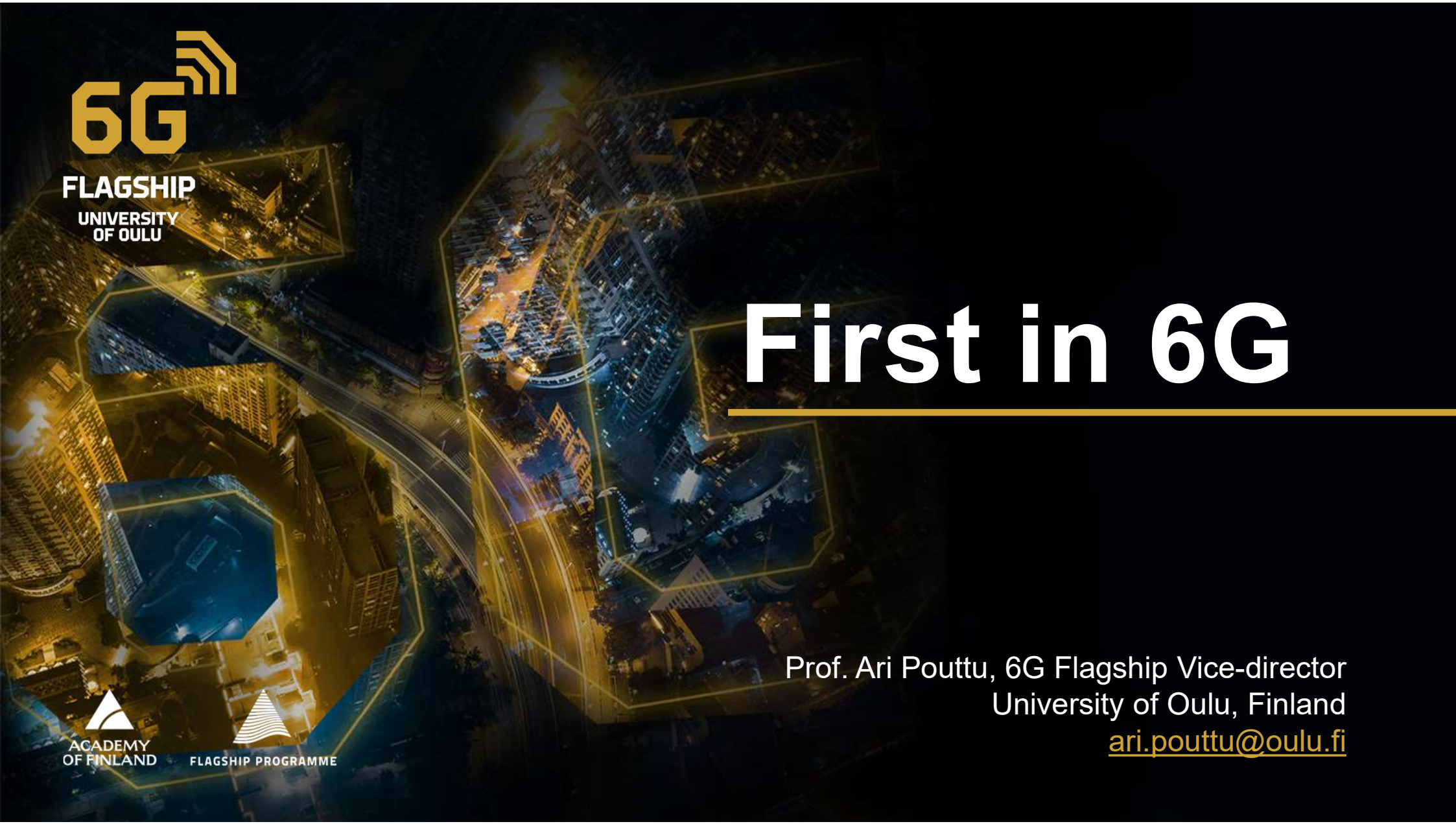

First in 6G

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University of Oulu, Finland
ari.pouttu@oulu.fi

What is 6G?

- A new mobile “generation” appears approximately every ten years, with 6G expected to emerge around 2030.
- The first release of 5G New Radio (NR) – 3GPP Release 15 – was ready in 2018, and global commercialization of 5G is currently underway. 5G performance and use cases will continue to evolve in the coming releases.
- 6G will take onboard new technologies and satisfy communication demands going beyond the 5G evolution.
- It is not clear yet what 6G will entail. It will include relevant technologies considered too immature for 5G or which are outside the defined scope of 5G. More specifically, the way in which data is collected, processed, transmitted and consumed within the wireless network will be a key driver for 6G.
- Now is the perfect time to identify future communication needs, performance requirements, system and radio challenges, and major technical options for 6G to establish the research goals towards the 2030s.

Source: 6G White Paper 2019 "Key drivers and research challenges for 6G ubiquitous wireless intelligence"

World’s First Major 6G Research Programme

6G Enabled Wireless Smart Society & Ecosystem

- Finnish Flagship for 2018-2026
- Volume 251 M€
- 300 experts
- Operated by University of Oulu
- Co-creation with Nokia, Keysight and InterDigital as well as VTT, Aalto University, BusinessOulu and OUAS.

1. 

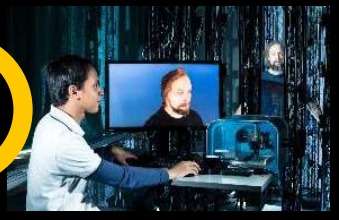
Wireless Connectivity

2. 

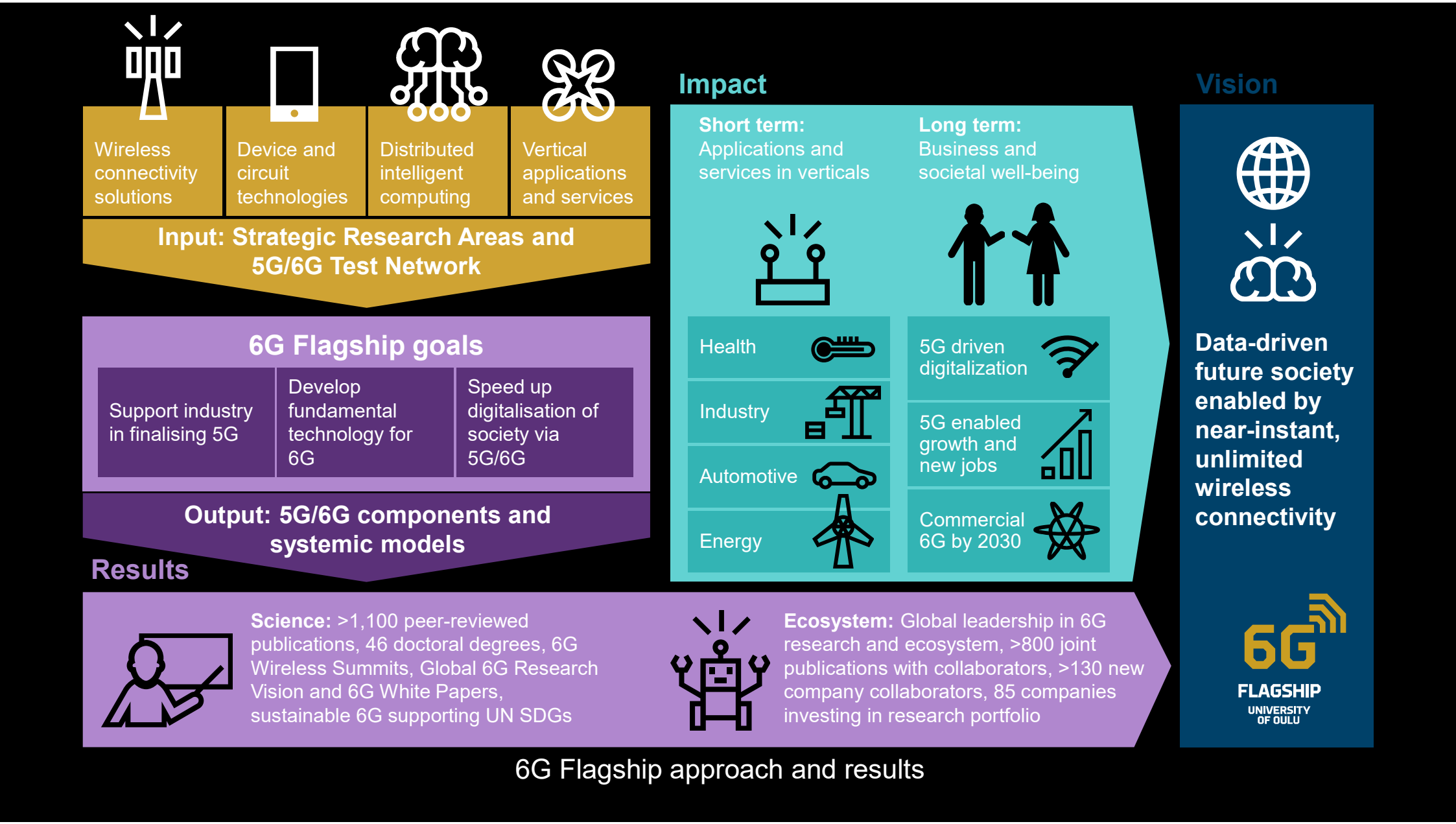
Devices & Circuits

3. 

Distributed Computing

4. 

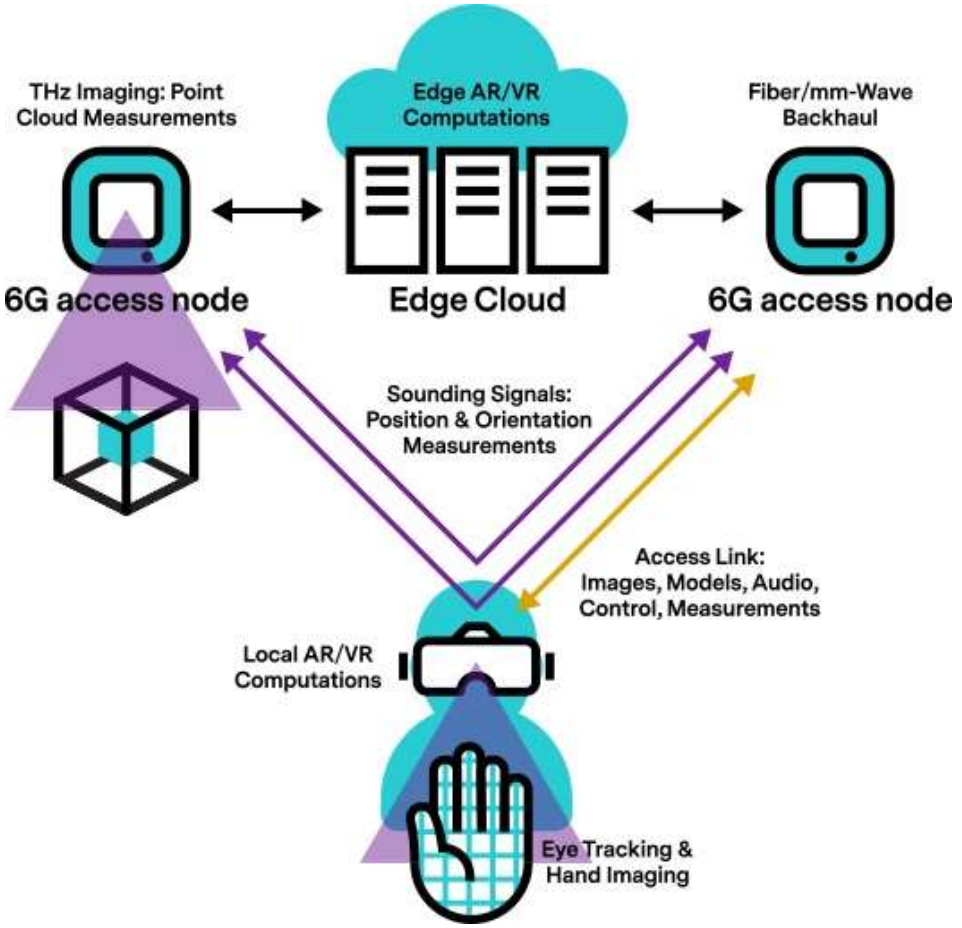
Services & Applications



6G Flagship approach and results

6G Merges Communications with New Applications

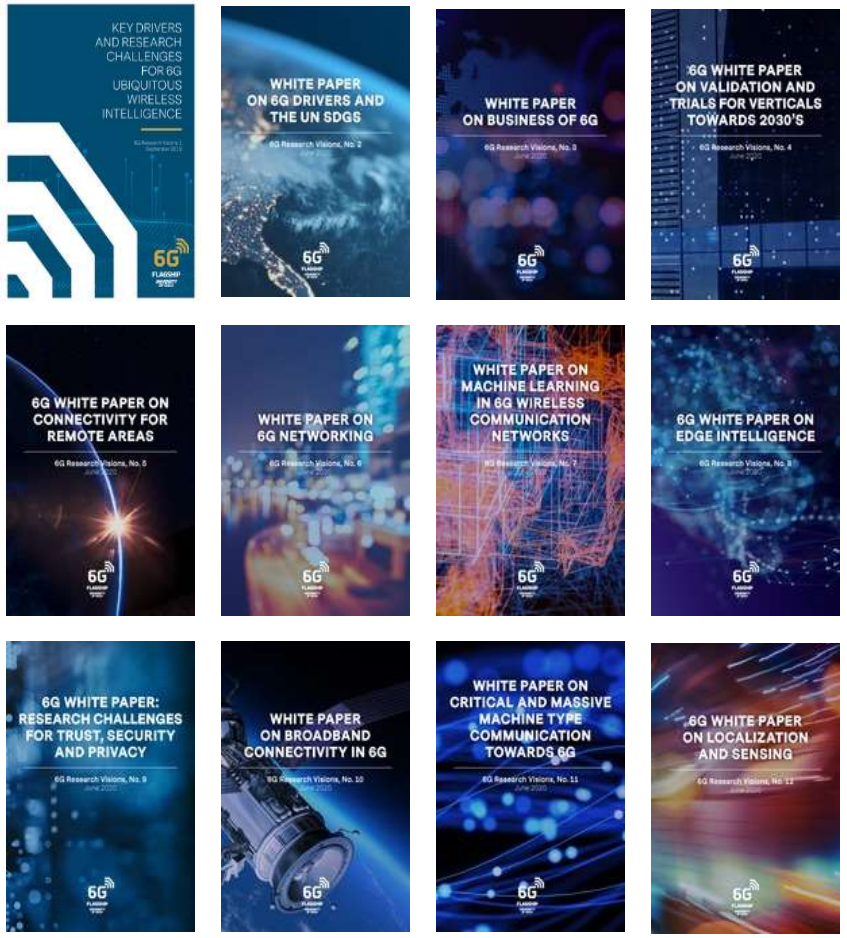
- Going to higher frequencies (>100GHz), 6G will facilitate the integration of sensing, imaging, highly accurate positioning and communications.
- These type of completely new capabilities, combined with mobility and Artificial Intelligence / Machine Learning, open a massive amount of new application possibilities with 6G leading to new business and a truly digitalized society.
- New applications and 6G also have tremendous potential for alleviating the digital divide.



Source: 6G White Paper 2019 "Key drivers and research challenges for 6G ubiquitous wireless intelligence“ 6gflagship.com/6gwhitepaper

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*

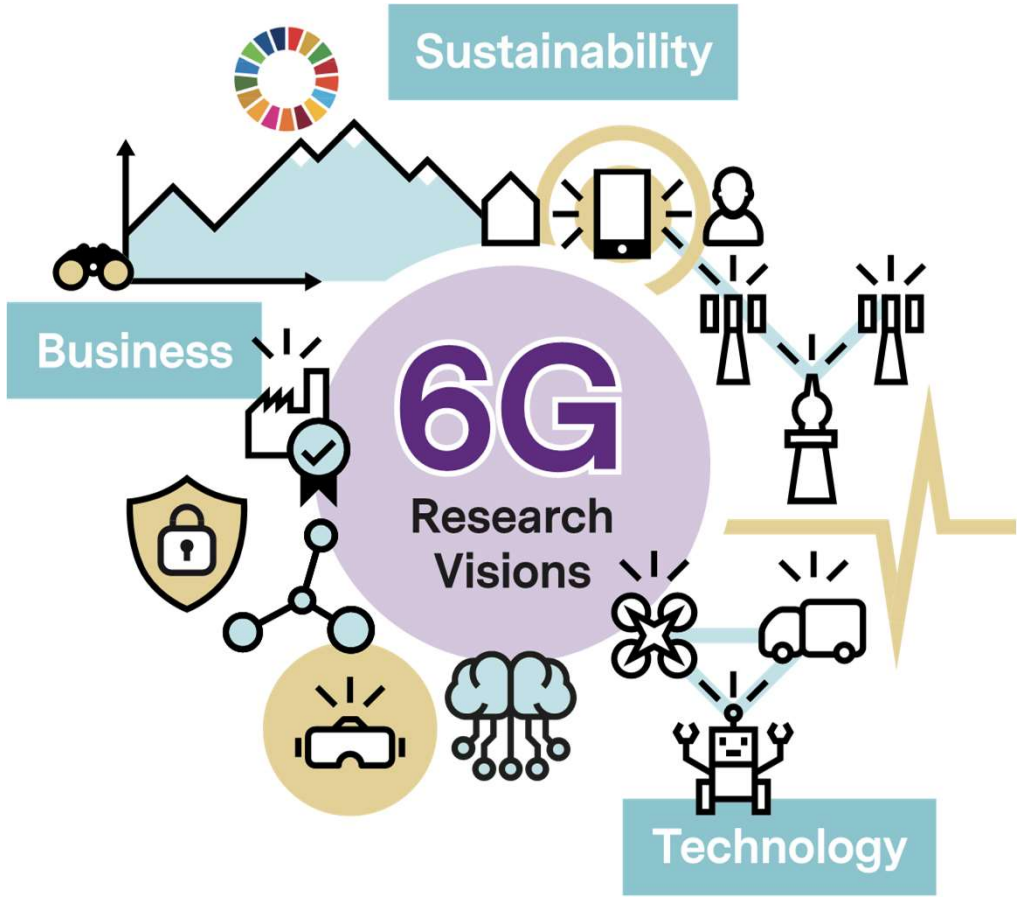


6G White Papers –Sustainability, Technology and Business

"The role of ICT in meeting United Nations Sustainable Development Goals is critical."

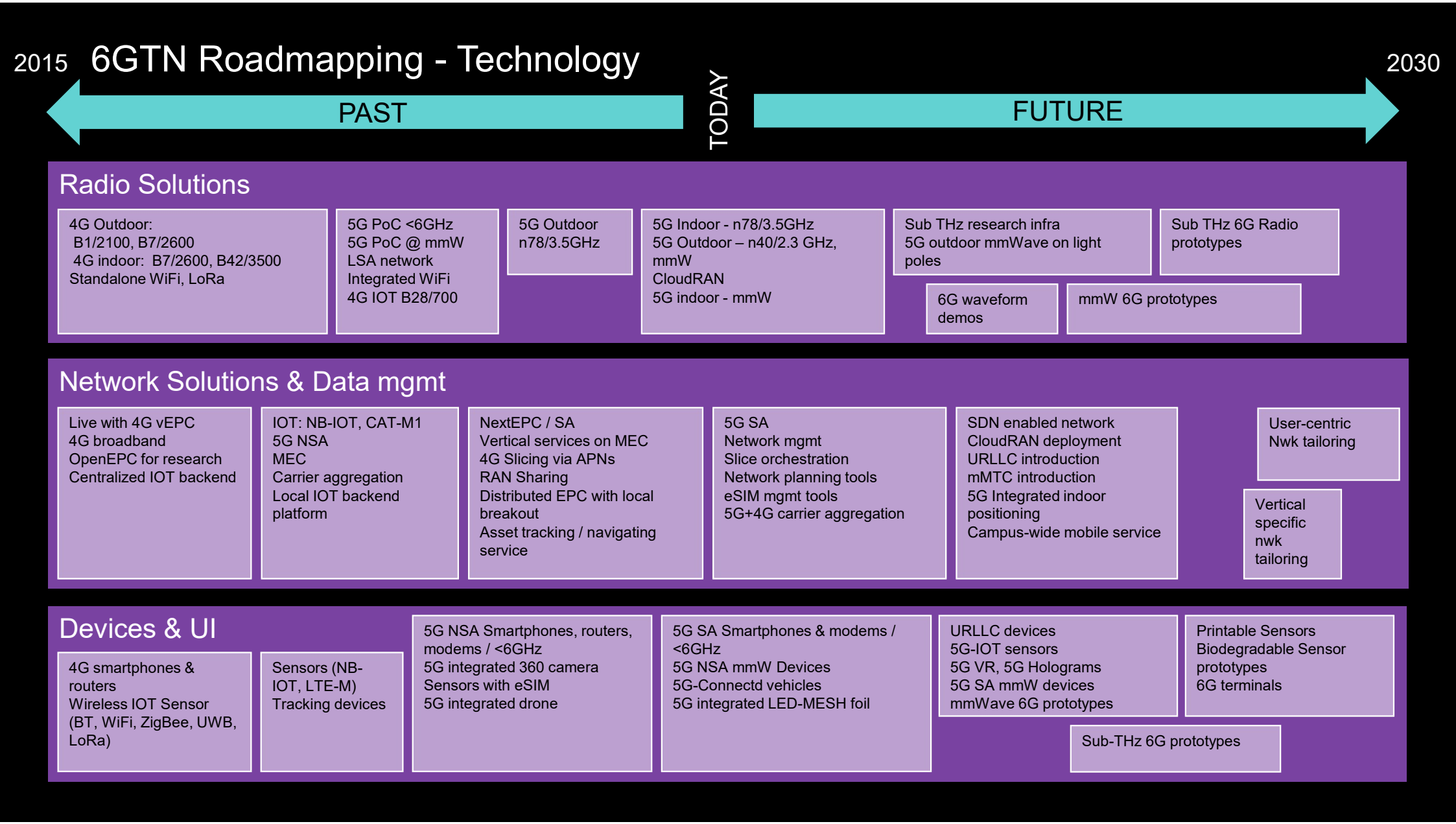
- Both 6G and the UN Sustainable Development Goals (SDGs) target year 2030.

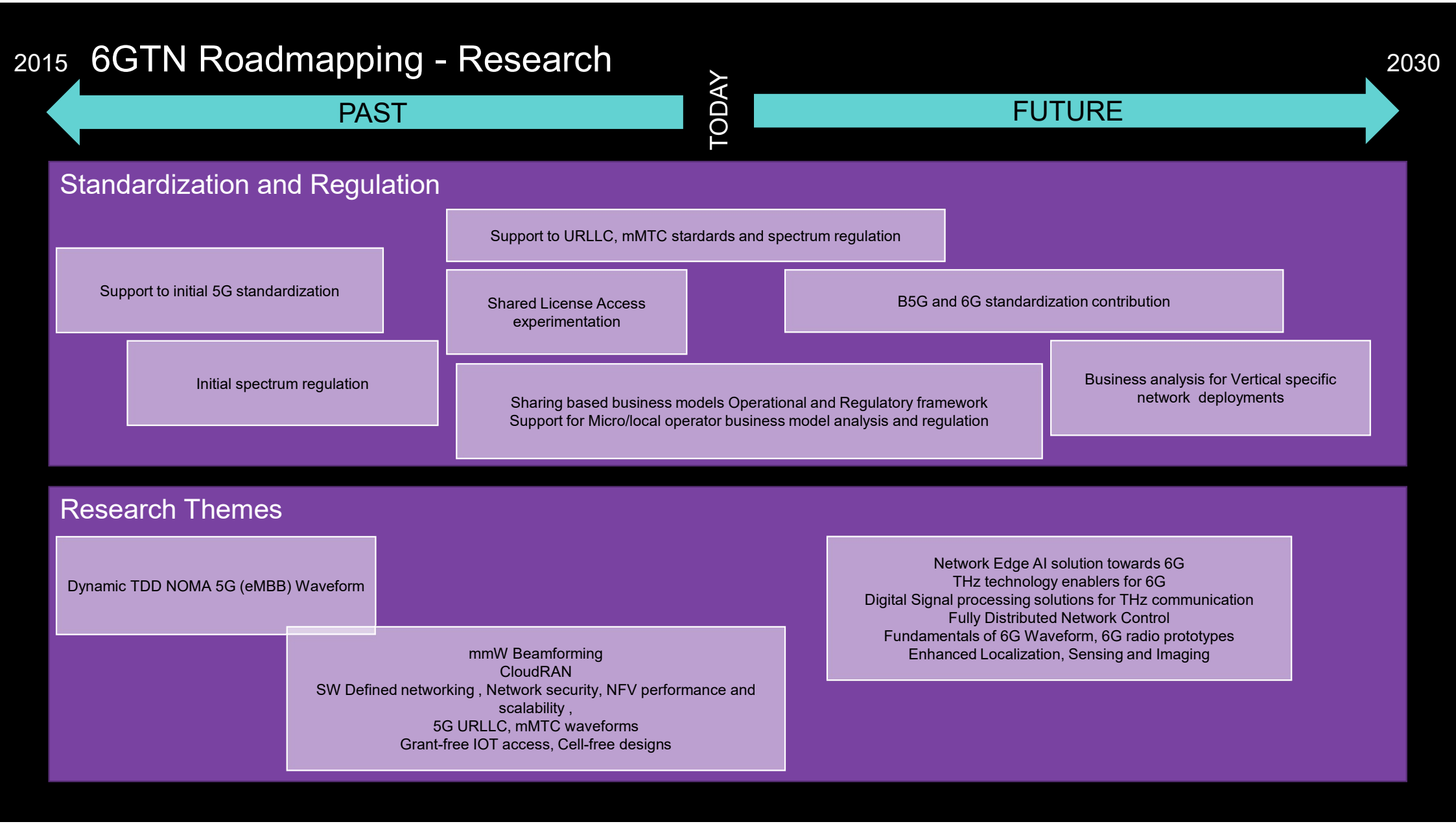
- **White Paper on 6G Drivers and the UN SDGs** defines a three-fold role for 6G as
  1) provider of services to help reaching the UN SDGs,
  2) enabler of measuring tools for data collection to help with the reporting of indicators, and
  3) reinforcer of a new ecosystem to be developed in line with the UN SDGs.



5G / 6G Test Network Roadmap

Technology & Research


2015
6GTN Roadmapping - Technology
2030
PAST
TODAY
FUTURE
Radio Solutions
4G Outdoor:
B1/2100, B7/2600
4G indoor: B7/2600, B42/3500
Standalone WiFi, LoRa
5G PoC <6GHz
5G PoC @ mmW
LSA network
Integrated WiFi
4G IOT B28/700
5G Outdoor
n78/3.5GHz
5G Indoor - n78/3.5GHz
5G Outdoor – n40/2.3 GHz, mmW
CloudRAN
5G indoor - mmW
Sub THz research infra
5G outdoor mmWave on light poles
Sub THz 6G Radio prototypes
6G waveform demos
mmW 6G prototypes
Network Solutions & Data mgmt
Live with 4G vEPC
4G broadband
OpenEPC for research
Centralized IOT backend
IOT: NB-IOT, CAT-M1
5G NSA
MEC
Carrier aggregation
Local IOT backend platform
NextEPC / SA
Vertical services on MEC
4G Slicing via APNs
RAN Sharing
Distributed EPC with local breakout
Asset tracking / navigating service
5G SA
Network mgmt
Slice orchestration
Network planning tools
eSIM mgmt tools
5G+4G carrier aggregation
SDN enabled network
CloudRAN deployment
URLLC introduction
mMTC introduction
5G Integrated indoor positioning
Campus-wide mobile service
User-centric Nwk tailoring
Vertical specific nwk tailoring
Devices & UI
4G smartphones & routers
Wireless IOT Sensor (BT, WiFi, ZigBee, UWB, LoRa)
Sensors (NB-IOT, LTE-M)
Tracking devices
5G NSA Smartphones, routers, modems / <6GHz
5G integrated 360 camera
Sensors with eSIM
5G integrated drone
5G SA Smartphones & modems / <6GHz
5G NSA mmW Devices
5G-Connectd vehicles
5G integrated LED-MESH foil
URLLC devices
5G-IOT sensors
5G VR, 5G Holograms
5G SA mmW devices
mmWave 6G prototypes
Printable Sensors
Biodegradable Sensor prototypes
6G terminals
Sub-THz 6G prototypes


2015
6GTN Roadmapping - Research
2030
PAST
TODAY
FUTURE
Standardization and Regulation
Support to initial 5G standardization
Support to URLLC, mMTC stardards and spectrum regulation
Shared License Access experimentation
B5G and 6G standardization contribution
Initial spectrum regulation
Sharing based business models Operational and Regulatory framework
Support for Micro/local operator business model analysis and regulation
Business analysis for Vertical specific network deployments
Research Themes
Dynamic TDD NOMA 5G (eMBB) Waveform
mmW Beamforming
CloudRAN
SW Defined networking , Network security, NFV performance and scalability ,
5G URLLC, mMTC waveforms
Grant-free IOT access, Cell-free designs
Network Edge AI solution towards 6G
THz technology enablers for 6G
Digital Signal processing solutions for THz communication
Fully Distributed Network Control
Fundamentals of 6G Waveform, 6G radio prototypes
Enhanced Localization, Sensing and Imaging

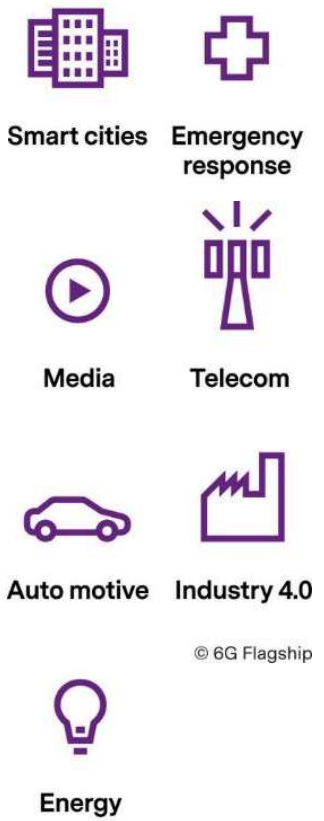
Verticals and Value Driving the Future

Requirements, Solutions & Indicators

Versatility of Vertical Requirements

Examples of Key Performance Indicators (KPIs) for verticals*

Vertical	Link DataRate	Latency	Link Budget	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
Industrye URLLC	< 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



*Vertical ~ Business area

Complementary Mobile Operator Solutions

- Transition to higher frequencies and increasing role of indoor networks will boost network sharing in cities and indoor spaces, and drive the “local operator” paradigm invented by University of Oulu experts.
- This gives rise to vertical specific service providers (local operators) with thorough understanding of the KPIs, dynamics and business within a vertical.
- A local operator can develop and deploy a private mobile network e.g. in an industrial plant, a shopping mall, a hospital or a harbour.
- More info: 6G White Paper on Validation and Trials for Verticals towards 2030’s

https://www.6gchannel.com/items/6g-white-paper-validation-trials

New Value Indicators for 6G

Technology key performance indicators (KPIs) include, e.g. bandwidth, latency, jitter, security, and resilience.

New value KPIs must be considered in 6G network design. They should also be linked with UN SDGs and reflect e.g.

- economic growth
- education
- health
- gender equality
- digital literacy
- happiness

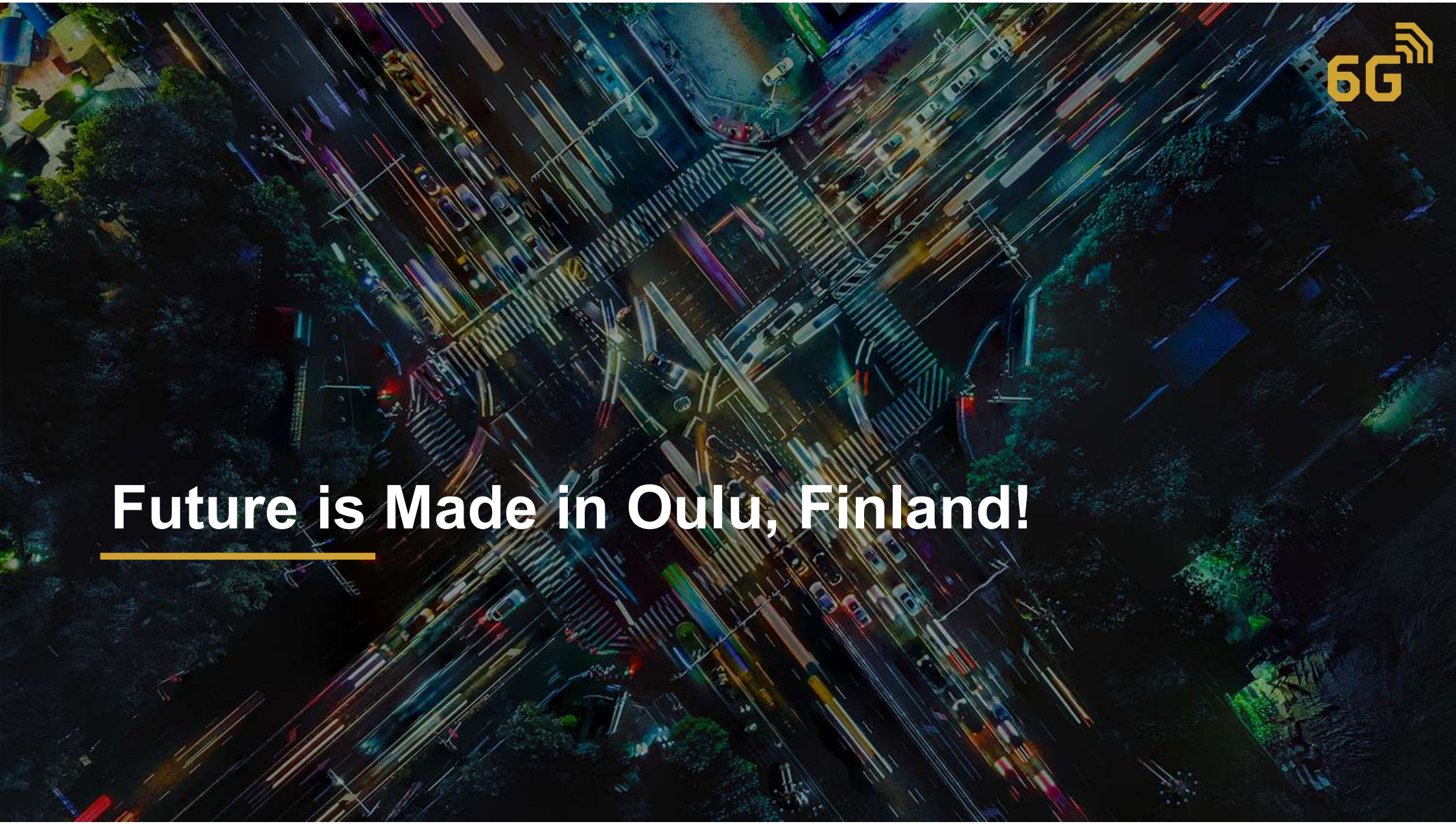
→ Coverage, energy efficiency, delay for some cases (mainly mMTC)

→ Coverage, Throughput, delay, reliability (mainly URLLC)

→ Coverage, Throughput, delay, reliability, energy efficiency (mainly mMTC and URLLC)

→ Capacity and throughput (mainly xMBB)

Security and Energy efficiency are present in all SDGs


6G
Future is Made in Oulu, Finland!

Future is Made in Oulu, Finland!

Study next-gen mobile technology & ICT at the University of Oulu

https://www.oulu.fi/6gflagship/study-opportunities

- Apply for ICT studies at the University of Oulu on **7-20 January 2021**
- As a student in our international degree and master's programs, you can gain globally leading expertise needed for creating new technology and products towards 2030 and the 6G era.
- Oulu is Finland's fastest growing city where the wireless future is created with 5G and 6G. https://investinoulu.com
- The research, development and innovation (RDI) hub in Oulu helps you to achieve your full academic potential and launch a successful career.

Examples of technologies and research areas in our international programs

International Degree Program in Digitalization, Computing and Electronics (DICE) (3+2 years)

- artificial intelligence
- printed intelligence
- current and next-generation communication technologies
- internet of things, IoT
- machine vision
- information security
- privacy

Master´s Programme in Electronics and Communications Engineering (ECE) (2 years)

- communication networks
- computer engineering
- electronics design
- electronics materials and components
- 5G and 6G wireless communication systems
- information theory
- photonics and measurement technology
- stochastical and digital signal processing
- radio channels
- radio engineering
- steerable Intelligent antennas for 5G MIMO and SDMA systems

Master's Programme in Computer Science and Engineering (CSE) (2 years)

- artificial intelligence
- augmented reality
- big data
- computer security
- computer vision
- data mining
- embedded systems
- internet of things
- machine learning
- mobile computing
- social networks
- virtual reality


6G
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Thank you!

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