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A new stakeholder paradigm to link 6G with sustainable development goals and spectrum management

This chapter will address the role of sustainability and spectrum access in the context of the next generation of mobile communication networks after 5G – namely 6G. The deployment of 6G systems is targeted for 2030, which is also the target year for the achievement of the United Nations' Sustainable Development Goals [UN 2015]. These two developments influence each other in multiple ways, which is discussed in this chapter.

The radio spectrum continues to be the key resource for any wireless connectivity solution and presents a major control point to stakeholders. In general, spectrum management decisions aim at maximizing the value of spectrum, its efficient utilization, and benefits to the society [Beltran 2017]. The role of spectrum management is crucial in defining which spectrum bands are used by the different wireless systems and by whom – important decisions that ultimately shape the market and operational models by defining which stakeholders can (re)use the precious natural resource. Given that sustainability has penetrated all aspects of our society starting from children's schoolbooks, it cannot be excluded from spectrum management.

Spectrum decisions are all about stakeholder management [Freeman, 1984] – an important theme that yet is under-examined in telecommunications research and not properly used when regulatory bodies are making spectrum management decisions. Ultimately, the spectrum decisions have long-term impacts, which are very different for the different stakeholders who have conflicting agendas. But no one really oversees what is best for our sustainable future. Those who hold a strong position today get to significantly influence the definition of the future. Those who bring disruptive ideas in the future are not necessarily represented in that decision making. Moreover, organizations participate in multiple ecosystems simultaneously, promoting not only the views of themselves but their partners. Some sway influence even when they are not the relevant stakeholder. These changing business ecosystems, and the simultaneous participation in multiple ecosystems, create a complex network of stakeholders with highly distinct and varying goals. A key constraint in spectrum management is how to ensure that long-term compromises are found that meet the changing needs in a sustainable way. The continuous need for more spectrum by a variety of wireless systems should be looked at from the perspective of spectrum sharing, where different systems can operate in the same band.

5G spectrum decisions have already shown growing fragmentation, not only about spectrum bands, but also spectrum management approaches covering administrative allocation, market mechanisms and the

unlicensed commons. Strict market structures are gradually opening for new operational models [Weber & Scuka 2016], such as the local operators [Matinmikko et al. 2017a].

For the future developments towards sustainability, spectrum sharing will be a key facilitator for new business models and disruptions. When you do not have long-term stability through massive investments in spectrum, sharing-based access is highly appealing. Spectrum sharing will be the key driver to facilitate new business models and greater inclusivity. The time for making money by creating artificial scarcity of spectrum must now transition to an era of sustainable resource management. If we fail to act soon, we will miss the target of 2030, when the UN SDGs should be achieved and the first 6G gadgets and systems will be available in the market.

1. Building a joint 6G vision

The global-scale deployment of 5G networks is on-going. At the same time, research towards 6G has started. Finland launched the world's first 6G research program – 6G Flagship [6G Flagship] in May 2018. Since then, several 6G research programs have started in many countries and continents, bringing together academics, industry and other stakeholders.

The 8-year long 6G Flagship research effort, appointed by the Academy of Finland and led by the University of Oulu, started 6G research with a vision for 2030, where our society will be data-driven, enabled by near instant, unlimited wireless connectivity. Joint vision building for 6G with stakeholders was globally launched in March 2019 when the 6G Flagship programme organized the world's first 6G event, the 6G Wireless Summit, that gathered major telecom players to present their first visions of 6G. The event started the preparation process of a 6G White Paper with an invited group of 70 experts from around the world. The outcome – the world's first 6G White Paper [Latva-aho & Leppänen 2019] published in September 2019, labeled 6G as "Ubiquitous Wireless Intelligence". The joint vision building reached a consensus that 6G research and development should be driven by United Nations' Sustainable Development Goals (UN SDGs) that also target the year 2030. The white paper also highlights the integration of sensing, imaging and highly accurate positioning capabilities with the communication service in 6G which in turn can open a myriad of new applications in 6G. New capabilities, combined with mobility and AI/ML, can open many new application areas leading to new business opportunities in a truly digitalized society, alleviating the digital divide.

The world's first 6G White Paper [Latva-aho & Leppänen 2019] emphasized the local operator paradigm [Zander 2017; Matinmikko et al. 2017a] where the role of local indoor networks is emphasized and different stakeholders can have their own networks, independent of mobile network operators, through local spectrum access. Regarding the performance of 6G networks, many of the key performance indicators (KPIs)

used for 5G continue to be valid also for 6G. However, there is a need to critically review the KPIs and consider new KPIs – especially towards sustainability.

Following the growing global interest towards the joint 6G vision building, the 6G Flagship programme launched another round of collaborative 6G White Paper preparation in late 2019. This time, an open call was published inviting experts to join 12 thematic groups. A set of 11 new 6G White Papers were published in June 2020 on themes that were identified based on the first white paper. A total of 250 experts from more than 100 organizations in 30 countries became contributors to the white papers. The white papers present a more detailed analysis of 6G's in terms of its linkage to the UN SDGs, business, trials for verticals, remote area connectivity, networking, machine learning, edge intelligence, trust, security and privacy, broadband connectivity, machine type communications and localization and sensing.

2. Connecting 6G with the UN SDGs

Following the consensus of using the UN SDGs as the key driver for 6G research and development in [Leppänen & Latva-aho 2019], one of the 2020 edition 6G White Papers [Matinmikko-Blue et al. 2020] specifically addressed the linking between 6G and the UN SDGs. The white paper identified megatrends influencing the sustainable development of 6G and reviewed existing work on the broader connection between ICT and the UN SDGs. The white paper proceeded to develop a novel linking between 6G and the UN SDGs through the existing indicators of the UN SDG framework and started the development of new 6G indicators. The white paper defined 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.

The role of ICT in helping the achievement of the UN SDGs follows a three-layer approach: deployment of infrastructure and networks that form the foundation for digital economy; access and connectivity allowing people to use mobile services; and enabling services and relevant content for people [GSMA 2018; ITU 2020]. Agenda 2030 for sustainable development consist of 17 goals that cover the major global challenges. The goals are broken down to specific targets whose achievement is measured with a set of indicators. The goals address significant global challenges such as poverty (SDG 1), hunger (SDG 2), gender equality (SDG 5), and climate change (SDG 13). The UN SDG framework with its 17 goals, 169 targets and 231 indicators, presents a comprehensive action plan whose achievement is can be significantly contributed to with ICT. However, out of the 231 indicators, only 7 indicators are identified as being ICT-related and address only four SDGs (SDG 4: quality education; SDG 5: gender equality; SDG 9: industry, innovation & infrastructure; and SDG 17: partnerships). These ICT related indicators include proportion of schools with access to the Internet for pedagogical purposes, proportion of schools with access to computers for pedagogical purposes and

proportion of youth/adults with ICT skills, by type of skills; proportion of individuals who own a mobile telephone; percentage of the population covered by a mobile network, broken down by technology; and fixed Internet broadband subscriptions, broken down by speed and proportion of individuals using the Internet.

In reality, there is linkage between ICT and each of the 17 SDGs. The 6G White Paper [Matinmikko-Blue et al. 2020] collected the current relation between ICT and the UN SDGs from various sources and developed a new linking between the upcoming 6G systems and the UN SDGs – both targeting the year 2030. The expert group preparing the white paper identified global megatrends, which will drive 6G research and shape the world, and looked at sustainability in a broad sense, covering political, economic, societal, technological, legal, and environmental perspectives. A key observation in the white paper was that the future 6G systems, where the communication capabilities are merged with sensing, location, imaging and other capabilities, could gather a variety of data to report on the achievement of the UN SDGs on a highly local granularity level. This could respond to the challenge that nations face in how the targets defined in the UN SDG framework are being reached, noting that counter effects could also emerge. Therefore, it is important to investigate what kind of data should be collected, and how and to whom it should be reported. The UN SDG framework itself is likely to evolve and during the full deployment of 6G in the 2030s, the indicator set for global challenges could be different.

In the 6G and UN SDGs white paper [Matinmikko-Blue et al. 2020] and the accompanying White Paper on Business of 6G [Yrjölä et al. 2020], the future 6G ecosystem is expected to be built around a number of new stakeholder roles and principles. Pure business-driven operations will be complemented with new societal models including community-driven networks, which will emerge depending on the regulatory environment. Another big transformation will come from the vertical industries and their public sector counterparts to whom the achievement of the UN SDGs will place significant economic constraints and they will need to take everything the future technologies can offer to improve existing systems and processes through digitalization. This requires an early engagement of the relevant stakeholders in the process of 6G development instead of waiting for the telecommunication industry to define what 6G can bring for them, which took place in the 5G development.

3. 6G and spectrum access

Spectrum regulators are in a key position to shape the future societies through their spectrum management decisions by allocating spectrum bands among different radio communication services and assigning access rights to different stakeholders. This is a complex decision-making process, where the high-level goals of maximizing the value of spectrum [Bazelon and McHenry 2013], its efficient utilization and benefits to the

society [Beltran 2017], can be interpreted quite differently. The decision making includes different types of inputs with potentially a high level of uncertainty when predicting what impact the spectrum management decision will have in the long term. Especially, the stakeholders involved can have highly conflicting views, providing different data to back up the positions.

The role of spectrum continues to be important in the development of the next generation of mobile communication systems. Competition over the scarce spectrum resource continues to be fierce between the different wireless services. Over time, spectrum management approaches have evolved from administrative allocation [Levin 1970] towards market-based mechanisms [Beltran 2017; Berry et al. 2010; Hazlett 2008; Melody 1980; Valletti 2001] and the unlicensed commons approach [Bazelon 2009]. Exclusive access to spectrum often is the desired model for many stakeholders. With a handful of exceptions, and despite decades of extensive research, development work and trials of spectrum sharing technologies and concepts [Guirao et al. 2017; Matinmikko et al. 2018a], not much has changed in regulation.

On one other hand, the complexity of spectrum bands and access models has increased in 5G, including very different types of spectrum bands to operate in terms of carrier frequencies and bandwidths. As an example, the European pioneer bands for 5G (700 MHz, 3.5 GHz and 26 GHz) have very different characteristics leading to highly distinct deployments in terms of e.g. cell sizes and indoor/outdoor feasibility. At the same time, the variety of spectrum assignment methods used in these bands for 5G deployments varies a great deal between countries including examples of both administrative allocation and market-based mechanisms [Matinmikko-Blue et al. 2019]. Additionally, 5G variants are aiming at unlicensed commons operations, further expanding the cellular networks to all known spectrum management models.

On the other hand, divergence between the spectrum assignment methods chosen for the bands to deploy 5G networks differ significantly between countries, even inside Europe. Moreover, some countries have used the very same assignment principles in all three bands, although their propagation and deployment characteristics differ drastically. Some countries have introduced new obligations in their spectrum awards decisions, while others have auctioned bands without the obligations, such as coverage requirements, that were attached to 4G spectrum. Some counties have reserved parts of the bands for local use through administrative allocation, but these bands vary from country to country. The high fragmentation between the spectrum management decisions made in the different countries about where, how and by whom 5G networks can be deployed, is a new phenomenon, which places the sovereignty of the countries in deciding how the handle the spectrum access above the larger market. The same procedural approach now heavily present in 5G could also continue in 6G if best practises are not analysed and developed properly.

Mobile communication market structures are changing [Weber & Scuka 2016; Yrjölä et al. 2020]. Existing stakeholders are taking new and different roles and entrants are emerging [Matinmikko et al. 2017a]. One

example is local and private 5G networks that are independent of the mobile network operators. These developments previously discussed [Matinmikko et al. 2017a] through the concept of local micro operators, were strongly opposed at first, but have recently become accepted in several countries [Matinmikko-Blue et al. 2019]. The emergence of the local 5G networks is dependent on spectrum availability, and if spectrum is in the hands of existing MNOs, the market will be fully controlled by current strong players, and there will be little incentive for change. The divergence of spectrum decision making to allow local 5G networks is high – some countries have made it happen through the availability of local spectrum licenses directly without MNO involvement, while other countries rely on MNOs willingness. These spectrum management decisions significantly shape the market and can lead to missed market opportunities.

The complexity in terms of the same device operating in a wide variety of spectrum bands under different spectrum access models is also significant and end users are typically unaware of which technology is being used. The traditional split into radiocommunication services in the spectrum management domain is not consistent with the use of wireless technologies (e.g., 5G, 6G) for digitalization of the entire society. 6G combines the communication service with other services which further blurs the split. Timescales of international-level spectrum management also present a challenge in terms of reacting to the fast pace of technology development and changing user needs when the same wireless technology can be used for multiple purposes.

An ever-increasing variety of spectrum bands for mobile communications, with drastically different propagation and deployment characteristics, fragmentation of spectrum management approaches, and rivalry between systems competing over spectrum access, is leading to a situation where spectrum sharing will finally become necessary. However, stakeholder management will be the bottleneck.

4. Time for proper stakeholder management in spectrum management

Both sustainable development and spectrum management call for proper stakeholder engagement. While the term “stakeholder” is commonly used in many contexts, especially in spectrum management decision making by the regulators and regulatory bodies, there is very little formal background for its use. In fact, stakeholder management [Freeman 1984] can provide a solid foundation for understanding and handling of conflicting views of the different parties. Proper spectrum management calls for understanding the stakeholder salience [Mitchell et al. 1997], which is the degree to which managers give priority to competing stakeholder claims.

In its basic form, stakeholder analysis [Freeman 1984] consists of three steps: identification of stakeholders; stakeholder dynamics and interactions; and stakeholder management actions. In the first step, stakeholders

are identified in the considered context, such as the future use of a specific spectrum band like the UHF band in [Matinmikko et al. 2017b], noting that an organization could have highly distinct stakeholder maps depending on the context. In the second step, the roles and relations of the stakeholders' networks are investigated. This is an important step since stakeholder relationships do not occur in a vacuum of dyadic ties but rather in a network of influences. These especially business relations significantly impact the positions of the stakeholders, but they are not often seen clearly if not analyzed properly. Moreover, a single company can have highly distinct relationships with other companies in another context, which impacts their positions on e.g. spectrum assignment. It is important therefore to characterize the partner network of the key stakeholders carefully. This can result in new information on why stakeholders present the view that they do – it is not always their own view but that of a major customer. In the third step, the stakeholder management strategies are developed to define the actions to be taken with the stakeholders.

Although heavily studied in many other fields, stakeholder analysis [Freeman 1984] had not been applied in spectrum management or wireless communications more generally until [Matinmikko-Blue 2018b] where a stakeholder analysis framework for sharing-based spectrum governance models to reach long-term compromises was proposed. The considered case studies, the future use of the ultra-high frequency (UHF) band [Matinmikko et al. 2017b] and the Licensed Shared Access (LSA) concept [Matinmikko et al. 2017], showed examples of different stakeholders' positions on the future spectrum use. The UHF discussions showed how mobile network operators wished to gain access to the band, while the incumbent broadcast network operators wished to continue using the band. This gives interesting insights into the decision-making process of the national regulators or the regulatory bodies in regional and international levels. The salience of stakeholders varies – some are heard more than others, and there are big national-level differences that propagate to multi-national fora. The methods used to seek compromises between these views are often incomplete and allow the current dominant players to continue to control the discussions.

The White Paper on 6G Drivers and the UN SDGs [Matinmikko-Blue et al. 2020] introduces a preliminary action plan for engaging different stakeholders to support the achievement of the UN SDGs with the help of 6G. The work recognizes that the role of ICT is critical in meeting the UN SDGs and it is not enough to treat them separately. 6G will be a new technology generation designed fully in line with the UN SDGs and to support the achievement of the UN SDGs. Defining 6G is not only a matter for technology companies and network operators, but also for the wider community that is working hard to complete the SDGs. The UN SDG framework will also need to evolve along with the technology development – current indicators do not fully reflect even today's ICT status. The white paper emphasizes that the role of ICT should be seen broadly, not only through the seven ICT related indicators in the UN SDG framework but through its role in helping to achieve all 17 SDGs. This can be identified through investigating how the use of new technology can contribute to the existing indicators of the UN SDG framework beyond the ICT related indicators. Stakeholder

management should be specifically addressed in the sustainable development - the technology itself is not a solution, but the use of the technology aligned with the goals is always a stakeholder's decision.

The action plan in [Matinmikko-Blue et al. 2020] identifies specific roles for stakeholder groups in the joint development and evaluation effort. Governments play a key role in contributing to coverage and low cost of service for everyone through the creation of the regulatory framework and incentives to invest and operate the systems. Often more flexibility is needed to allow low-cost solutions in challenging areas that are not of business interest to operators. For the mobile communication sector, 6G is not only about developing yet another generation, but a true opportunity to contribute to sustainability at large. The role of the research community is important in facilitating stakeholder interactions and providing unbiased research results.

Spectrum management decisions should be a result of a careful and transparent stakeholder analysis process. Currently, what is called stakeholder analysis is conducted quite differently by different decision-making bodies. Stakeholder views are often collected in public consultations, but how these views are considered varies significantly. In some cases, point-to-point analyses are done addressing the stakeholders' inputs and carefully justifying the decisions taken. In other cases, stakeholder viewpoints are collected but not much is reflected in the decision making and justifications are not given. It can be observed that decisions made regarding 5G spectrum awards were dominated by the needs of those with existing strong market positions. Incumbents views on future needs were considered above all others. In instances where input from different stakeholder was considered, and where innovation, experimentation and disruption were encouraged, new practices (e.g. local licensing and new obligations that benefit consumers being included as part of the auction process) created meaningful positive change. The voices of the different stakeholders need to be heard regarding a future where sustainability must become the new norm. How do we make sure that the stakeholders developing our sustainable future can be heard? This leads to important questions - who oversees the stakeholder analysis process of spectrum assignments? Who makes sure there is room for innovation? Who looks after the interests of end users and those without a dominant position?

One thing is clear - there is not enough spectrum for every company and organization requesting it. Stakeholders have different positions, but only some stakeholders are heard in the process of today's spectrum management decisions that will impact our future. This has been particularly evident in the spectrum sharing related discussions – those who currently control spectrum access rights are not in favour of sharing-based spectrum access models. But if sharing is a stakeholder's only opportunity to access spectrum, and the users basic needs can be met, it becomes the most attractive option.

5. Conclusions

It is of utmost importance to involve the relevant stakeholders in the process of spectrum access and the sustainable development of future wireless systems. Understanding stakeholder intentions and interactions – why they say what they say must be made important. The connectivity market structure and associated stakeholder landscape is changing. What is the role of different stakeholders in envisioning the future? How will we reconcile the needs of newcomers with innovative ideas, existing players with strong market positions, and authorities in charges of sustainable decisions, not to mention the citizens with growing concerns that range from legitimate to conspiratorial.

6G research is well underway globally with the Finnish 6G Flagship's start in 2018. There is a common consensus that the UN SDGs should be considered as the starting point for 6G research and development. While they both target the same year, one should be achieved by 2030 while the other will only start to be deployed then, yet their interaction is important in realizing a sustainable future. The world's first 6G white paper [Latva-aho & Leppänen, 2019] built a connection between 6G and the UN SDGs. The second white paper [Matinmikko-Blue et al. 2020] specifically stressed the urgency of investigating the role of ICT in helping the achievement of the UN SDGs through providing services, collecting data, and developing the telecommunication systems in accordance with the UN SDGs. In fact, the UN SDGs and related regional and national-level policy goals have already started to impact various verticals, placing increasing requirements on renewing their operations to become sustainable. The achievement of the sustainability goals is highly dependent on the use of ICT solutions which themselves also need to be sustainable.

When it comes to spectrum management for future systems, spectrum sharing is the way towards a sustainable future. To make it happen, stakeholder management needs to undergo a major transformation. The variety of bands and fragmentation will keep increasing as we head towards 6G – the role of spectrum sharing is critical in the landscape of changing market structures and stakeholder needs.

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