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**Conference Paper**

## Linking Mobile Communications with the United Nations Sustainable Development Goals: Mapping Process

ITS Online Event, 14-17 June 2020

**Provided in Cooperation with:**

International Telecommunications Society (ITS)

*Suggested Citation:* Ojutkangas, Kirsi; Rossi, Elina; Aalto, Sirpa; Matinmikko-Blue, Marja (2020) : Linking Mobile Communications with the United Nations Sustainable Development Goals: Mapping Process, ITS Online Event, 14-17 June 2020, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/224869>

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# *Linking Mobile Communications with the United Nations Sustainable Development Goals: Mapping Process*

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## Abstract

United Nations Sustainable Development Goals (SDGs) are becoming an increasingly important theme for researchers in multiple fields to investigate. In this paper we look at the process of how 6G researchers and other experts identified ways in which mobile communications is linked with the UN SDGs while writing a new 6G white paper on the topic. In a team of around 40 members consisting of representatives of academia, industry, and governmental bodies, we developed a sustainable vision for 6G, identified linkages between 6G mobile communications and the UN SDGs, and came up with a preliminary plan of action for how to reach the set goals, all published in a white paper. It is to be noted that the technological development for 6G is very much in its infancy, thus we concentrated our work on mobile communications in general and looked at the possible linkages between 6G and the UN SDG's from the perspective of what could be and what should be. In this paper we look into the detailed operations of the expert group and describe the mapping process for finding the linkage between the UN SDGs and 6G in a way that may guide other researchers in related endeavours. *The aim of this paper is threefold: 1) to briefly present the relevant linkages between the UN SDGs and mobile communications, 2) to look at the process of identifying the relevant UN SDGs for mobile communications research from a theoretical perspective, and 3) to formulate a working mapping process to be widely adopted. We will describe the background, i.e. the findings of the white paper expert group, and then move on to describing the process itself, and finally present a mapping process to be adopted.*

## 1. Introduction

The United Nations Sustainable Development Goals (UN SDGs) were introduced in 2015 [UN 2015]. Agenda 2030 for sustainable development includes 17 goals covering the biggest threats facing the world. The agenda itself together with specific targets and indicators forms an action plan for achieving the goals. The goals address important global challenges including climate change, poverty, hunger and inequalities among others. The UN SDGs also represent a high-level guideline for governments, companies and other organisations to plan their future strategies. The mobile communications community including its latest steps on research towards beyond 5G and future 6G systems has already identified that all the UN SDGs are important targets for the 6G networks to address, see the first 6G White Paper from 2019 [Latva-aho & Leppänen 2019, p. 5]. The White Paper also defined societal and business drivers for 6G using a PESTLE analysis framework (Political, Economic, Social, Technological, Legal and Environmental).

In 2020 a series of twelve new 6G white papers were published. One of the papers written by an expert group was about 6G drivers and the UN SDGs [Matinmikko-Blue et al. 2020]. In that white paper, the connection between 6G and UN SDGs was elaborated by investigating the existing linkages between the mobile communications and UN SDGs. 6G is expected to bring new opportunities to help tackle global challenges, but at the same time all stakeholders should consider the ethical premises of the development of 6G and the UN SDGs. The white paper was written by an international expert group, led by the Finnish 6G Flagship program (6gflagship.com) at the University of Oulu, including researchers from universities and research institutes, specialists of sustainable development, and representatives of mobile communications industry and governmental organisations.

In this paper we look at the process of the expert group as they identify the linkages between UN SDGs and mobile communications. We will describe the mapping process in a way that can guide others in similar endeavours. The aim of this research is threefold: 1) to present the relevant linkages between the UN SDGs and mobile communication research and 2) to look at the process of identifying the relevant UN SDGs for mobile communications research from a theoretical perspective and 3) to formulate a working mapping process that can be widely adopted.

The paper is organised as follows:

- § Chapter 2 presents the background for this paper, i.e. the white paper expert group's conclusions on the connection of mobile communications and the UN SDGs. It presents the SDGs and the so-called entry points which are crosscutting all SDGs.
- § Chapter 3 concentrates on the organising of the mapping process and describes how critical participatory action research approach can be applied.
- § Chapter 4 is dedicated to the results. It reveals which SDGs were found most relevant by the expert group and what kind of approach the expert group took to link 6G and SDG-related indicators. The mapping process itself is described step by step.
- § Finally, we present our key findings and recommendations.

## 2. Mobile communications and UN SDGs

### 2.1. Background and aim

The UN Sustainable Development Goals are a part of the 2030 Agenda for Sustainable Development, adopted in 2015 [UN 2015]. The Agenda aims to tackle issues such as inequality, poverty and hunger, climate change, and invites all levels and actors of society to take part in tackling them, from governments and international organisations to grassroot-level groups and individuals. The Agenda has identified 5 Ps for sustainable development: People, Planet, Prosperity, Peace and Partnership. The goals and targets set out "a supremely ambitious and transformational vision" [UN 2015]. The mobile communications community has previously recognised that it can play an important role in achieving the goals [GSMA 2018], but the understanding of the scope and possibilities seemed somewhat limited. When the planning of the possibilities of 6G began, the SDGs were considered to be crucial [Latva-aho & Leppänen 2019]. That is why a multidisciplinary expert group led by communications technology academics was formed to work on a new white paper on 6G and the SDGs [Matinmikko-Blue et al. 2020]. In the beginning, the work

focused mainly on 6G, but it soon became clear that a more holistic view is needed to look at mobile communications, ICT in general, and to include a more human approach.

The aim of the 6G White Paper [Matinmikko-Blue et al. 2020] was to examine how 6G research and development are connected to the UN SDGs and to define a vision for the operational environment of 6G. The starting point was that 6G will open a new era of 'Internet of Intelligence' connecting people, things and intelligence. The white paper also outlined prior work on the linkage between the UN SDGs and ICT or mobile communications industries, and extensive attention was paid to the renewed linkage between 6G and the UN SDGs, as well as identifying relevant indicators. Technical, regulatory and business-related challenges and obstacles were also identified. Finally, an action plan as well as further research questions were presented to guide the development of 6G and support the linkage between 6G and UN SDGs [Matinmikko-Blue et al. 2020]

Before attempting to come up with a vision of how 6G should be developed to tackle global challenges, it is important to understand what the state of the art is in terms of the UN SDGs and the telecommunications community. The white paper expert group reviewed publications by international organisations such as OECD [OECD 2019], The United Nations [UN 2018, 2019], European Commission [European Commission 2020], and by the community itself, including International Telecommunication Union [ITU 2020], ITU/UNESCO Broadband Commission for Sustainable Development [Broadband Commission 2019], Institute of Electrical and Electronics Engineers [IEEE], Global System for Mobile Communications Association [GSMA 2018, 2019], Broadband Commission and the International Organisation for Standardisation [ISO 2018, 2019] to name a few as well as different companies [Huawei 2019].

Prior scientific research on the linkage between digitalization in general and the UN SDGs [Van der Velder 2018] has identified that the ICTs are specifically mentioned in SDGs 4, 5, 9, and 17, where the enabling and empowering role of ICTs is emphasized. On the other hand, the SDGs that were identified to address the need for sustainable ICT included SDGs 8 and 12. Other researchers [Wu et al. 2018] have identified that ICTs in fact are the key catalysts to the achievement of all 17 SDGs. They also highlight the need to pay attention to less obvious SDGs including 5, 10, and 16. Authors in [Tjoa & Tjoa 2016] stress the importance of ICT in meeting the SDGs and claim that "sustainability" should be self-evident for every IT professional. Moreover, inclusion of sustainability requires auditable standards and best practices on internal sustainability controls as well as performance indicators.

The mobile communication sector's linkage to the UN SDGs is many-fold, and the previous reports and publications range from general to more specific recommendations. Mobile communications can contribute to the achievement of the SDGs by offering infrastructure and access to digital services that will result in growth, efficiency and sustainability [ITU; GSMA 2018]. This is particularly true for economies where existing services are limited, or existing service infrastructure is poor. Digitalization in general can create new opportunities and services, such as micro-banking and micro energy grids to name a few. The core principle of the Agenda 2030 is to "leave no one behind", and mobile technologies are the core for connectivity and Internet access [UN 2019a]. Universal access to information is recognized as a crucial factor to achieve the UN SDGs.

Examples of existing linkage are presented in Table 1 (shortened from [Matinmikko-Blue et al. 2020]):

Table 1: Examples of existing linkage between mobile communications and UN SDGs

| SDG   | Existing linkage with mobile communications/ICT   |
|---|---|
|  1 NO POVERTY                                | Mobile communications can provide a communication infrastructure to stimulate local economy growth in poor communities; lowers barriers to access economic resources by providing access to mobile money and micro-financing; and generates employment opportunities for people living in extreme poverty [GSMA 2018].  |
|  2 ZERO HUNGER                               | ICT helps farmers improve crop yields and business productivity through better access to market information, weather forecasts, training programs, and other tailored online content [ITU].   |
|  3 GOOD HEALTH AND WELL-BEING                | Mobile communications enable communication with medical practitioners, monitor well-being through mobile, provide access to health programs, provide digital identity service to access healthcare, improve water quality through IoT, and provides big data for epidemics [GSMA 2018]. It allows access to digital medical records, remote patient monitoring and AR/VR for medical training [Huawei 2019].  |
|  4 QUALITY EDUCATION                         | ICT powers a revolution in digital learning; mobile devices allow students to access learning assets anytime, anywhere; teachers use mobile devices for everything from literacy and numerical training to interactive tutoring; mobile learning has the ability to help break down economic barriers, divides between rural and urban, as well as the gender divide [ITU].   |
|  5 GENDER EQUALITY                          | Use of mobile phone can help women in low- and middle-income countries feel safer and more connected, and provide access to information, services and life-enhancing opportunities [GSMA 2019]. Mobile can connect women to sharing economy and allow access to female-specific (e-health) services [GSMA 2018].  |
|  6 CLEAN WATER AND SANITATION              | ICT enables smart water management, facilitating the measurement and monitoring of water supplies as well as necessary interventions, and enabling practitioners at the local level to ensure the equitable and sustainable extension of water, sanitation and hygiene services; ICT can be integrated into monitoring and evaluation frameworks to optimize operations [ITU].  |
|  7 AFFORDABLE AND CLEAN ENERGY             | Mobile communications can help via providing data analytics to determine viability of renewable energy sources; online resource for clean energy procurement; smart grid solutions; blockchain facilitating distributed energy systems; and smart metering [Huawei 2019].<br>ICT and energy efficiency are connected in two ways: 'Greening of ICTs' and 'Greening through ICTs' [ITU].   |
|  8 DECENT WORK AND ECONOMIC GROWTH         | Mobile communications can increase market size by online channels with consumer connectivity and provide access to mobile financial services for companies [GSMA 2018].<br>ICT skills are a prerequisite for almost all forms of employment. ICT transforms the way that business is being done everywhere and create new employment opportunities [ITU].   |
|  9 INDUSTRY, INNOVATION AND INFRASTRUCTURE | Mobile networks are a critical infrastructure to provide affordable access to voice and data services and connect remote areas to employment opportunities. IoT solutions can be used for sustainable manufacturing. [GSMA 2018; GSMA 2019].<br>ICT provides industrial IoT solutions for manufacturing and logistics; smart metering; and smart building automation systems [Huawei 2019].<br>Broadband is essential infrastructure due to its capacity to power industry and innovation; globally harmonized spectrum and standards are essential to facilitate the development of transformative digital infrastructure [ITU]. |
|  10 REDUCED INEQUALITIES                   | Mobile communications enable access to information/social networks to promote social and political inclusion, allows access to marketplaces, and facilitates mobile money and digital identity services [GSMA 2018].<br>ICT enables access to information and knowledge to disadvantaged segments of society – including those living with disabilities, as well as women and girls [ITU].  |

|   |   |
|---|---|
|    | <p>Advanced communications techniques can attract and retain workers in rural areas by improving the teleworking experience, allowing for collaborative innovation systems among firms and research centres, and increasing efficiency of rural business and training of workers; self-driving cars can improve public transport and increase attractiveness to live and work in rural areas while drones can boost productivity of rural business, improve access to goods, and reduce productions and delivery costs [OECD 2019a, p. 15].</p>   |
|    | <p>Increased dematerialization and virtualization as well as innovative ICT applications enable sustainable production and consumption. Cloud computing, smart grids, smart metering, and reduced energy consumption of ICTs have a positive impact on reducing consumption. ICT energy consumption and negative impacts of ICTs, such as e-waste, need to be minimized [ITU].</p>  |
|    | <p>Mobile communication can help avoid greenhouse gas (GHG) emissions by enabling other sectors to reduce their GHG emissions, facilitate smart traffic management, smart urban lighting, smart parking, smart logistics, building energy management systems, remote working, sharing economy, smart grids, connected health, and precision agriculture [GSMA 2019].</p>  |
|    | <p>ICT facilitates conservation and sustainable use of the oceans through improved monitoring and reporting delivering timely and accurate data, while local sensors deliver updates in real-time. Big data can be used to analyse short- and long-term trends in terms of biodiversity, pollution, weather patterns and ecosystem evolution, and to plan mitigation activities [ITU].<br/>Enabling technologies in the ocean economy can improve data quality, data volumes, connectivity and communication from the depths of the sea. Blockchain and big data analytics applications are being deployed in port facilities and maritime supply chains. Autonomous ships and autonomous underwater vehicles (AUVs) [OECD 2019b, p. 48].</p> |
|  | <p>ICT allows conservation and sustainable use of terrestrial ecosystems and the prevention of the loss of biodiversity through improved monitoring and reporting by delivering timely and accurate data on a global basis, while local sensors can deliver on the spot updates in real-time. Big data can be used to analyse short- and long-term trends in terms of biodiversity, pollution, weather patterns and ecosystem evolution, and to plan mitigation activities [ITU].</p>   |
|  | <p>Mobile technology for authorities (e.g., police) helps to prevent violence and adheres strict data privacy and security policies that align to national and international law [GSMA 2018].<br/>Growing use of open data by governments increases transparency, empowers citizens, and helps to drive economic growth by record-keeping and tracking government data and local demographics. In natural or man-made disasters ICT can help in obtaining, communicating and transmitting accurate and timely information [ITU].</p>  |
|  | <p>Mobile sector supports collaboration between public and private sector [GSMA 2019].<br/>ICT is crucial in achieving all of the SDGs, since ICT acts as catalysts that accelerate all three pillars of sustainable development – economic growth, social inclusion and environmental sustainability – as well as providing an innovative and effective means of implementation in today's inter-connected world [ITU].</p>  |

Although the mobile communications community has recognized the important role that mobile communications play in reaching all UN SDGs, the approach taken so far has been mainly economically or commercially driven. With a purely commercially driven approach, there is the risk that it will not always serve the under-represented groups in the community, e.g. those who for some reason do not see the value in the Internet. Instead, community networks could be established as individuals see the necessity of connectivity, though the economic viability is not in place. Therefore, communities need to be made an integral part of any policy making and decision-making bodies so that the actual users' voices are heard [Matinmikko-Blue et al, 2020].

The expert group also considered that while the advancement of one goal may advance other goals, it may also have adverse effects on some. When considering 6G and mobile communications technology and its development, it is important to keep in mind that the developed technology (and devices) itself should be sustainable and used in a sustainable way. To further mitigate this risk, the expert group also paid attention to the six cross-cutting factors (“entry-points”) mentioned in the UN Global Sustainable Development Report 2019 [UN 2019b]:

- Strengthening human well-being and capabilities;
- Shifting towards sustainable and just economies;
- Building sustainable food systems and healthy nutrition patterns;
- Achieving energy decarbonization and universal access to energy;
- Promoting sustainable urban and peri-urban development; and
- Securing the global environmental commons.

The entry points are factors which concern all the SDGs and should be considered in all activities aiming to fulfil the SDGs. The rationale for highlighting these factors is that progress on all the UN SDGs “will only be achieved if important trade-offs are addressed and transformed” [UN 2019b]. The expert group recognized that the mobile communications community must pay attention to matters such as overall energy consumption, use of non-toxic materials, environmentally friendly base stations (including locating them where they do not adversely impact the environment), and sustainable supply chains. While not all adverse interactions between goals can be avoided, the trade-offs that are made should be openly addressed and mitigated. This is where the entry points offer useful tools so that adverse interactions between the goals are minimized. The white paper states that *“besides technology, 6G has a clear potential to directly contribute to the UN SDGs by addressing digital inclusion and societal empowerment. For example, placing a base station in a remote area may advance the quality of life and work opportunities in peri-urban or remote locations, but have negative effects on the surrounding wildlife. The entry points offer a more a holistic approach to avoid such adverse interactions between the goals and have proved to be useful when examining how 6G can help achieve the UN SDGs [Matinmikko-Blue et al. 2020].*

The UN SDGs also require consideration of external costs and bringing together a wide range of stakeholders to work towards the common goals. As of today, there are still major technological bottlenecks and constraints in achieving the UN SDGs’ targets including: Opening up, democratizing and improving data; breaking down information silos; shifting the existing paradigm of policy making; towards an evidence driven approach enabled by big data; leveraging advanced tooling and prediction capability of machine learning and artificial intelligence while assuring privacy, trust and security of the users [European Commission, COM 2020; EBA report 2020]

## 2.2. Vision for 6G

Recent white papers on 6G [Latva-aho & Leppänen 2019, Matinmikko-Blue et al. 2020] have created a vision for 6G to tackle global challenges and to solve them in alignment with the UN SDGs. The latter states that the *“vision of 6G accentuates a development that will provide much more than innovative use case driven mobile communication solutions but rather serve higher societal ambitions. Foremost amongst them are the UN SDGs. We foresee that our future society will be increasingly digitized, hyper-connected and globally data driven” [Matinmikko-Blue et al. 2020].* The expert group preparing the white paper

envisions that by supporting the UN SDGs, 6G, and mobile communications in general can take a leading role by a) empowering the people by providing services and solutions to individuals and society, b) sensing the environment by extensive hyper-local measuring associated to essential indicators and c) strengthening the world by reinforcing the ecosystem according to the SDGs. Policy frameworks and regulations must be aligned and have to reach up to the task level required to create the mobile communications and 6G future. Societal ambitions are huge, including “societal readiness” on all levels for the digital future. Exemplified by the current COVID-19 pandemic, prioritizing use cases that have the greatest potential to improve the lives of people can lead into rapid solutions if different stakeholders are prepared to work together. During the abnormal circumstances of the 2020 pandemic, we have seen for example that automotive companies started to develop emergency ventilators for intensive care units. This stresses the importance of collaboration in responding to changing environment and developing quick and agile solutions that could save lives. Therefore, the expert group envisions that the development of 6G should facilitate open collaboration and open standardization between different stakeholders in multi-disciplinary manner, ultimately to create true partnerships for the benefit of society at large.

In addition to creating a vision for 6G and finding novel linkage between mobile communications and the UN SDGs, the expert group aimed to recognize existing indicators used to measure the impact mobile communications can have on the goals and to develop novel indicators that could be used to follow-up on the progress mobile communications has. Most of the existing linkage is very general, such as number of cell phones users in a given region. For example, ITU lists the following indicators <https://www.itu.int/en/ITU-D/Statistics/Pages/SDGs-ITU-ICT-indicators.aspx>:

- Goal 4 Quality education: proportion of schools with access to the Internet for pedagogical purposes; proportion of schools with access to computers for pedagogical purpose; proportion of youth/adults with ICT skills, by type of skills.
- Goal 5 Gender Equality: proportion of individuals who own a mobile telephone, by sex.
- Goal 9 Innovation and Infrastructure: Percentage of the population covered by a mobile network, broken down by technology
- Goal 17 Partnerships for the Goals: Fixed Internet broadband subscriptions, broken down by speed; Proportion of individuals using the Internet

While this kind of information can be quite easily measured and informative, it does not necessarily say much about the real impact 6G or mobile communications can have on people’s lives or the environment. Most of the existing UN indicators are not technology specific, but the expert group concluded that mobile communications can play a significant role in achieving them, nevertheless. The intention is to make visible what the concrete actions of the mobile communications community can be to reach goals where technology is not explicitly mentioned. Table 2 presents an example from the White Paper [Matinmikko-Blue 2020]:



Table 2: An example of how mobile communications in achieving UN SDGs

| UN Targets   | UN Indicators  | 6G can   |
|--|--|--|
| 1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions | 1.1.1 Proportion of population below the international poverty line, by sex, age, employment status and geographical location (urban/rural)<br>1.2.1 Proportion of population living below the national poverty line, by sex and age | <ul style="list-style-type: none"> <li>• Expand the connections between people with processes, data, and businesses.</li> <li>• Help incorporate one-man shops into the market</li> <li>• Facilitate the use of micro-payments and digital money.</li> <li>• Provide advanced life-long learning opportunities to previously marginalized areas.</li> <li>• Help train local educators with remote virtual platforms.</li> <li>• Maximize the use of ICT by delivering virtual computational power to remote areas.</li> </ul> |

The white paper expert group also identified possible challenges that could hinder the progress. These challenges can include political, legal and regulatory issues such as the ownership of data, economic issues such as affordability, societal challenges such as demographic equality, technological challenges, and environmental challenges such as energy consumption. All these issues need to be considered when implementing 6G solutions in the future. That is why it is also vital to include as many of the stakeholders as possible, from legislators and standardisation bodies to research organisations, users and technology makers and mobile network operators.

### 3. Developed mapping process

#### 3.1. Organisation of the mapping process

In conjunction with the 6G Summit 2020 in Levi, Finnish Lapland, experts and enthusiasts of future 6G technologies were encouraged to join the writing process of twelve new themed 6G research white papers that were led by 6G Flagship senior researchers. There was an open call for participation in 12 expert groups that each aimed at developing a white paper on a thematic 6G topic to be published at the end of April 2020 in draft version and end of June in final version. The expert groups started their work in January 2020 leaving only four months of time to complete the work. The purpose of the expert group addressed here was to transfer the relevant UN SDGs into tangible drivers and KPIs for 6G research in a multi-disciplinary way. However, as the COVID-19 pandemic closed the world in spring 2020 and the Summit had to be organised virtually, also the work around the white paper had to be conducted online. Just when the decision to not organise the live event was made, many organisations and companies shifted to working remotely. So instead of live meetings, we started to have remote meetings.

There were all together 40 registered participants for the white paper expert group on 6G drivers and the UN SDGs. The work started with a kick-off meeting on 24 January, 2020. The participants represented various disciplines (wireless communications, information processing sciences, humanities, business studies), industry (mobile device manufacturers), and governmental bodies. There were participants from Europe, Asia, Australia and Africa and at least 10 different nationalities were present. It was agreed that inputs from expert group members are collected via video conferences, questionnaires and other calls for contributions and that the authorship to the white paper will be based on contribution. Attendance to

remote meetings alone was not enough. Each of the twelve 6G White Paper Expert Groups had the freedom to decide on additional outcomes, for example scientific publications.

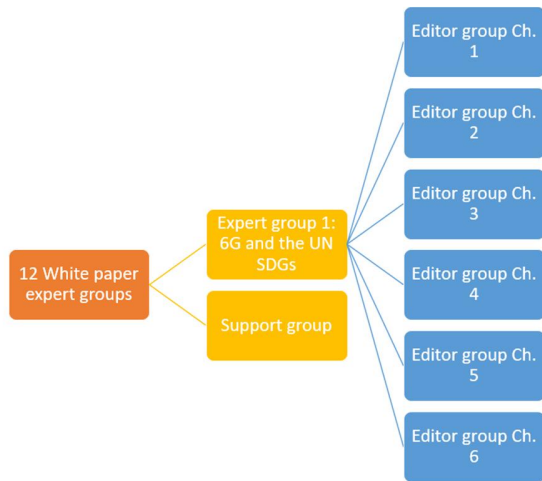


Fig. 1: Organisation of the groups partaking the process

The work in the expert group on 6G drivers and UN SDGs was led by a nominated chairperson and done in various groups (Fig. 1): 1) The expert group consisting of all 40 participants, 2) a “support group” that consisted of the leader/ moderator of the expert group and 3 staff members of University of Oulu, namely us, specialists in UN SDGs and 3) groups formed by 16 chapter editors. The support group was later reinforced by another staff member. This group created and conducted a questionnaire, collected existing data from other sources, compiled a mapping spreadsheet and analysed the results of both the questionnaire and the spreadsheet. In addition, there were altogether 6 chapter editor groups consisting of 3-6 members.

The task of the chapter editors was to finalise the chapters based on the initial outputs collected from the expert group and align them with other chapters. Dividing the expert group into smaller editor groups gave enough responsibility to everyone and ensured that the workload was manageable. The editor groups turned out to be very multi-disciplinary, and it was without doubt easier to negotiate different views in smaller groups.

All in all there were 9 remote meetings between 24 January and 28 May, 2020 where the sections of the white paper were thoroughly discussed (Fig.2). The chapter headings and contents were jointly negotiated and agreed upon and chapter editors were selected from the expert group based on their expression of interest. Chapter editors had the freedom to decide how to best work on their chapters.

Documents were stored and worked on in Microsoft Teams working space where all participants were given access to. All contributors were asked to also store relevant publications and other contributions related to mobile communications and SDGs to Teams.

To establish the current understanding of the topic we first conducted a survey using Webropol online questionnaire. The contents of the questionnaire were presented in the second remote meeting. After the questionnaire and having collected relevant existing work a mapping spreadsheet was prepared where it was easy for participants to see what had already been done and add their own ideas or missing data to the spreadsheet.

The draft paper was available in the working space all the time for real-time access to update the draft white paper and it was circulated regularly in the expert group and also the other white paper working groups to get feedback. It was the chapter editors’ task to elaborate the feedback and make necessary edits in the text.

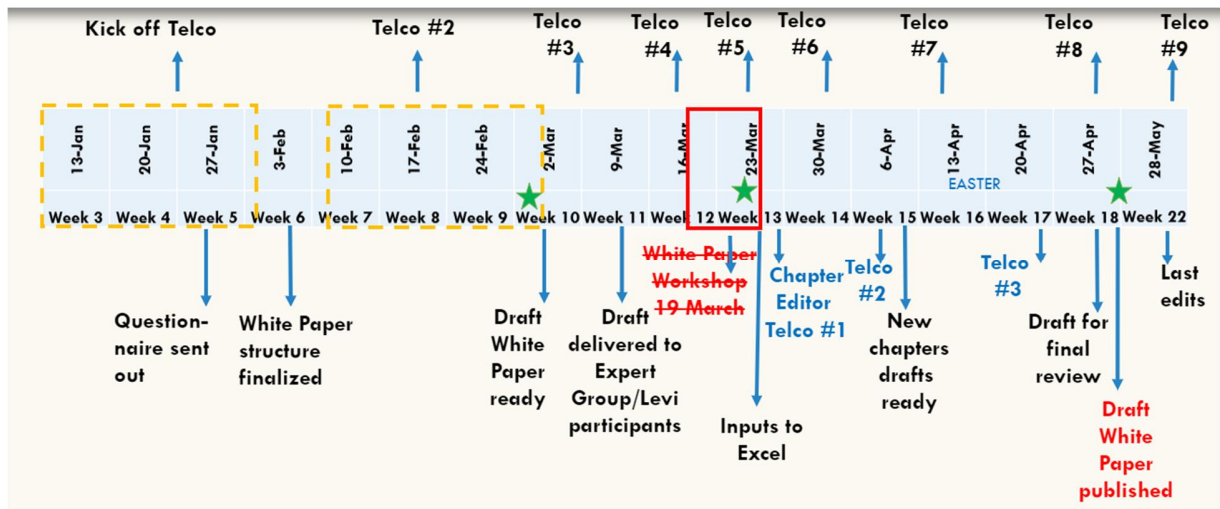


Fig. 2: Timeline of the process

### 3.2. Analysing the mapping process through the lens of participatory action research

The process of adopting the SDGs as part of research can only be investigated by using qualitative methods because this kind of research is in the first-hand interpretation of human activity. To study the mapping process, we used a participatory approach, that is, we were not only observers but also active participants in the work.

It was clear from the beginning that people have a varying level of knowledge on the topic at hand, some were very familiar with the technology but less so with the UN SDGs, while others knew much about the UN SDGs but little about the technology. It was soon established that the whole process is to be a learning process for all. We decided to go for a very collaborative manner of working, which meant having numerous remote meetings and common online platforms to actually work together.

From the theoretical perspective, learning can be described as a multidimensional process that results in a relatively enduring change in a person or persons [Alexander, Schallert, & Reynolds, 2009]. Collaborative learning happens when participants are brought together to simultaneously work on a task to learn from this task work and teamwork [Van den Bossche, Gijssels, Segers, & Kirschner, 2006]. Essential for effective collaborative learning are among other things a) building a safe space (psychological safety) and b) establishing common understanding (mutually shared cognition) [Van den Bossche et al. 2006]. These issues were discussed, and tools given in a workshop organised by educational specialists at the University of Oulu tailored especially for the white paper leaders. Initially it was planned that we will have dedicated group exercises to create a safe space at the physical workshop so that discussion in the expert group is as free as possible from excessive concern about others' reactions to actions that have the potential for embarrassment or threat, which learning behaviours often have [Van den Bossche et al. 2006]. Moving totally to working remotely due to COVID-19 challenged us also regarding this aspect, and the ice-breaker exercises were completely left out. First it was thought that we would have time for them at the actual physical workshop in Levi, and then when it turned out that we will not meet in person, it seemed pointless: we had already been working together online after all. To establish common understanding of the topic at hand, we went through the contents of the white paper in the first remote meeting and discussed what they meant. A loose working title of the white paper "6G Drivers and UN SDGs" was

defined upon registration but the contents suggested by the leader of the expert group were mainly indicative and they were thoroughly negotiated in the first meeting and did change along the process.

Mutual understanding and shared cognition can be reached in interaction among members of the group and it is the characteristics of their discourse that defines the process in which it is reached. The social process of building common ground is called the learning behaviour of the team, where above all negotiation determines which kind of interactions and which patterns in discourse are the forms that finally lead to mutually shared cognition [Van den Bossche et al. 2006]. In other words, negotiation determines whether shared cognition will be achieved. We wanted to enable plenty of discussion and negotiation and did therefore have multiple meetings remotely. The expert group but also the smaller support and editor groups turned out to be very multi-disciplinary. This ensured that during the writing process different views had to be negotiated, which in fact turned out to be very fruitful. The expert group was also very multicultural, there were at least 10 different nationalities present. When a team consists of different cultural backgrounds, there is the risk that the social level, i.e. how the team interacts, takes most of the attention instead of the content level (the task at hand). It has been argued however, that cultural differences can even boost creativity as they are associated with differences in mental models, modes of perception, and approaches to problems [Stahl, G., Maznevski, M., Voigt, A. *et al.* 2010]. The advantage in our case was, that all participants were used to work in multicultural teams, so it didn't seem to present problems for the collaboration. Of course, to really study the effect of cultural diversity in this process would require much more attention so it should be noted that it is not objective of this paper.

All participatory methods require careful attention in order to prevent the "loudest" participants from intimidating or blocking out people who are more passive. This requires sound moderation or facilitation of the discussion processes. Our expert group was led by a senior mobile communication researcher, Dr. Marja Matinmikko-Blue who took the role of a moderator. The moderator directed and scheduled the writing process and chaired the remote meetings. She was in contact with the editor groups and orchestrated the compiling of the final paper. We experienced the expert group to be rather equal, nobody dominated the discussions and in the course of the remote meetings, each participant voiced themselves at once. We also deliberately gave plenty of opportunities to contribute in a written form, even anonymously. The diverse possibilities to participate in the writing process guaranteed that the working process did not favour just those who are used to express their ideas in meetings.

In this paper we are looking at the actual mapping process of finding the possible linkages between 6G and the UN SDGs through the lens of *critical participatory action research* method. Participatory Action Research, as defined by McIntyre [2014], includes the following underlying tenets: "*a) a collective commitment to investigate an issue or problem, (b) a desire to engage in self- and collective reflection to gain clarity about the issue under investigation, (c) a joint decision to engage in individual and/or collective action that leads to a useful solution that benefits the people involved, and (d) the building of alliances between researchers and participants in the planning, implementation, and dissemination of the research process.*". Critical participatory action research goes further and recognizes that action research itself is a social practice. It happens when people come together to change social practices, including research itself, to make them more reasonable, sustainable and more just and inclusive. It aims to change the practitioners' practices, their understandings of their practices, and the conditions in which they practice. The essence of this research approach builds around a co-creative process that relies strongly on conversation among and empowerment of the participants, who come from various backgrounds and represent a wide variety of perspectives however all sharing the common interest [Kemmis et al, 2014].

Even though this method stems from educational field, we see it fit in this context very well. After all we were learning and changing the practices in which we normally function. We dare to claim that this was the first attempt to gather people from so many different fields of research, industry and governmental bodies to work on finding a sustainable framework for the future 6G development. We had no idea how this topic should be best approached and had to quickly learn to work together on this issue and adopt different views stemming from various disciplines. In critical participatory action research, the responsibility for the research is taken collectively, by people who act and research together. Also, decisions about what to do and how are taken collectively [Kemmis et al., 2014]. We see, maybe a bit idealistically even, that the motivation of the expert group members was to change the current direction of 6G development into a more sustainable direction, so there was a will to change things and change the way things were previously done as already identified in the first 6G white paper [Latva-aho & Leppänen 2019]. It was the concern of many, that the technology is developed accepting the current sustainability work mainly done driven by business from the point of view 6G being the enabler for sustainable development forgetting that the actual development of the technologies and operating models play an important role too. The technology must be sustainable and the enabling, empowering function of 6G can only happen if the current modus operandi changes too. Otherwise the 6G will only deepen the digital divide which has been one of the critique points for 5G development in the rural and remote areas observed for example in [Saarnisaari et al. 2020].

We noticed how during the process the focus shifted from the seemingly pressing need to develop hard and soft indicators to measure how 6G would advance the SDGs to an understanding that what actually is more important is to make visible how, and under what conditions 6G can empower people to a more sustainable life. Also, the systemic prerequisites such as the current mobile operator business models were discussed lengthily and elaborated in a chapter titled: Action plan: What needs to change? The shift from the importance of developing KPI's for 6G in relation to the SDGs can be seen in the fact that in the beginning there was a dedicated chapter for solely the KPI's (Indicators: Soft and hard KPIs) whereas at the end this chapter was moved under a chapter titled: Linking UN SDGs with 6G and related indicators.

In action research outside collaborators not only support the participating researchers but they can also, for the purposes of the research, become engaged participants alongside others. Also, in this case we, outsiders, became more active than initially planned. Our role as observants and supporters changed into the role of editors of some chapters thus contributing to the actual contents of the paper.

Kemmis and McTaggart (1988a) have introduced the "self-reflective spiral", a cycle of steps of planning a change, putting the plan into action, observing what happened, and re-formulating the plan in the light of what had happened. The cycle consists of:

- *planning a change,*
- *acting and observing the process and consequences of the change,*
- *reflecting on these processes and consequences, and then*
- *re-planning,*
- *acting and observing,*
- *reflecting, and so on...*

Of course, later Kemmis et al. have stated that in reality the process is likely to be more fluid, open and responsive [Kemmis et al. 2014]. This cycle describes our workflow very well. In chapter 4.5. we describe the actual mapping process reflecting it to Kemmis' and Mactaggart's self-reflecting spiral.

## 4. Results

### 4.1. New classification

Starting at the very beginning it was clear to us that the possible linkages between 6G and the UN SDGs had to be considered from three perspectives: 1) 6G as technology to be developed in line with UN SDGs and 2) 6G supporting the advancement of UN SDGs, 3) new indicators for 6G. The previous contributions had mainly concentrated on how ICT and/or mobile communications can help advance the SDGs [ITU 2020, GSMA 2018, 2019] whereas the viewpoint of 6G as a technology requiring a lot of energy, manufacturing resources, toxic materials creating e-waste was something that device manufacturers or trade organisations seemed to have “overlooked”.

After analysing the inputs from the first questionnaire related to the linkages, we actually realised that 6G could help collect data on how the various targets of the SDGs are being advanced. After iterating the vision for 6G and linkage to the SDGs, we created a new three-tier classification where we present 6G as: 1) provider of services to help steer communities and countries towards reaching the SDGs, 2) enabler of measuring tool for data collection to help reporting of indicators with hyperlocal granularity, and 3) reinforcer of a new technological ecosystem to be developed in line with the UN SDGs.

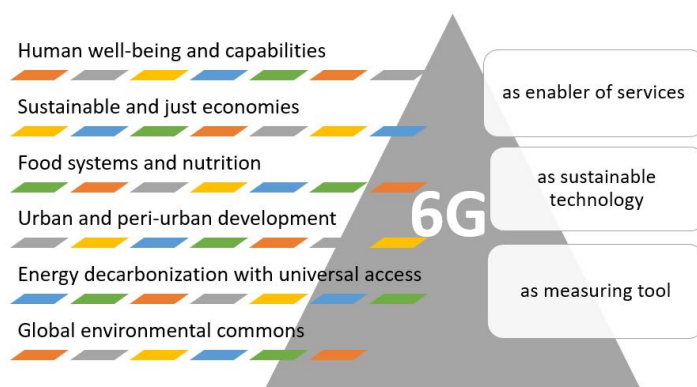


Fig. 3: The UN entry points and 6G's role

### 4.2. Bibliometric analysis

To go into more details on prior work on the linkage between ICT and UN SDGs in the research literature, a bibliometric analysis was conducted very early on in the study. In an effort to identify research that supports the UN SDGs, Elsevier has generated a set of Scopus queries related to each of the SDGs. These queries can be taken into use in their SciVal solution to describe the work research institutions are doing on each SDG and the outcomes. The results come from the same data set, ensuring consistency across the comparisons and analyses. The University of Oulu bibliometrics team conducted a search in SciVal with the SDG query tool analysing publications from 1996-2020 adding ICT specific key words to the search (for example: wireless, mobile, cellular, communication, network, "mobile industry", 4G, 5G, 6G, telecommunication). According to the query, the SDGs that came up most often in the field were: Affordable and clean energy (SDG 7); good health and well-being (SDG 3), sustainable cities and communities (SDG 11), peace, justice and strong institutions and reduced inequalities (SDG 9).

### 4.3. Questionnaire

In the beginning we made a questionnaire for the participants to fill in. The purpose of the questionnaire was two-fold: 1) get the participants acquainted with the UN SDGs and 2) collect their inputs on which UN

SDGs they thought were linked to 6G and how. We also asked people to name five most important of these goals regarding 6G and, also, if they thought some of the goals were irrelevant for 6G. Furthermore, we asked participants to think about possible indicators to measure the effect of mobile communications towards the SDGs. It should be noted at this point that nobody knows what exactly 6G will be like. But we expected all participants to have an idea how it would differ from 5G and what it should enable. Before the link to the questionnaire was distributed to the participants the definitions and the content of the questionnaire were discussed in a remote meeting and the contents were modified accordingly.

We received 20 answers to the questionnaire. The answers came from representatives of 5 different universities, 1 trade association, and 3 different telecommunication companies. 26% of the respondents were female and the rest male. Even though the number of total respondents remained rather small, the group of respondents represented quite well different interest groups.

The first step was to look at the SDGs the participants of the questionnaire thought to be most important regarding 6G. The question we asked was: (Q1) *Which of these UN Sustainable development goals would you connect with mobile communication and especially 6G? You can choose as many as you wish.* The 5 most often mentioned goals are summarized in Table 3.

Table 3: Q1: 5 most often mentioned SDGs

| Goal  | Responses | Percentage |
|---|-----------|------------|
| Goal 3: Good Health and Well-being                | 20        | 87%        |
| Goal 4: Quality Education                         | 20        | 87%        |
| Goal 11: Sustainable Cities and Communities       | 20        | 87%        |
| Goal 9: Industries, Innovation and Infrastructure | 19        | 83%        |
| Goal 6: Clean Water and Sanitation                | 17        | 74%        |

We also asked the participants to (Q2) *name five most important of these goals regarding 6G. Which goals can 6G advance the most in your opinion?* The results to this question are presented in Table 4.

Table 4: Q2: 5 most important SDGs

| Goal  | Responses | Percentage |
|---|-----------|------------|
| Goal 3: Good Health and Well-being                | 20        | 87%        |
| Goal 9: Industries, Innovation and Infrastructure | 15        | 65%        |
| Goal 11: Sustainable Cities and Communities       | 15        | 65%        |
| Goal 8: Decent Work and Economic Growth           | 14        | 61%        |
| Goal 4: Quality Education                         | 13        | 57%        |

The 5 most important goals (Q2) were in line with the “most important” goals (Q1) that the respondents mentioned. The only difference was that when asking for the 5 most important goals (Q2) that 6G could advance the most, *Goal 8: Decent work and Economic growth* was mentioned, whereas it came on place 8 when we asked which of the goals people would connect with mobile communications and especially 6G (Q1). In our questionnaire all SDGs were seen relevant for 6G.

We also asked respondents to write down (free text field) how they thought that 6G could help advance the SDGs. We looked at the results by forming a word cloud of the words coming up most often (Fig. 5). The 30 most often used words came up between 32-57 times.





#### 4.4. Indicators

In the beginning of the process it seemed that the most pressing issue at hand was to define key performance indicators for the future 6G in terms of sustainable development. As already stated in chapter 3.2., it was soon noted that this is more difficult than anticipated. The expert group however did come up with more than 100 different indicators, some of which concentrating on the technical performance of 6G (use of energy) and others measuring softer issues such as welfare of a state (number of homes using a certain defined level of IoT such as electricity, water consumption, waste management). 6G's role as providing data on sustainable development came up in many suggested indicators, for example: 6G transmitting sensor data on: living conditions (temperature, humidity, inhabitants per m<sup>2</sup>); natural disasters, diseases (epidemics); mobility of humans & animals; quality of water, air etc. The indicators were presented per entry points and categorised according to the new three tier classification. Table 5 presents examples of the indicators suggested by the expert group summarised from the white paper [Matinmikko-Blue et al. 2020].

Table 5: Examples of indicators suggested by the expert group

| Entry points                                 | 1) 6G as provider of services  | 2) 6G as enabler of hyperlocal measuring tool  | 3) 6G as reinforcer of ecosystem aligned with SDGs  |
|--|--|--|---|
| Human well-being and capabilities            | The availability of appropriate technologies and services related to quality basic services. | Mobile coverage.   | Price of connectivity.                              |
| Sustainable and just economies               | Mobile subscription considered a basic need in any given society (yes/no).                   | Data subscription models available and their relative proportion.                                    | E-waste management of new devices.                  |
| Food systems and nutrition patterns          | Availability of public mobile services such as weather forecast for farmers.                 | Data gathered from sensors used in agriculture (for instance the use of fertilizers).                | Number of non-toxic, non-leaking devices.           |
| Energy decarbonization with universal access | Number of mobile apps that help reduce energy consumption.                                   | Number of sensors monitoring energy consumption.   | % increase of energy efficiency.                    |
| Urban and peri-urban development             | Unrestricted access to internet and mobile services (yes/no).                                | Area coverage to include the rural areas where agriculture, forestry and tourism are big industries. | Number of operators operating in the region.        |
| Global environmental commons                 | Coverage of monitoring systems used for protecting fauna and flora.                          | Number of sensors monitoring fauna and flora.  | Percentage of recycled materials in new 6G devices. |

## 4.5. The mapping process

In the following we are describing the actual mapping process that was developed within the expert group. The activities are not presented exactly as they happened, rather we tried to simplify the process grouping similar activities under one title. For example, data collection was done at various stages of the process. First, we conducted the questionnaire and at the same time people were continuously reminded to add to the SotA collection. The data collection spreadsheet to combine the available information on previous work on the topic (ICT/ mobile communication and UN SDGs) was prepared after remote meeting number 5.

### 1. Planning phase (PLAN)

The first task of the expert group was to establish the contents and set the common aim for the white paper. In the first telco we discussed a draft plan and table of contents created by the moderator and decided which topics should remain, be added or be changed from based on the suggestion. Also, the working and data collection methods were discussed. This phase formed the common ground for the work and allowed the registered participants to reconsider whether they wanted to actively engage in the work towards the white paper.

### 2. Data collection (ACT)

#### a. SotA

We asked all participants to collect any relevant information on the linkages of ICT and SDGs from different sources such as: standards organizations (e.g. ISO, IEC, ITU-T, ETSI...), regulatory bodies (e.g. ITU-R, CEPT; the European Union; national governments; other institutions (e.g. WorldBank, Broadband Commission, WSIS); trade organizations (e.g. GSMA) and companies. Participants brought their individual knowledge to the use of the expert group.

#### b. Questionnaire

In order to collect the views of all participants on the topic of mobile communications (and/or 6G) and the SDGs we conducted a survey. The questions were introduced in the first meeting and modified according to the feedback of the participants. In the questionnaire we asked which UN SDGs they thought were linked to 6G and how. We also asked people to name five most important of these goals regarding 6G, and also, if they thought some of the goals were irrelevant for 6G. Furthermore, we asked participants to think about possible indicators to measure the effect of mobile communications towards the SDGs.

#### c. Bibliometric analysis

In an effort to identify research that supports the UN SDGs, Elsevier has generated a set of Scopus queries related to each of the SDGs. Our bibliometrics team analysed ICT related publications and their linkages to the UN SDGs (see chapter 4.2.).

#### d. Data collection spreadsheet

To collect data and present already conducted work on the topic of ICT/ mobile communication and UN SDGs we compiled a mapping spreadsheet that included the UN SDGs with their targets. The results from the first questionnaire were added to the spreadsheet. We added columns for

the following information and asked the participants multiple times to add their contributions to build on top of the collective results from the first questionnaire:

*SotA collection:*

- § How mobile communications can contribute to goals and targets? (Results from the questionnaire)
- § How mobile communications can contribute to goals and targets? (From other sources/reports/forums)
- § Indicators from other sources
- § Actions/recommendations to achieve targets from other sources

*New suggestions/ wild ideas were asked to be added under the following categories:*

- § How mobile communications can contribute to goals and targets?
- § Challenges, opportunities and key obstacles
- § New proposed indicators
- § New proposed 6G specific indicators
- § New proposed actions to achieve targets

### 3. Presentation of results & reflection & negotiation (REFLECT -> REPLAN)

We presented all the findings (input from other sources, results from the survey and the bibliometric analysis) in the second telco, and after having collected them in one spreadsheet (listed per each of the 169 targets), we asked all the group members to add any other linkages they could think of. Presenting of “wild ideas” was encouraged and the suggestions could be left either anonymously or with a name. We also decided to form smaller working groups consisting of the editors of the chapters.

### 4. Work in smaller (editor) groups (ACT)

In the third expert group meeting the chapter editors were chosen based on the interest of participants on a voluntary basis based on the draft table of contents of the white paper. The editor groups collected and analysed all inputs coming from the wider expert group, elaborated feedback from the other white paper expert groups and also actively contributed to the contents.

### 5. Reflection and re-planning in the support and in the expert group (REFLECT -> REPLAN)

All contributions and findings of the editor groups were presented to the expert group to get feedback from wider audience and make sure the contents were aligned with each other. After reflection and negotiation in the expert groups, the work was continued in the support groups and/ or in the editor groups. This process was repeated multiple times, until end of April, when a complete draft version was published. Until then, the draft version had also been distributed to all 12 white paper expert groups to be commented and the feedback was elaborated in the chapter editor groups. After publishing of the draft version openly online, the expert group further continued to refine the contents, especially the figures, but no major changes were made.

The process was following the Plan-Act-Reflect-Replan-Act-Reflect cycle, where after each planning phase in either the expert group or the smaller groups (support/ editor groups) followed a concrete action, e.g. data collection in some form or analysing the results, which was followed by reflection and negotiation in the expert group.

In the picture below we show our mapping process combined with Kemmis et al. Action Research cycle [Kemmis et al. 1998].

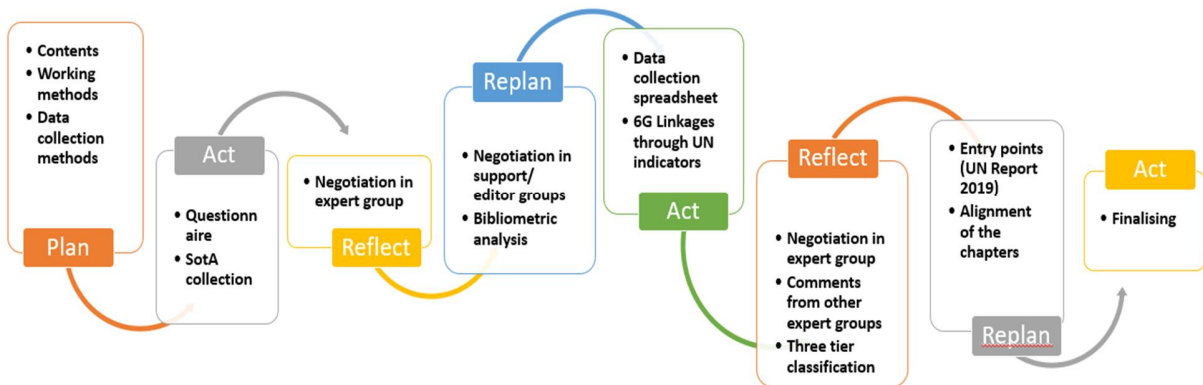


Fig. 3: The mapping process aligned with Kemmis' et al action research cycle

## 5. Key findings and recommendations

We found that this manner of working in a group of experts with versatile backgrounds following a strict time schedule towards a common goal of publishing a white paper was rather labour intensive but also very fruitful. We dare to say that had there not been such a multi-disciplinary group working together in such an interactive manner the three-tier classification, which we consider to be one of the most important findings of the process, would not have been formed. By collecting first everyone's ideas on how 6G can advance the SDG's and then doing this again and again via the data collection spreadsheet we found some interesting new linkages between 6G and the SDGs not only from technical perspective but also from human perspective. Also looking at the UN indicators set for the diverse targets within the goals enabled us to see a direct link between numerous indicators and 6G. The expert group also came up with an extensive list of possible indicators, some of which represent a rather new way of looking at 6G. So far few of the work on ICT and the UN SDGs has actually considered the entry points and their linkage to ICT/ mobile communication. They are however uttermost important when trying to see the whole picture and the negative and positive trade-offs between the various goals. We recommend everyone interested in the SDGs to get familiar with the entry points and concentrate on them instead of single goals.

For the overall success of the process we found out that following factors were crucial: the composition of the group, the motivation of the participants, before-hand knowledge/preparations, and innovative interaction. In this case, the group participating in the process was heterogenous representing different fields of sciences and stakeholders from different countries. This led to productive and innovative

interaction during the process meaning that discussions were versatile, and participants would bring in ideas stemming from their own expertise. The participation to the group work was based on voluntariness and the main reward was to be included in the white paper. The number of participants to the remote meetings stayed high until the very end and discussions continued very lively. However, in order to keep the writing process on-going, it was necessary to facilitate meetings with regular interval and do beforehand preparations such as the questionnaires. They would ensure that on the one hand the brainstorming and writing process begin promptly, and on the other hand that the participants are aware of the essentials (i.e. the UN SDGs). As a result of this process, a massive list of indicators was compiled meaning that the most relevant ones had to be filtered out.

After the experience of the working process, we can recommend the chosen methods: a) choosing one moderator who orchestrates the whole process, encouraging participants to ideation via different channels, b) dividing the writing process with "sub-groups" (chapter editor teams), c) circulating a draft version to a wider audience for collecting feedback and d) multi-disciplinary composition of the group.

## 6. Identified challenges

As always, time was our biggest enemy in this exercise as the whole white paper writing process was scheduled to last only four months from the start in January 2020 until the publishing of the draft version at the end of April. Another two months was available to finalize the white paper before final publishing at the end of June. At the beginning of the process lack of time hindered us from examining how well the participants were familiar with the UN SDGs. Looking back now it would have also been interesting to check the status of participants' knowledge at the beginning of the process and at the end. We also noticed that for example the entry points, as important as they were especially for research, were not known to most of the participants and introducing them earlier could have changed the process. It would have also been interesting had we taken the time for each of the group members to shortly present their previous work or ideas related to the SDGs. It also turned out to be mostly the support groups task to collect the SotA and afterwards it is easy to say, that we could have done this also in beforehand had we known that this will remain for us to do. Of course, in large groups and challenging tasks as this was, the contribution from people might leave something to hope for.

It can be said afterwards that it seemed to take a bit longer before all participants actively participated to the discussion. To find out whether a safe space was actually being achieved, would require a study of its own, thus the statements here are based merely on our observations. We were not really able to affect the composition of the group and it is to be noted that not all interest groups were presented.

A few suggested improvements could be made if this kind of approach is chosen: 1) explaining and discussing the key concepts among the participants, in this case for example the entry points (shared cognition), 2) enabling and encouraging also other forms of discussions possibly within an even wider forum (for example on Twitter), 3) having more time to get to know each other (psychological safety).

## 7. Conclusions

In this paper we have described the current status of the linkages between mobile communication and the UN SDGs and shown, how a multi-disciplinary, multi-actor, collaborative process can work to identify new, not yet found linkages and possible indicators. We presented a mapping process leaning on an existing model based the action research cycle presented in [Kemmis et al. 2014] that can be adopted by others to find linkages between research and the sustainable development goals. We also presented the

results of our mapping process and combined the findings of various sources on which are the most relevant UN SDGs for mobile communication.

6G is foreseen to be on the market 2030, at the same time when the Agenda 2030 should be fulfilled. The developed white paper [Matinmikko-Blue et al. 2020] building on the world's first 6G white paper [Latva-aho & Leppänen 2019] set a vision for 6G to become sustainable, to empower the people to achieve the SDGs and to actually measure how some of the goals are advancing. It seems that developing KPIs to measure sustainability of companies' activities is becoming the new black and several companies are offering their services to build the linkage to SDGs for big money. The danger is that this sort of only short-term business-driven thinking turns the noble idea into green-washing and not enough thought is spent on how to really advance the SDGs if the mapping is not done properly. Thus, more research needs to be done on how the entry points are taken into use and to ensure that the future KPIs for 6G and other technological solutions are developed together, in a sustainable manner by all relevant interest groups in the field together maximising the positive trade-offs. In that development, the research sector will play an important role as the provider of unbiased new knowledge and facilitator of the work.

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