E.M. De Oca, D. Houatra, H. Zhang and J. Gross, "Toward Deterministic Communications in 6G Networks: State of the Art, Open Challenges and the Way Forward," in IEEE Access, vol. 11, pp. 106898-106923, 2023, doi: 10.1109/ACCESS.2023.3316605

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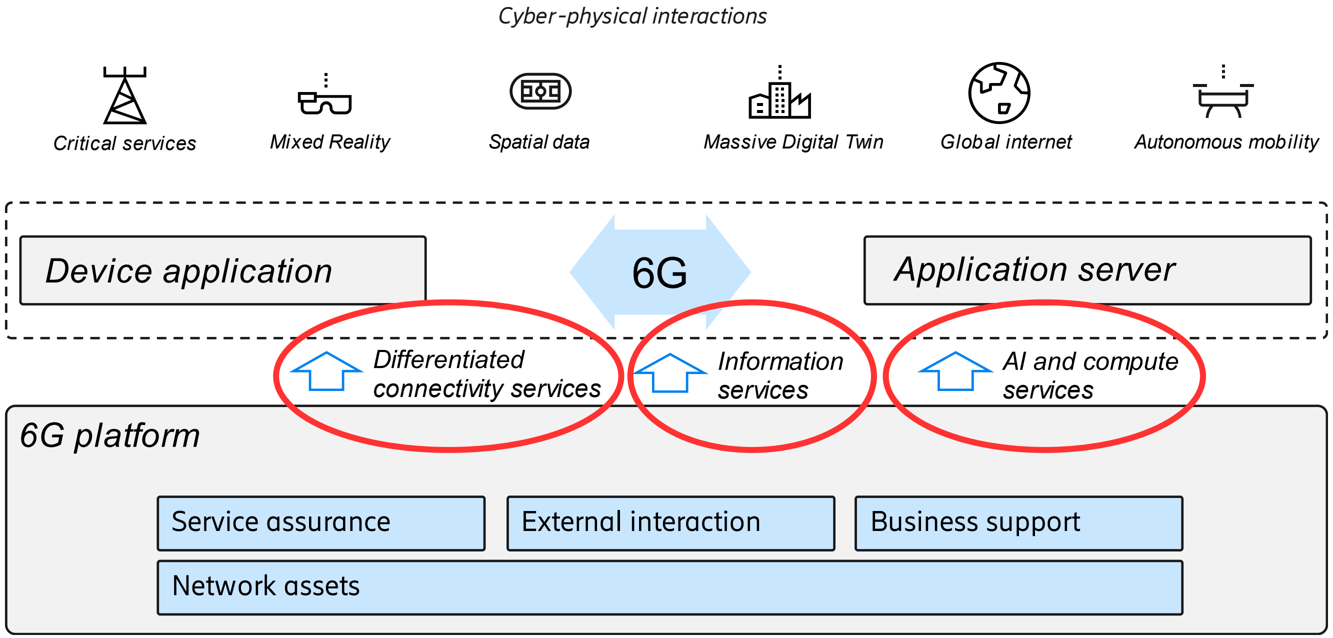
A programmable network platform

A platform is a product that enables other products or services to be built on top of it.

→ The 6G platform aims to expand the scope of networks beyond communication services to enable the delivery of broad support for applications.

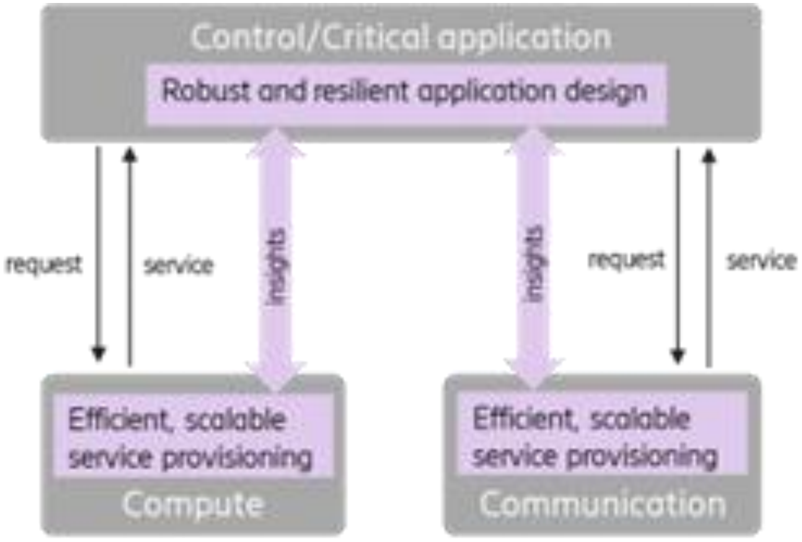
Combined offer of expanded network capabilities

- Differentiated connectivity services
  - Quality on demand
- Information services
  - Positioning, sensing, timing data
  - Communication status & predicted performance
  - Anti-Fraud (SIM Swap, Call state, etc.)
- AI and compute services
  - Computational device offloading
  - AI as a service
  - Situational awareness
  - Edge AI, Digital twin support, etc.



Maximizing the value to the application considering resource constraints

- Communication-compute-control Co-design allows exploiting flexibility and varying needs of applications to provide the performance needed by the application in a resource efficient and resilient way



- L. Grosjean, J. Sachs, J. Ansari, N. Reider, A. Hernandez Herranz, C. Holmberg, "A framework for communication-compute-control co-design in cyber-physical systems," in *Electronics*, vol. 14, no. 5, February 2025, https://doi.org/10.3390/electronics14050864.

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https://www.ericsson.com/en/6g

Further reading

5G communication for new use cases

- Book: Cellular IoT: from massive deployments to critical 5G
- Cellular IoT in the 5G era
- Enabling time-critical applications over 5G
- Critical IoT connectivity – Ideal for Time-critical Communications
- 5G for Smart Manufacturing
- 5G TSN - integrating for industrial automation
- Ensuring required network robustness with the 5G System
- 5G Spectrum for Local Industrial Networks
- Toward 5G Advanced: overview of 3GPP releases 17 & 18
- Performance of 5G Trials for Industrial Automation. Electronic
- A Prototype of 5G Integrated with TSN for Edge-Controlled Mobile Robotics
- Differentiated connectivity: Unleashing the full potential of 5G

6G vision and concepts

- 6G spectrum - future mobile life
- Co-creating a cyber physical world with 6G
- Why 6G must put sustainability first
- Delivering Net Zero – What it takes in the Telco industry
- Report on Dependable Communication within DETETRMINISTIC6G
- 6G Network Architecture – a proposal for early alignment
- Beyond bit-pipes – new opportunities on the 6G platform
- 6G security – drivers and needs
- Toward Deterministic Communications in 6G Networks: State of the Art, Open Challenges and the Way Forward

Use cases

- Technology Review Magazine 2023 – Spotlight on extended reality
- The spectacular rise of holographic communication
- The impact of connectivity on digital and real-world experiences
- Cloud robotics: reports D2.1, D2.2, D2.3, and D4.1, D4.2, D4.3, D4.4 at https://5gsmart.eu/documents/ and video at https://youtu.be/I5-zpM7mqJI
- Industry 5.0: https://www.ericsson.com/en/about-us/new-world-of-possibilities/imagine-possible-perspectives/industry5-0-human-centric-manufacturing/
- The future of enterprise reports: https://www.ericsson.com/en/reports-and-papers/industrylab
- Enabling holographic communication with 5G technology
- Towards Deterministic Communications in 6G Networks: State of the Art, Open Challenges and the Way Forward
- L. Grosjean, J. Sachs, J. Ansari, N. Reider, A. Hernandez Herranz, C. Holmberg, "A framework for communication-compute-control co-design in cyber-physical systems," in Electronics, vol. 14, no. 5, February 2025,
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