"We have launched the world's first and leading 6G research program."

6G Flagship – First in 6G

Ari Pouttu
Vice Director – 6G Flagship

Miten 6G muuttaa verkkoja ja palveluja - mihin 6G:tä tarvitaan ?

Why and what is 6G?

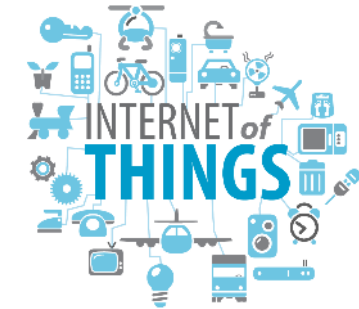- Mobile communications have driven major societal changes in 20-year cycles

1G - 2G

3G - 4G

5G – 6G

**1980s – 2000s
Millions of voice users**

**– 2020s   Billions of Mobile
Broadband users**

**– 2040s   Trillions of
connected objects & intelligence**

- **Massive automation of society** needs more than 5G can offer**.**

- 6G will **merge physical, digital and biological worlds** fulfilling UN SDGs of digital societies.

- 6G requires more radical transformations:
    - capabilities of **wireless transmission must be pushed to the limits**
    - **massive utilization of artificial intelligence** in networks and applications
    - radical **innovations needed for future wireless business ecosystems**

We have defined global 6G research agenda
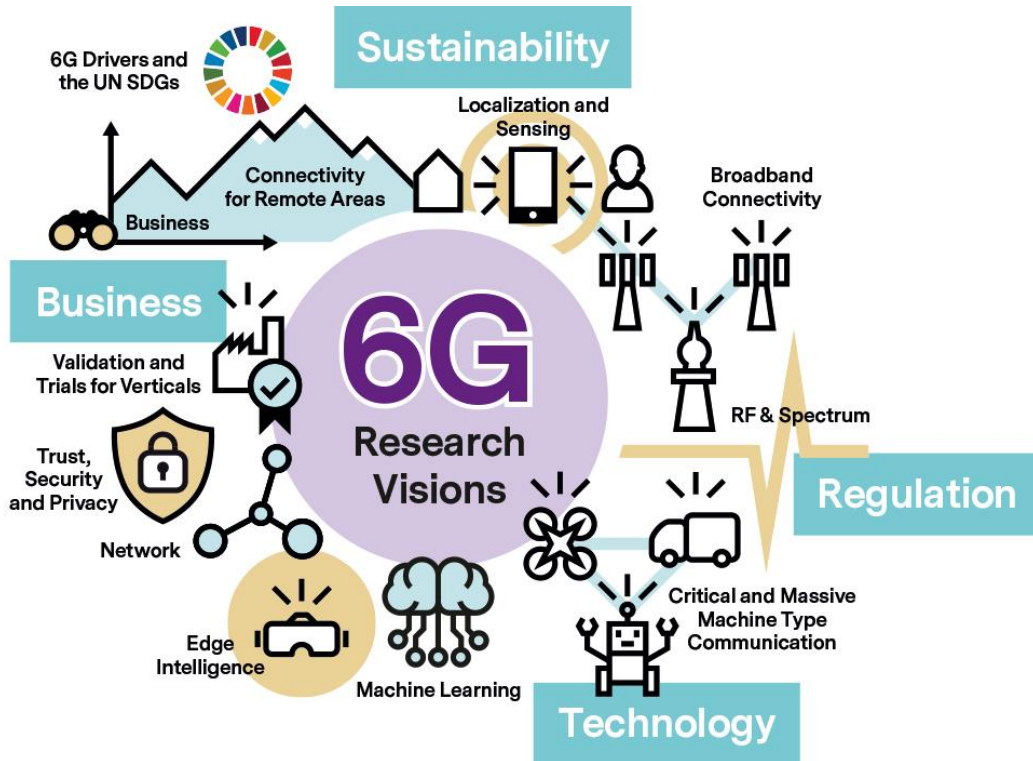
1.

Wireless Connectivity
Ultra-reliable low-latency communications vs. 1 Tbps

Enabling **Unmanned Processes**

2.

Devices & Circuits
THz communications materials & circuits

Enabling **Unlimited Connectivity**

3.

Distributed Computing
Mobile edge intelligence

Enabling **Time Critical & Trusted Apps**

4.

Services & Applications
Multidisciplinary research accross verticals

Enabling **Disruptive Value Networks**

Groundbreaking 6G Research Visions

- University of Oulu has established "6G Research Visions" publication series to make 6G Flagship findings openly available to a wider community.

- 12 thematic 6G White Papers have so far been published - including world's first 6G White Paper - with one more to appear shortly.

- They cover key business areas, regulatory aspects and technology enablers towards 2030.

- 250 global experts contributed to the novel research visions discussed in the publications which are available at: *6gchannel.com/6g-white-papers* or *jultika.oulu.fi*

Key 6G features
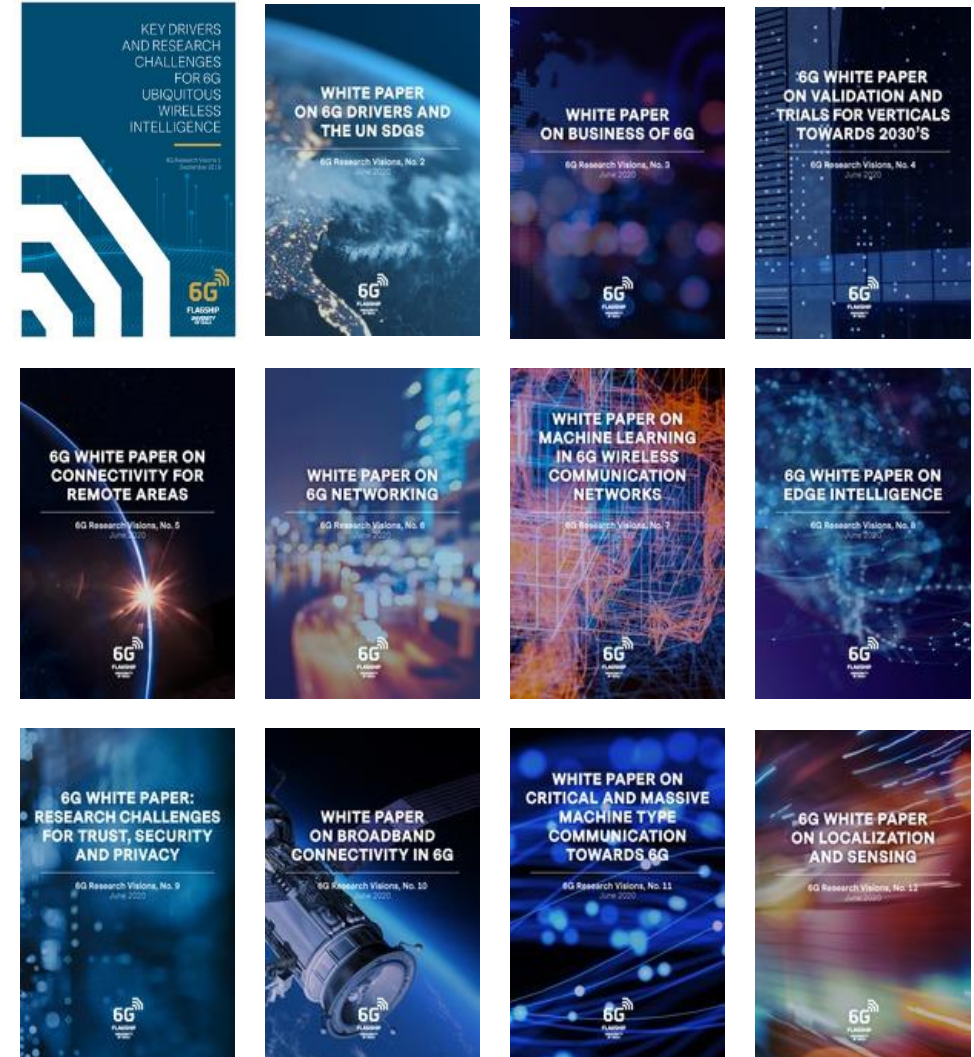
Sentient Things — Sensor · Radio · Edge AI

Health — Sensor · Radio · Cloud · AI

Smart City — Sensor · Radio · Edge AI · Cloud

Smart Home — Sensor · Radio · Edge AI · Cloud

Smart Buildings — Sensor · Radio · AI · Security

Smart Traffic — Sensor · Radio · Swarm

Electric Vehicles — Sensor · Radio · Platform

Delivery Logistic — Sensor · Radio · Cloud

Automated Factories — Sensor · Radio · Cloud

Remote Ops — Sensor · Radio · Edge AI · XR

Personal Experiences — Sensor · Radio · AI · Security

Circular Economy — Sensor · Radio · AI · Platform

Digital Nexus — Sensor · Radio · Edge AI · Cloud

Global Connectivity — Radio · Edge AI · Platform

Continuous Learning — Sensor · Radio · Edge AI

Critical drivers towards 6G

6G

1. Society

- **Digital inclusion via global coverage**
  - Connectivity is key to satisfy UN SDGs and needs of digital societies; current terrestrial technologies with evolutionary features need to be complemented by specific remote areas solutions including satellite.

2. Business

- **New ecosystems and disruptive business models**
  - Digital societies and emergence of new verticals create new ecosystems and disrupts current business models requiring field specific regulation changes; ownership of customers and networks changes.

3. Standards

- **Global collaboration and standards**
  - 6G coalitions forming in a new geopolitical landscape; a new standard is introduced after every 10-years – business reshaped in 20-year cycles; spectrum regulation principles changing ~25++ year cycles.

4. Technology

- **Data privacy and security**
  - Expansion of verticals with new stake holders and emergence of large number of new players providing different network elements, critical applications and operating different parts of networks sets new privacy & security requirements.

Security

- **Service driven network architecture**
  - Having the connectivity everywhere and is needed for the smart society. Networks are ubiquitous, can and will be built by different operators for different purposes. Local specialized services with various connectivity mechanisms are becoming more and more popular. Service driven architectures are becoming dominant after the network ownership driven era.

Network

- **Super efficient connectivity at high spectrum bands**
  - Extreme speeds, reliability, low latency and localization/sensing accuracy can be achieved only locally in rather short-range networks utilizing the higher frequency bands even above 100GHz.

Radio
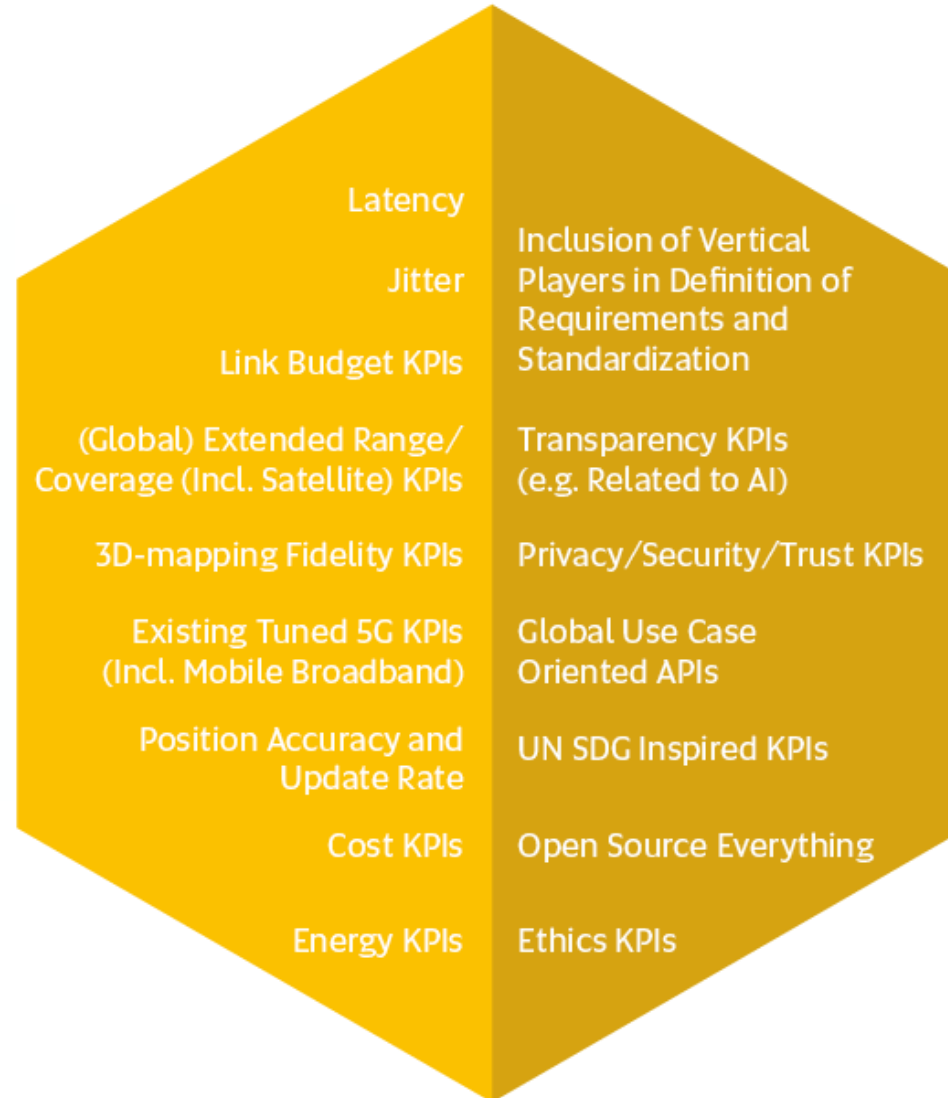
- **Smart AI enabled networks and applications**
  - Networks and applications become intelligent, self-learning and context dependent; edge intelligence is the key technical enabler and challenges/complements centralized cloud solutions.

AI

Sustainability targets defining 6G

Technology and verticals productivity driven KPIs

Latency

Jitter

Link Budget KPIs

(Global) Extended Range/ Coverage (Incl. Satellite) KPIs

3D-mapping Fidelity KPIs

Existing Tuned 5G KPIs (Incl. Mobile Broadband)

Position Accuracy and Update Rate

Cost KPIs

Energy KPIs

Inclusion of Vertical Players in Definition of Requirements and Standardization

Transparency KPIs (e.g. Related to AI)

Privacy/Security/Trust KPIs

Global Use Case Oriented APIs

UN SDG Inspired KPIs

Open Source Everything

Ethics KPIs

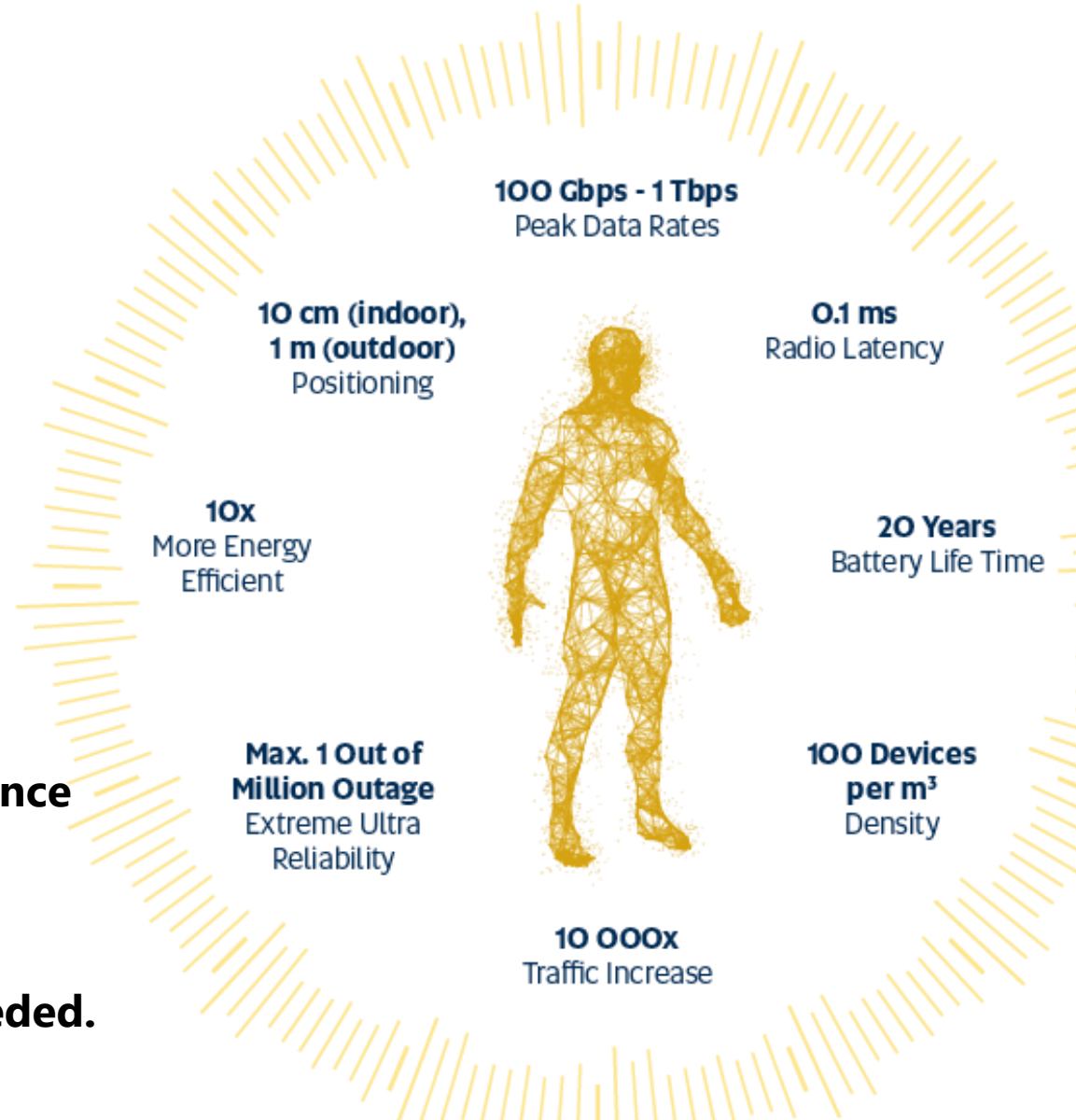**Society and sustainability driven key values**

6G for super efficiency

6G

- **Tbps connectivity**

- **Absolute communication reliability**

- **100% security**

- **Zero latency**

- **Cm-level positioning accuracy and 3D radio imaging**

- **Global coverage including remote areas**

- **Fully automated networks optimization and deployment**

- **Smart context dependent content delivery**

- **Uilization of all human senses for immersive user experience**
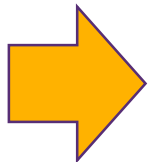
➡️ **Contradictory system requirements.
Deployment/application specific optimization needed.**

100 Gbps - 1 Tbps
Peak Data Rates

**10 cm (indoor),
1 m (outdoor)**
Positioning

0.1 ms
Radio Latency

10x
More Energy
Efficient

20 Years
Battery Life Time

**Max. 1 Out of
Million Outage**
Extreme Ultra
Reliability

**100 Devices
per m³**
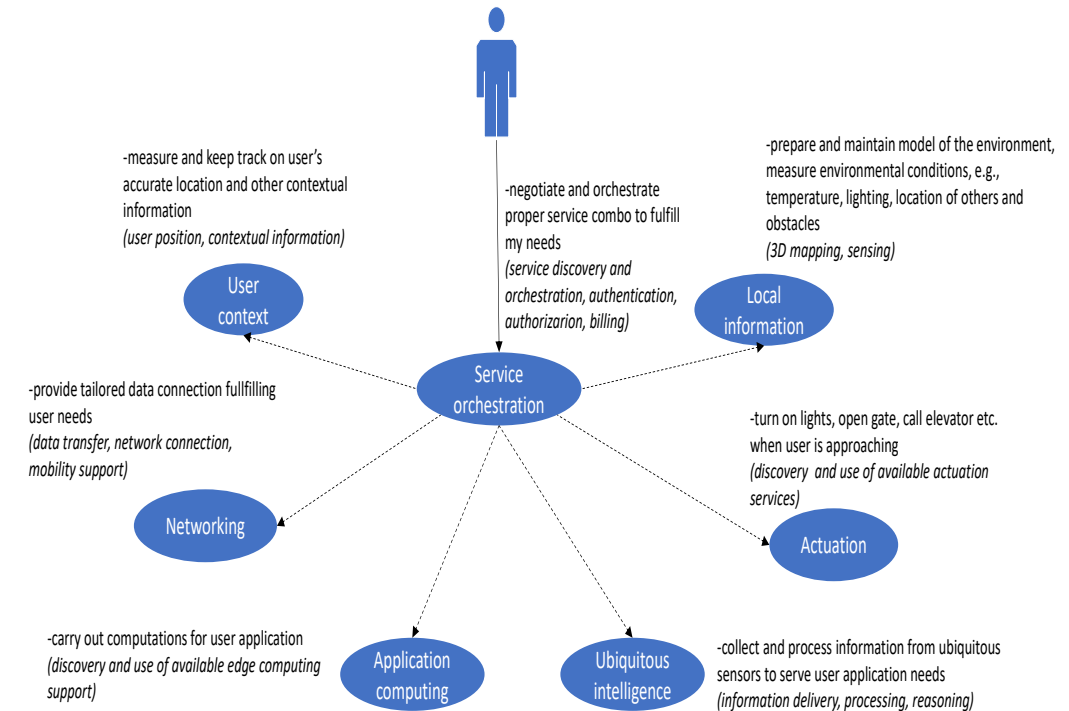Density

10 000x
Traffic Increase

Our proposal on service-centric 6G System Architecture

The 6G system consist of six main services and one additional supporting service:

- **Networking** service: connectivity functionality.

- **User context:** user situation, especially the user position and contextual data management.

- **Local information:** utilize sensing and radar capabilities of the 6G wireless system to e.g. create 3D maps.

- **Actuation:** control actuators and initiate changes in the physical environment.

- **Ubiquitous intelligence:** information delivery, processing and reasoning for applications.

- **Application computing:** data processing from the 6G system side, support for application mobility.

- **Service orchestration:** holistic service combination to satisfy the 6G user and application needs; also authentication, authorization, and billing etc.

Partnering via Test Network

Test Network - key tool for co-creation

5GTN

PyeongChang 2018

ACADEMY OF FINLAND

ESFRI European Strategy Forum on Research Infrastructures

6G

First open test network (https://services.5gtn.fi/).

5G mmW trials in Olympics with Nokia

Operator grade live 5G micro-operator network

Selection to AoF FIRI roadmap

Selection to ESFRI FIRI roadmap

First 6G PoC devices

First 6G "network"

6G Standardization begins

2015   **2018**   **2019**   **2020**   **2021**   **2023**   **2025**   **2026**

5GTN   **4G-LTE**   **5G PoC**   **5G NR**   **5G+**   **5G+** ... **6G**   **6GTN**

LTE small cell
@2.1 and 2.6 GHz

5G PoC/5GNR

5G Macros at 3.5GHz
For IoT - NB IoT/LTE-M

Cloud RAN based 5G
@3.5GHz
5GNR @24 GHz

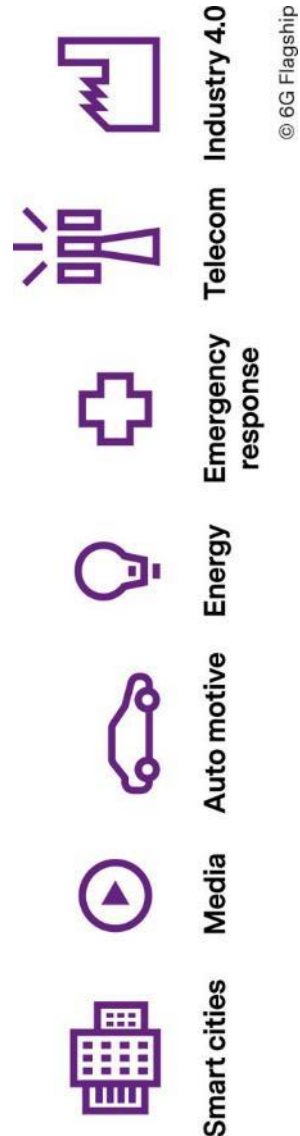3GPP Rel. 16
3GPP Rel. 17
3GPP Rel. 18

Why bother with experimental test networks?

Answer: Versatility of Vertical Requirements

Examples of KPIs for verticals

Vertical	Link DataRate	Latency	LinkBudget	Jitter	Density	Energy Efficiency	Reliability	Capacity	Mobility
Industry mMTC	< 1 Mbps	< 100ms	+ 10 dB	100 µs	100/m^3	High	$1-10^{-6}$	< 10 Gbps	240 km/h
Industry eURLLC	< 5 Mbps	< 100 µs	+ 20 dB	< 1 µs	10/m^3	Nominal	$1-10^{-9}$	< 100 Mbps	240 km/h
Mobility	<10 Gbps	< 100 µs	+ 20 dB	100 µs	100/m^3	Nominal	$1-10^{-7}$	1 Tbps	1200 km/h
eHealth	< 1 Gbps	< 1 ms	+ 10 dB	100 µs	1/m^3	High	$1-10^{-9}$	< 10 Gbps	240 km/h
Energy	<1 Mbps	< 500 µs	+ 40 dB	< 1 µs	10/m^3	Nominal	$1-10^{-6}$	< 100 Mbps	N/A
Finance	< 1 Gbps	< 10 ms	varies	N/A	1/m^3	High	$1-10^{-9}$	< 10 Gbps	Low
Public Safety	<1 Gbps	< 1 ms	+ 20 dB	100 µs	1/m^3	Nominal	$1-10^{-7}$	< 10 Gbps	240 km/h
Agri-business	100 Mbps	< 10 ms	+ 40 dB	100 µs	100/km^2	Nominal	$1-10^{-7}$	1 Gbps	240 km/h

How do we facilitate service pull and avoid technology push!

Industry 4.0

Telecom

Emergency response

Energy

Auto motive

Media

Smart cities

Thank you!