Challenges for 6G

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6G

FLAGSHIP

UNIVERSITY
OF OULU

6G ???
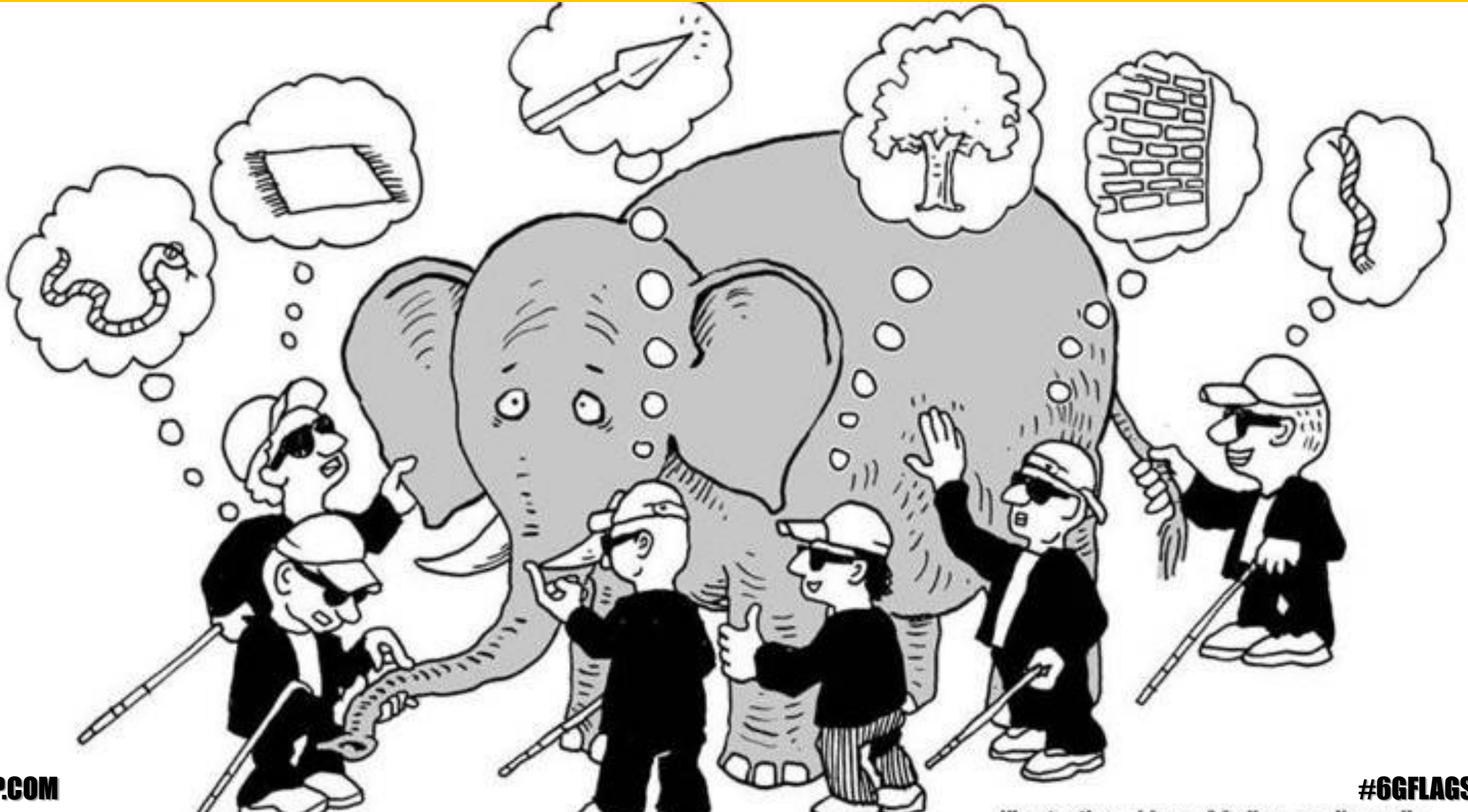
Wireless connectivity is driving major societal changes:
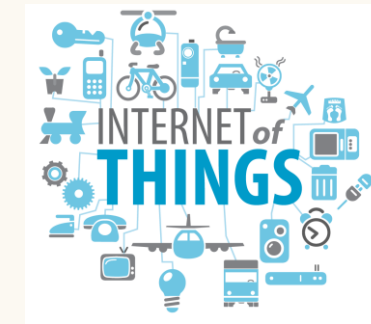
1G - 2G

3G - 4G

5G and beyond

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

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

**– 2040s   Trillions of
connected objects**

Applications range explodes and new value chains emerge:

Logistics

Shopping

Agriculture

Industry 4.0

Health

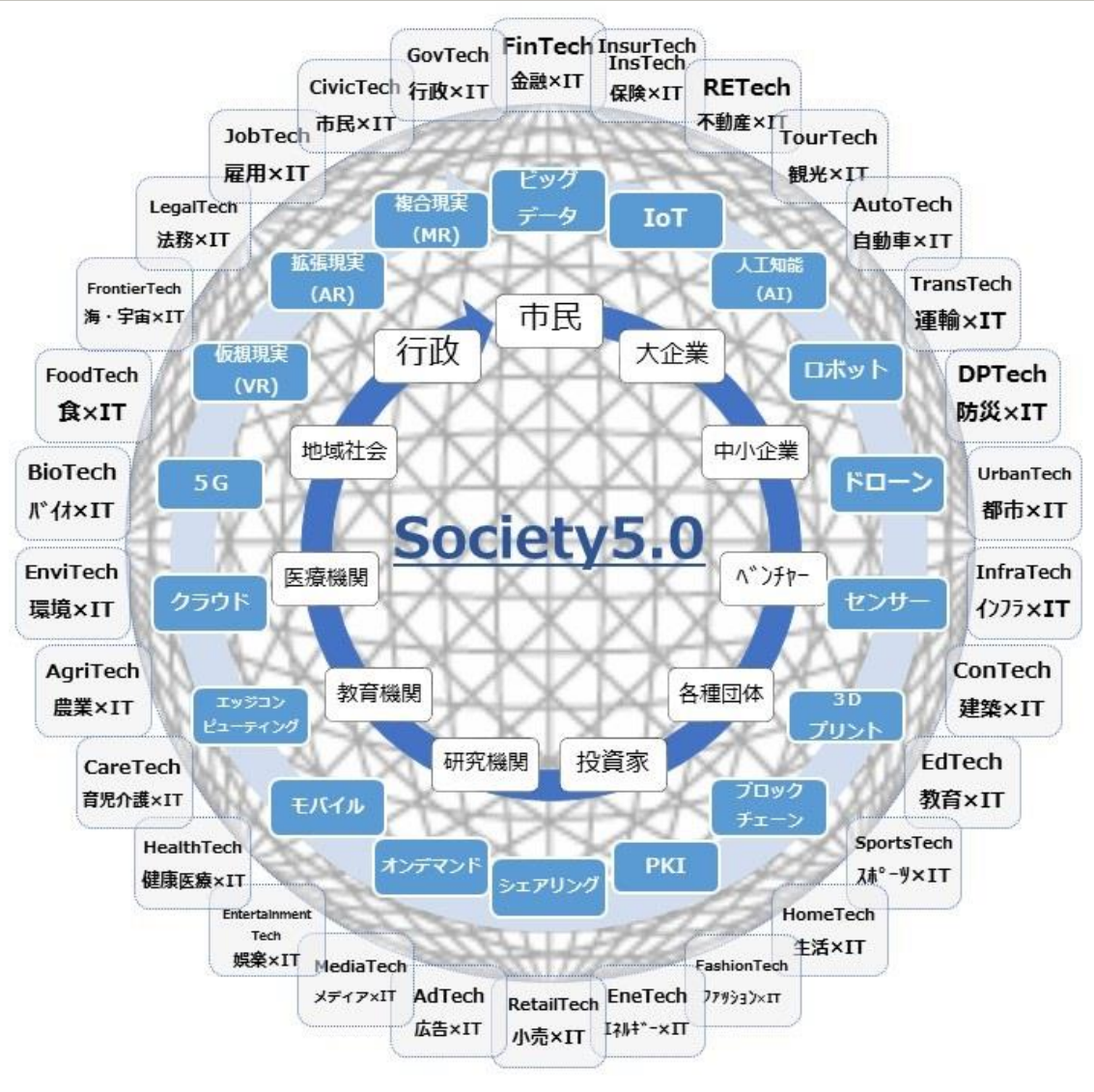Sustainable energy

Automotive & transportation

Verticals specific service providers are needed to complement MNOs offerings.

URLLC type solutions will be tailored for different verticals.

Example:

Japanese vision for Society 5.0:

- Savings in public expenditure
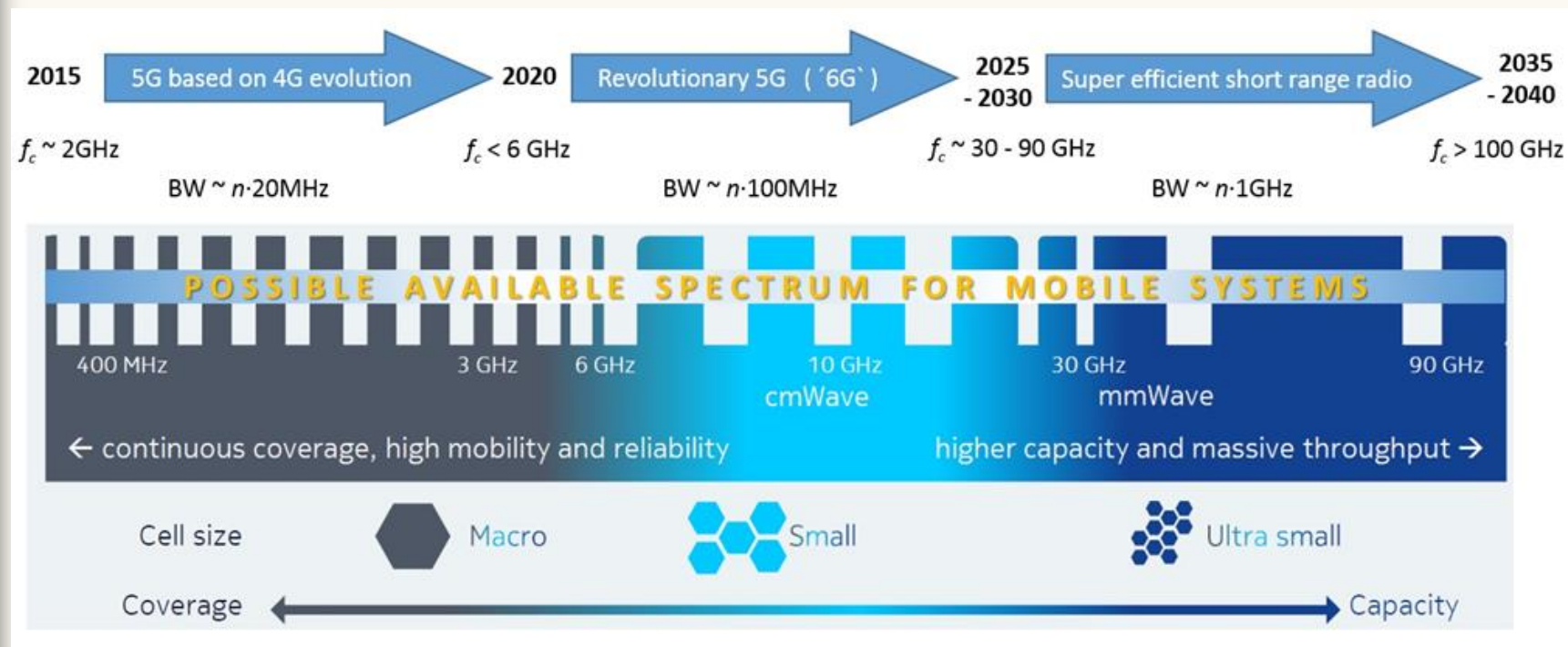- Creation of new businesses
- Sustainable society

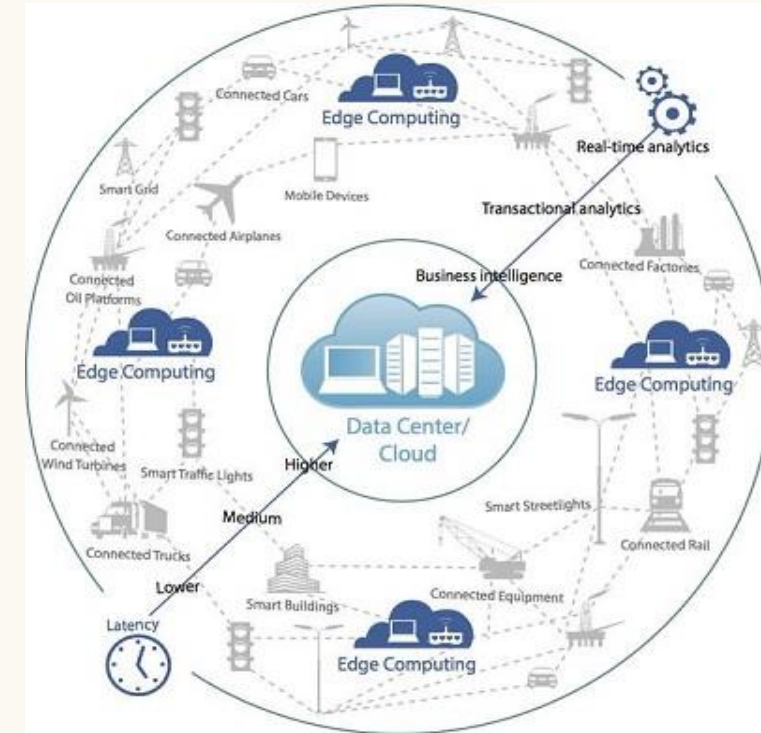**Disruptions** needed for realisation:

- New wireless enabled **technologies**
- ICT **legistlation & regulation**
- **new value chains** serving different verticals

Short Range Connectivity with Edge Computing

6G

Need for higher frequency bands towards THz regime

AI at edge

Huge capacity increase possible with extreme densification and utilization of higher spectrum bands.

BSs installed very close to users, i.e., indoors & vehicles.

Local spectrum licensing would be needed.

AI solutions are **driven by different verticals**.

What AI/ML brings to wireless systems and what wireless connectivity offers to AI/ML based apps.
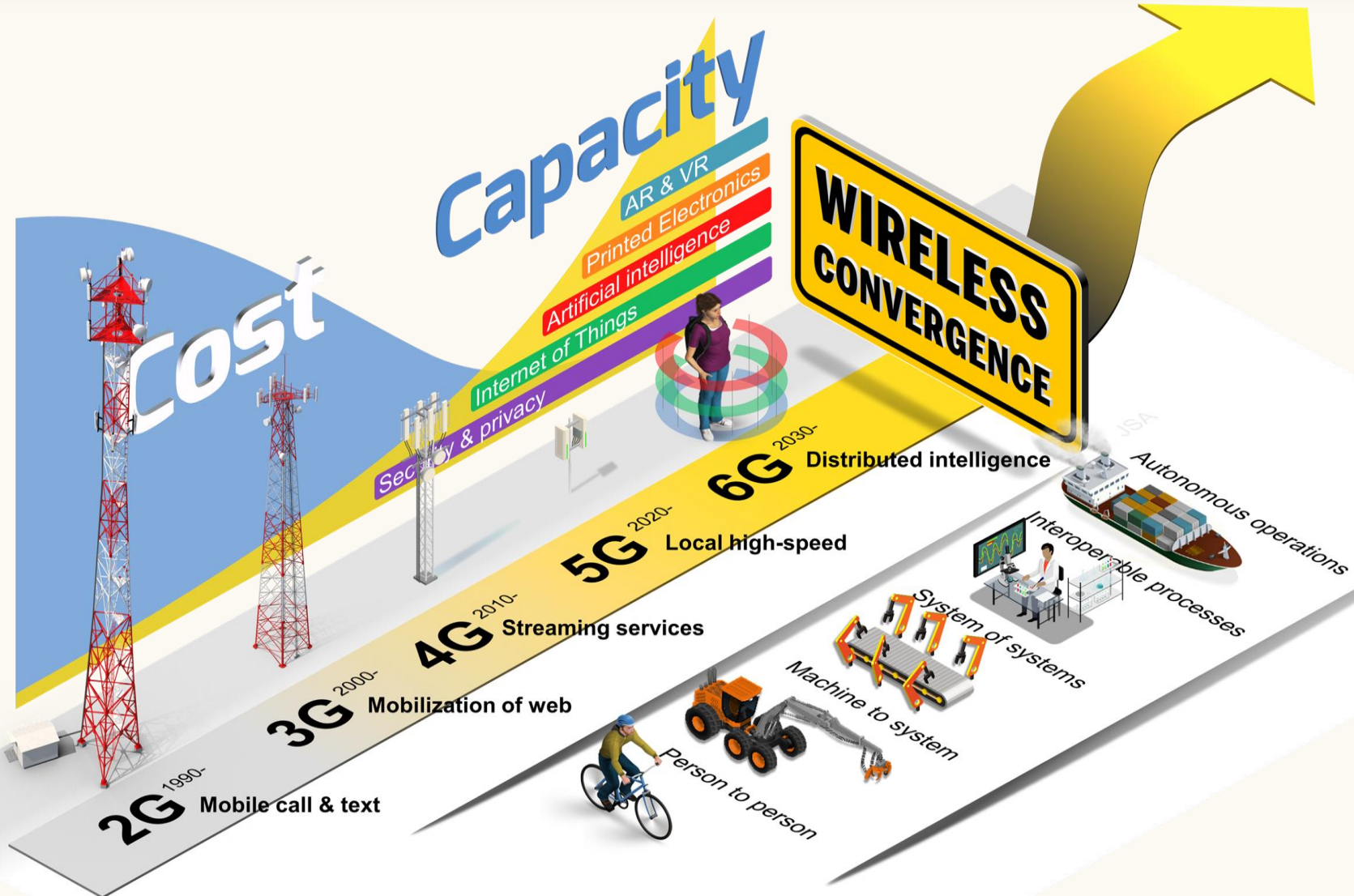
Autonomous Wireless Systems

Capacity

AR & VR
Printed Electronics
Artificial intelligence
Internet of Things
Security & privacy

Cost

WIRELESS CONVERGENCE

2G 1990- Mobile call & text

3G 2000- Mobilization of web

4G 2010- Streaming services

5G 2020- Local high-speed

6G 2030- Distributed intelligence

Person to person

Machine to system

System of systems

Interoperable processes

Autonomous operations

Security, privacy & trust/reliability besides technical superiority!

6G Enabled Wireless Smart Society & Ecosystem (6Genesis)

National Flagship for 2018-2026

Volume 251M€

Operated by University of Oulu, in collaboration with: Nokia, VTT, Aalto University, BusinessOulu, Oulu University of Applied Sciences

CWC view from 2015:

2015 — 5G based on 4G evolution → 2020 — Revolutionary 5G ('6G') → 2025-2030 — Super efficient short range radio → 2035-2040

$f_c \sim 2\text{GHz}$ — $f_c < 6\text{ GHz}$ — $f_c \sim 30 - 90\text{ GHz}$ — $f_c > 100\text{ GHz}$

$BW \sim n \cdot 20\text{MHz}$ — $BW \sim n \cdot 100\text{MHz}$ — $BW \sim n \cdot 1\text{GHz}$

POSSIBLE AVAILABLE SPECTRUM FOR MOBILE SYSTEMS

400 MHz — 3 GHz — 6 GHz — 10 GHz cmWave — 30 GHz mmWave — 90 GHz

← continuous coverage, high mobility and reliability — higher capacity and massive throughput →

Cell size: Macro — Small — Ultra small

Coverage ← → Capacity

MNO dominated evolutionary path — Verticals driven revolutionary path
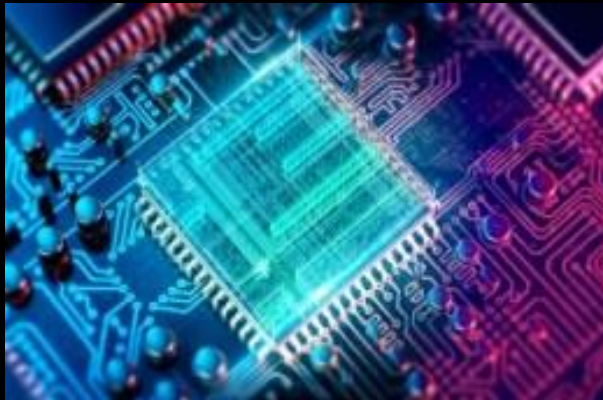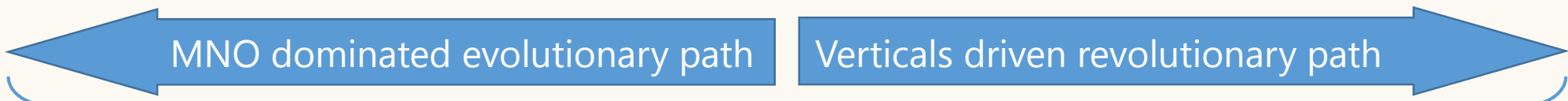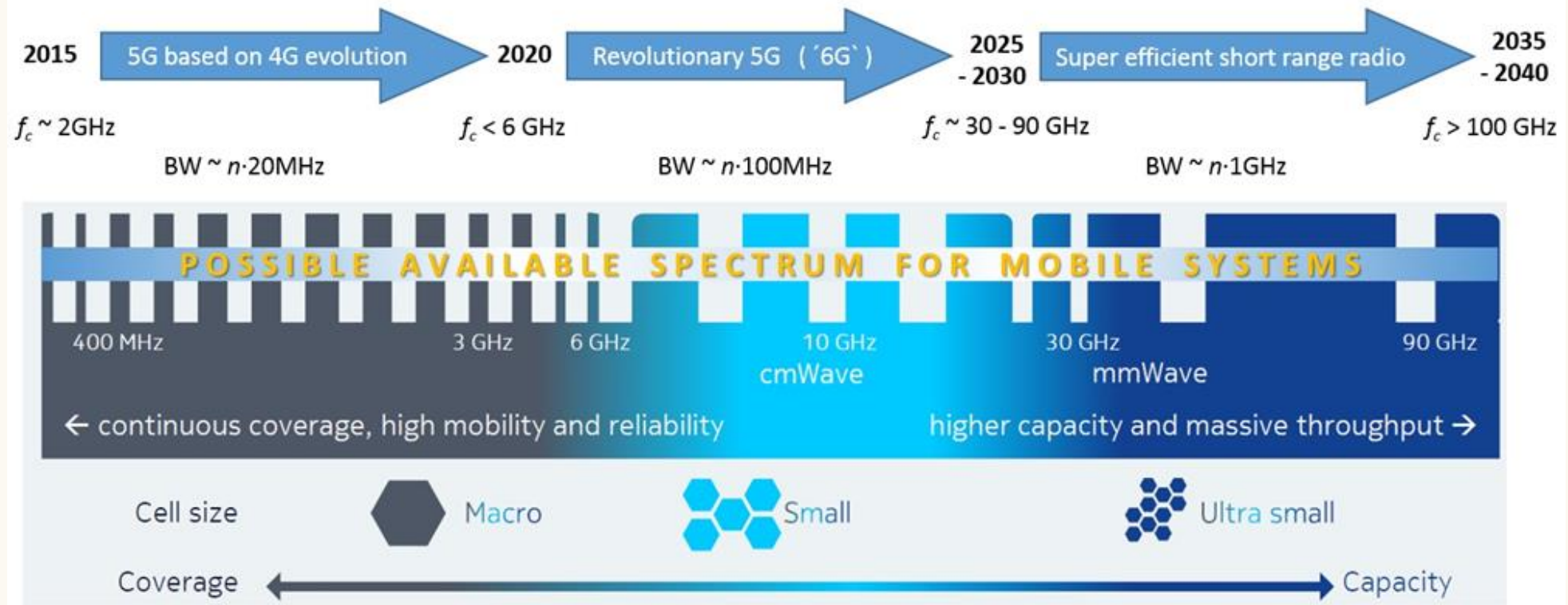
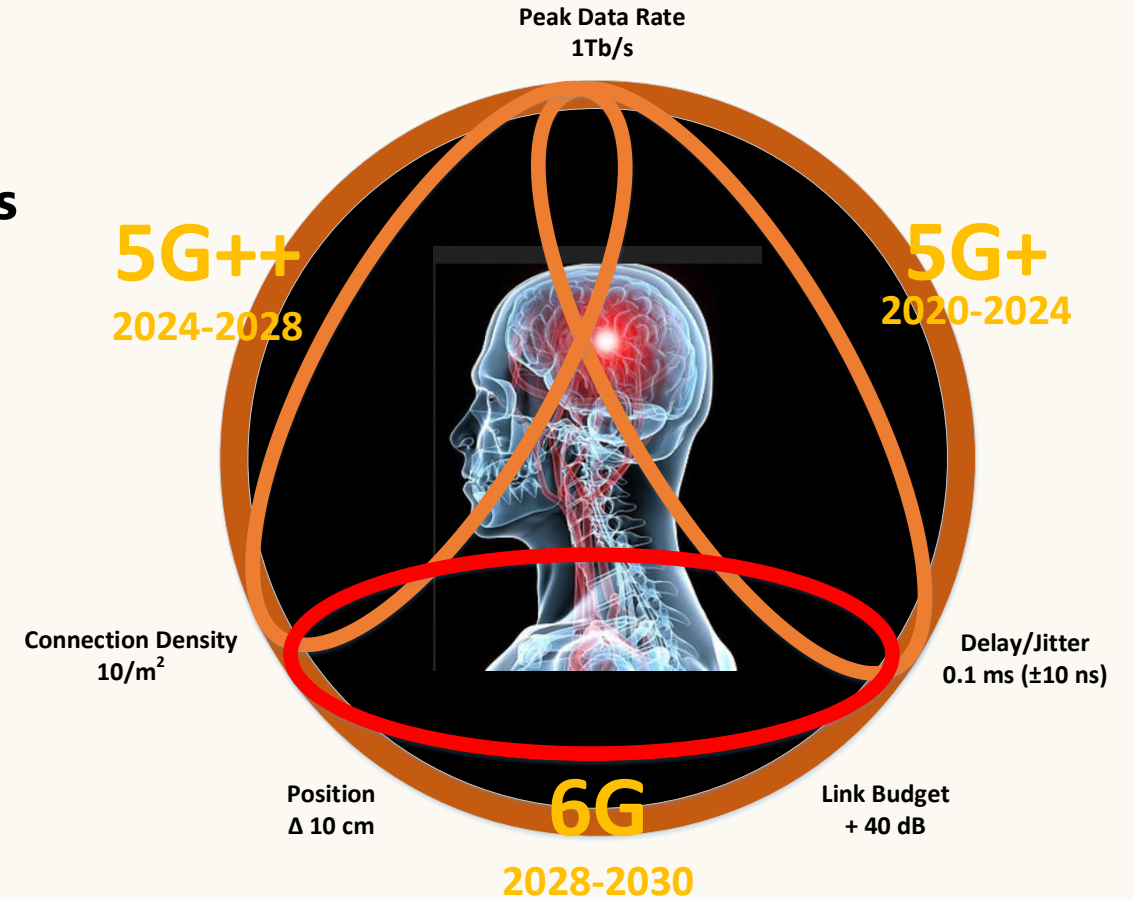**Seamless joint-operation of all access networks**

Relevant Areas for Research

- Global coverage
- Support for ambient/novel sensing/sensors
- 4D-Imaging and image projection and XR
- Remote telepresence
- Terahertz technologies
- Cm level positioning
- Extreme URLLC
- Tactile haptic internet
- RAN agnostic/automatic orchestrated transceivers – AI inspired air interfaces
- Pervasive user identification and authentication
- Non-device centric communications
- Zero-energy communications
- Small data AI (distributed learning)
- Net neutrality – exploring new billing models
- Distributed trust
- Consent and privacy preserving data sharing
- Cyber-physical security
- Cognitive automation
- Proactive decision making/information offering

KPIs should be redefined

- **UN SDG driven KPIs**

- **Privacy/Security/Trust/Reliability/Ethics KPIs**

- **Position Accuracy and update rate, 3D-mapping Fidelity**

- **Latency, Jitter**

- **Transparency KPIs (e.g. related to AI)**

- **Energy KPIs**

- **Reliability KPI for critical communications**

- **Existing 5G KPIs (incl. mobile broadband)**

- **Coverage & service availability KPIs (Global, extended range/coverage incl. satellite)**

Peak Data Rate
1Tb/s

5G++
2024-2028

5G+
2020-2024

Connection Density
10/m^2

Delay/Jitter
0.1 ms (±10 ns)

Position
Δ 10 cm

6G

Link Budget
+ 40 dB

2028-2030

Beyond 5G vision by Huawei

The First 6G Summit in Finland, March 2019

- The first 6G white paper drafted with 60 selected participants; released June 2019.
- 2ⁿᵈ 6G Summit @ Levi, Lapland, 17-20.3.2020.
- New 6G white paper edition released annually.
- The target for the first edition: identify the key drivers, requirements, challenges and critical research questions related to 6G.
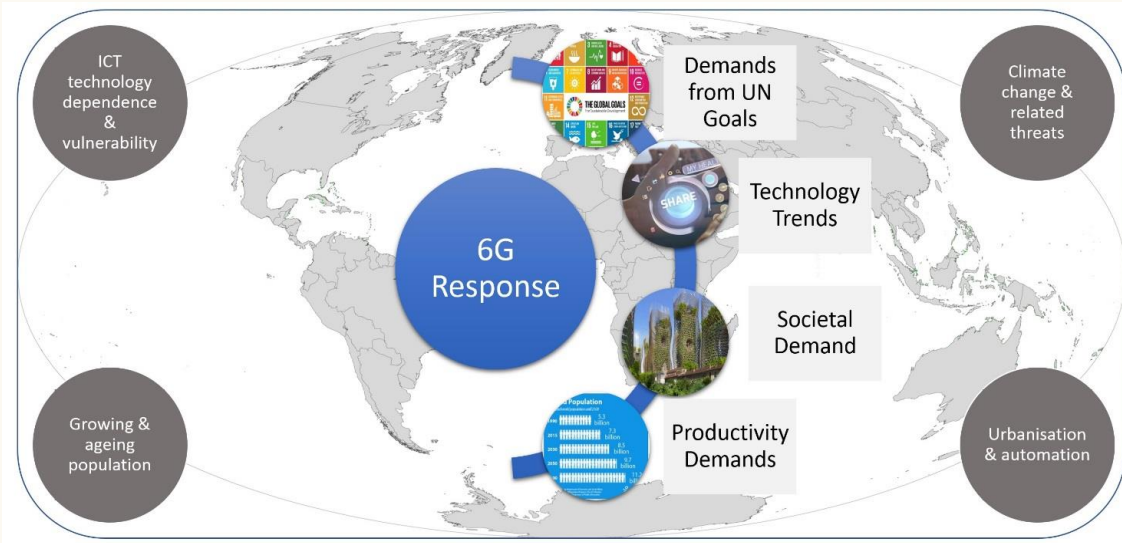
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Keynotes and presentations:
www.6gsummit.com

300 participants including leading manufacturers & operators