6G FLAGSHIP
UNIVERSITY OF OULU

6G Flagship inputs to RSPG “6G strategic vision” hearing

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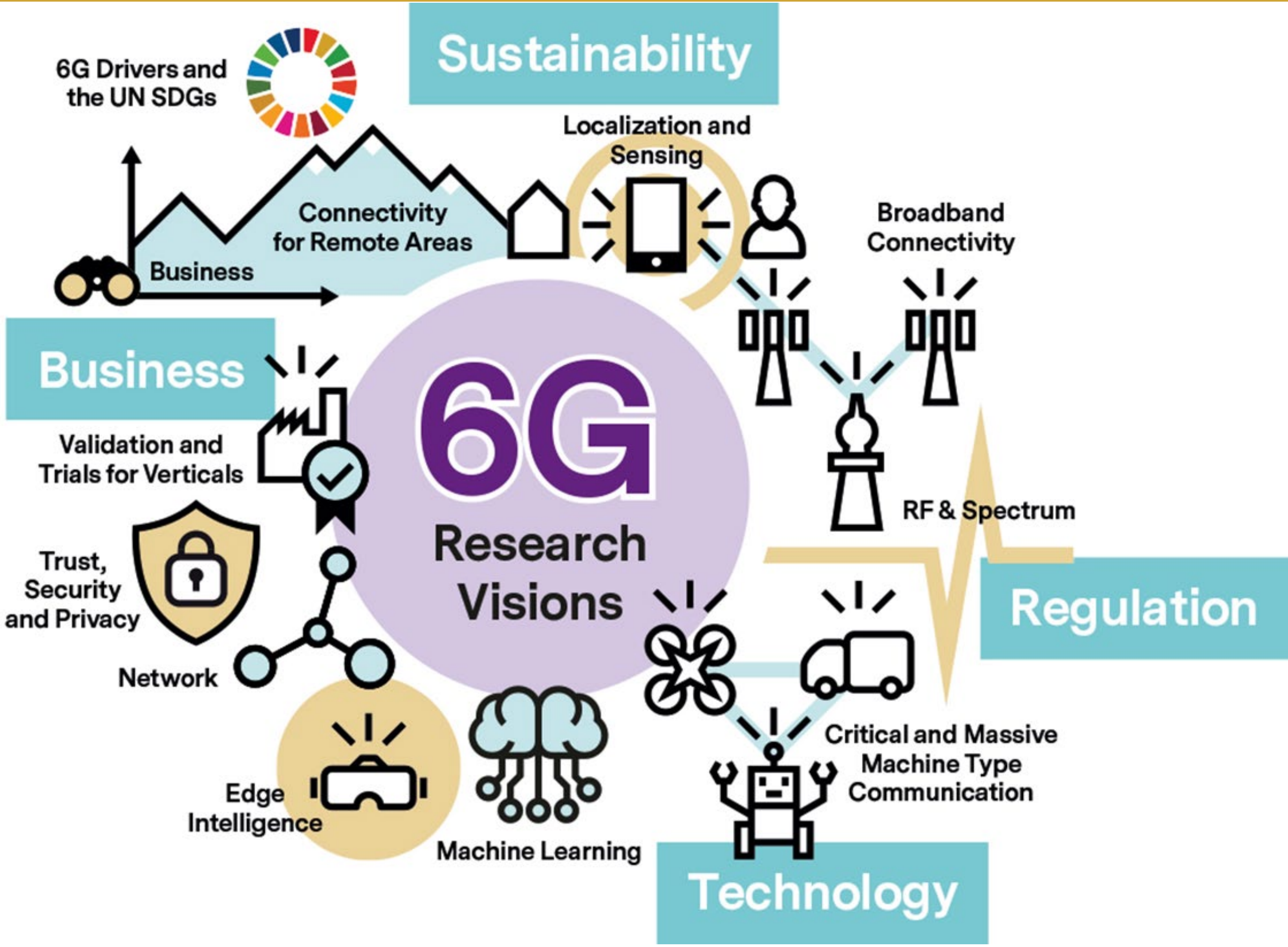
ACADEMY OF FINLAND
FLAGSHIP PROGRAMME

FINNISH 6G FLAGSHIP

Finnish 6G Flagship's multi-disciplinary agenda (2018-2026)

- 6G Flagship's multi-disciplinary research roadmap includes technology, business, sustainability, and regulation perspectives.
- Multi-stakeholder collaboration emphasises academia, industry, and public sector interplay.
- Sustainability and UN SDGs identified as global drivers for 6G R&D.
- Contributions to ITU-R process on IMT-2030.



Success story: **Local 5G operator concept with local spectrum licensing introduced in EuCNC 2017.**

RESPONSES TO HEARING TOPICS

#2 - Use cases for future spectrum needs

- **On spectrum challenges expected by 6G usage scenarios:**
  - **Market structures** change – local 5G networks that were strongly opposed 8 years ago are a reality today.
  - **Competition** over the scarce spectrum resource continues to be fierce between the different wireless services. There are no "clean" spectrum bands for 6G. Spectrum sharing is a necessity in the 6G era even more than in the 5G era.
  - **Traditional spectrum requirement estimations** have provided high-level total amounts of spectrum needed for mobile communication systems to justify new spectrum allocations based on assumptions of services, technology and deployments. They do not accurately characterize the expected spectrum needs of actual stakeholders in the future.
  - **Complexity and range of spectrum bands and spectrum access models** has increased with 5G where administrative allocation, market-based mechanisms, and the unlicensed commons were all present. The same will continue in 6G.
    - Different technologies, spectrum access models and use cases are suitable for different frequency bands. For example, lower bands are better suited for mobility and wide area coverage. Higher bands are local by nature but can be used for longer distance links with highly directive antennas.
    - As THz and upper mmW bands will be increasingly used for different purposes, including connectivity, mobile positioning, environment sensing, and wireless links, the resulting use cases and applications will vary in different locations.
    - Something that is not possible outdoors, should not restrict what can occur indoors.

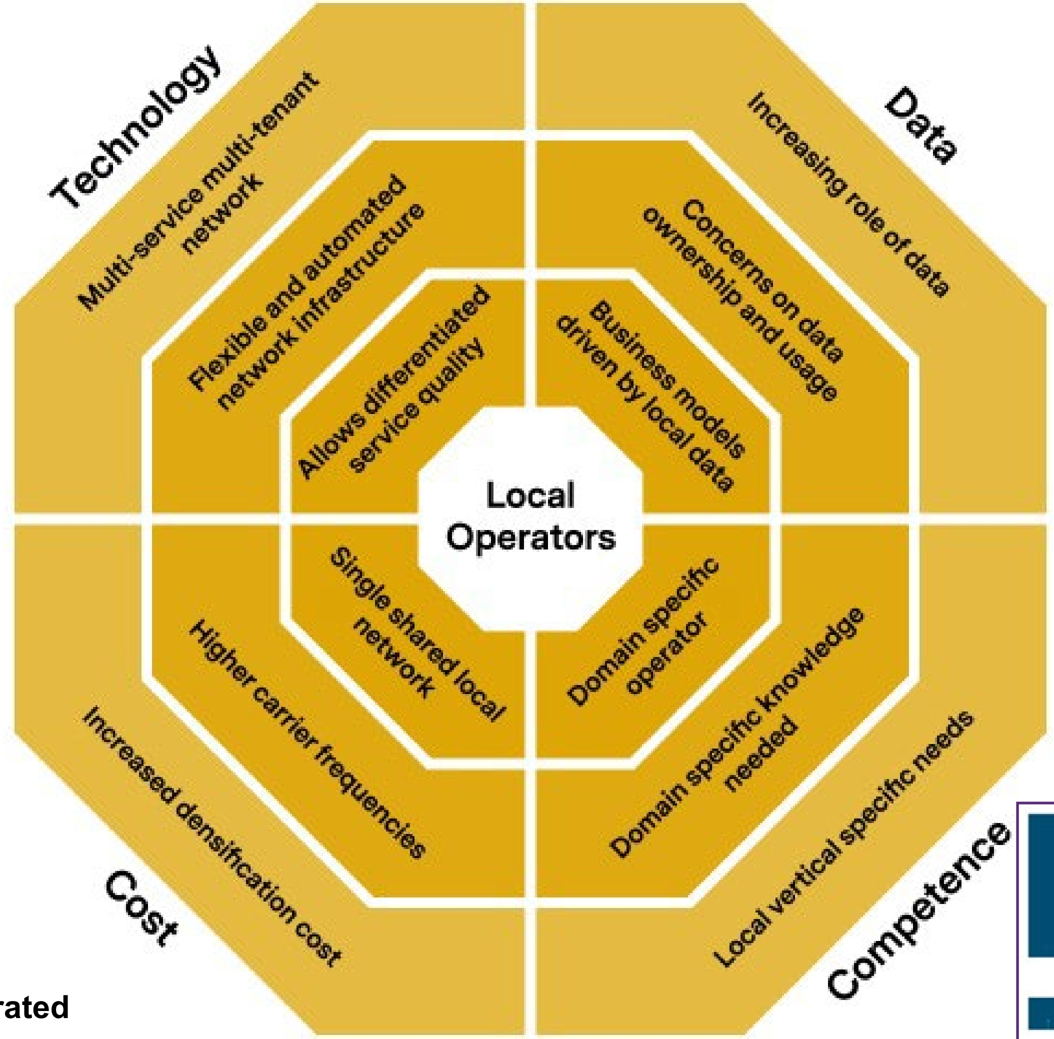
#2 - Use cases for future spectrum needs

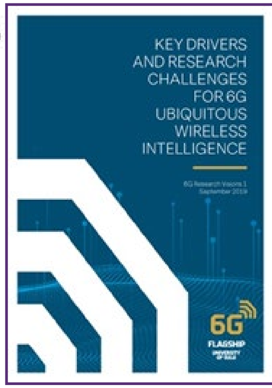
- **On use cases for 6G:**
  - **Local 6G networks** will be an important deployment model, relying on access to spectrum. Local 6G networks can be public or private, and deployed by different stakeholders using different spectrum access options, whose availability varies between countries.
  - **Networks for vertical applications** may or may not be local. There is not enough spectrum for everybody to build separate vertical specific systems for all verticals, which calls for sharing in multiple fronts including virtual networks via network slicing.
  - **Rapid access to spectrum for new innovative wireless services** that address major sustainability challenges in verticals or digital inclusion is not supported in European spectrum regulatory framework. Timely access to markets could take place via spectrum sharing.
  - **Serving the unconnected** is still a challenge. Making spectrum available where and when it is not used by existing holders of spectrum usage rights is still not a reality widely.

#2 - Use cases for future spectrum needs: Emergence of a large number of local 5G and 6G networks

Success story from collaboration between academia, industry and regulatory bodies: New local 5G networks and local operator models 2016-2018.

- Different stakeholders can deploy their own local 5G/6G networks[1].
- Local networks can be public or private, depending on end user groups and national conditions.
- Local spectrum availability[2] is a key pre-requisite. Currently, divergence between countries is high[3], leading to market fragmentation and competitive disadvantages.





[Key Drivers and Research Challenges for 6G Ubiquitous Wireless Intelligence - 6G Flagship]

[1]M. Matinmikko, et al. (2017) **Micro operators to boost local service delivery in 5G**. Wireless Personal Communications, 95(1), 69-82.
[2]M. Matinmikko, et al. (2018) **On regulations for 5G: Micro licensing for locally operated networks**. Telecommunications Policy, 42(8), 622-635.
[3]M. Matinmikko-Blue, et al. (2019). **Analysis of Spectrum Valuation Elements for Local 5G Networks: Case Study of 3.5-GHz Band**. IEEE Transactions on Cognitive Communications and Networking, 5(3), 741-753.

#2 - Use cases for future spectrum needs: Spectrum access options for local 5G/6G networks

- **On spectrum access options for stakeholders to establish local 5G/6G networks:**
  - **Local networks deployed by an MNO on the MNO's bands**.
  - **Local spectrum licenses from the national regulatory authority (NRA) to different stakeholders** (incl. MNOs)
    - spectrum bands that are cleared from incumbent use;
    - spectrum bands that are in use by MNOs, where additional local licenses are awarded by the NRA;
    - spectrum bands that are in use by other incumbent spectrum users than MNOs, where additional local licenses are awarded by the NRA.
  - **Local spectrum access rights acquired from incumbent** spectrum user(s)
    - existing and possible new bands, where the MNO holds spectrum access rights
    - existing and possible new bands where other incumbents hold spectrum access rights.
  - **Local spectrum access rights acquired from a third party** (brokerage model)
    - spectrum bands without incumbent spectrum users
    - spectrum bands with existing incumbent spectrum users
  - **Unlicensed access**
    - existing unlicensed bands (e.g., 2.4 GHz, 5 GHz, 6 GHz, 60 GHz)
    - possible new unlicensed bands in the 6G era.

➢ ***A lot of fragmentation exists between countries approaches to making different spectrum access options available.***

M. Matinmikko-Blue, S. Yrjölä & P. Ahokangas. (2023). Spectrum Management for Local Mobile Communication Networks. IEEE Communications Magazine, vol. 61, no. 7, pp. 60-66, July 2023.

M. Matinmikko-Blue, S. Yrjölä & P. Ahokangas. Spectrum Access Options for Local 6G Networks. To appear in S. Iyer, A. Kalla, O. Alcaraz Lopez, C. De Alwis (eds.) Intelligent Spectrum Management: Towards 6G, January 2025.

#3 - Be ready for a launch of 6G in 2030 for mass market for services and equipment

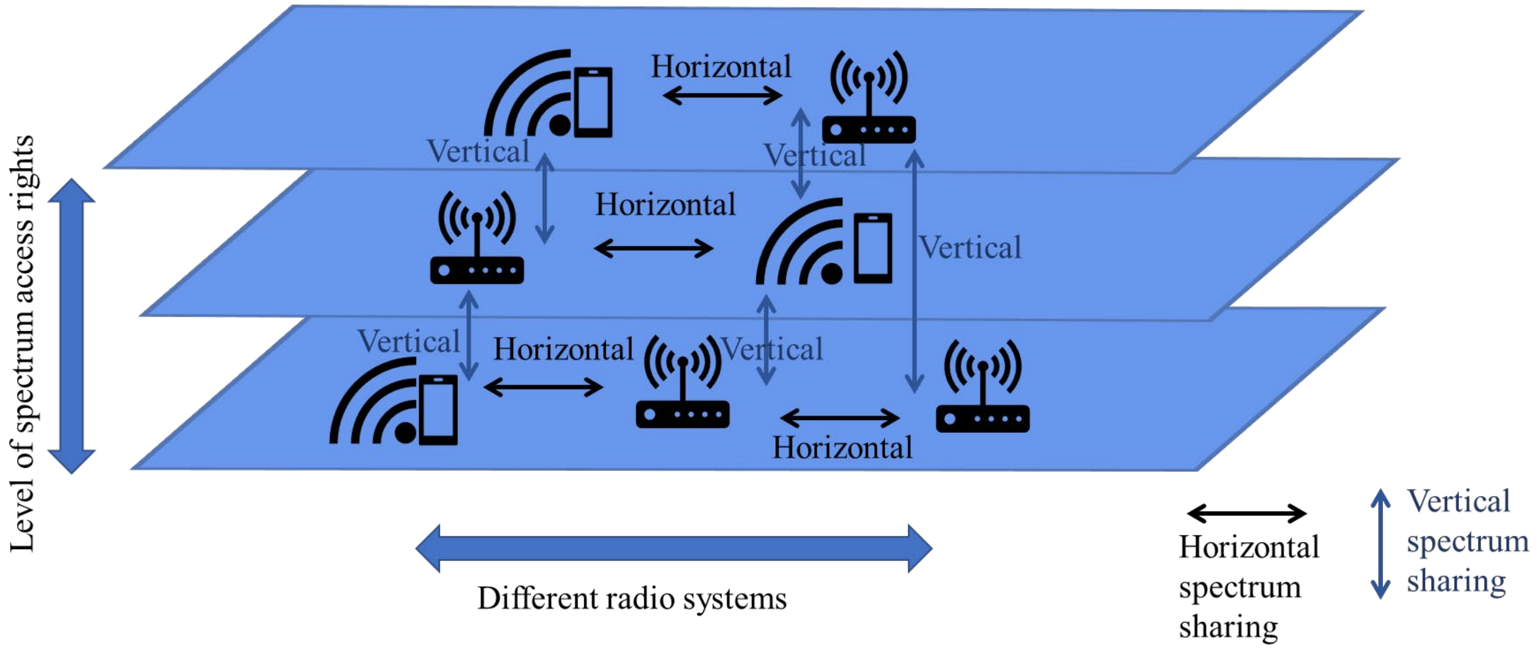
- **Coverage is crucial**. Indoor coverage as well as remote and rural area coverage present challenges and should be a priority in the 6G era, as highlighted in ITU-R's IMT-2030 work. They benefit from different technology and regulatory solutions.
- **Predicting capacity needs** for 6G use cases and usage scenarios for 2030s considering both future service and technology development **is futures studies, which has a lot of uncertainty.**
  - Technology developments aiming at efficiency enhancement can reduce the actual capacity demands. Especially the role of edge computing and increasing processing power in end devices will reduce the amount of data that needs to be transferred. This needs to be taken into account in spectrum needs.
- **Countries' different launch times are not a real issue**. Announcements are often marketing. Ranking forerunner countries by the launch date, which are within weeks or months, is irrelevant.
- **Ranking countries according to most consumed total mobile data is not relevant either** (and not sustainable).
- What matters is making the same spectrum bands available in different European countries for achieving economies of scale (e.g., in local licensing). Researchers would also need specific frequency bands to focus their research on.
- **Increasing role of spectrum sharing** calls for understanding what spectrum sharing means and its implications on technology, regulation and markets, which is still a challenge.

#3 - Be ready for a launch of 6G in 2030 for mass market
Understanding the concepts of spectrum sharing

- **Spectrum sharing refers to the situation, where two or more radio systems use the same frequency band*. Yet, there are no commonly agreed approaches in Europe despite decades of active R&D.**

Vertical spectrum sharing* occurs when a radio system with lower level of spectrum usage rights shares a spectrum band with radio system(s) having higher spectrum usage rights.

Horizontal spectrum sharing* occurs between radio systems at the same level of spectrum usage rights.



Vertical and horizontal spectrum sharing are not mutually exclusive and both are present in real-life sharing situations.

*Report ITU-R M.2330-0 (11/2014) Cognitive radio systems in the land mobile service.

#3 - Be ready for a launch of 6G in 2030 for mass market
Understanding the role of spectrum sharing

- **Today's spectrum sharing discussion are** still emphasing so called "*dynamic spectrum sharing*" for intra-operator single-MNO sharing between its own 4G and 5G (later expected for 6G) technologies within their spectrum blocks, and **avoiding real spectrum sharing scenarios**.
- Spectrum sharing including both vertical sharing between entrant 6G and other incumbents as well as horizontal sharing between e.g., several local networks deployments will play a key role in 6G development.
- Spectrum sharing considering the specifics of wireless technologies and system deployments in the bands can make local sharing particularly feasible with advanced capabilities to manage interference.
  - For example, at high spectrum regime at sub-THz frequencies, novel spectrum sharing methodologies and models including e.g., dynamic local licensing, are a viable way in practical deployments.
- Technological innovations for spectrum sharing will rapidly improve with the introduction of **AI driven interference management techniques** and increasing processing capabilities. The impact of AI on spectrum managment in the 2030s is not taken into account in the existing regulatory framework. The **flexibility to balance the needs and supply of spectrum resources across multiple systems at the local level provided by AI** cannot be exploited under current static regulatory framework.
- Developments in technological and policy innovations in spectrum occur outside of the European Union – it is important to **keep track on what happens in the US (and the UK) and develop spectrum innovations to remain competitive.**

#4 - Role of private networks in 6G

- First of all, **clarity on terminology and definitions is needed**. Private network in general serves a closed user group. Not all local networks are private and not all private networks are local. Even the term “private spectrum” comes up.
- The **concept of local 5G/6G network** is wider and better suited. It denotes a 5G/6G network covering a geographically constrained area, deployed by different stakeholders including the MNOs. Depending on the served end user groups and national conditions, a local 5G/6G network can be private or public.
- Additionally, a local 5G/6G network can serve its own end users and/or another stakeholders’ end users (e.g., neutral host).
- It is important to acknowledge the deployment of different types of networks by different stakeholders in the 6G era beyond MNO deployments.

P. Ahokangas, M. Matinmikko-Blue, A. Basaure and S. Yrjölä, "Use Cases for Local 6G Networks," 2024 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit), Antwerp, Belgium, 2024, pp. 1127-1132, doi: 10.1109/EuCNC/6GSummit60053.2024.10597019.

M. Matinmikko, M. Latva-aho, P. Ahokangas, V. Seppänen, On regulations for 5G: Micro licensing for locally operated networks, Telecommunications Policy, Vol. 42, No. 8, 2018, https://doi.org/10.1016/j.telpol.2017.09.004.

M. Matinmikko, M. Latva-aho, P. Ahokangas, S. Yrjölä, T. Koivumäki. Micro operators to boost local service delivery in 5G. Wireless Personal Communications, vol. 95, no. 1, pp. 69–82, May 2017.

#5 - Role of license exempt spectrum

- Wireless technologies operating in the license exempt spectrum have been a **playground for innovation and experiments for decades**. The role of technologies operating under license-exempt spectrum access regime is **significant in delivering indoor broadband connectivity**.
- **Understanding and accepting the roles of different wireless technologies without biases**, especially in the context of indoor usage, is important. **End users use a variety of wireless technologies** in a variety of spectrum bands under different spectrum access models without noticing it or the need to notice it. **Unnecessary confrontations** emphasizing communities (e.g., WiFi/3GPP/satellite community) are not helpful in promoting digitalization of societies but have created barriers.
- **Principles of license-exempt spectrum use are open to different technologies, including 5G/6G.**

#6 - Role of Non Terrestrial Networks (NTN)

- The **interworking** of terrestrial IMT-2030 (here 6G) network with its non-terrestrial networks (NTN), including satellite communications, high altitude platform stations as 6G base stations (HIBS), is expected to enhance achieving required connectivity objective*.
- IMT-2030 (here 6G) is expected to support service continuity and provide flexibility to users via close interworking with non-terrestrial network implementations, existing IMT systems and other non-IMT access systems*.
- Deployment scenarios, where end user or base station equipment are mounted on objects moving above the ground level, results in different and challenging interference scenarios, depending on the wireless systems using the specific band. These sharing studies and techniques required to manage the resulting interference are studied in research community.
- **Role of partnerships in solving conflicting stakeholder claims for interference management** in the context of sharing between terrestrial and non-terrestrial systems has shown to work – when incumbent and entrant are partners, spectrum sharing discussions become solution oriented instead of blocking or delaying developments.

*https://www.itu.int/rec/R-REC-M/recommendation.asp?lang=en&parent=R-REC-M.2160

#7 - Sustainability and Security
Understanding sustainability concepts and principles

Sustainable development refers to the "**development that meets the needs of the present without compromising the ability of future generations to meet their own needs**" [Brundtland report 1987].

- It is importance of understand different sustainability perspectives, which are interrelated, and state the limitations when focusing on a specific perspective:
  - Environmental, social and economic sustainability perspectives
  - Sustainable ICT and ICT for sustainability
  - Positive and negative impacts / handprint and footprint / benefits and costs
  - Life cycle approach; end to end system approach
- Overall goal is to maximize positive sustainability impacts and minimize negative impacts.
- Today's sustainability discussions are focusing on **energy efficiency**, which is an environmental sustainability indicator of sustainable ICT and a ratio of output and input. It is not an absolute measure. **Improved energy efficiency does not directly lead to reduced energy consumption**. Reduced energy consumption is an environmental sustainability target for sustainable ICT.

#7 - Sustainability and Security
Towards sustainable spectrum management

- **Sustainability is a cross-cutting priority** that needs to enter different thematic topics, including spectrum management, considering environmental, social and economic sustainability perspectives.
  - Environmental sustainability examples:
    - The capabilities of devices increase, impacting spectrum use. Processing of data locally in end user device or network edge changes how data flows occur in the future. With sustainability thinking, the goal is to minimize transmitted data and only transfer what is needed. Total amount of consumed data is not sustainable.
    - High energy efficiency per bit can be achieved only when data rates are extremely high requiring wide bandwidths. Only use cases that will need it and can utilize it should be promoted.
    - Selection of communication solutions which cause the lowest environmental impact once this info is available.
  - Social sustainability: Digital inclusion – affordable access to digital services.
  - Economic sustainability: reasonable auction prices that allow investment in the networks.
- **Question: How do long-term exclusive spectrum licenses without obligations to share unused spectrum fit in the new sustainable spectrum management framework?**

#7 - Sustainability and Security
Sustainability in the spectrum management context

- Example of sustainable spectrum management

Table 4
Sustainability and business/regulation/technology perspectives in spectrum management for 6G.

	Business	Regulation	Technology
Environmental sustainability	Rapid access to spectrum for new wireless solutions for solving environmental sustainability challenges as a new business opportunity.	Criteria for assessing spectrum usage footprint. Selection of most sustainable technology and spectrum combination.	Comparison of environmental footprint of spectrum access techniques.
Social sustainability	Frugal innovations from communities enabled by local access to spectrum.	Setting requirements for connecting the unconnected. Introducing social sustainability related obligations in all spectrum decisions.	Affordable techniques to operate in challenge areas under different spectrum access models.
Economic sustainability	Opportunities for local business via local network availability. Functioning spectrum markets.	Reasonable licensing fees. Predictability and certainty of spectrum availability.	Timely introduction of global affordable solutions.

M. Matinmikko-Blue, S. Yrjölä, P. Ahokangas, Multi-perspective approach for developing sustainable 6G mobile communications, Telecommunications Policy, Vol. 48, No. 2, 2024, https://doi.org/10.1016/j.telpol.2023.102640.

#7 - Sustainability and Security
Security and resilience implications

- **Spectrum policy is a tool for governments** to safeguard national security, protect consumer data and ensure resilience against cyberattacks by posing restrictions and requirements on stakeholders **to address security**, when they award spectrum access rights to deploy the systems. These include banning technology originating from some countries, security audits, certifications, standardized approaches, mandatory security updates, etc.
- Local 5G/6G networks are a new deployment model that introduces security challenges, such as trusting that all emerging local operators are legitimate players. Spectrum policy through local licensing conditions can address this.
- **Security technologies should not considerably affect the transmission spectral efficiency***. However, serious denial of service attacks can momentarily impact network performance and decrease spectral efficiency.
- **Resilience** in the 6G real-time economy is critical cross-cutting theme for maintaining uninterrupted operations, mitigating risks, and adapting to disruptions and requires building measures using redundancy, fault-tolerance and impact mitigation. Many of the topics discussed earlier (NTN, remote area connectivity, etc.) are relevant for resilience. Spectrum policy is a tool to pose requirements in licensing conditions.

*M. Ylianttila, R. Kantola, A. Gurtov, L. Mucchi & I Oppermann (Eds.). (2020). 6G White Paper: Research Challenges For Trust, Security And Privacy. (6G Research Visions, No. 9). University of Oulu. http://urn.fi/urn:isbn:9789526226804

Conclusions

- Spectrum decisions are long-term compromises between conflicting stakeholder claims. In reality, those with existing strong market positions still dominate the discussions about the future. **Proper stakeholder management is needed**.
    - Developments outside Europe are building on spectrum sharing, which is still not properly discussed in Europe.
    - How to make sure that there is room for innovation? Who looks after the interests of end users and those without dominant position?
    - Local mobile communication network deployments by different stakeholders have become a reality.
- **Spectrum sharing needs to be incorporated into 6G spectrum discussions from the beginning** of the technology development phase and not a restriction posed afterwards.
    - Impact of new technological developments (AI, local processing, increased device capabilities) and deployment models (local 5G/6G, flying objects) on interference management within existing regulatory framework needs to be understood and taken into consideration when developing regulations.
    - Suitable spectrum regulatory enablers will be key a success factor for developing future wireless solutions via society pull with market impact to make Europe a forerunner in the global race towards 6G
- **Strengthening the role of research community** in providing evidence-based results and new spectrum innovations to decision making benefits everybody. There is a need to identify bands where researchers could focus on.
- **Terminology needs to be clarified**: private network; “private spectrum”; spectrum sharing; spectrum bands (low bands; mid bands; high bands; lower mmW band; upper mmW band; THz band), etc. Especially, **sustainable spectrum management** framework needs to be defined.

Thank you!

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