



6G

FLAGSHIP
UNIVERSITY
OF OULU

Why 6G?

CWTe 6G Vision Workshop
31 March 2021

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ACADEMY
OF FINLAND



FLAGSHIP PROGRAMME

OUTLINE:

**INTRODUCTION TO 6G FLAGSHIP
BUILDING A JOINT 6G VISION
MORE ABOUT SUSTAINABILITY
CONCLUSIONS**

- § Mobile communication research is increasingly addressing **5G in verticals**, which has led to local 5G network operator models and changing logics in the 5G business ecosystem, in addition to technological developments.
- § Research on 6G has started, with a bold goal of building a strong linkage with the **United Nations Sustainable Development Goals** (UN SDGs).

Ø This calls for a highly multi-disciplinary research approach, covering **technology, business and regulation perspectives** in collaboration with stakeholders, to develop next generation mobile communication systems.

World's first 6G research program started in Finland in 2018



6G Flagship - 6G Enabled Wireless Smart Society & Ecosystem 2018-2026

1.



Wireless Connectivity

2.



Devices & Circuits

3.



Distributed Computing

4.



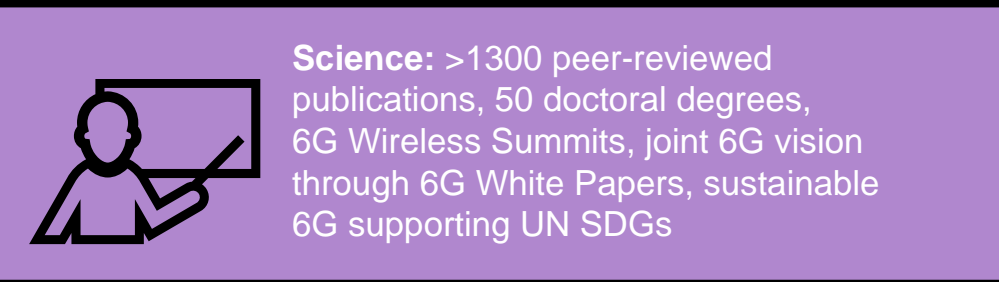
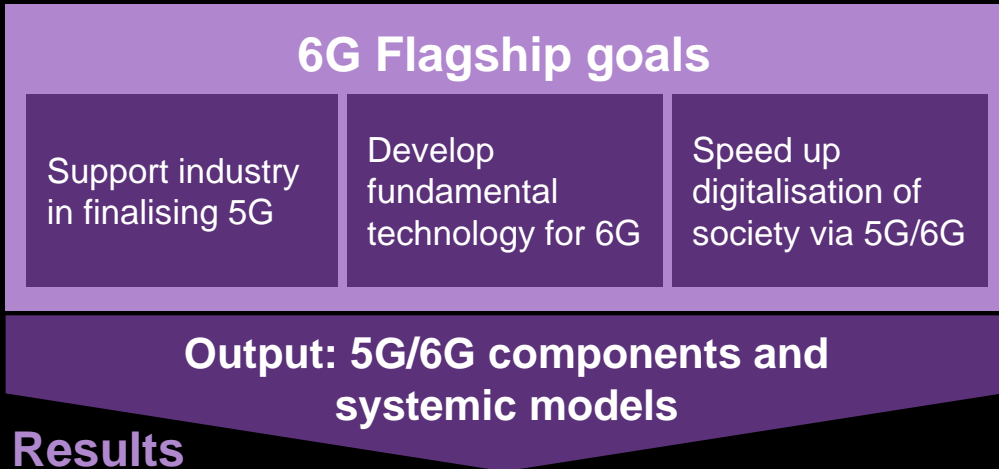
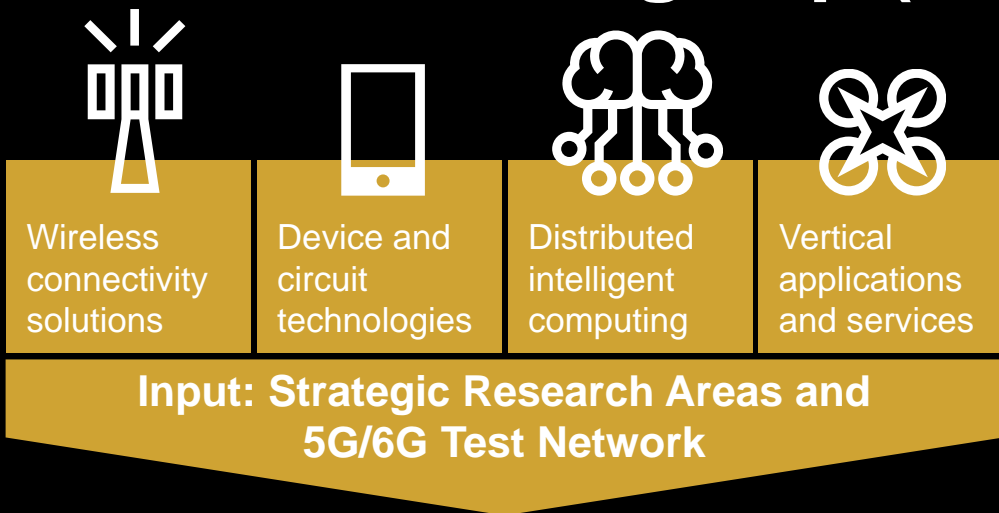
Services & Applications



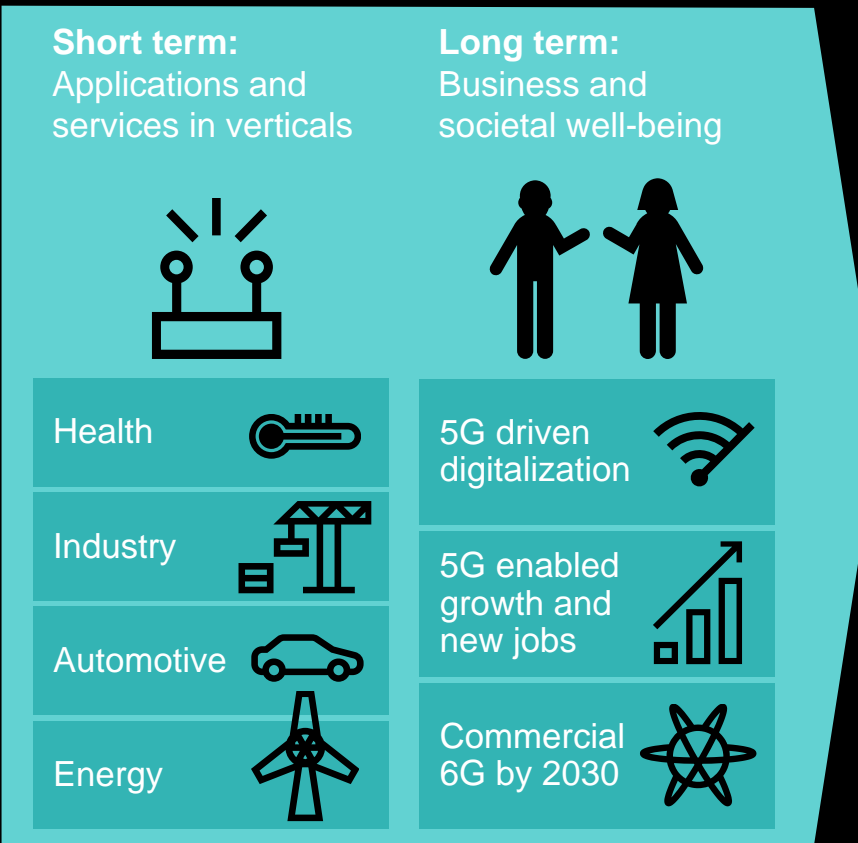
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Finnish 6G Flagship (2018-2026) approach and results



Impact



Vision for 2030



6G Flagship Activities



§ 6G Channel is your pathway to innovations and research outputs of the Finnish 6G Flagship, www.6gchannel.com



Thirteen **6G White Papers** published in 2019-2021:
<https://www.6gchannel.com/6g-white-papers/>



Eleven 6G Research Visions **Webinars** in 2020 with key findings of 6G White Papers:
6gchannel.com/events



Two "**6G Waves**" magazines in 2020. Total 250 000 downloads of the editions. Next appears in April 2021:
6gchannel.com/6gwaves

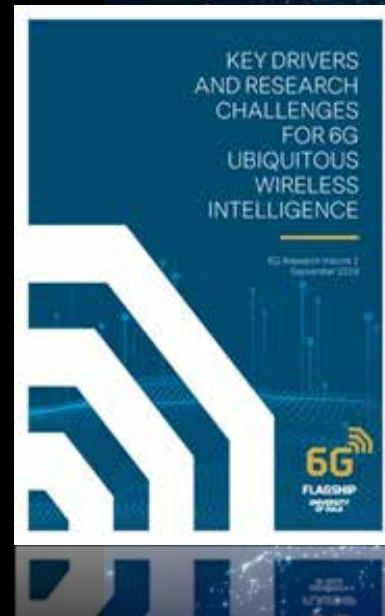
BUILDING A JOINT 6G VISION WITH 6G FLAGSHIP

The World's first 6G White Paper 2019

- **World's first 6G Wireless Summit gathered major telecom players to vision 6G in Finland in March 2019.**
- **The Summit launched 6G White Paper development with 70 experts from around the world.**
- **Consensus that 6G is driven by United Nations' Sustainable Development Goals (UN SDGs).**

Published in September 2019:

<http://6gflagship.com/6gwhitepaper/>



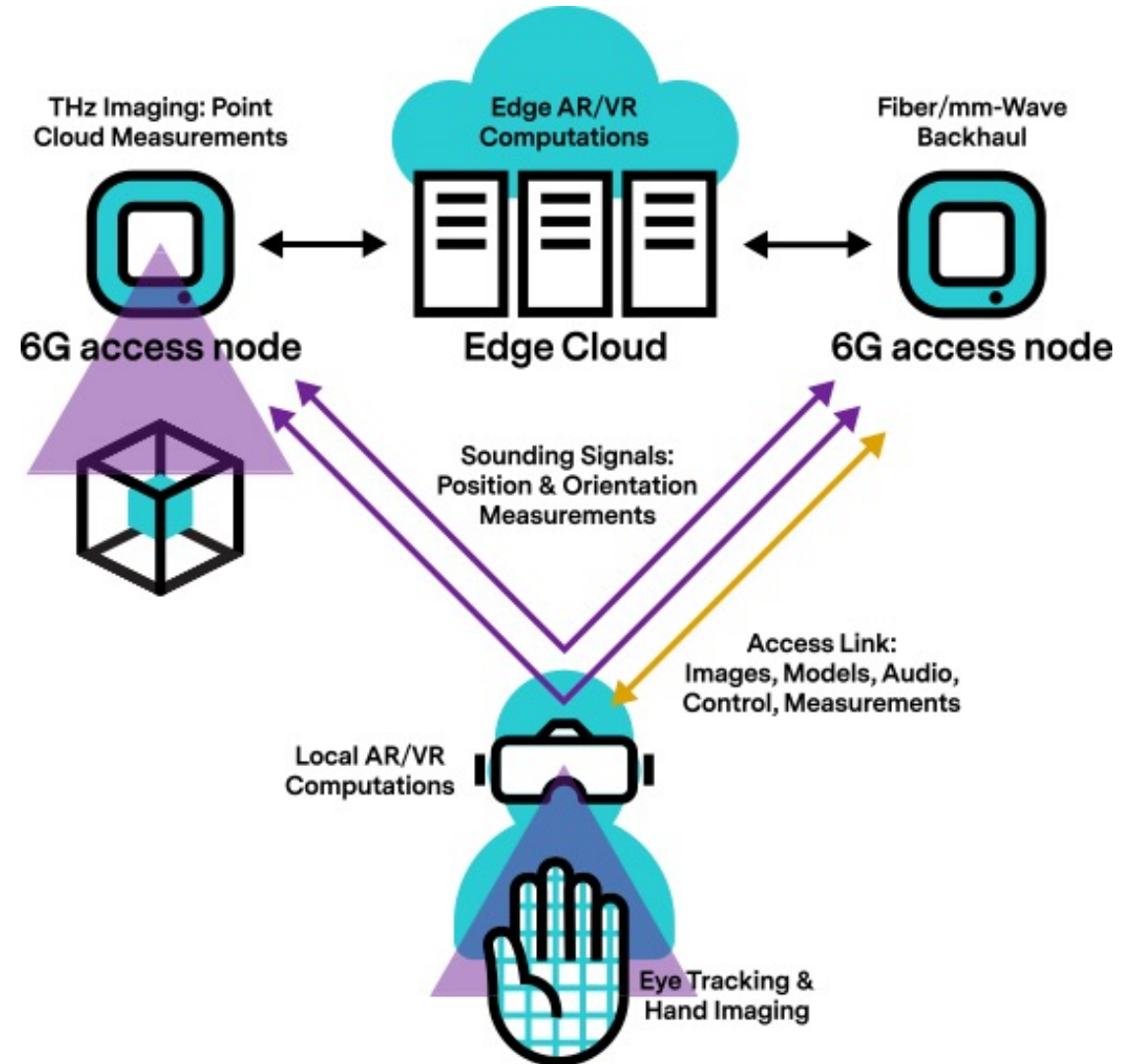
M. Latva-aho & K. Leppänen (eds.) (2019). Key drivers and research challenges for 6G ubiquitous wireless intelligence. [White paper]. (6G Research Visions, No. 1). University of Oulu, Finland.

<http://urn.fi/urn:isbn:9789526223544>

6G Merges Communications with New Applications



- § Going to higher frequencies (>100GHz), 6G will facilitate the integration of sensing, imaging, highly accurate positioning with communication service.
- § New capabilities, combined with mobility and AI/ML, open a myriad of new applications with 6G leading to new business and a truly digitalized society, alleviating the digital divide.

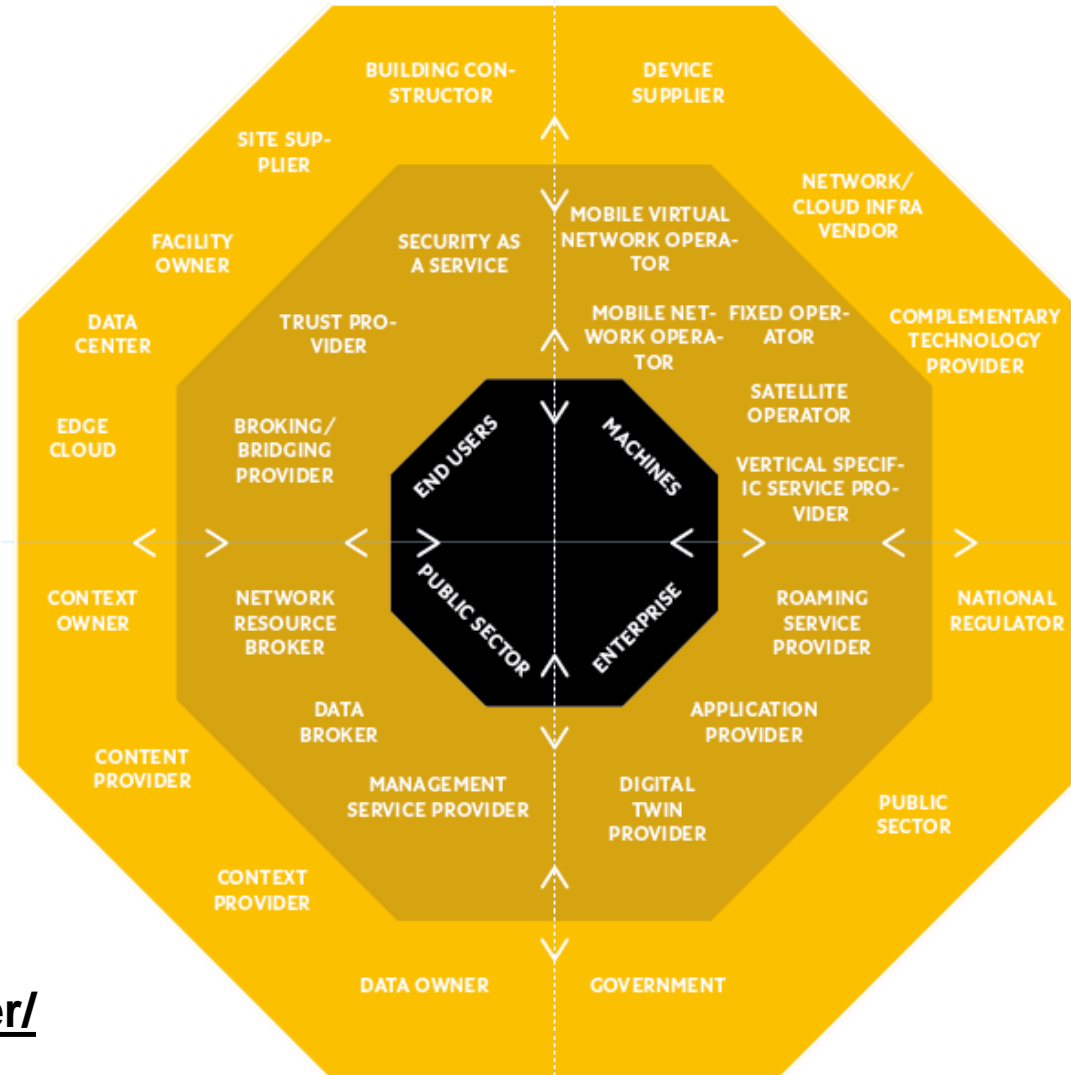


<http://6gflagship.com/6gwhitepaper/>

Future 6G Business Ecosystem



§ Stakeholder roles will change in 6G compared to the current mobile business ecosystem and new roles will emerge.



<http://6gflagship.com/6gwhitepaper/>

Towards Local Operator Paradigm



- § Different stakeholders can deploy their own local 5G/6G networks¹, independent of mobile network operators, through local spectrum access rights².
- § This opens many business, regulation and technology related aspects to consider in research. Currently, divergence between countries is high, leading to market fragmentation.



<http://6gflagship.com/6gwhitepaper/>

¹M. Matinmikko, et al. (2017) **Micro operators to boost local service delivery in 5G.** Wireless Personal Communications, 95(1), 69-82.

²M. Matinmikko, et al. (2018) **On regulations for 5G: Micro licensing for locally operated networks.** Telecommunications Policy, 42(8), 622-635.

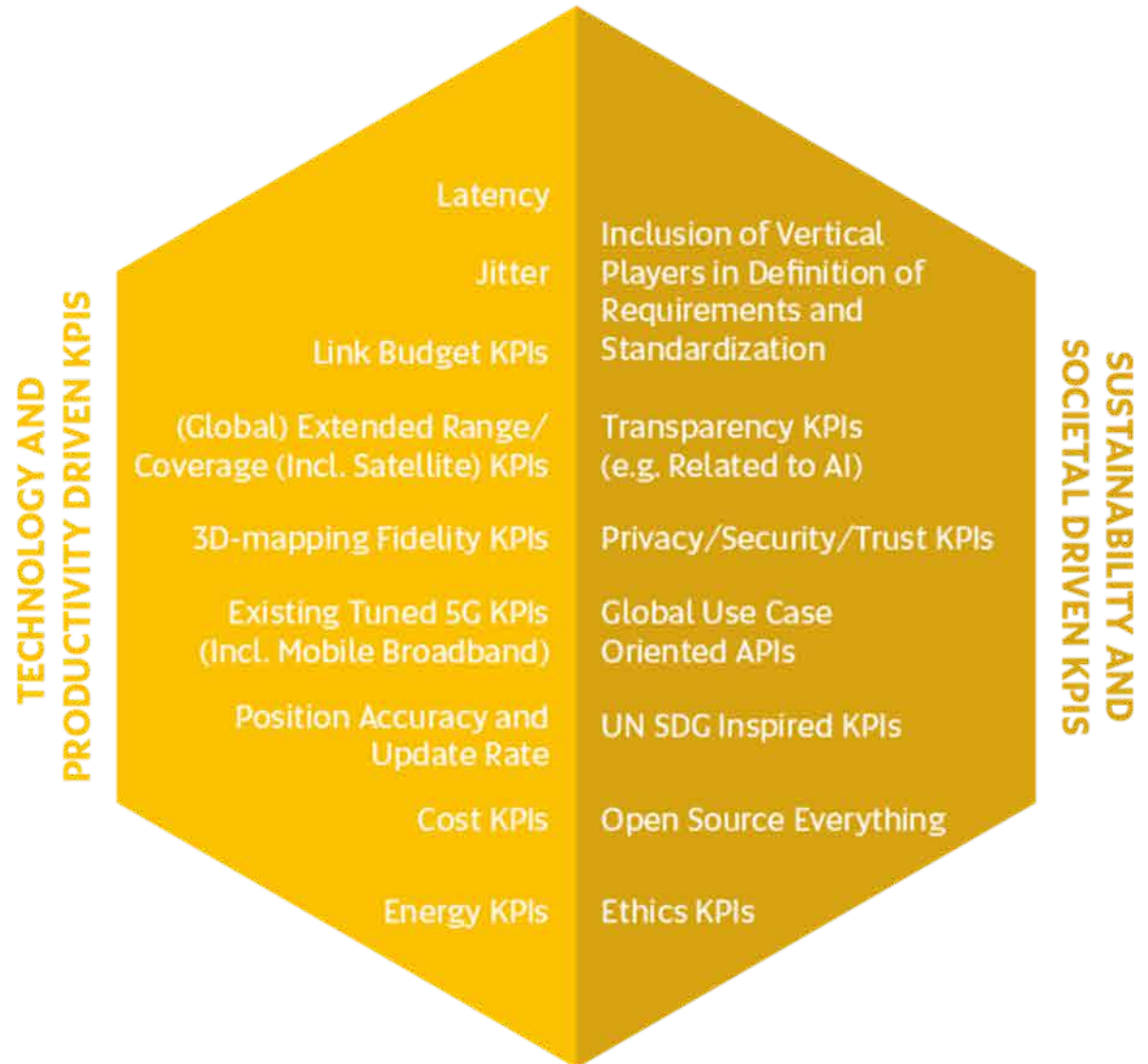
Key Performance Indicators (KPIs)



§ Many of the KPIs used for 5G are valid also for 6G. However, the KPIs must be critically reviewed and new KPIs must be seriously considered.

§ Key value indicators (KVI) will need to be defined.

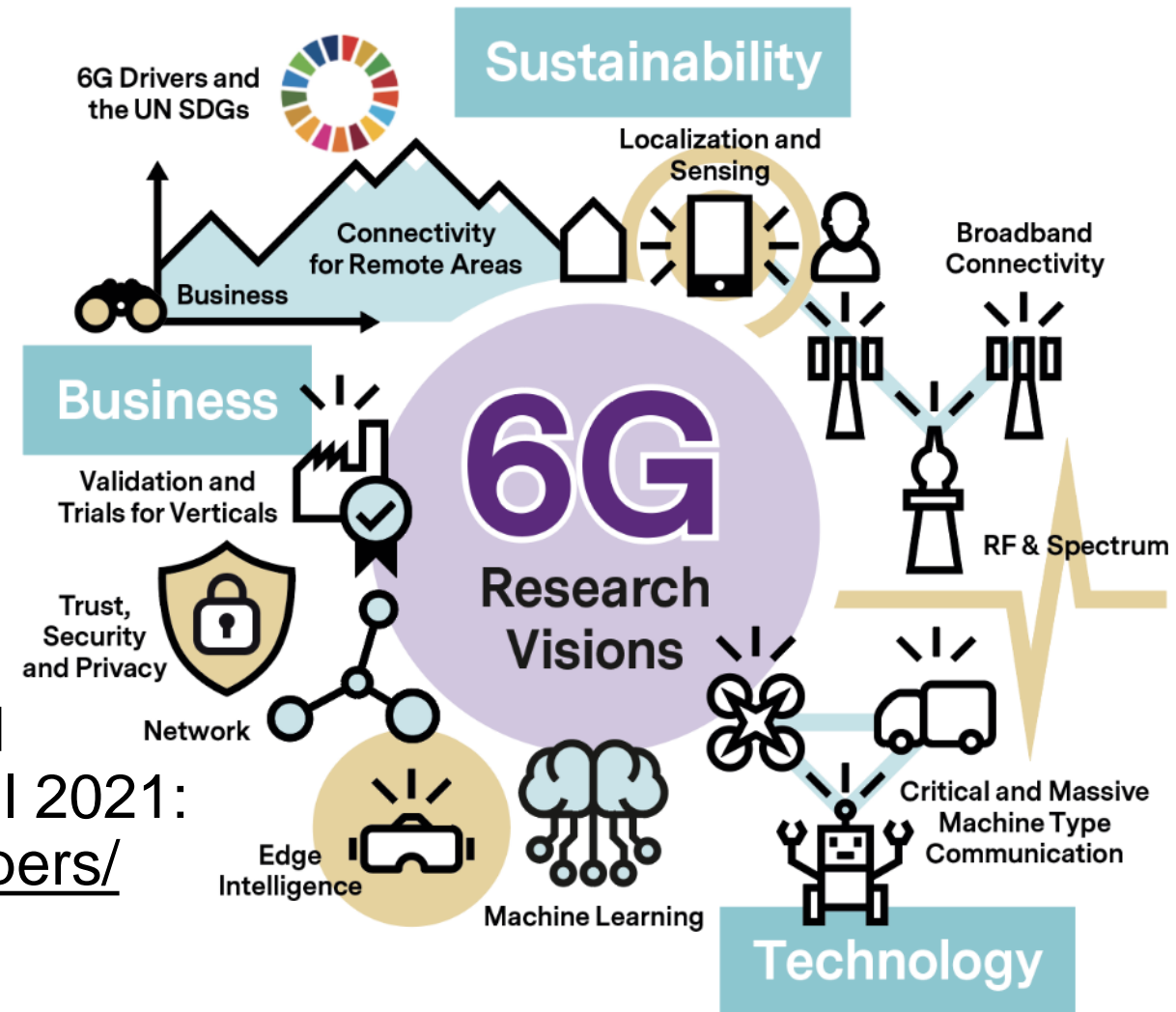
<http://6gflagship.com/6gwhitepaper/>



THE 2020 EDITION OF 6G WHITE PAPERS: MORE ABOUT SUSTAINABILITY

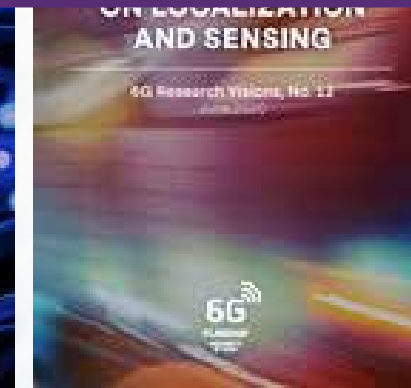
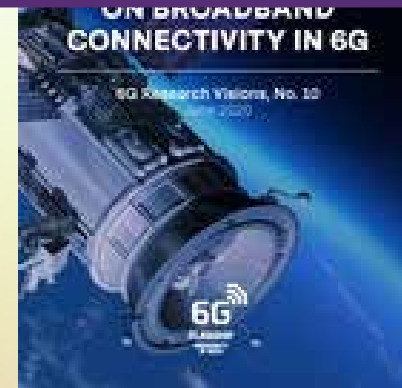
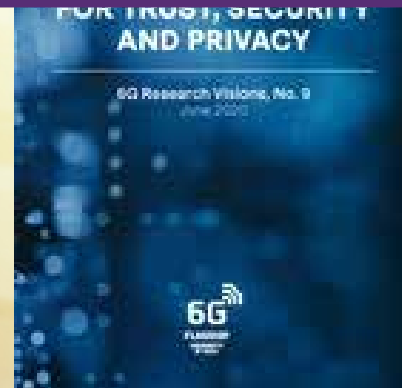
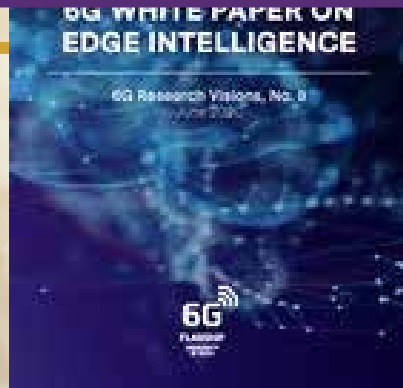
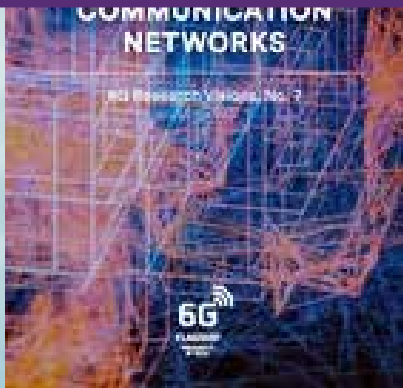
The 2020 edition of 6G White Papers – Sustainability, Technology and Business Perspectives

- Expert groups with **250 participants from 100 organizations and 30 countries** worked on 12 new white papers in conjunction with the 2nd 6G Wireless Summit held virtually in 2020. <https://www.6gsummit.com/>
- 11 new 6G White Papers were published in June 2020, and one will appear in April 2021: <https://www.6gchannel.com/6g-white-papers/>





6G and the UN SDGs – where is the connection?



White Paper on 6G Drivers and the UN SDGs led by Marja Matinmikko-Blue

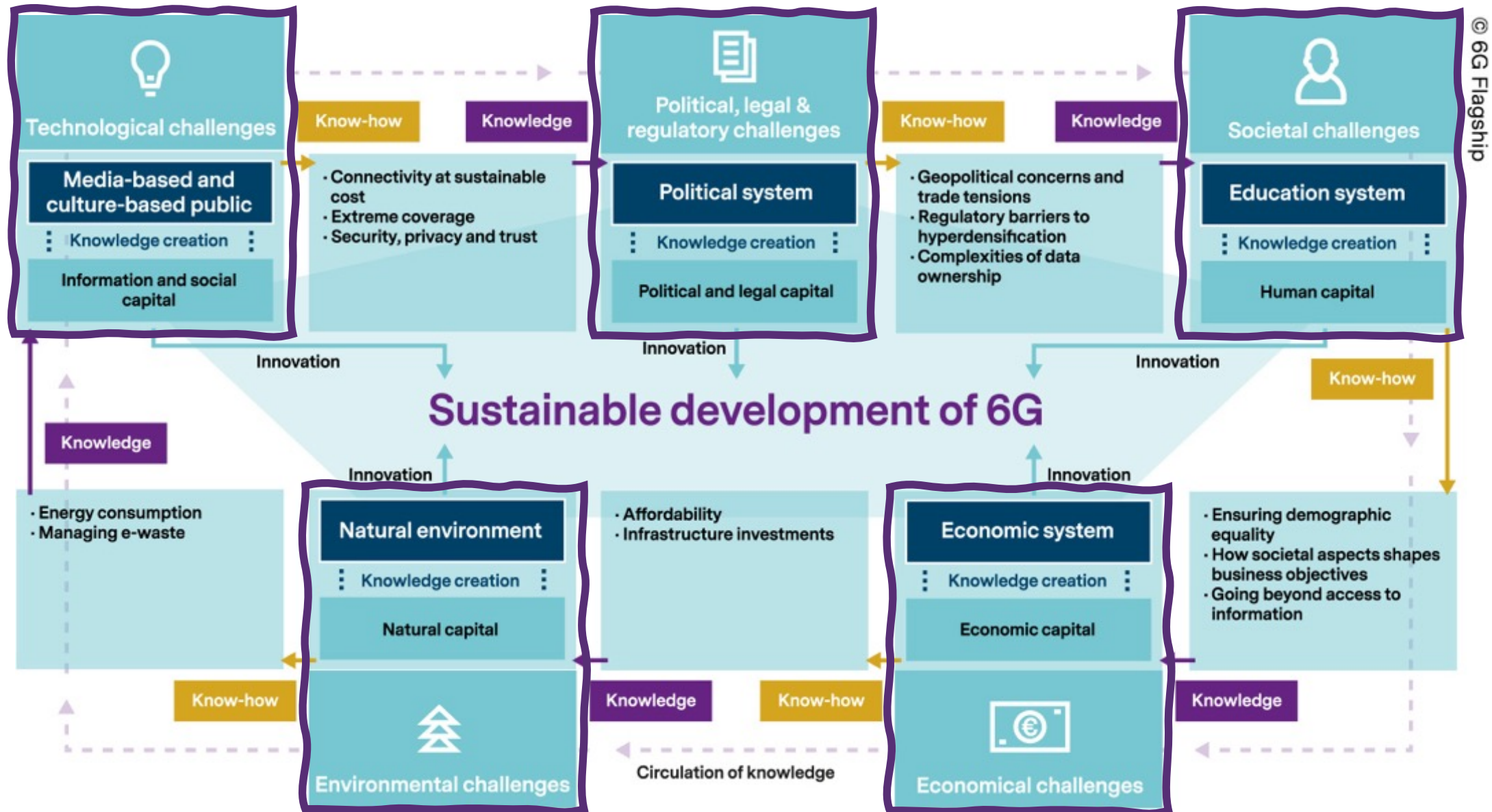
HIGHLIGHTS:

- § We identify megatrends influencing the sustainable development of 6G.
- § We develop a novel linkage between 6G and the UN SDGs that are both targeted for 2030.
- § We envisage three-fold role of 6G as:
 - 1) a provider of services to help support activities towards reaching the UN SDGs,
 - 2) a measuring tool for reporting of indicators;
 - 3) a reinforcer of developing 6G in line with the UN SDG.

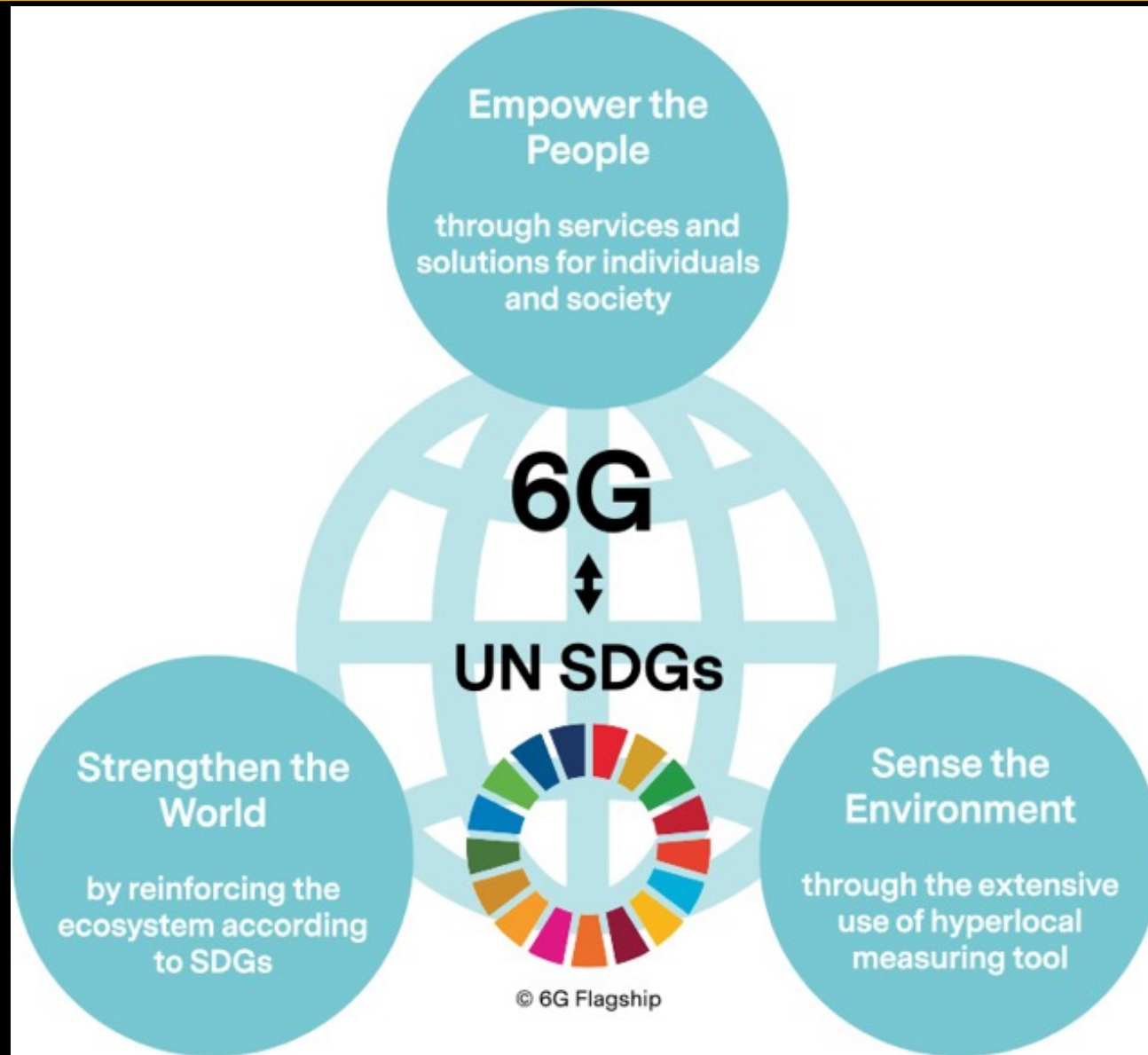
<https://www.6gchannel.com/portfolio-posts/6g-white-paper-6g-drivers-un-sdgs/>



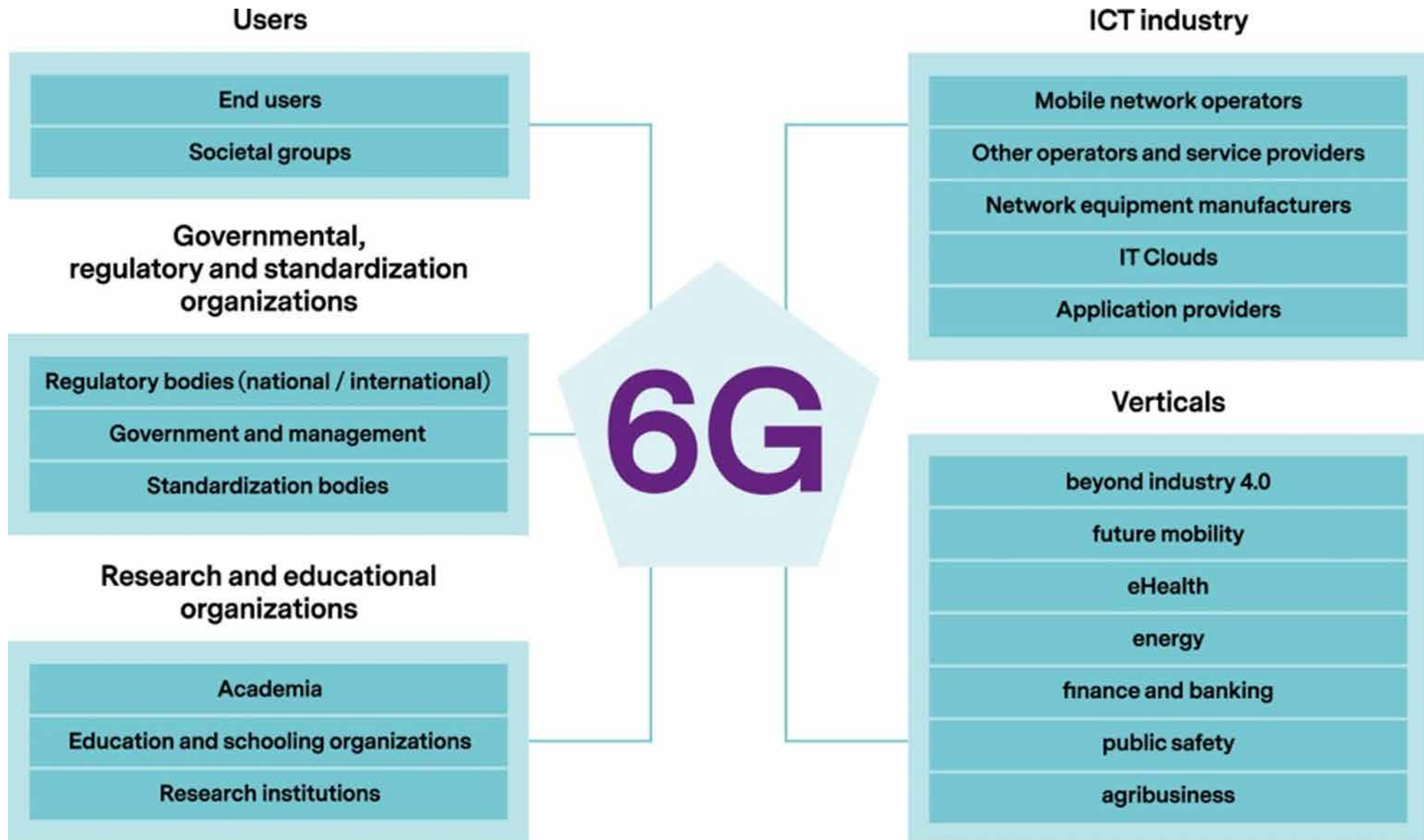
Identified key challenges of 6G-driven sustainable development using Quintuple Helix model



Role of 6G in UN SDGs



Key stakeholders in 6G development



Preliminary action plan on 6G and the UN SDGs



Users

Inclusion of a variety of users into human-centric 6G development.

**Governmental,
regulatory and standardization
organizations**

Lead in pro-active manner with long-term visions of the role of ICT/6G in achieving UN SDGs and formulate policies. Develop new indicators to complement pure technical performance indicators.

**Research and educational
organizations**

Conduct unbiased research and facilitate stakeholder interactions.

ICT industry

Flexible approaches to serving different challenge areas. Develop cost and consumption optimized solutions. Develop services matching the varying level of skills of people.

Verticals

Early engagement in 6G development to transform their operations towards UN SDGs.

6G

© 6G Flagship

SUMMARY OF OTHER 6G WHITE PAPERS BY 6G FLAGSHIP

White Paper on Business of 6G

led by Seppo Yrjölä

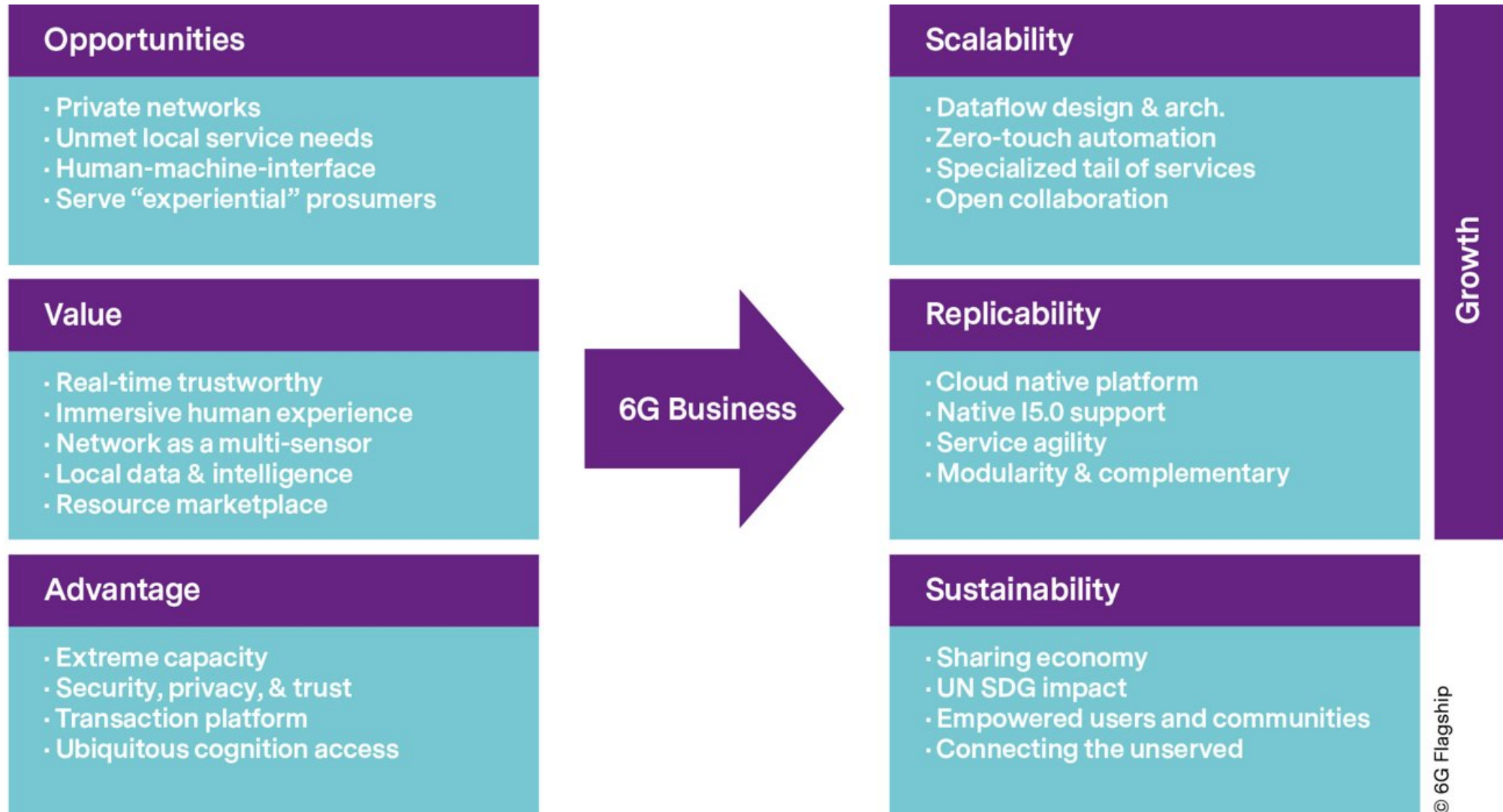
HIGHLIGHTS:

- § Value-capture in 6G era requires understanding dynamics of platforms and ecosystems. Access to data and data ownership are major factors and limiting is a means of control.
- § Modularity and complementarity of technology solutions raise difficult openness and transparency as well as collaboration vs. competition issues.
- § 6G business ecosystem for solving sustainability problems needs open value configuration and decentralized power configuration focusing on specialized user requirements that cross a variety of industries.

<https://www.6gchannel.com/portfolio-posts/6g-white-paper-business-of-6g/>



White Paper on Business of 6G

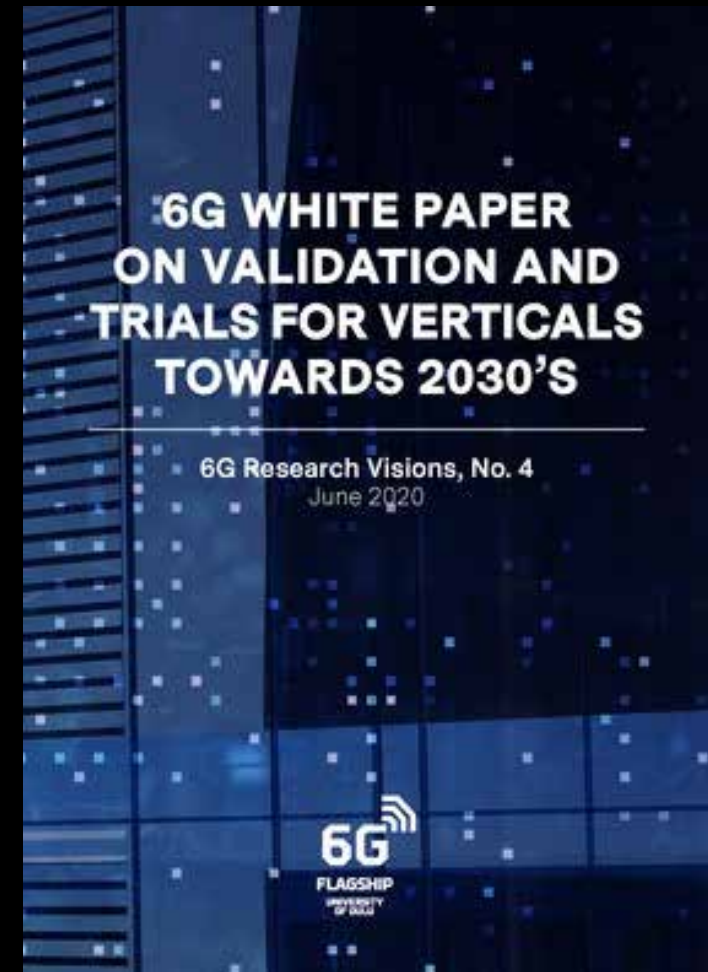


White Paper on Validation and Trials for Verticals towards 2030's led by Ari Pouttu

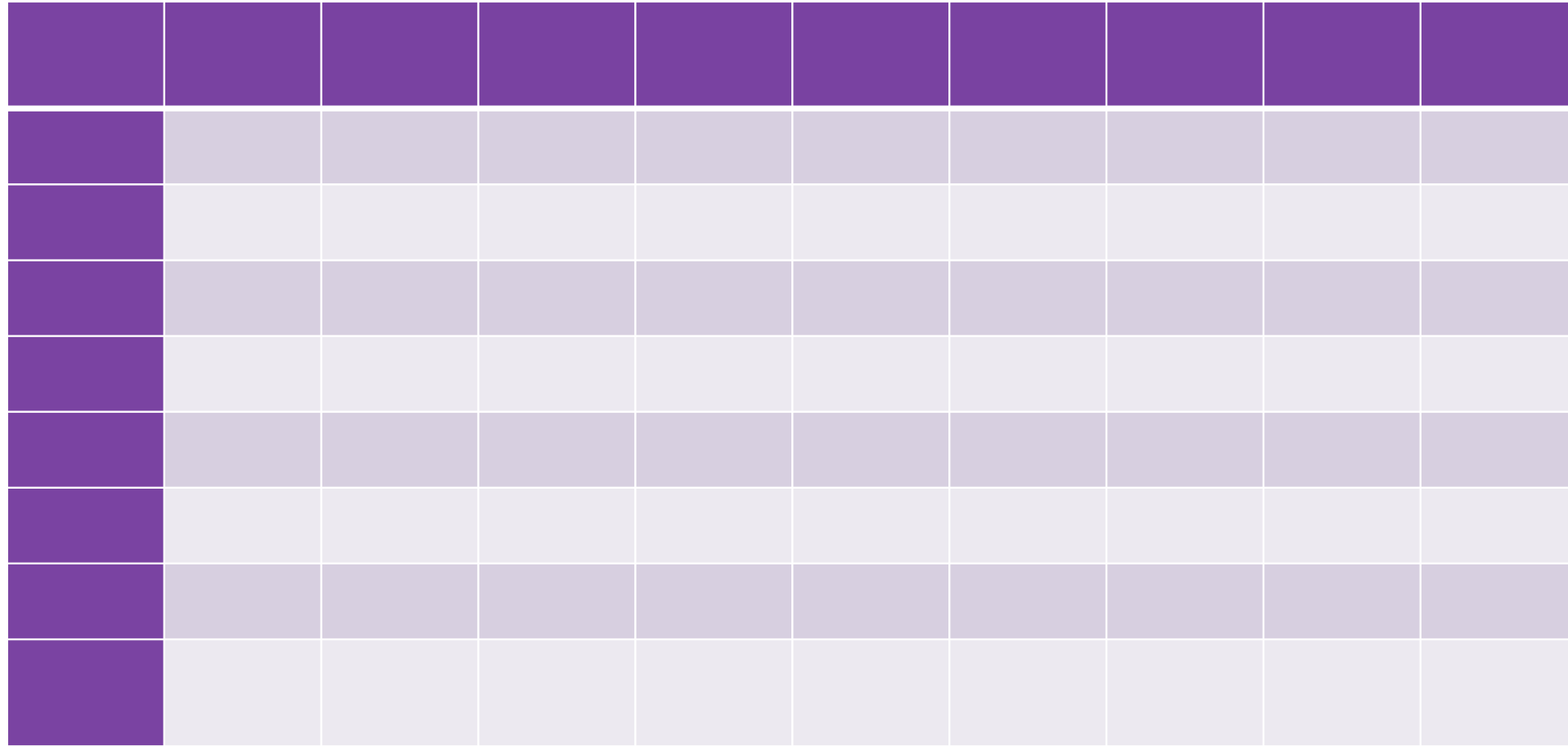
HIGHLIGHTS:

- § We take a close look on 6G drivers within selected verticals and propose a set of key performance and value indicators.
- § We propose golden references for trialing within different verticals for commonly measurable results.

<https://www.6gchannel.com/portfolio-posts/6g-white-paper-validation-trials/>



White Paper on Validation and Trials for Verticals towards 2030's



Smart cities



Media



Auto motive



Energy



Emergency response



Telecom



Industry 4.0

6G White Paper on Connectivity for Remote Areas

led by Harri Saarnisaari

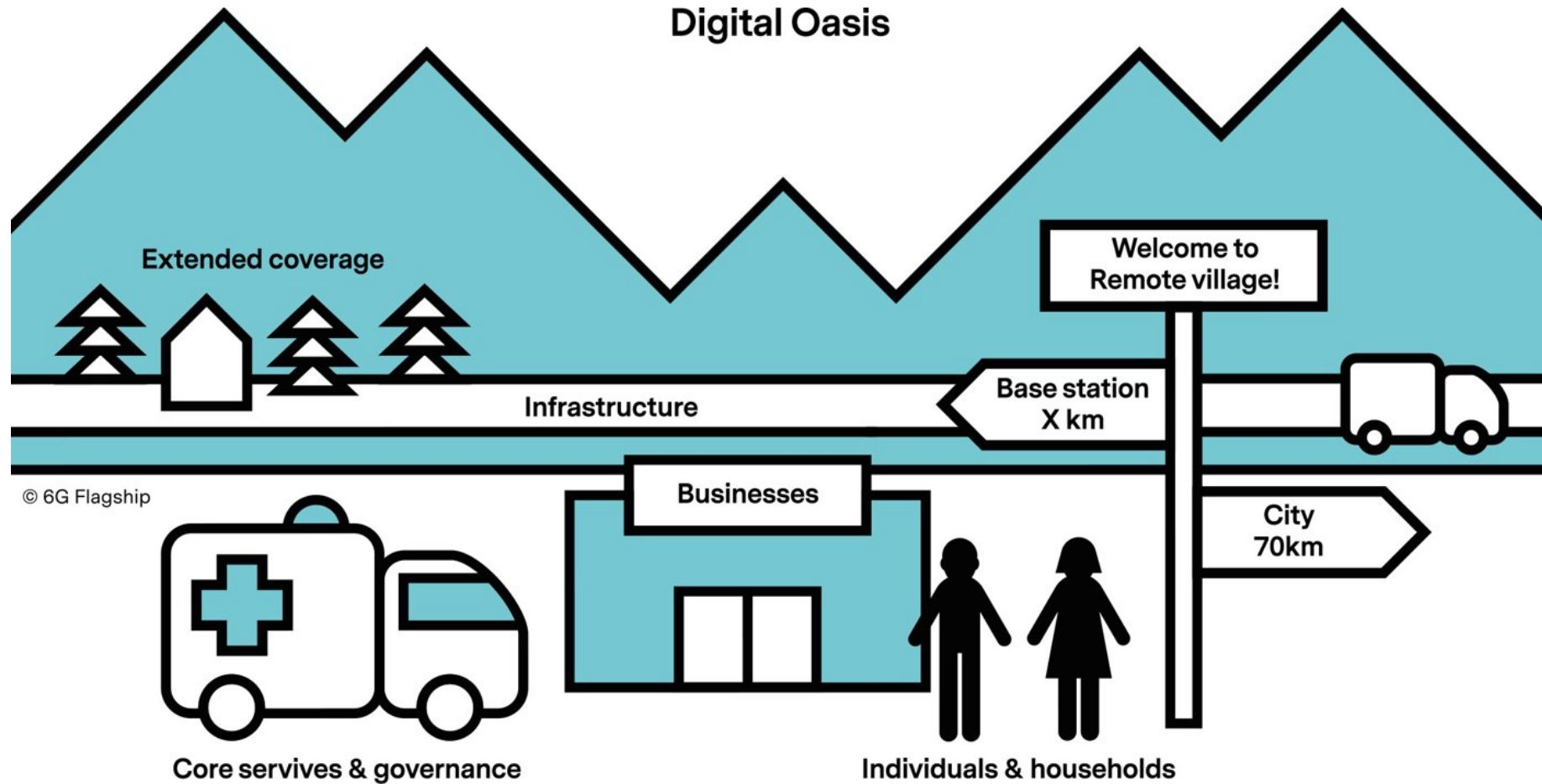
HIGHLIGHTS:

- § We emphasize that solutions to bridge digital divide in rural and remote areas must be easy to use, affordable and provide sufficient data rate and availability.
- § 6G could be the first mobile generation to close the digital divide. 6G needs to concentrate on challenges of rural and remote areas from the beginning of the design cycle.
- § Technical solutions can use mobile cellular solutions where people live and work (digital oases) and various backhaul solutions including large cells, relays and satellites.
- § Novel regulation and cooperation between various stakeholders is also needed.

<https://www.6gchannel.com/portfolio-posts/6g-white-paper-connectivity-remote-areas/>



6G White Paper on Connectivity for Remote Areas **6G**

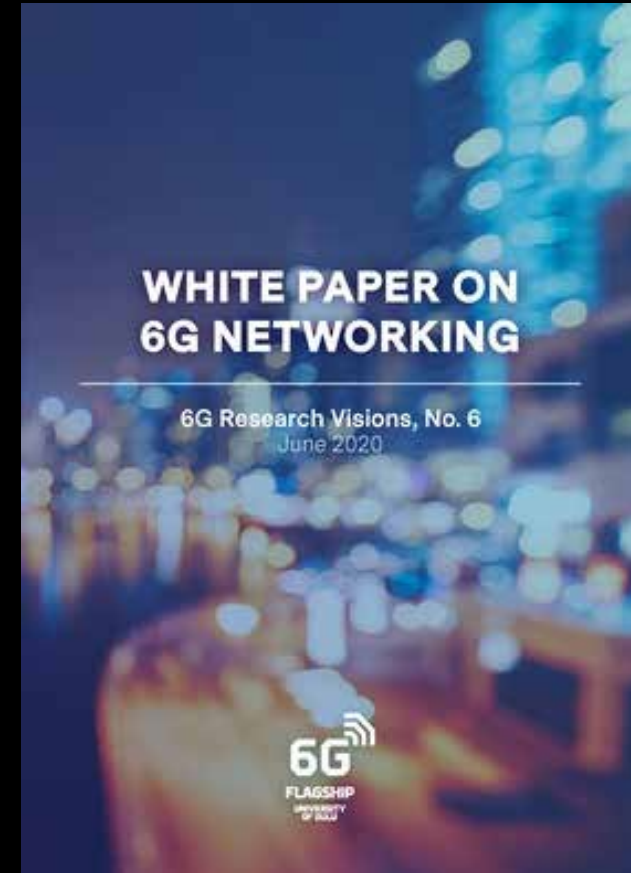


White Paper on 6G Networking led by Tarik Taleb

HIGHLIGHTS:

- § We present network advancements and implications introduced by the evolution of softwarization and service-based architecture.
- § We present key technologies that constitute the pillars for the evolution towards 6G networking, considering the evolution toward a cloud native mobile communication system and the adoption of a new IP architecture that supports high precision services.
- § We explore the different analytics that can be gained from the different segments involved in the delivery of a particular communication service.

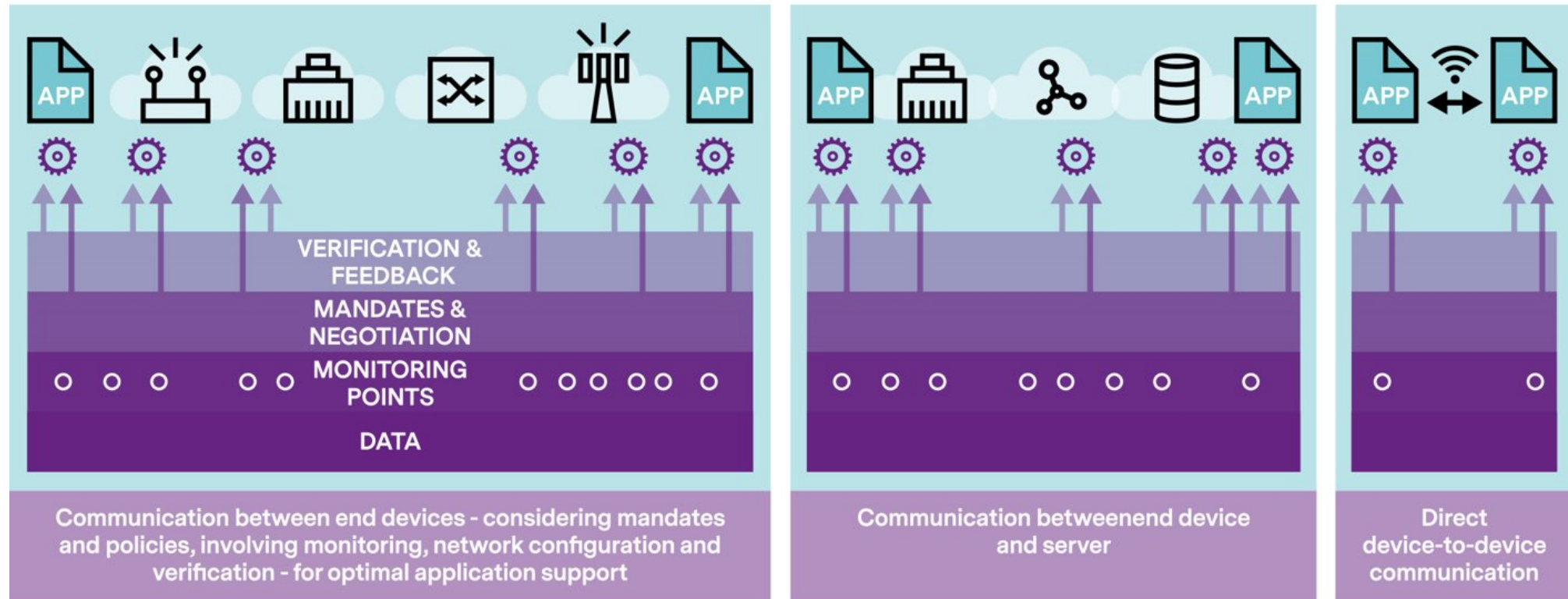
<https://www.6gchannel.com/portfolio-posts/6g-white-paper-networking/>



White Paper on 6G Networking



Connectivity view



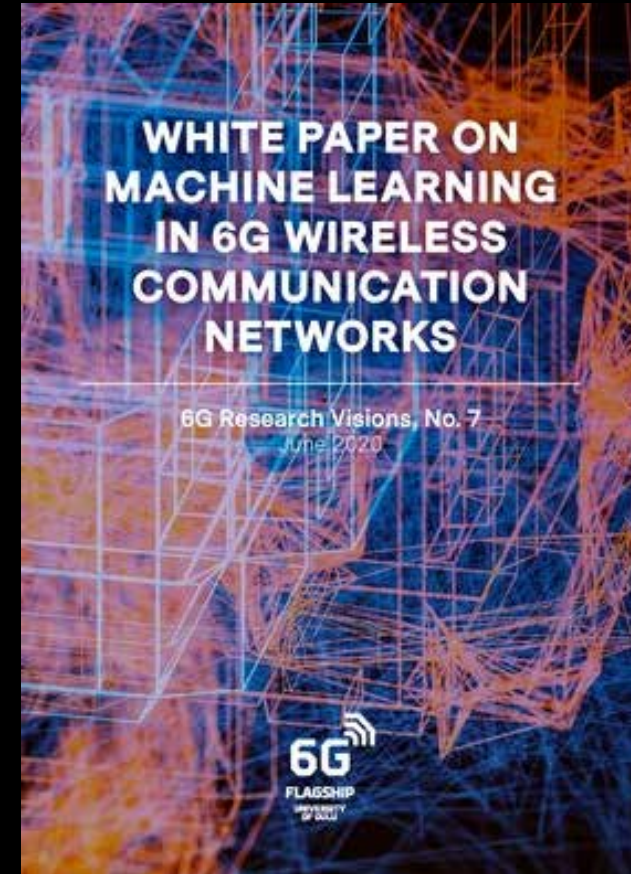
White Paper on Machine Learning in 6G Wireless Communication Networks

led by Samad Ali

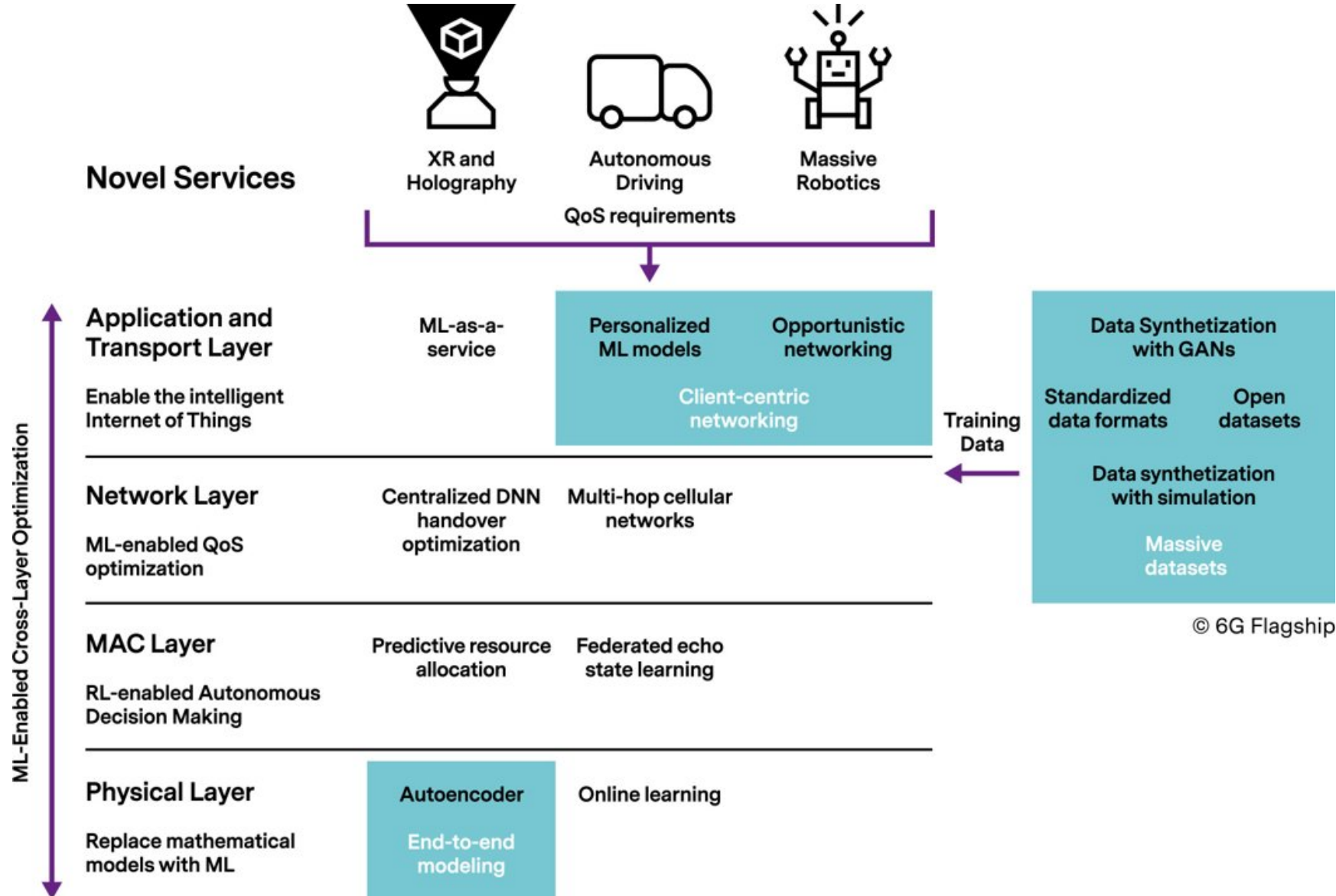
HIGHLIGHTS:

- § We provide an overview of the role of machine learning in 6G networks. By looking at various problems in different layers of the communications protocol stack, we propose a machine learning tool for each problem.
- § Applications that will be able to utilize machine learning within the broader scope of wireless communications such as UAV communications and networking are also studied and novel ideas and future directions for them are provided.

<https://www.6gchannel.com/portfolio-posts/6g-white-paper-machine-learning/>



White Paper on Machine Learning in 6G Wireless Communication Networks



6G White Paper on Edge Intelligence

led by Ella Peltonen

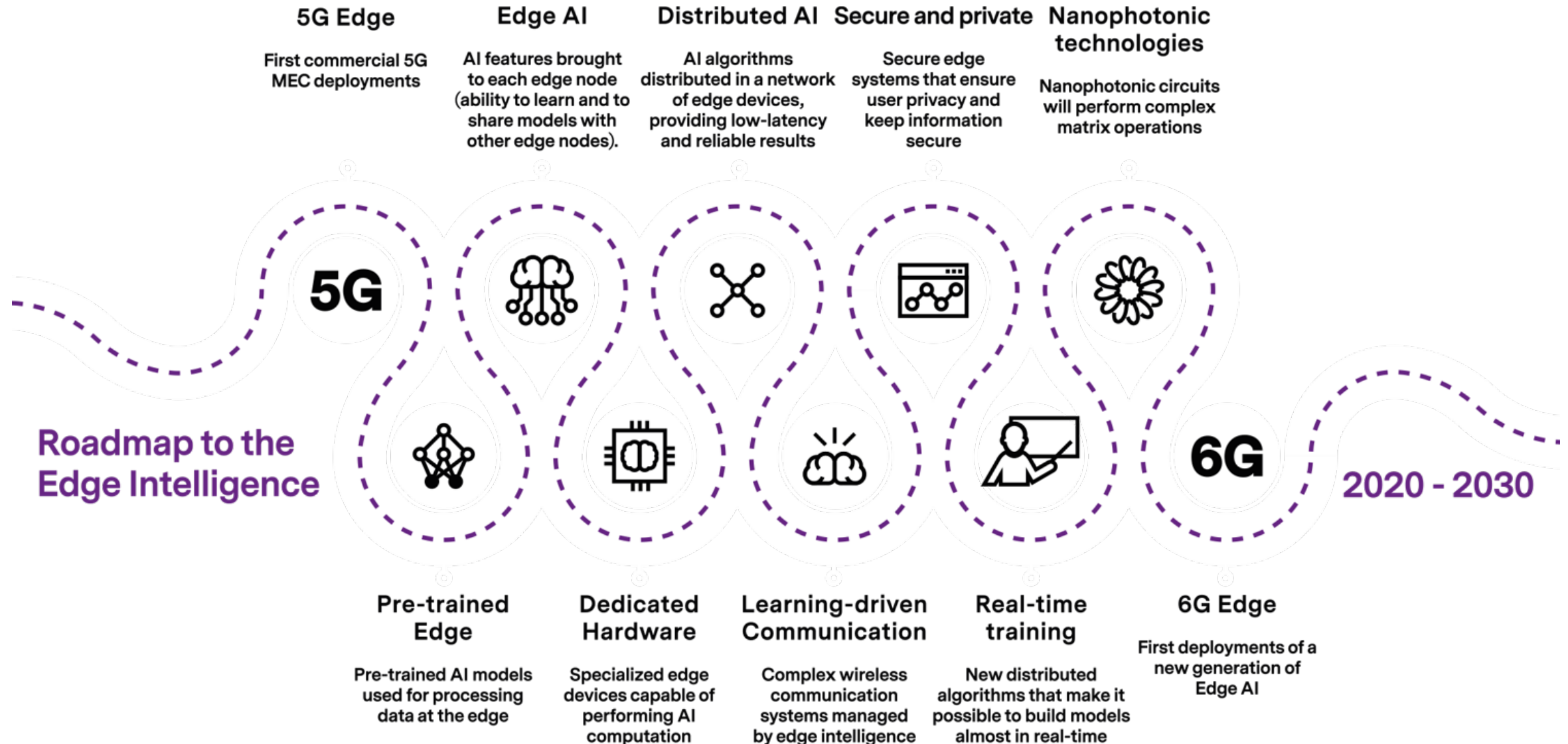
HIGHLIGHTS:

- § We identify the need for an “Intelligent Internet of Intelligent Things” to make Internet more reliable, efficient, resilient, and secure, where 6G with edge-driven AI can play a fundamental role.
- § We claim that performance, cost, security, efficiency, and reliability are key features and measurable indicators of any edge intelligence solutions.
- § The evolution of a new generation of edge intelligence systems, applications and services will take place during the next ten years, with the completion of different technological steps that will provide new devices, technology, and applications.

<https://www.6gchannel.com/portfolio-posts/6g-white-paper-edge-intelligence/>



6G White Paper on Edge Intelligence



6G White Paper: Research Challenges for Trust, Security and Privacy

led by Mika Ylianttila

HIGHLIGHTS:

- § We address fundamental research challenges of 6G in three key areas – trust, security and privacy.
- § The roles of trust, security and privacy are somewhat interconnected, but different facets of next generation networks.
- § The challenges in creating a trustworthy 6G are multidisciplinary, spanning technology, regulation, techno-economics, politics and ethics.

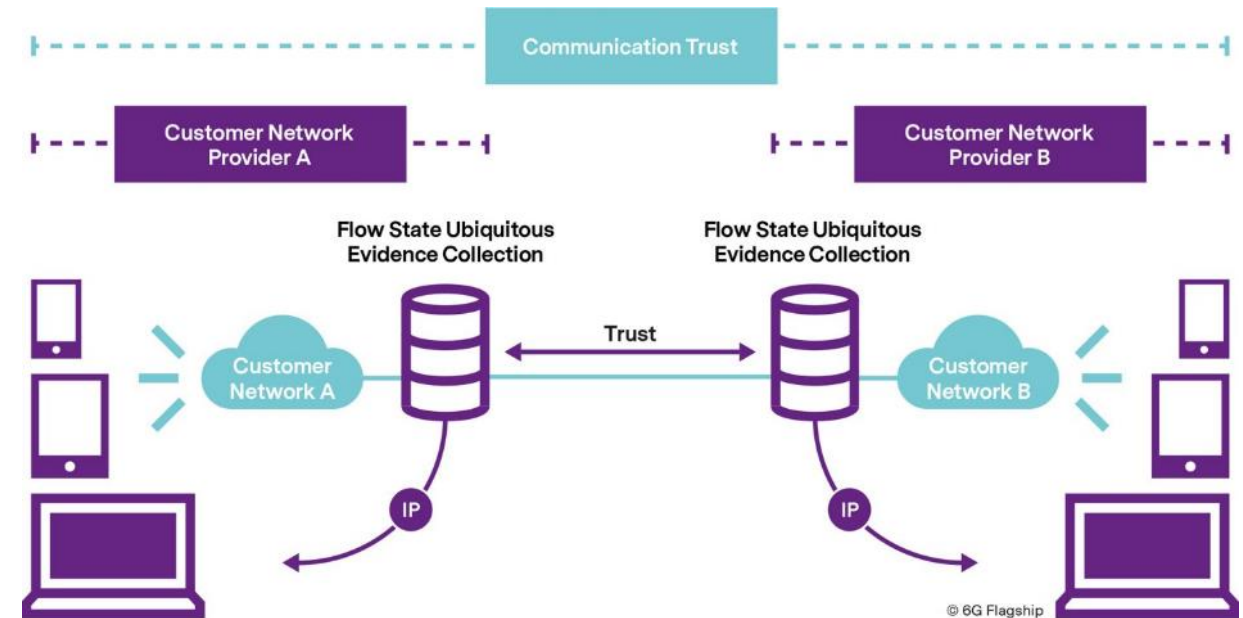
<https://www.6gchannel.com/portfolio-posts/6g-white-paper-trust-security-privacy/>



6G White Paper: Research Challenges for Trust, Security and Privacy



- § **Trust:** 6G network must support embedded trust for increased level of information security. Trust modeling, trust policies and trust mechanisms need to be defined.
- § **Security:** The role of IT and networks in security keeps rising. We need holistic 6G network security architecture planning. Machine learning can be used to make safer systems but enables dangerous attacks. Physical layer security techniques can represent efficient solutions.
- § **Privacy:** There is currently no means to determine when linked, deidentified datasets cross the threshold of becoming personally identifiable. Courts are making decisions about whether privacy is being infringed without formal measures of the level of personal information, while companies seek new ways to exploit private data.



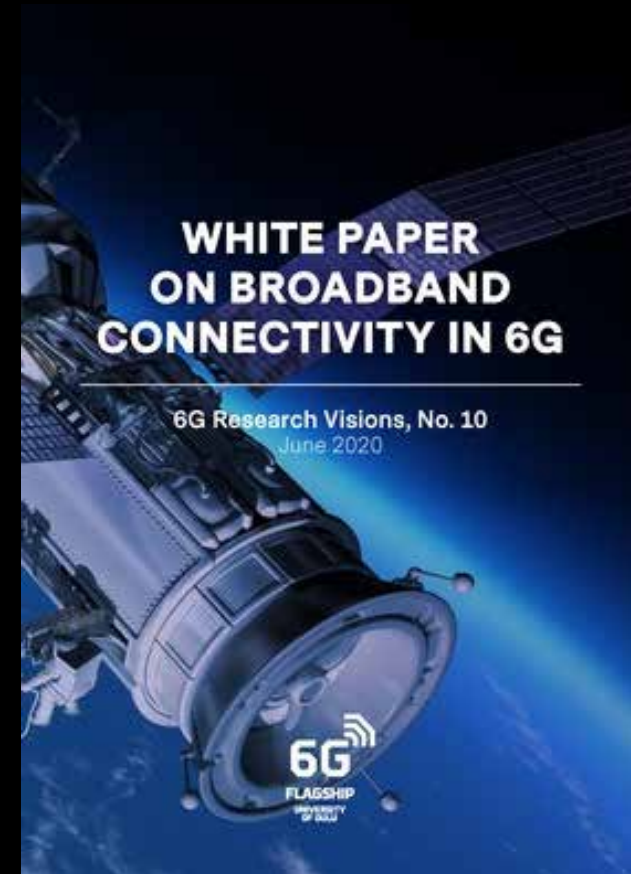
White Paper on Broadband Connectivity in 6G

led by Nandana Rajatheva

HIGHLIGHTS:

- § We expect ultra massive MIMO to be realized with fully digital arrays and holographic radio to enable ultra-high density and ultra-high resolution spatial multiplexing.
- § We expect user-centric and scalable cell-free networking to enable the densification of network infrastructure with access points in 6G.
- § We expect THz communications to provide high capacity point-to-point links complementing the wide area coverage at lower frequencies.
- § We believe that intelligent reflecting surfaces (IRS) will be integrated to wireless systems to create a smart, programmable, and controllable wireless propagation environment.

<https://www.6gchannel.com/portfolio-posts/6g-white-paper-broadband-connectivity-6g/>



White Paper on Broadband Connectivity in 6G



Challenges	Potential 6G solutions	Open research topics
	User-centric cell-	Scalable synchronization, control, and
	Integration of a spaceborne layer, ultra-massive MIMO from tall towers, intelligent	Joint control of space and ground-based APs, real-
	Sub-	Hardware development and mitigation of
	Faster forward error correcting schemes,	
	Ultra-massive MIMO, waveform adaptation,	Holographic radio, use-case-based waveforms, full-duplex, rate-
		Dynamic resource allocation framework using
		Channel estimation, hardware development, remote
	Cell-free massive MIMO, suitable	Novel modulation methods with limited
Modeling or algorithmic deficiencies in	ML-/AI-based model-free, data-driven	End-to-end learning/joint optimization, unsupervised learning for radio resource

White Paper on Critical and Massive Machine Type Communication towards 6G

led by Nurul H. Mahmood

HIGHLIGHTS:

- § We present the main drivers, potential use cases, key requirements and new service classes pertinent to machine type communication (MTC) in 6G networks.
- § We provide a bird's eye view of a holistic end-to-end MTC network architecture.
- § We discuss the challenges and potential 6G enablers of ultra-low power, massive and critical MTC.
- § We touch upon privacy, security and trust concerns in an MTC optimized 6G network.

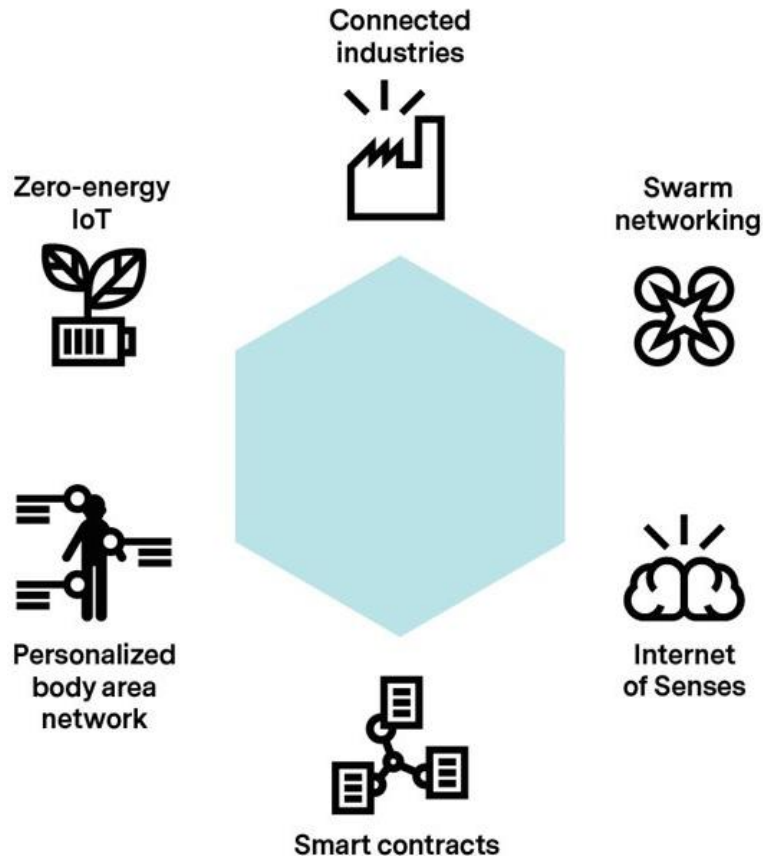
<https://www.6gchannel.com/portfolio-posts/6g-white-paper-critical-massive-type-communication/>



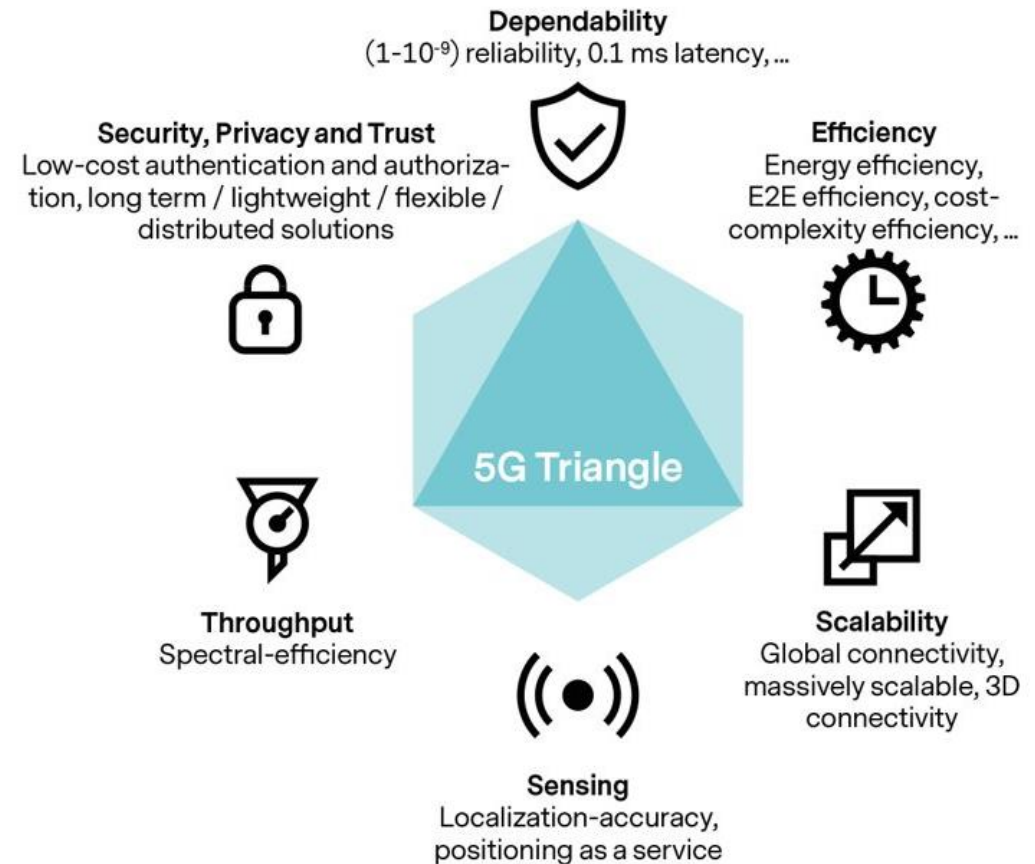
White Paper on Critical and Massive Machine Type Communication towards 6G



Selected Use Cases



Requirements



6G White Paper on Localization and Sensing

led by Carlos de Lima

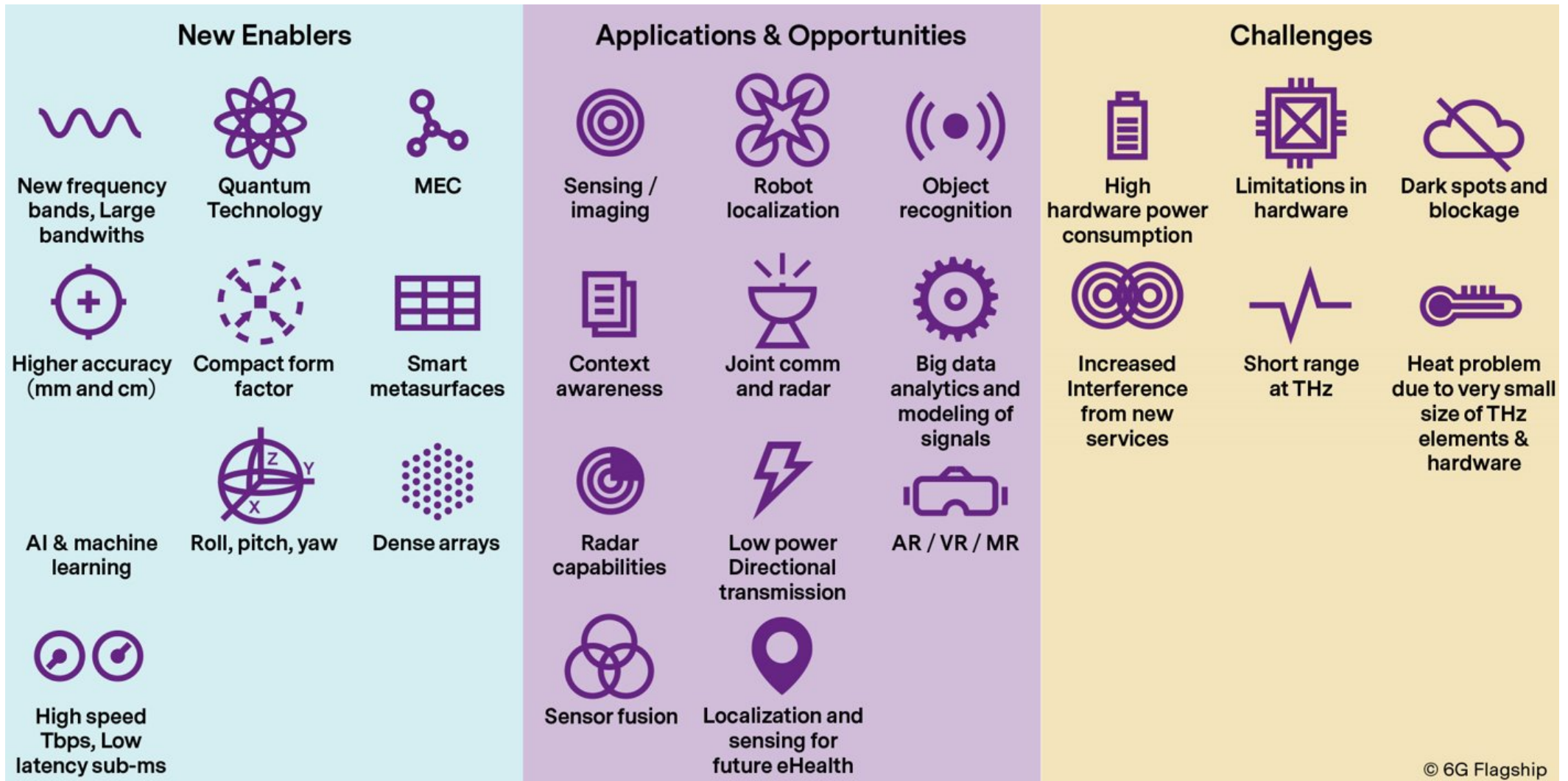
HIGHLIGHTS:

- § We identify potential enabling technologies and main features for localization and sensing, assess new opportunities of the environment-aware applications, recommend latest trends on and pose key research questions.
- § We expect 6G systems to be intelligent context-aware networks exploiting built-in localization and sensing features to enhance communication with no or limited human intervention.
- § We expect 6G systems to achieve high-accuracy positioning and high-resolution sensing/imaging enabling autonomous navigation and advanced XR applications with rich and accurate virtual imagery of the environment.

<https://www.6gchannel.com/portfolio-posts/6g-white-paper-localization-sensing/>



6G White Paper on Localization and Sensing



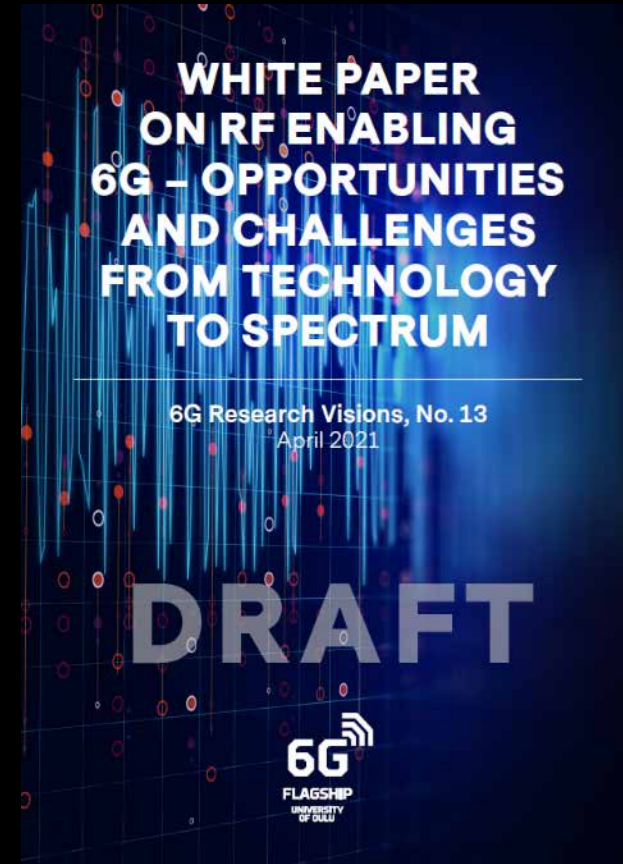
6G White Paper on RF Enabling 6G

led by Aarno Pärssinen

UPCOMING WHITE PAPER IN APRIL 2021:

- § Transceivers and emerging communications concepts
- § Semiconductor technologies
- § Antennas and packaging
- § Radio channel
- § Spectrum sharing
- § Prototyping and testing

To appear in: <https://www.6gchannel.com/6g-white-papers/>

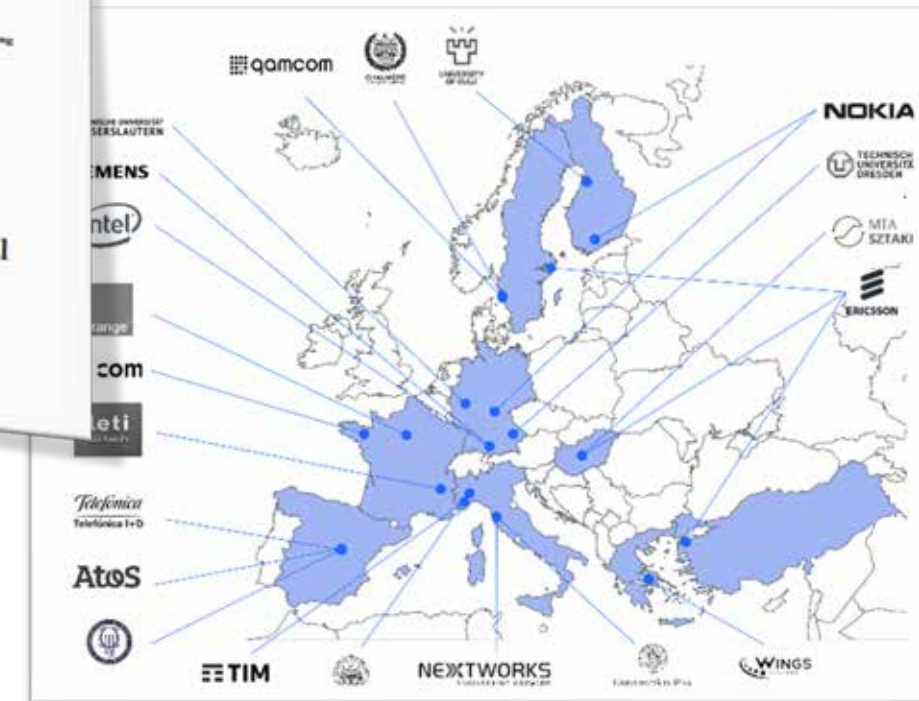


European 6G Flagship Hexa-X started in 2021



Finnish 6G Flagship's research inputs are fed into the new European level Hexa-X Flagship, funded by the EC.

https://hexa-x.eu/wp-content/uploads/2021/02/Hexa-X_D1.1.pdf



<https://hexa-x.eu/>



Twinning and control

Cognition and synched bio

Physical World

Human World

Real time control

Summary - 6G Flagship in Numbers



Staff

416
experts in 2020



46
Nationalities

56% International



Publications (2018 – 2020)

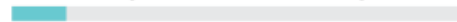
1 324
Peer-reviewed publications
/ Journal and conference articles



88% Joint publications with collaborators

70% Joint international publications

12% Joint publications with companies



Doctoral Degrees (2018 – Feb 2021)

53
Doctoral degrees



Investments & Funding (2018 – 2020)

267
Research projects with
external funding



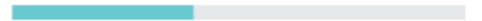
109
Companies investing in
research portfolio

Company Collaboration (2018 – 2020)

327
Company collaborators



40% International



6G White Paper (2018 – Feb 2021)

White Paper
2019 **134 381**
downloads

White Papers
2020 **394 176**
downloads



Number of downloads of 6G White Papers in
University of Oulu repository <http://jultika.oulu.fi/>

Conclusions



- Finnish 6G Flagship has engaged the larger community for **joint 6G vision building** since 2018.
- 13 White Papers present this joint 6G vision, with a consensus that the **UN SDGs drive 6G R&D**.
- Important topic to address is how 6G could become a truly **general-purpose technology**, to support vertical sectors in meeting increasing requirements for sustainability.

Coming events



<https://www.6gworld.com/6gsymposium/>

EUCNC | 6G Summit 

Virtual Conference (Porto, Portugal) ■ 8-11 June 2021

<https://www.eucnc.eu/>

IEEE pimrc

**IEEE International Symposium on Personal, Indoor
and Mobile Radio Communications**

13-16 September 2021 // Virtual Conference // By 6G Flagship

<https://pimrc2021.ieee-pimrc.org/>

Thank you!



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