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6G

FLAGSHIP

UNIVERSITY OF OULU

On the road to 6G

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Vision for 2030

Our society is data-driven, enabled by near-instant, unlimited wireless connectivity.

6G will emerge around 2030 to satisfy the expectations not met with 5G, as well as, the new ones fusing AI inspired applications in every field of society with ubiquitous wireless connectivity.

[Click here for our vision video](#)

A large, semi-transparent graphic of the year '2030' is overlaid on the right side of the image. The background features a silhouette of a person's head in profile, looking towards the right. Behind the head is a dark, futuristic cityscape with glowing windows and structures, suggesting a vision of the future. The overall aesthetic is high-tech and futuristic, with a dark color palette and glowing elements.



World's First 6G Research Program

6G Enabled Wireless Smart Society & Ecosystem

- National Flagship for **2018-2026**
- Volume **251 M€**
- Operated by **University of Oulu**
- Collaboration with **Nokia, VTT, Aalto University, BusinessOulu, OUAS.**

6G Flagship General Goals:

- **Introduction of 5G to markets via innovative vertical solutions**
- **Develop fundamental 6G technologies**
- **Speed up digitalization of society**

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 across verticals

Enabling **Disruptive Value Networks**

Numbers & Collaboration



Staff

305
experts in 2020



58
Nationalities

Publications (May 2018 – September 2020)

1 151
Peer-reviewed publications
/ Journal and conference articles



65% International joint publications
75% Joint publications with collaborators
11% Joint publications with companies

Collaboration (May 2018 – September 2020)

259
Research projects with
external funding



136 New company
collaborators
85 Companies investing in
research portfolio



www.5gtn.fi

5G NR (<6GHz) NSA integrated

800MHz @26/28GHz 10Gbps

Hybrid Beamformer

700 MHz

2.1 GHz

2.3 GHz

2.6 GHz

3.5 GHz

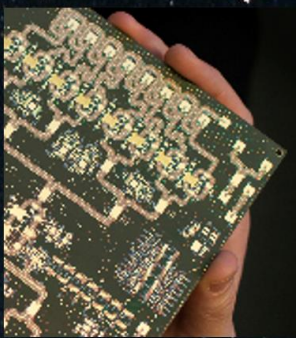
26 ... 28 GHz

NB-IoT/LTE-M1

LTE small cells

WiFi, BLE, LoRa

Dedicated SIM Cards





Value Chains Reformed Every 20-Years

Wireless connectivity is driving major societal changes:



1G - 2G

1980s – 2000s

Millions of voice users



3G - 4G

– 2020s Billions of Mobile Broadband users



5G and beyond

– 2040s Trillions of connected objects & intelligence

Applications range explodes and **new value chains** emerge:



Logistics



Retail



Agriculture



Industry 4.0



Health



Energy



Automotive

5G will be successful once the value chains related to key verticals are thoroughly understood driving evolution towards new business ecosystems.

Critical Drivers Towards 6G



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.

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.

Security

- **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.

Radio tech

- **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 existing frequency bands and the new ones above 100GHz.

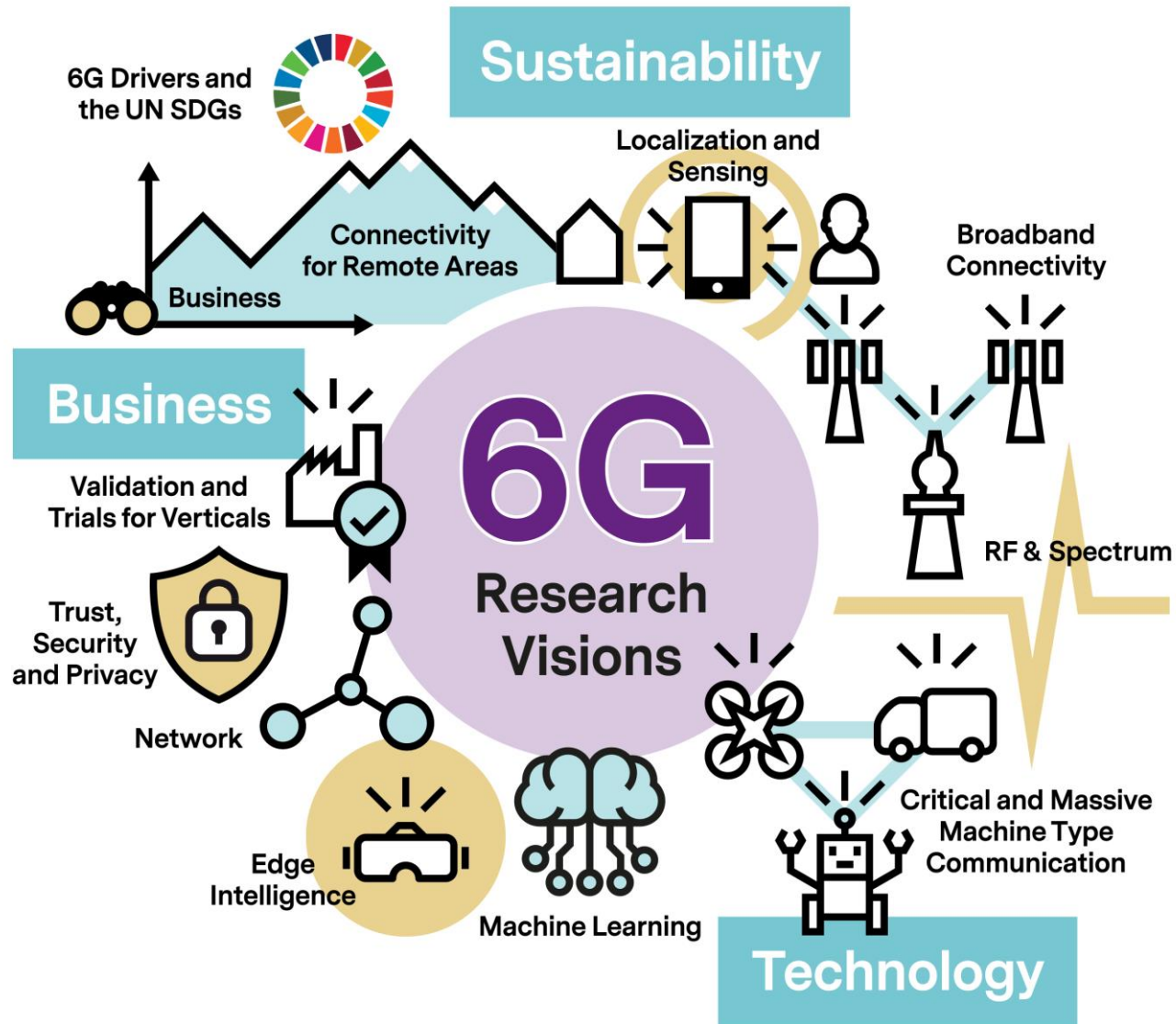
AI

- **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.

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.

6G Playground



All these aspects are considered in 12 White Papers produced by 250 leading experts from 100 organizations:
<https://www.6gchannel.com/6g-white-papers/>

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

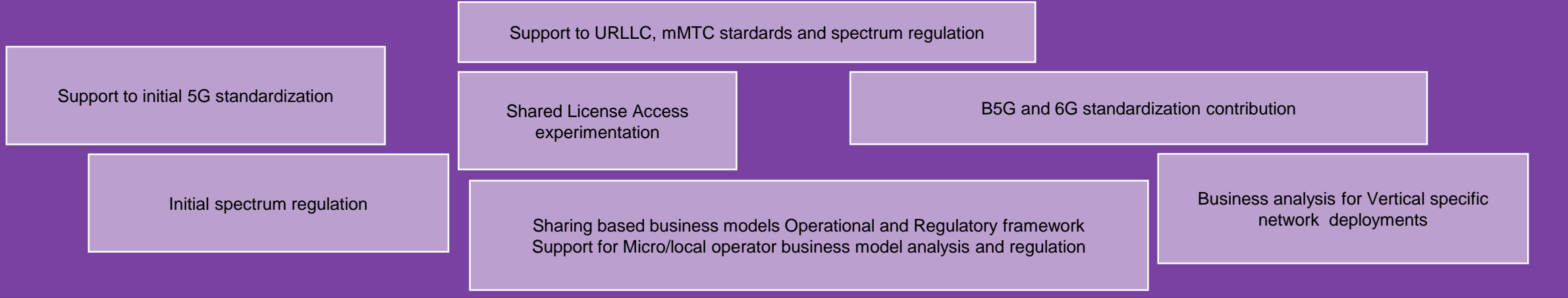
Sub-THz 6G prototypes

2015 6GTN Roadmapping - Research

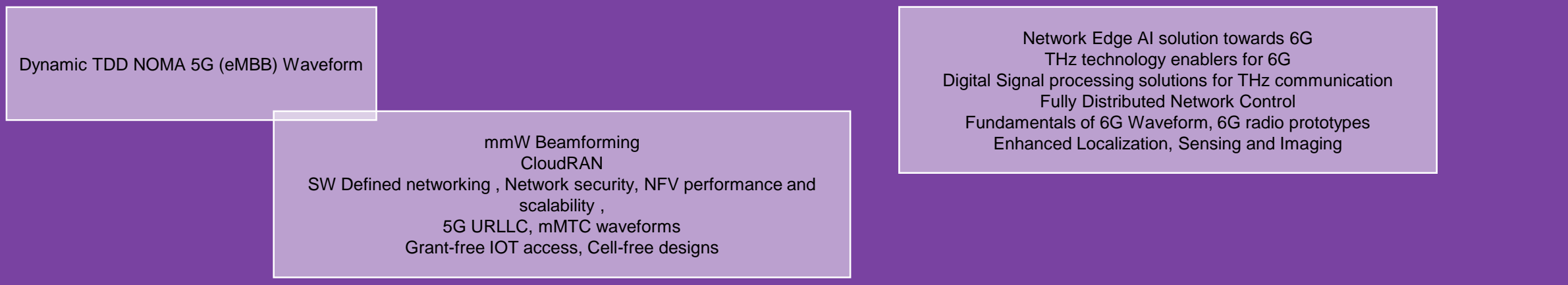
2030



Standardization and Regulation



Research Themes



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 μ s	100/m ³	High	1-10 ⁻⁶	< 10 Gbps	240 km/h
Industry URLLC	< 5 Mbps	< 100 μ s	+ 20 dB	< 1 μ s	10/m ³	Nominal	1-10 ⁻⁹	< 100 Mbps	240 km/h
Mobility	<10 Gbps	< 100 μ s	+ 20 dB	100 μ s	100/m ³	Nominal	1-10 ⁻⁷	1 Tbps	1200 km/h
eHealth	< 1 Gbps	< 1 ms	+ 10 dB	100 μ s	1/m ³	High	1-10 ⁻⁹	< 10 Gbps	240 km/h
Energy	<1 Mbps	< 500 μ s	+ 40 dB	< 1 μ s	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 μ s	1/m ³	Nominal	1-10 ⁻⁷	< 10 Gbps	240 km/h
Agri-business	100 Mbps	< 10 ms	+ 40 dB	100 μ s	100/km ²	Nominal	1-10 ⁻⁷	1 Gbps	240 km/h



Smart cities



Emergency response



Media



Telecom



Auto motive



Industry 4.0



Energy

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*Vertical ~ Business area <https://www.6gchannel.com/items/6g-white-paper-validation-trials>



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Thank you!