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ABSTRACT

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Abstract

Mobile wireless technologies and services have long become an indispensable platform for communication, work, or business for people living in the modern world. Mobile technologies have gone through several stages of evolution, from the first generation, 1G in 1979, to the latest 5G in 2019. Today, the mobile wireless industry is already looking ahead of 5G and has kick-started researches for the next mobile wireless generation, 6G.

While visions of 6G hold promises to bring new digital experiences to society, the question which has not been highlighted is whether the novel 6G would bring transformative impacts on the business operations of the industry under criticism of the oligopoly. This Master's Thesis attempts to shed a light on the landscape surrounding businesses of the current mobile wireless industry and explore possible future development pathways of major incumbent players in the industry in the time of 6G, with scenarios.

Through the scenario building process, driving forces to impact the development of businesses in the 6G era are identified. Interviews with forerunners engaged in researches for 6G are conducted along with environmental scanning to produce four scenarios narratives. The scenarios as the result are composed from the focal point of whether the incumbent players may collapse with the current business structure, or obtain a new form of success through transformation.

Key words	Futures Studies, mobile wireless communications, 6G, scenarios, business model

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MOBILE WIRELESS BUSINESS WORLD IN THE 6G ERA

Future scenarios in the mobile wireless business in the time of 6G

Master's Thesis
in Futures Studies

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The originality of this thesis has been checked in accordance with the University of Turku quality assurance system using the Turnitin OriginalityCheck service.

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LIST OF ABBREVIATIONS

3D	Three-Dimensional
3GPP	3rd Generation Partnership Project
AAL	Anticipatory Action Learning-Based
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
AWS	Amazon Web Service
BTS	Base Transceiver Station
C-RAN	Cloud RAN
CAGR	Compound Annual Growth Rate
CDMA	Code Division Multiple Access
CSR	Corporate Social Responsibility
DARPA	Defense Advanced Research Projects Agency
eMBB	enhanced Mobile Broadband
eNodeB	evolved Node B
eSIM	embedded Subscriber Identity Module
Gbps	Giba bit per second
GSM	Global System for Mobile Communication
ICT	Information and Communication Technology
IoS	Internet of Senses
IoT	Internet of Things
IR	Immersive Reality
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LTE	Long Term Evolution
mMTC	massive Machine Type Communication
MNO	Mobile Network Operator
MVNO	Mobile Virtual Network Operator
NATO	North Atlantic Treaty Organization
NMT	Nordic Mobile Telephones
NSaaS	Network Slice as a Service

NTT	Nippon Telegraph and Telecom
OECD	Organization for Economic Co-operation and Development
OTT	Over The Top
PESTEC	Political, Economic, Social, Technological, Environmental, Cultural
RAN	Radio Access Network
SDGs	Sustainable Development Goals
SDN	Software Define Network
SNS	Social Network Service
TACS	Total Access Communication Systems
Tbps	Tera bit per second
TDMA	Time Division Multiple Access
The UN	The United Nations
URLLC	Ultra-Reliable and Low Latency Communications
VR	Virtual Reality
WCDMA	Wideband Code Division Multiple Access
WiFi	Wireless Fidelity

1 INTRODUCTION

It was 1973 when the first prototype of the mobile handset was built by Martin Cooper and his team at Motorola, Inc, one of the largest telecommunications companies based in the United States. Cooper made the public demonstration to make the first call on that prototype phone to his engineering nemesis at Bell Labs (Anjarwalla 2010). This very first call made a historical beginning of the mobile era, and completely changed the way people communicate, work, or live for good. Over the several decades since their birth, mobile phones have established their position as an indispensable platform in society. For many people today, the ability to communicate while on the move is now considered to be essential for every aspect of modern life, from business to individual lifestyles and everyday social interaction (Lacohée et al. 2003).

While mobile phones have penetrated modern society and many people find it difficult to spend a day without them, what was less emphasized by most consumers is the power behind the scene to have driven the progress of the mobile world. It is the industry which has been providing mobile services to society, namely, the mobile wireless industry. In reality, during the period of more than 40 years since the first call made by Cooper, the mobile wireless technologies and industry have seen significant changes and development.

Since its birth, the mobile wireless world has seen a rapid evolution in its techniques, products, and services. In general, the development of mobile wireless communication technology is defined to have had five major evolution stages represented with “G”, which stands for generation. Each generation has its own features, techniques, or frequency bands, capabilities and they differentiate each other.

The world’s first commercial mobile service started in Japan back in 1979, which was later called “1G”, the first generation of mobile wireless technologies and networks. The industry has continued to renovate technologies since then in a cycle of about every 10 years to see the advent of the latest generation today, 5G, the fifth generation starting from the year 2019.

Over the development from 1G to 5G, technologies used for mobile communications have been expanded significantly to offer innovative new functionalities to consumers. However, ordinary mobile users may not usually give a thought to such underlying technologies to sustain their mobile services, or how the industry is operating to enable these technologies, even though the outcome of the development of this industry has considerable impacts on the way they communicate and lead daily lives.

The mobile wireless industry consists of several distinct enablers. The telecom operators, or Mobile Network Operators (MNOs), are the direct interface to consumers who deliver the mobility service in exchange for mobile fees. Users may enjoy the connectivity and various applications on their phone devices but may not even consider the background infrastructure to enable such services. In reality, their service is enabled by a complicated network with numerous components built by vendors for infrastructure, contents, applications, and so on. In a closer view, one may find that this industry, expressly, collective players to develop and provide technologies to enable mobile communications, have many unique characteristics. For example, taking a look at the market size alone, according to statistics (Grand View Research 2020) calculated in the year 2020, the global market size reached 1,657.7 billion USD in the year. As phones are an essential platform for modern society, the continued growth is expected in the future. It is the market in the volume of billions, however, only a selected few companies dominate the market and are subject to criticism for oligopoly. Main actors in this industry such as Mobile Network Operators (MNOs), network infrastructure vendors influence the pathways of industry and technology developments. Yet, the number of MNOs and vendors in the market is fairly small. Current players have established a bubble of the ecosystem, to which new market entry is challenging.

Although continued growth is expected, the question to be imposed here is whether the industry shall keep its current shape spanning from today to the future. The industry is now looking beyond the current fifth-generation of technologies and taking a step toward the researches of new generations, 6G or the sixth generation of mobile wireless technologies to be targeted in the year 2030. The research of 6G is still in its infancy, however, the unprecedented performance of mobile communication and accompanying novel services are already anticipated. The current visions of 6G address hyper-fast networks, revolutionary mobile devices, a fusion of the digital and physical world. The glitter of such new promises is mesmerizing many stakeholders in the industry. At the same time, the progressive visions invoke a question, whether proclaimed technologies and services anticipated in 6G are continued to be provided solely by a subset of incumbent players in the market, or invigoration by new entrants is indispensable. New and radical changes in the future technologies and expectations from consumers may invite new competitors into the market, which may threaten the existing players and affect their business operations.

This Master's Thesis attempts to answer this question by exploring driving forces to shape the future of the industry and generate multiple, alternative future options for the

mobile wireless industry in the 6G era. As a methodology, expert interviews and scenario building are chosen. The focal point is the business operations of incumbent players in the industry, specifically MNOs and network infrastructure vendors. Although more and smaller corporations exist in the value chain in the mobile wireless industry, such as smartphone application vendors, MNOs and network infrastructure are the two key axes to lead and decide the course of the development of the industry itself. Therefore, data is collected through interviews of experts who belong to either MNOs or network infrastructure vendor companies.

Unfolding potential changes to the existing, quite established business operations and ecosystems of an existing industry shall be a useful exercise in Futures Studies to attempt the foresight on technology and strategic decision making. Furthermore, industry stakeholders may benefit from this Master's Thesis to have any insight to bullet-proof themselves against the future. As Masini (1993:38) stated, Futures Studies is a tool to address the complexity and reduce uncertainty. In a world that is rapidly changing, full of uncertainty and complexity, researches empowered by Futures Studies may be the sole guiding light to navigate toward the future.

1.1 Aim of the Research

After the breakthrough of Cooper's first phone call made on a prototyped phone, mobile communications and commercial services have gone through substantial evolution. In 1979, Nippon Telegraph and Telephone (NTT), a publicly owned telecommunication company in Japan back then launched its commercial cellular network for an automobile telephone system for the first time in the world. This first commercial wireless network was born in the metropolitan area of Tokyo, and quickly expanded its service to cover the whole population of Japan. This is the stage of the so-called "1G", the first generation of mobile wireless networks to provide audio communication over analogue systems.

Since 1G, mobile wireless technology has evolved to the next phase in the cycle of about 10 years. In the next stage, 2G, voice and text service over the digital network was made available. In 3G, high volume movement of data with emails and videos was offered, and the demand by end-users for larger data volume has ever been growing. Barely 40 years have passed since 1G was brought to the world, but the number of mobile users worldwide has reached 6.95 billion as of today (Statista 2020). Mobile wireless industry

has been driven to cater to higher capacity, faster network with the demand for such a huge number of end-users.

The latest generation of the mobile networks is 5G. Several countries started deployment of 5G networks and commercial services in 2019, but the true value of 5G is yet to appear in society. The year 2020 is marked as the year of 5G proliferation (Qualcomm 2020), and the applications of 5G in various vertical industries are on their way. 5G does not mean the mere improvement of speed and accessibility of communications among individuals, however, massive connectivity and fast speed of this generation significantly widen the use cases of mobile networks. Machine-to-machine communication and automation represented by autonomous vehicles have become keywords to promote 5G penetration.

Although 5G has not yet achieved as wide coverage as 4G has done, the mobile wireless industry is already looking ahead – the next, sixth generation, 6G. From late 2019, more than 100 research papers have been published about 6G at present (Yazar et al. 2020). Those researches of 6G available today are still high-level, focusing on the vision, challenges, and key technological requirements to fulfill the vision. However, it is already anticipated that 6G will bring about more revolutionary changes to society as the development of mobile wireless technology has brought cataclysmic changes to the world throughout its history. In 6G, super-fast, ultra-reliant networks are expected to enable various outstanding innovations which were not feasible with existing mobile wireless technologies up to 5G. For example, Virtual Reality (VR), Augmented Reality (AR), Holograms are expected to become more widely available for consumers through wireless networks, making the boundary between the physical and virtual worlds blurred.

This Master's Thesis aims to perform strategic foresight by examining such 6G visions and potential changes to the existing, established business models and value chains of the current mobile wireless technology industry. As a method of achieving this aim, scenario creation is selected to explore potential future pathways of the well-established industry with a free, unbridled mindset. The main purpose of this research is to identify phenomena and signals surrounding the mobile wireless industry which could shape future business in the 6G era, and seek alternative future options. However, proposing concrete business models with details on profit-making is not the target of this Master's Thesis.

1.1.1 Argument for strategic foresight

Numerous authors in Futures Studies domain treat the benefits of foresight in organizations and similarly a warning for the absence of foresight practice in strategic planning. Future preparedness of organizations makes a critical difference in success in the future especially in the age of a rapidly changing world with growing uncertainty. Strategic foresight or corporate foresight performed in a business setting helps corporate leaders to break away from path dependency and enable them to make better decisions toward the future. For instance, Rohrbeck & Kum (2018) demonstrated through case studies that a robust practice of corporate foresight has positive impacts on the performance of organizations.

It is also discussed that in the time of rising uncertainties, a viewpoint not bound from the existing business convention is indispensable. Wilenius (2008), for example, emphasizes the importance of better preparation for the future in the wake of growing uncertainties. Organizations today are not only in the need of finding novelty and a capacity for renewal, but the very existence of their business is at stake. To survive uncertain world, it is now required for organizations to adopt “an explorer’s world view” to identify business opportunities with free mindset.

As a provider of the indispensable communication platforms, or a taken-for-granted mediation, the mobile wireless industry has enjoyed its prosperity since the beginning of its business. Especially, the business model and value chain of representative players in this industry – MNO and network infrastructure vendors have been established and set in the same framework for a long time. The advent of 6G offers an opportunity to question the business operations of incumbent players with the aforementioned “an explorer’s world view”.

1.1.2 Argument for scenario building

Scenarios are stories about the future. They are stories about alternative possibilities for the future, with various levels of probabilities of occurrence under various conditions (Bell 1997). Scenarios are not intended to be predictions of future events. Rather, they are a useful tool to explore alternative options of multiple future possibilities. They are meant to make stakeholders realize various and possible future pathways and serve as guiding light in decision making and action-taking. Masini (1993 : 90) summarizes scenarios as “an instrument that aids decision-makers, by providing a context for planning

and programming, lowering the level of uncertainty and raising the level of knowledge, in relation to the consequences of actions, which have been taken, or are going to be taken, in the present".

Scenarios are especially useful in the strategic planning and decision-making of organizations. Naturally, the focal issue, from where the scenario building process expands, is the utmost and impending concern that a target organization is currently facing. The issue is usually chosen by stakeholders within the organization with the insider's view, and the actual scenario building process is also conducted by themselves. Schwarz (1996) also suggests that considering the scenario building process "from the inside out" rather than "from the outside in" is a useful start point. In this context, scenario building in the research of this Master's Thesis is lacking the viewpoint of a certain, specific organization. Direct participation of stakeholders from a target organization is not feasible, therefore there could be an argument that scenarios created by one person may not bring out the normative purpose of scenarios creation. However, the true value of scenarios is not limited to decision-making. As discussed by Ralston and Wilson (2006, 45), the power of scenario is that it enables us to realize what is moving the world around us, what could be the possible ways for the world to develop. Produced scenario narratives give clear pictures of future images spawning from the focal issue, however, the process itself is valuable and it gives a hint to realize vast possibilities of future development. Therefore the author concluded that the characteristics of scenarios suit the purpose of this research to explore multiple possibilities in the business of mobile wireless industry in the future.

1.2 Motivation of Research

The technologies are not meant only for individual communications any more. What started as a tool of peer-to-peer, man-to-man distant communication morphed itself into an indispensable medium for business, work life, and social interaction for people living in this modern world. Mobile wireless technology will continue to be so in the future (Harris & Cooper 2019).

The motivation toward the research of this Master's Thesis is triggered by the contrast between the critical role mobile phones play in our everyday life and the low attention toward almost secluded business operations of the mobile wireless industry. Although the general audience is becoming more aware of the latest generation of mobile wireless technologies, 5G, how the bearers of mobile services would survive is a question

out of consumers' interest. Furthermore, as the research for 6G is still under conceptual level, less literature is released on the business aspects of the 6G era.

1.2.1 Critical platform

Merely 40 years have passed since the birth of commercial mobile networks, however, mobile wireless technologies are penetrating every aspect of our everyday lives. Mobile phones, what had been regarded as a gadget of luxury in their initial days have now established their position as an indispensable platform for social life. Mobile technologies have diffused into society, and mobile phones have now become a taken-for-granted mediation (Ling 2011).

Simply put, mobile communication has made individuals to available each other, all the time. Calls can be made regardless of the current status of interlocutors, often forcing holders of mobile phones to be connected and such mobility and availability have reshaped the way we interact completely (Ling 2014). On top of voice communications, message exchange while on move has evolved significantly. Not only peer-to-peer communications, but group interaction also becomes feasible, which has changed the communication landscape by facilitating multi-sided interactions (Ling 2017). Mobile communications have even been invoking ethical issues, such as how individuals behave when they are engaged with others in shared spaces, or the ability to cheat physical whereabouts (Ling & McEwen 2010).

Today, not only people engaged in the line of technical work but also the general audience have sharp eyes on the development of emerging technologies, especially if they are in Information and Communication Technology (ICT) domain. In the earlier times, terminology such as 1G or 2G was not familiar for the most consumers. However, with the latest generation, the term 5G has been remarkably visible on media headlines to have caught the attention of wider audience. The penetration of 5G is quite high since the world's first 5G commercial service launch was in 2019 (Reuter 2019). One survey conducted in the US in the same year by a consulting company (PricewaterhouseCoopers 2019) showed that almost 80% of survey participants were aware of 5G. Consumer expectations on this new generation are higher than any of previous generations, especially the promise of ultra-fast 5G service is associated with striking emerging technologies such as automation, autonomous vehicles, advanced smart technologies to name a few. Consumers are now keenly aware that future development of mobile wireless

technologies, or the industry as a whole world will have the power to change the course of their lives.

The word "6G" has not reached the general audience yet as the researches of 6G have just been kicked off in late 2019 and there have not been a concrete set of requirements or standards. Still, it is fair to expect the same, or even larger fever and higher expectation to be accumulated among consumers when 6G commercial launch is materialized, within 10 years from today if the target set by researchers is achieved. What can also be expected is that the spotlight of 6G will be dominated by the deliverable, namely the service for users enabled by mobile wireless technologies in the 6G era, and the enablers of such services are pushed into a shadow. Looking at 6G from the perspective of novel technologies and their impacts on consumers, the effort and pathways of key players in the industry have taken are often ignored. However, innovative technologies have often brought disruptions not only to markets but also to players themselves. Disruptions often impact established business and value chains and stakeholders are forced to revisit traditional strategic planning (Moqaddamerad et al. 2017). The current 6G visions and potential technical requirements under research are summarized in the later chapter in this Master's Thesis. Considering the gravity of technological advancement proclaimed in 6G research papers, disruptions in the 6G era are expected to be enormous. Thus, examining alternative future options for stakeholders in the mobile wireless industry is logical as strategic foresight research in Futures Studies.

1.2.2 Preliminary expert interviews

Another critical reasoning to have motivated the author to focus on the business aspect of 6G development is the rising sense of urgency among stakeholders in the current mobile wireless industry to take strategic actions as preparation for the 6G era. Preliminarily the goal of this Master's Thesis was to perform foresight on future beyond 6G – preemptive technological foresight to explore the potential new set of mobile wireless technologies after 6G. The interest was to identify the motivation and triggers of the advent of the next generation of the mobile wireless world after 6G, to probably be called 7G if the naming convention would follow the same path in the past. The motivation was to identify visions, key requirements, and trigger to invoke 7G research and development. As the data collection of this 7G topic, interviews of experts in the industry were conducted. Four experts who are working for MNO or network infrastructure vendor companies participated in the interviews, all of who have the expertise and long years of

experience in the mobile wireless industry. As a result, these preliminary interviews proved that the theme of exploration of 7G is premature, as 7G has significant dependence on the development of 6G which has not yet materialized. The research objective to outline 7G development was therefore discarded, however, expert interviews brought out valuable input from forerunners of the industry. Stakeholders are fully acknowledging that novel features in 6G will bring disruptions to their existing value chains and they showed interest in building new strategies and new business and value creation in the era of 6G. Such empirical data from the voice of the industry convinced the author to make this Master's thesis one foresight research to seek alternative futures in the 6G era from the business perspective of incumbent players in the industry.

1.2.3 Literature review

The researches for 6G will continue to be vigorously aiming to launch a 6G commercial service around 2030. At present, numerous visions and targets advocated in 6G white papers published by research institutions and corporations focus mainly on the novelty of future technologies themselves, while there is only a limited number of works addressing the future of the businesses of the current major enterprises and organizations in the mobile wireless world.

First, theoretical literature are reviewed. Among numerous academic papers are being released to address expectations, researchers at the University of Oulu are studying the business aspect of the mobile wireless industry expanding from the 5G to 6G era. For example, Moqaddamerad et al. (2017a) adopt scenario building method to explore business models in the telecommunications market in 5G. In this paper, an anticipatory action learning–based (AAL) research approach is chosen to facilitate the participation of expert industries and sense-making, agile strategic creation for the stakeholders. Another work by Moqaddamerad et al. (2017b) aims to create value-based, entrepreneurial business opportunities in 5G, by utilising foresight workshops and visioning. The work by Ahokangas et al. (2018) approaches the business model in 5G from a more specific view. As the 5G requirement includes location-specific high-quality wireless networks, researchers anticipate the disruption of the existing business ecosystem as this novel requirement invites new competitors in the market. Scenarios are also created to anticipate possible development pathways with new entrants in the market.

Secondly, for 6G-related materials, empirical materials are mainly referred to. The empirical materials used for the research of this Master's Thesis are various white papers

on 6G, published by research organizations, MNOs, and network infrastructure vendors. In 2019, the world's first 6G white paper was published by "6G Flagship", the research program led by the University of Oulu in Finland. It aims to conduct vigorous researches and co-create an ecosystem for 5G adoption and 6G innovation. The collaborative effort was appointed by the Academy of Finland, a governmental funding agency for high-quality scientific research (BUSINESS FINLAND 2019). Their white paper, "Key Drivers and Research Challenges for 6G Ubiquitous Wireless Intelligence" (Latva-aho & Leppänen 2019) has become the guidepost for subsequent researches. It presented a strong vision of 6G "ubiquitous wireless intelligence", which indicates that wireless connectivity will be a critical infrastructure of society and connect intelligence of humans and non-humans (Latva-aho & Leppänen 2019).

Based on the baseline visions set by 6G Flagship, numerous academic bodies and corporations such as MNOs, network infrastructure vendors followed suit to publicly state their own visions toward 6G in their white papers. More than 100 research papers and white papers combined have been published to address the vision, possibilities, challenges of 6G.

White papers by the following organizations and companies in Table 1 are examined in this Master's Thesis.

Table 1. 6G White Paper examined in this Master's Thesis

Number	Title of white paper	Publisher	Type of Publisher
White Paper #1	Key Drivers and Research Challenges for 6G Ubiquitous Wireless Intelligence	6G Flagship	Research Program
White Paper #2	White Paper on RF enabling 6G – opportunities and challenges from technology to spectrum	6G Flagship	Research Program
White Paper #3	White Paper on 6G Drivers and the UN SDGs	6G Flagship	Research Program
White Paper #4	White Paper on Business of 6G	6G Flagship	Research Program
White Paper #5	6G White Paper on Validation and Trials for Verticals towards 2030's	6G Flagship	Research Program
White Paper #6	6G White Paper on Connectivity for Remote Areas	6G Flagship	Research Program
White Paper #7	White Paper on 6G Networking	6G Flagship	Research Program
White Paper #8	White Paper on Machine Learning in 6G Wireless Communication Networks	6G Flagship	Research Program
White Paper #9	6G White Paper on Edge Intelligence	6G Flagship	Research Program

White Paper #10	6G White Paper: Research Challenges for Trust, Security and Privacy	6G Flagship	Research Program
White Paper #11	White Paper on Broadband Connectivity in 6G	6G Flagship	Research Program
White Paper #12	White Paper on Critical and Massive Machine Type Communication towards 6G	6G Flagship	Research Program
White Paper #13	6G White Paper on Localization and Sensing	6G Flagship	Research Program
White Paper #14	White Paper 5G Evolution and 6G	NTT Do-como	MNO
White Paper #15	Communications in the 6G Era	Nokia	Vendor
White Paper #16	Ever-present intelligent communication	Ericsson	Vendor
White Paper #17	6G The Next Hyper Connected Experience for All.	Samsung	Vendor

Among these white papers, White Paper#4 in the table above, ” White Paper on Business of 6G” shed a light on the discussions of business aspects in the 6G era. The paper creates scenarios for three scenario themes – “User experience”, “Business”, “Sustainability”. For each theme, four scenario narratives are generated to differentiate alternative future developments. Especially, “Business” scenarios highlight the possible future disruptions to the current closed ecosystem of the mobile wireless industry. Whether or not new competitors take over the market is one of the critical axes to compose their scenarios. The work of White Paper#4 covers the future images of mobile communication service providers in a general way, can be described as a guidepost to subsequent researches in businesses opportunities in the 6G era.

This Master’s aims to follow the path taken by the work of White Paper#4 and attempt to expand it by using a new scenario axis. Based on expert interviews and information found in desktop research, further driving forces are collected to enrich the viewpoint of scenario making.

1.3 Research Questions

To explore possible future developments of the mobile wireless industry in the 6G era, the research questions of this Master’s Thesis are summarized into two questions below.

(1) Which drivers of future changes are anticipated to reshape the business operations of incumbent MNOs and network infrastructure vendors in the transformation to the 6G era ?

(2) How can alternative futures for the mobile wireless world in the 6G era be explored through a set of scenarios for the year 2035, when commercial deployments of 6G networks progress ?

As the outcome of these research questions, scenarios to illustrate the potential future development of businesses are created. The focal point of scenarios is selected from the viewpoints of MNOs and network infrastructure vendors, not from one of end-users.

1.4 Structure of the Thesis

This Master's Thesis is comprised of the following structure. First, the background surrounding the mobile wireless world today, including the history of the evolution of the mobile wireless technologies are briefly summarised in the following chapter to overview the radical advancement of the mobile wireless industry in the past 40 years. Then in chapter 3, the current mobile wireless technologies which could bring about major disruptions in the future are discussed. In chapter 4, the visions of 6G researches and key features are briefly described. Subsequent chapter 5 is dedicated to methodology, data collection, and analysis. Lastly, the built scenarios are given in chapter 6. The Thesis concludes with chapter 7, the conclusion section.

1.4.1 Disclaimer

Clarification must be made here that the target technology of this Master's Thesis is mobile wireless, specifically cellular networks. Many MNOs and vendors are categorized as telecommunications or telecom companies as they own businesses not only in wireless networks but also in fixed-line networks. However, this Master's thesis aims to highlight the potential disruptions and changes brought by a new generation of mobile wireless technology, 6G. Therefore the business aspects in fixed-line networks are not in the focus.

2 MOBILE WIRELESS INDUSTRY – A CLOSE VIEW

In this chapter, the basic landscape surrounding the mobile wireless industry is discussed. To consider the novelty of mobile technologies in 6G and their business impact, an indispensable step is to have a basic understanding of the brief history of evolution from 1G to 5G, the network architecture and the current landscape of market sustaining the current mobile business today.

2.1 Behind our phones

For regular users of mobile communications nowadays, mobile wireless technologies mean mobile devices such as smartphones, tablets, wearable devices, and any other forms of mobile gadgets. In reality, the scope of services and capabilities of commercial mobile networks have been expanded significantly since the first generation, 1G.

The following picture (Figure 1) gives simplified visual images of representative devices and services for consumers. The perception of consumers against mobile wireless services was merely a tool of communication. From 3G, the arrival of the smartphone has multiplied user experiences, bringing personal entertainment with mobility to users. 4G amplified multimedia user experiences with significantly improved speed. Then the subsequent 5G is bringing mobile wireless service to the next level of evolution, which steps out of the boundary of personal communication tools to an indispensable platform where new emerging technologies are tightly incorporated with wireless service.

Figure 1. Summary of evolution

(Image source : https://www.linkedin.com/pulse/mobile-wireless-communication-technology-journey-0g-mutabazi/)

Behind such visible services to consumers, complicated networks consist of numerous network elements are built and under operation.

When looking at a mobile network in a simplistic view, it consists of two domains – Radio Access Network (RAN) and Core network. Simply put, RAN is a network between individual devices and base stations over a radio link. In Core network, various functions are condensed. It provides for instance user authentication, charging per user profile, routing of calls to the public switched telephone network or to the internet.

Figure 2 below shows a simplified overview of mobile networks. User traffic goes from user devices aligned on the left side of the figure through Base Stations over RAN and then reach Core Network.

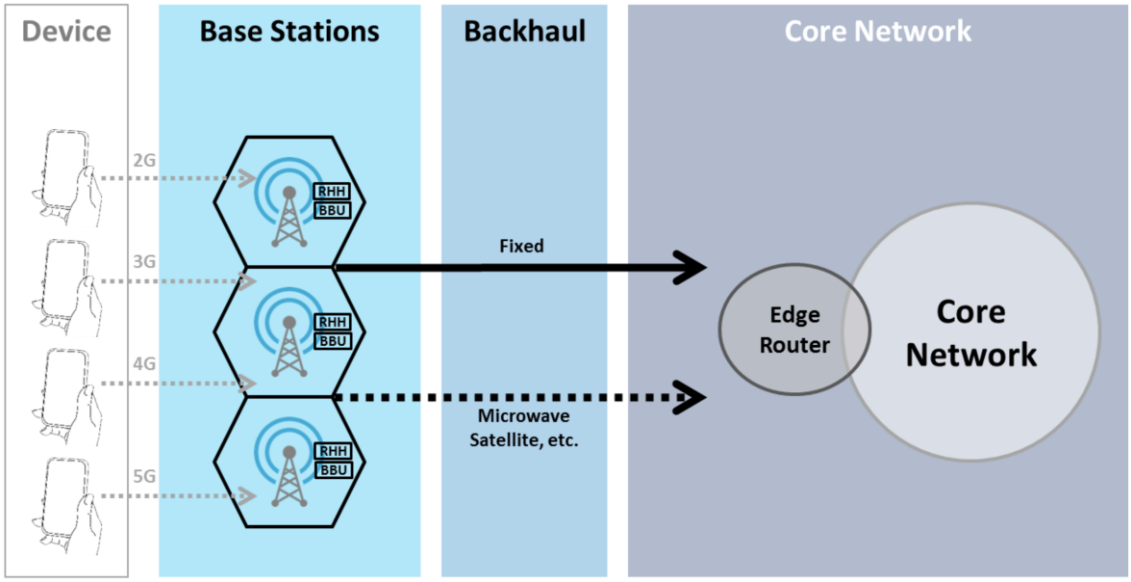

Figure 2. Simplified overview of mobile network

(Source: https://medium.com/@miccowang/5g-c-ran-and-the-required-technology-breakthrough-a1b2babf774)

However, in reality, network architecture and underlying technologies are not as simple as regular consumers imagine. Before mobile networks have reached the way it is today, technologies composing and enabling mobile communications have gone through drastic evolution. The pathway of evolution started with 1G, the first generation which is characterised by analogue voice call service. NTT in Japan launched the first commercial cellular network for automobiles in the world in 1979 in the metropolitan area of Tokyo. Soon after this first network, the cellular era reached Europe as well by 1981. The two major analogue systems were Nordic Mobile Telephones (NMT) and Total Access Communication Systems (TACS). However, the service in this first generation was limited to voice only and the network was unreliable without security (Salih et al. 2020).

In the second generation, 2G, the underlying technology was switched from analogue to digital. Low bit digital data service was introduced on top of the existing voice service. 2G started the utilisation of digital multiple access technologies, such as Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). In Europe, Global System for Mobile Communication (GSM) was deployed as a unified standard. GSM enabled international roaming throughout Europe (Pulkit 2013).

Next, 3G was introduced around the year 2000 to provide high-speed data transfer and reliability. 3G is also described as the era in which the industry took a step forward to form a global standardization. The International Telecommunication Union (ITU) defined the demands for 3G mobile networks into the IMT-2000 standard (Pulkit 2013). Furthermore, an association called the 3rd Generation Partnership Project (3GPP) has continued that work by defining frameworks of networks that satisfy IMT-2000. Wideband Code Division Multiple Access (WCDMA) and CDMA2000 are major technologies featured in the 3G era. The higher transmission speed and larger capacity of 3G enabled end-users to enjoy the web-based applications, audio and video file transfer.

The subsequent generation offers a new level of user experience with wider bandwidth, higher security and high-speed internet access. The manifestation of this fourth generation, 4G, was triggered by the ever-increasing growth of user demand for data and the emergence of new technologies in the mobile wireless systems (Pulkit 2013). This generation is based on Long Term Evolution (LTE), the standard set by 3GPP. 4G is taking similar headways as 3G focusing on the higher capacity and are offering improved multimedia, video streaming, worldwide transportability through a wide range of gadgets (Salih et al. 2020), mostly for individual end-users. 4G LTE is still the dominant technology adopted in commercial cellular networks in a major part of the world.

Since the year 2019, the latest generation 5G has been dominated the headline of the mobile industry. In 5G, an advanced level of speed and connectivity is required to quench the ever-growing thirst of data demand. ITU and 3GGP have been acting as the leading bodies to explore and define the vision of new mobile wireless generations since 3G, and their requirements for 5G are mainly characterised by 3 features. The first one is eMBB (enhanced Mobile Broadband) to offer fast and large-capacity communication. Next, URLLC (Ultra-Reliable and Low Latency Communications) to define a super reliable but with low latency network, and the last one is the novel concept, mMTC (massive Machine Type Communication). The concept of mMTC marks the point where mobile wireless technologies have taken a new, historic turn from the development path seen in the

previous generations. Although the speed and connectivity have significantly improved through the era of 1G to 4G, the development was not stepping out the boundary of the conventional notion that mobile wireless technologies are for human-to-human communications. In 5G, however, expected use cases have shaped new forms of connectivity – namely, human-to-machine, and machine-to-machine communication. The ultra-reliable, massive connectivity of 5G is not solely designed for use by humans but also for industrial purposes amid the increasing demand for automation. Thus 5G heralded itself through the general audience, i.e. people who do not have a strong interest in the mobile wireless industry, as the enabler of glorious novel technologies such as autonomous vehicles, Internet of Things (IoT).

The summary of characteristics in each generation, from 1G to 5G are summarised in Table 2 below. Taking alone a bandwidth to represent the data volume transferred, the improvement throughout the past is significant. Compared to the time of 1G, in theory, end-users can enjoy more than 1000 times faster communications over their devices in 4G. These significant evolutions in capacity has brought about enhanced user experiences and services.

Table 2. Comparison of Mobile Technologies

(Source : Kalra, Bharti – Chauhan, D K (2014) A Comparative Study of Mobile Wireless Communication Network: 1G to 5G.)

Technology	1G	2G	3G	4G	5G
Requirements	No official Requirements Analog technology	No official Requirements Digital Technology	ITU's IMT-2000 required 144 kbps mobile, 384 kbps pedestrian, 2 Mbps indoors	ITU's IMT Advanced requirements include ability to operate in up to 40 MHz radio channels and with very high spectral Efficiency.	at least 1 GB/s or more data rates to support ultra-high definition video and virtual reality, applications, 10 GB/s data rates to support mobile cloud service
Data Bandwidth	1.9 kbps	14..4 kbps to 384 kbps	2 Mbps	2 Mbps to 1 Gbps	1Gbps & Higher (as demand)
Core network	`PSTN	PSTN Packet Network	Packet network	All IP Network	Flatter IP Network & 5G Network Interfacing(5G-NI)
Service	Analog voice	Digital voice Higher capacity, packetized data	Integrated high quality audio, video and data	Dynamic information access, wear-able devices, HD streaming; global roaming;	Dynamic information access, wear-able devices, HD streaming; any demand of users; upcoming all technologies; global roaming smoothly;
Standards	NMT, AMPS, Hicap, CDPD, TACS, ETACS	GSM,GPRS, EDGE ETC.	WCDMA, CDMA 2000.	All access convergence including: OFMDA,MC-CDMA Network-LMPS	CDMA & BDMA
Multiple access	FDMA	TDMA CDMA	CDMA	CDMA	CDMA & BDMA
Starts from	1970-84	1990	2001	2010	2015
Switching	Circuit	Circuit Packet	Circuit Packet	Packet	All Packet
Frequency	800-900 Reference Mhz	850-1900MHZ	1.6-2.5GHZ	2-8GHZ	

2.2 Research Cycle

After the advent of the first commercial cellular network later named as "1G", the explicit cycle of development is recognised when new generations appear in the mobile wireless industry. In short, researches and standardization of technologies for each generation are occurring in the cycle of every 10 years. Figure 3 below shows the representative year when each generation started to be deployed and became available the market. Following this past example, the first roar announcing the commencement of 6G research was made by the researchers at the University of Oulu in 2019. The launch of 6G, the next generation of mobile wireless technologies are targeted to take place around 2030, exactly 10 years after the flourishment of 5G which we are witnessing today.

The vision of 6G is outlined in chapter 4 in this Master's Thesis.

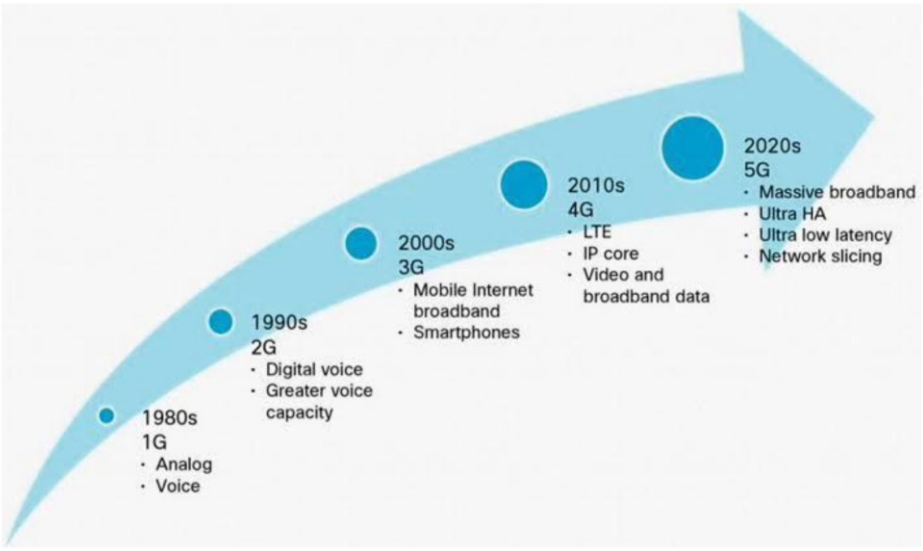

Figure 3. Evolution of mobile wireless generations

(Source : Salih et al. (2020) Evolution of Mobile Wireless Communication to 5G Revolution)

Today, modern mobile networks have increased complexity in architecture to cater to various demands of end-users. In a more detailed view, Figure 4 below shows basic elements composing mobile networks from 2G to 4G. The figure displays that the complicated networks are built behind mobile communications. There still exist other elements not visible in this picture, such as network management server, however, this picture alone tells that mobile networks comprise of these various elements. Traditionally, network infrastructure vendors offer each network element with both software and hardware combined. Hardware can be dedicated one manufactured by themselves or general-purpose hardware is offered, however, in most cases, proprietary and dedicated hardware are used for radio base stations.

Throughout the history of evolution from 1G to 5G, network architecture and building blocks within mobile networks have also evolved, introducing new components or eliminating obsolete ones. For example, as in Figure 4, radio base stations have gone through upgrades from 2G to 4G. In 2G, they are called Base Transceiver Station (BTS) and later named Node B in 3G, then evolved Node B (eNode B) in 4G. Evolution and renaming of base stations have been performed to support new radio frequencies introduced in new generations of mobile wireless technologies. Core network as well has gone through upgrades with new elements introduced according to new technologies.

This renewal of equipment indicates that MNOs are required to make significant investments in their network every time a new generation of mobile networks is introduced,

while network infrastructure vendors make sales by offering new a set of software and hardware.

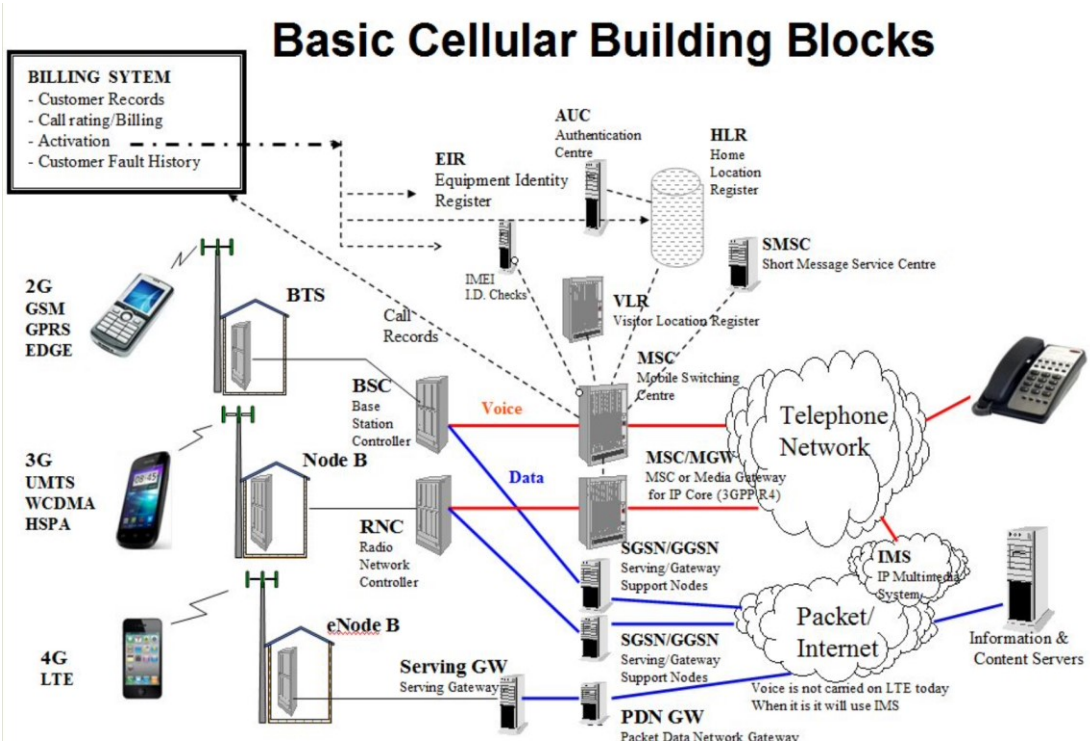

Figure 4. Basic architecture of mobile network from 2G to 4G

(Source: Statistica - https://www.statista.com/statistics/262950/global-mobile-subscriptions-since-1993/#:~:text=The%20total%20number%20of%20mobile,subscriptions%20from%202018%20to%202019)

2.3 Players in mobile wireless industry

To provide aforementioned mobile networks and services, various enterprises make businesses in the mobile wireless industry. M. Al-Debei and Avison (2011) discuss the business model of mobile telecommunication sector from the perspective of mobile operators. In their work, they define the relevant stakeholders and services which interacts and be engaged in collaboration with mobile operators in the following categories.

(0) Mobile Network Operators (MNO)

(1) Hardware Vendors

- Cellular device manufactures – provider of phone devices and gadgets
- Network engineering equipment vendors – provider of physical cellular network infrastructure

(2) Software, Content, and Application Providers

- Network engineering application vendors – provider of soft infrastructures such as network and telecommunication management, control, network diagnostic, and optimization systems
- Middleware providers – provider of software interfaces
- Content providers – provider of the needed information to be communicated to cellular customers
- Content Aggregator – provider of content customization

(3) Third Parties and Payment Gateways

- Payment Gateways vendor – provider of different methods of payments to cellular users.
- Billing Services vendor – provide billing services

(4) Network and Service Providers

- Wireless Internet Service Providers – provider of the internet accessibility to cellular customers
- Other MNOs – provider of additional services such as roaming
- Mobile Virtual Network Operators – other operators who buy or lease network capacity

It is beneficial to acknowledge that such various hardware and service providers are sustaining the mobile wireless industry. However, this Master's Thesis highlights the future development of businesses of only two stakeholders - MNOs and Network engineering equipment vendors. The reasoning is that these two are the main actors who form collaborative research efforts and decide the pathways of future generations of mobile wireless technologies. Other parties listed above are followers of the development set by them and provide services according to requirements and specifications.

Furthermore, in this Master's Thesis, Network engineering equipment vendors are referenced as network infrastructure vendors, as they provide not only hardware but also software and services comprehensively.

2.4 Market Volume

To understand the gravity of business development of the mobile wireless industry in the 6G era, it is beneficial to briefly touch market volume in these years. In short, the

scale of the mobile wireless business is colossal. When looking at the market size from the comprehensive telecommunication service perspective, one statistic (Grand View Research 2020) suggests that the global market size was calculated to be 1,657.7 billion USD in 2020. Furthermore, the growth in the future is expected to be steady with 5.4% of Compound Annual Growth Rate (CAGR). Among these figures, the mobile wireless domain accounts for the largest growth within telecommunications. Figure 5 below indicates that mobile service, specifically mobile data service is projected to grow sharpest among other services. This expected growth is attributed to data consumption by smartphone users and soaring demand for high-speed data connectivity in industrial use. The penetration of smart technologies empowered by IoT and AI in the 5G era is driving the market growth. According to statistics (Statista 2021), the number of IoT devices worldwide counted to be 22.2 billion in 2018, but the number is expected to reach 50 billion in 2030. Another research company, Allied Market Research also analyses that IoT will be expanding at a rapid pace and continue the steady growth in the coming years, as our dependency on IoT enabled technologies such as surveillance and real-time monitoring is growing (Allied Market Research 2020).

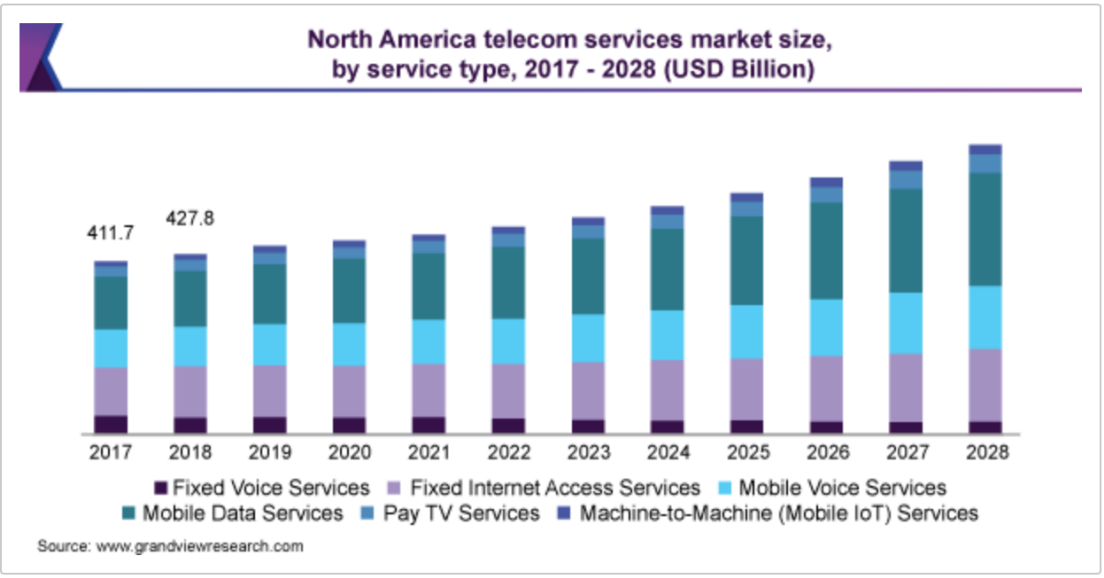

Figure 5. Telecom services market size in North America

(Source: Grand View Research < https://www.grandviewresearch.com/industry-analysis/global-telecom-services-market>)

Based on these projections available from today, it is fair to assume that the mobile wireless industry will continue the growth up until 2030 before the first form of 6G

deployment emerges in the market. The development of mobile wireless technologies affect the behaviour of people in the modern world, and at the same time, it directly impacts millions of workers in this industry.

2.5 Market oligopoly and maturing market

Another distinct characteristic of the mobile wireless industry is that the industry especially up to the 4G era can be described as an almost closed ecosystem – the specific nature of the mobile wireless industry that involves radio spectrum handling and massive capital makes the market entry of new players significantly challenging. In many countries the number of major players in the mobile wireless market is limited. Often oligopoly of Mobile Network Operators (MNOs), network infrastructure vendors, smartphone vendors are subject to criticism. Additionally, while mobile communication is indispensable in modern life, it also means that the market is mature. It suffers a lack of drastic market expansion.

2.5.1 Oligopoly of MNOs

The current mobile wireless industry is taking criticism to be embracing oligopoly. Taking an example of MNO, typically only a few MNO exist the most countries. The characteristic of the mobile wireless industry is that there is only a limited allowance of the radio spectrum to be commercially utilised. As a common practice, the distribution of frequency is controlled by political authorities. This fact makes the market entry or exit by new entrants extremely challenging, leaving the market only for existing, a limited number of MNOs who have licensed frequency allowance. Building network facilities is another obstacle, as it requires substantial capital to deploy networks with wide coverage. As consumers are accustomed to ubiquitous connectivity anywhere they are, the lack of coverage area or degraded quality of voice and data calls directly means the loss of subscribers and profit. As a result, small scale operators who do not have the capability to provide nationwide, through coverage tend to vanish or be merged by larger competitors.

Such structure of the mobile wireless sector is causing sluggish competition and insufficiency of innovation. The research conducted by OECD in the year 2014 revealed that in countries where there are a larger number of MNOs stand a higher likelihood of more competitive and innovative services being introduced and maintained (OCED 2014). A market with a larger number of MNOs can stimulate the competition and facilitate

innovative business opportunities. On the other hand, the market with a lower number of participants tends to be relatively conservative, where incumbent players rather aim to maintain or increase the existing profitability through cost savings than investing in new opportunities.

An example of oligopoly in the mobile wireless sector is Japan, where three MNOs – NTT Docomo Inc.(Docomo), KDDI Corporation (KDDI), and Softbank Group Corp (Softbank). had dominated the market for most of the time in the history of the mobile wireless market in the country. As the end result, consumers in Japan are forced to accept relatively higher prices of mobile fees compared to the rest of the world while these three corporations have been enjoying the high-profit margin rate. Nikkei Asia, a news media company based in Tokyo, Japan reported in the year 2020 that the profit margin of Docomo, KDDI, and Softbank are all between 23% to 25%. The report also points out that this high rate of profit margin is seen in the US as well, where an oligopoly is also being criticized. On the other hand, MNOs in Europe is reported to have a lower profit margin around 12% (Noguchi 2020). The Japanese government has been continuously pressuring Docomo, KDDI, and Softbank to lower the fee. However, the progress is less than ideal.

To break this market dominance by only three operators, The Japanese government had pushed forward an entry of new operators to stimulate competition. In 2019, the fourth operator, Rakuten Mobile was given birth by a large e-commerce company in Japan, Rakuten Group, Inc (Rakuten 2020). The service and coverage of Rakuten Mobile have not reached the same level as the existing three vendors, however, the newcomer is waging a price war against them. While the company is still under intense pressure to extinguish the costs of laying out its greenfield network, Rakuten Mobile has pushed forward competitive pricing schema, some of which are even lower than half of the competitors (Hardesty 2021). Such an attempt to break the existing regime by a few operators is key when considering the future business of existing major companies in the mobile wireless industry in the 6G era.

However, at the same time, whenever new generations of mobile wireless technologies emerged, there had been new requirements of speed and capacity, which pushed forward the use of new spectrum and bandwidth. Such new requirements had obligated MNOs, network infrastructure vendors, and other stakeholders to invest in new infrastructure. For example, the change in spectrum used directly means the renewal of radio equipment as old radio components do not support new frequency. Clearance of spectrum handling shall remain critical when inviting new players into the market.

2.5.2 Oligopoly of network infrastructure companies

Network infrastructure business is also dominated by a small number of global corporations. Figure 6 below displays the market share of network infrastructure companies worldwide from 2017 to 2018. It is clearly observed that only a subset of vendors is thriving in this particular market. A Chinese telecom giant Huawei Technologies Co, Ltd. (Huawei) accounts for more than 30% of the market share in 2018. Telefonaktiebolaget LM Ericsson (Ericsson) in Sweden is the second largest with a 27% share, followed by Nokia Corporation (Nokia) in Finland. The fourth place is another Chinese company ZTE Corporation (ZTE) with a smaller share of 11%. The fifth is The Samsung Group (Samsung), a Korean conglomerate, however, the share is marginal to be 5%.

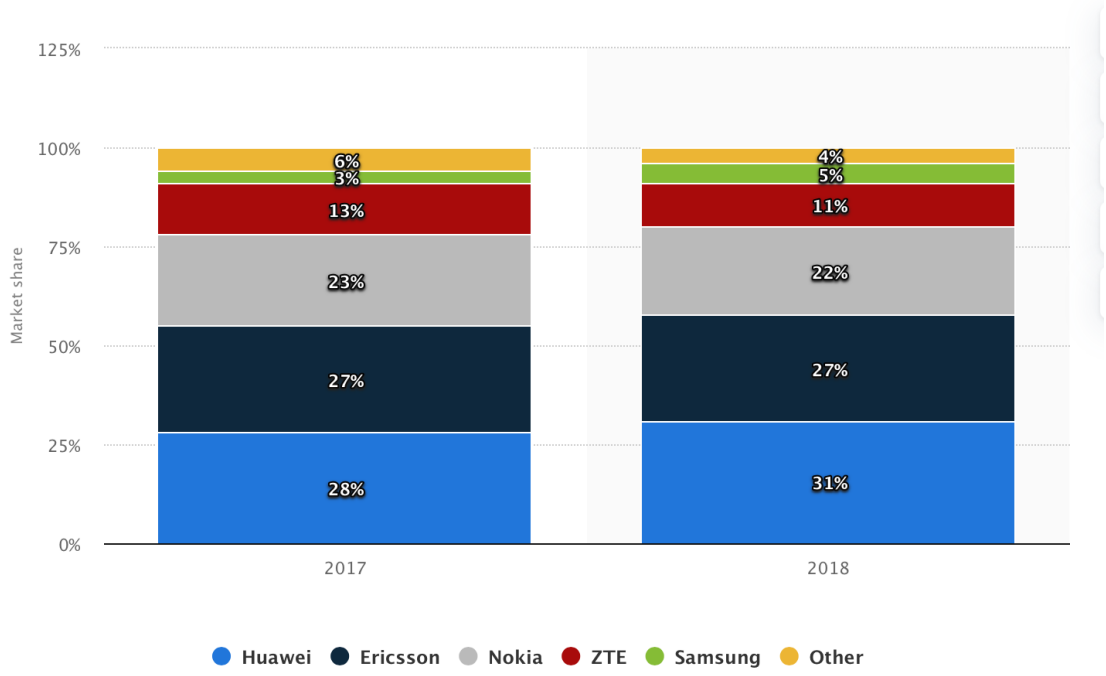

Figure 6. Market share of mobile infrastructure companies worldwide from 2017 to 2018

(Source: Statistica - https://www.statista.com/statistics/526037/global-telecom-equipment-market-share/)

These statistics indicates that the mobile network infrastructure built worldwide have been built by almost these four gigantic companies alone. It also suggests the difficulty for start-ups to make new market entries. Generally speaking, newcomers in the electronics industry need to invest significantly in R&D to prepare a product portfolio to sell. However, it is often the case that major existing companies own patents and licenses in

an established market. New start-ups are also required to invest in R&D significantly to stand on the start line. In the meanwhile established existing companies benefit from economic scale and scope, and it makes them easier to increase the production output or consider launching a new portfolio (Investopedia 2021). On top of these facts, in the case of mobile networks, infrastructure vendors need to be capable of mass production of products in case their customers, MNOs, desire nationwide level networks to be built with novel products offered by such start-ups.

Another characteristic specific to network infrastructure vendors is their susceptibility to geopolitical influence. As a result of high barriers to entry, the dominance by four giants, Huawei, Ericsson, ZTE, and Nokia has been explicit in the past decade in the mobile market. However, these seemingly robust four companies are easy to be drawn into a political fray. In May 2019, the US administration led by former President Trump banned the use of telecommunications equipment made by Chinese vendors. The executive order was intended to remove network equipment that might impose national security risks (Android Authority 2021). Although there was no use of the term "Huawei" or "Chinese" in the order, the intention was obvious. The order was squarely aimed at Chinese companies, namely Huawei and ZTE. The allegation was that both companies may exploit network vulnerabilities and compromise the critical communications infrastructure of the country in the favor of the Chinese Communist Party and China's military apparatus. The accusation by the US government severely damaged Huawei's fight for supremacy in becoming a champion 5G equipment vendor in the world. Not only the US but also the allied nations such as Japan and European countries followed the order of the US and barraged out Chinese vendors from their markets. For example, British Telecom (BT) has chosen Nokia to be their main provider of 5G network equipment. This means BT effectively ended a strong relationship between Huawei and them that dated back to 2005 (BBC 2020). What to be noted is that the lost deal by Chinese vendors is now covered by the remainder of major players, Ericsson, Nokia, and Samsung. This fact also tells that the other new players could not make any substantial move to make an entry even under the rare opportunity that the top vendor in the market is facing a predicament.

2.6 Maturing market

As discussed in the previous sections, the structure of the mobile wireless industry exhibits a picture that the selected, limited number of existing major companies are enjoying the oligopoly. These incumbents may look to be robust in their business operations.

However, there exists a fundamental challenge from several years back – the maturity of the market itself.

For MNOs, the obvious and dominant revenue stream is the mobile fees earned from users based on subscription. Through the history of the evolution in mobile wireless technologies, the industry has received the full benefit of a rapidly growing market. The number of mobile users worldwide had soared while it was bringing in enormous revenues to operators. However, as mobile phones have become an indispensable communication medium to humans, the number of subscriptions are finally hitting the ceiling. Figure 7 below shows the number of mobile subscriptions worldwide from 1993 to 2019. The number of subscription in 2019 exceeds 8 billion, which means that mobile subscriptions already covers more than the world population of 7.9 billion as of 2021 (Worldmeter 2021).

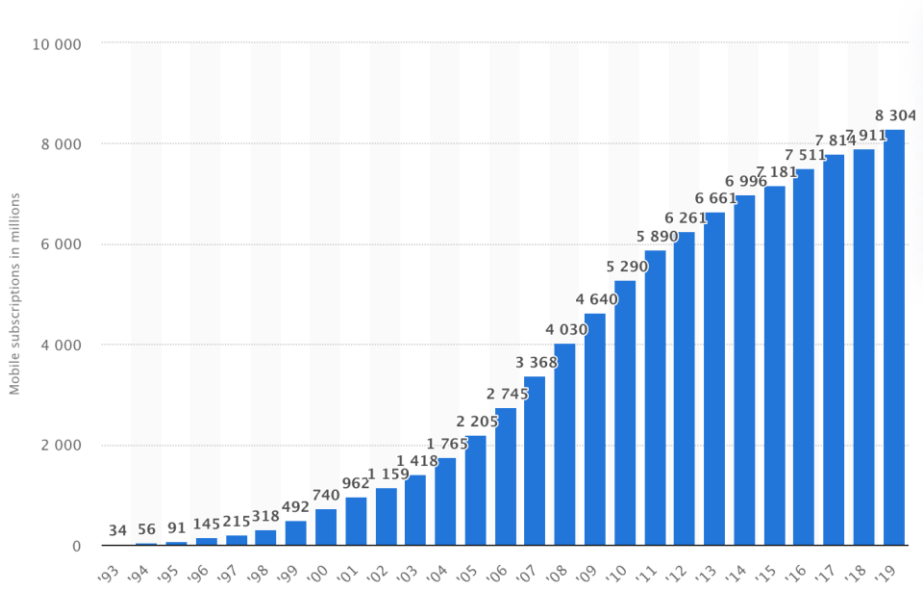

Figure 7. Number of mobile subscriptions worldwide from 1993 to 2019

(Source: Statistica - https://www.statista.com/statistics/262950/global-mobile-subscriptions-since-1993/#:~:text=The%20total%20number%20of%20mobile,subscriptions%20from%202018%20to%202019)

Figure 8 below displays another statistic. It represents mobile subscriptions worldwide per 100 people. The latest value after the year 2015 reaches the value of 110, meaning that 110 subscriptions are contracted by 100 people. Simply, one person may have more than one subscription.

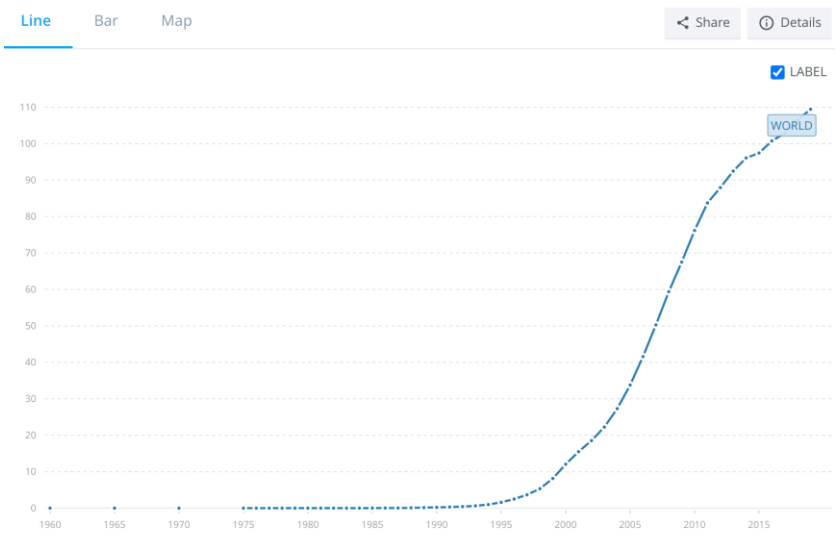

Figure 8. Mobile Cellular Subscriptions (per 100 people)

(Source: https://data.worldbank.org/indicator/IT.CEL.SETS.P2?end=2019&start=1960)

This matureness of mobile networks worldwide indicates that MNOs may not be able to rely on mobile subscriptions alone to make a profit going forward.

Similarly, network infrastructure vendors are facing a challenge. In the early days when MNOs were spending a fortune on building their initial mobile networks, vendors flourished by selling basic infrastructure equipment and service to them. However, along with subscriptions, networks, or mobile infrastructure as well have well matured. There are no major new rollouts to build new networks from scratch anymore. Operators have no need to build major, macro networks at the same rate and scale as previous years They continue to invest in infrastructure to deliver better coverage and better quality of voice and data calls, however, such investment is costly while the return is small (telecoms 2015).

Amid the latest generation of 5G and with the future generation of 6G ahead, both MNOs and network infrastructure vendors are facing the moment of truth to survive the upcoming disruptions.

3 DISRUPTIVE TRENDS IN INDUSTRY

To discuss the novelty of mobile technologies in 6G and their business impact, an indispensable step is to know trends in technologies sustaining current mobile networks today. Technologies referred to here are the ones to build and maintain infrastructures, to which MNOs make investments and network infrastructure vendors make a profit. Advancement in this technological area has significant influence in the way how mobile networks are managed, and how the businesses are operated by both parties. Already several trends such as virtualization and Open RAN are visible to reshape the industry.

3.1 Virtualization and Cloudification

Virtualization is a technology that allows one to create virtual, simulated computer environments from a physical hardware system. It offers software-based IT services such as applications, servers, storage and network in virtual space, decoupled from physical hardware (Citrix 2020). Virtualization enables more efficient use of physical computer resources by flexibly distributing resources to virtualized entities. Investment in hardware is optimized so that a greater return on an organization is expected (IBM 2021). Furthermore, virtualized environments have more competitiveness compared to the conventional physical environments. For example, the reliability of a virtual system is enhanced as it is easier to build redundant systems or restore the system from backups. In addition, the management of systems is more smooth for administrators as the addition or deduction of virtual resources allocated for their system is easy. Not only computing nodes, but networking is also being transformed to be virtual in Software Defined Network (SDN) approach. Instead of traditional, dedicated hardware devices such as switches and routers, the SDN approach uses software-based controllers or application programming interfaces (APIs) to communicate with underlying hardware infrastructure and control traffic. It enables the creation and maintenance of networks with more speed and flexibility (VMWare 2021).

Virtualization is the foundation of cloud computing which is recently becoming almost a new normal in ICT for enterprises. Cloud computing is defined to be on-demand access to computing resources such as applications, servers, data storage and more hosted at a remote data centre accessed over the internet (Vennam 2020). Cloud computing brings about significant benefits to users. For example, lower IT cost is achievable as it eliminates the necessity of purchasing, installing, configuring, and managing physical

devices. Furthermore, agility, flexibility, and scalability are given to infrastructure. With traditional hardware-based infrastructure, organizations have to invest in new hardware and scale up the capacity of the computing platforms. However, with a cloud solution, instead of purchasing extra capacity that is required only for a peak hour but remains unused for normal time, resources can be flexibly expanded on demand, in response to the spike of data.

Such benefits of virtualization and cloud platforms are reshaping the way how organizations build their ICT solution, and the mobile wireless industry is no exception. Network elements in mobile Core networks are gradually being migrated to virtualized platforms. Instead of having a set of dedicated hardware and software for each network element, multiple software instances are operating on the same virtual platform by sharing underlying hardware resources. RAN side as well, the concept of Cloud RAN, or C-RAN has been established to run radio access functions on off-the-shelf hardware except for antennas. There is a high expectation that the flexibility and optimization brought by Cloud RAN will build a foundation for openness and innovation in 5G (Ericsson 2021).

MNOs are welcoming the trend of virtualization and cloud as their investment in networks can be optimized with these solutions decoupling software from hardware. At the same time, it means that network infrastructure vendors must make a shift to provide more software-oriented solutions than pre-packaged, pre-installed products on dedicated hardware. More directly put, vendors are in the need of novel solutions and make enough profit out of them, even without the sales of dedicated hardware.

3.2 Network slicing

The diversified requirement from various industries in 5G has generated a new form of service over the network. The network is no longer occupied by communications and entertainment of individual uses, but it has become an indispensable infrastructure of industrial backdrops. This change has triggered the demand to utilise networks in a more optimized way – namely, a subdivision of networks and differentiation of service over subdivided networks are gaining popularity. It is network slicing, meaning that multiple virtualized, logical networks are running on the same physical network infrastructure. Each network slice can offer its own logical topology, security rules and performance characteristics (Burke 2021). For example, one business customer may require the most robust, super-fast communications for self-driving vehicles, while others desire more relaxed requirements but with lower service costs (GSM Associations 2017). Slicing is one

of the key features in 5G to optimize the network as a precious resource. ZTE (2021) is even offering 5G E2E network slicing solutions to MNOs and enterprises in other industries, proclaiming the novel concept of NSaaS (Network Slice as a Service).

3.3 Open RAN

Another major movement seen in the mobile wireless market is Open RAN. Open RAN aims to have industry standards for RAN interfaces so that compatibility and interoperation are ensured across different vendors' equipment. Traditionally MNOs have had to select the same vendor to provide RAN equipment as interoperability between RAN equipment vendors was "deprioritised at the expense of adding overall functional capability" (Nokia 2021). It is difficult for MNOs to have mixed vendors for RAN. In most cases the same supplier provides the whole RAN, or even if MNOs have different RAN vendors, each vendor burden partial set of network, which is independent of each other. Open RAN defines the standard of protocols in RAN, so that equipment provided by different vendors shall work compatibly. The major outcome is flexibility and cost-effectiveness, which could result in preventing a lock-in of vendors. Until the arrival of O-RAN, RAN techniques are a proprietary asset of radio vendors. However, Open RAN could open a door for the open mobile wireless market. It can invite more competition of RAN vendors into the market, and threaten the current structure of the market dominated by a subset of existing major vendors.

3.4 MVNO

A Mobile Virtual Network Operator (MVNO) is an operator who does not own their wireless network infrastructure. It is also called a virtual network operator. Services by MVNO started in Europe in the 1990s and the European models soon became popular in the rest of the world. Over the last several years, MVNOs have become a disruptive market force (Roberts 2019). The values of MVNO model is multi-folded. For entrant MVNOs, swift market entry is possible as they are exempted from making massive investments in mobile networks creation. MNOs also benefit from partnering with MVNOs. Traditional operators usually provide their services and marketing to mass segments in a "one-size-fits-all" manner. However, this approach may not serve certain customers as they all have different tastes and purposes in their usage in mobile service. By partnering with MVNOs, MNOs can target such niche segments where they have had less success.

As a result, MNOs can avoid customers churning to their competitors. Even if end-users of an MVNO service are not direct customers to an MNO, an MVNO will still send back revenue to MNO for the use of the network (Rasmussen 2021). End-users as well enjoy the benefit of MVNO service as they can have more options of operators to choose. Compared to the services provided by traditional MNOs, subscriptions and services offered by MVNOs may be limited, however, they can choose lower mobile fees.

The emergence of MVNO service was disruptive in the sense that it broke the common concept that only MNOs owning their own network can serve as telecom operators. MVNO has brought a stimulant to the mobile wireless industry.

4 6G – UNPRECEDENTED ERA

4.1 Inception of 6G researches

Researches of 6G is vigorous, after 6G Flagship mentioned in the literature review section has set out the foundational visions. Many enterprises such as MNOs and network infrastructure vendors in the industry are releasing white papers, and discussions aside from white papers are also becoming active among stakeholders. Another large initiative for 6G research is the 6G Symposium. It periodically organizes workshops and seminars to stimulate the discussion among experts for the 6G vision, requirements, and targets. Participants of the symposium expand into many key stakeholders in the industry. Top experts who are the forerunners of 6G researches at each organization are contributing for the forum via article writing, workshop participation. Such effort to build collaborating space had existed since the 5G era, but 6G looks to bring about a more robust, monolithic structure in the research.

In this chapter, key 6G features suggested by these organizations are examined. Although each organization creates its own 6G white paper, the same set of visions and features are shared as the key requirements regardless of publishers. Visions in white papers are crucial in the development of actual technological requirements from now on, which will eventually affect the business operations of stakeholders in the industry. Key features discussed in white papers are summarised as below.

4.2 Key features of 6G

The vision of 6G is quite ambitious. Especially, the target speed, latency, robustness, and density of the network are raised to a whole new level even compared to the latest 5G requirements.

4.2.1 Performance

Looking at Key Performance Indicator (KPI) to indicate the speed and capacity of target 6G performance, the target of 6G is unprecedented to any of the past generations. Figure 9 below summarizes important KPIs of 6G proclaimed in “Key Drivers and Research Challenges for 6G Ubiquitous Wireless Intelligence” (Latva-aho - Leppänen 2019). For example, “Peak Data Rates” is the indicator of how much data can be transferred within a second. The target value of this item is from 100 Gbps (Giga bit per

second) to 1 Tbps (Tera bit per second). This means the target volume of data transmitted in 6G is from 100 to 1000 times higher than that of 5G, which is 1Gbps. Not only the data volume, but the target level of network reliance is close to perfect robustness, with the allowance of only 0.1-millisecond latency and a maximum 1 out of million outages. Considering the future growth of IoT devices and other machine intelligence to use 6G network, the number of devices connected in the certain areas simultaneously (density) is quite high, also with the positioning of centimetre level precision. Furthermore, as environmental sustainability is one of the critical global agendas nowadays, energy efficiency and battery life is another key requirement for every 6G device.

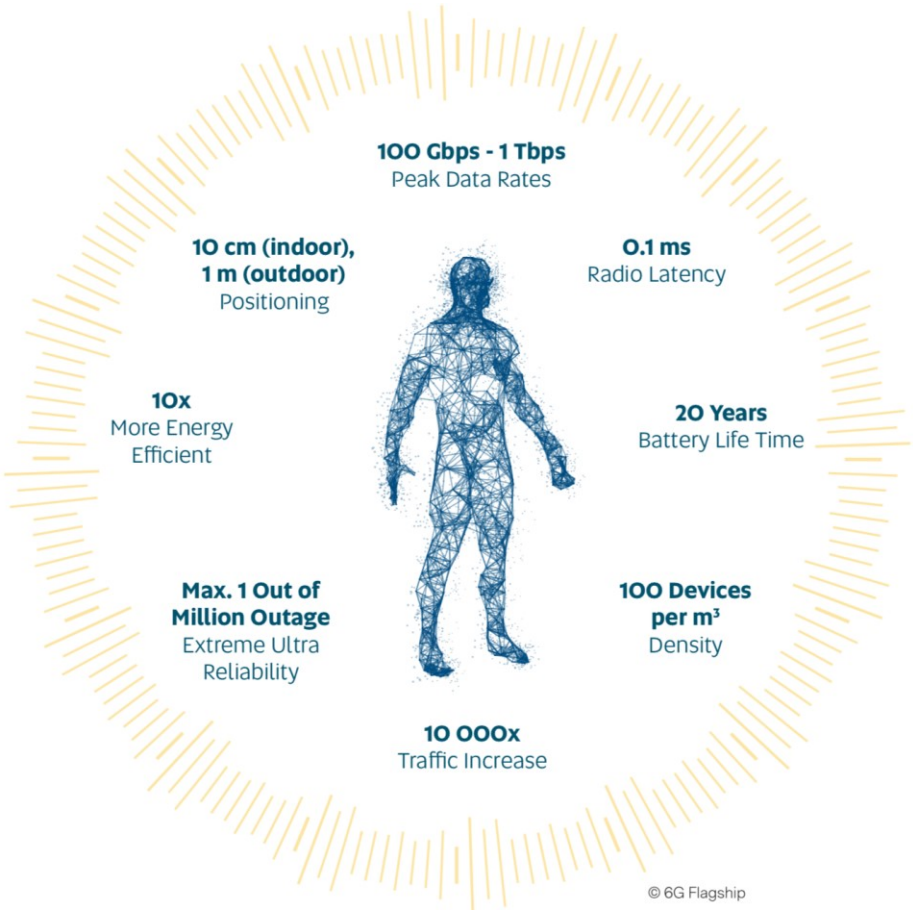

Figure 9. Generic 6G targets from Oulu University's 6G white paper

(Image source : http://jultika.oulu.fi/files/isbn9789526223544.pdf)

4.2.2 Extreme coverage

In the time of 6G, there may not exist a single spot without mobile service. All places that are not currently covered by mobile networks, such as the sky, sea, and space are

aimed to be thoroughly covered in 6G vision. This indicates that even areas without human habitation are to be covered by mobile communication systems, which may open up new opportunities for businesses such as space development or logistics stations for drones, and so forth (NTT Docomo, Inc. 2021).

Such extreme coverage in 6G is anticipated to provide solutions to the digital divide, in which general urban citizens have access to digital service and information while rural inhabitants are having fewer digital services. One white paper from 6G Flagship, "6G White Paper on Connectivity for Remote Areas" specifically discusses this issue of remote access in detail. The white paper suggests future options of mobile technologies to enable extreme terrestrial coverage, and it also mentions the possibility of disruption. Typical MNOs are reluctant to extend coverage to the less populated areas due to insufficient profit generation. Here, micro operators may play an important role to provide connectivity to niche areas, catering to local and customized needs depending on target areas (Saarnisaari 2020). This may invite new operators and more active competition in the market in the future.

4.2.3 Immersive XR and a new form of devices

If the requirement of the aforementioned KPI is achieved, one of the new and distinctive features in 6G will be the novel consumer experiences enabled via an ultra-fast and reliable 6G network. Namely, new user experiences in the digital world through Virtual Reality (VR), Augmented Reality (AR), Immersive Reality (IR), and so on. Often these simulated realities are called "XR" as a whole. Samsung Research (2020) calculated that the current wireless capacity even by 5G is not sufficient to support truly immersive XR. High expectation is on the target capacity of 6G for consumers to experience XR seamlessly. They also estimate that the market sizes for VR and AR will reach 44.7 billion USD and 87 billion USD respectively by 2030. Integration of XR and mobility could be a key factor in the business operations especially for content providers in the era of 6G.

Another distinct characteristic in mobile services in 6G may be a new form of devices. In recent days, smartphones have become the most common mobile device for end-users, however, devices are expected to evolve into smarter, smaller, or more sophisticated forms of wearable devices. In their white paper, Nokia Bell Labs suggest that embedded devices would become common even to the point skin patches or bio-implants may not be so unusual. Touchscreen devices and typing will likely become obsolete, being replaced by gesturing and voice command instead. Furthermore, such devices may

become fully context-aware, predicting users' needs. Combined with artificial intelligence, our interaction with digital world may see a whole new dimension than today (Viswanathan - Mogensen 2020). Figure 10 below shows such a concept of the evolution of devices.

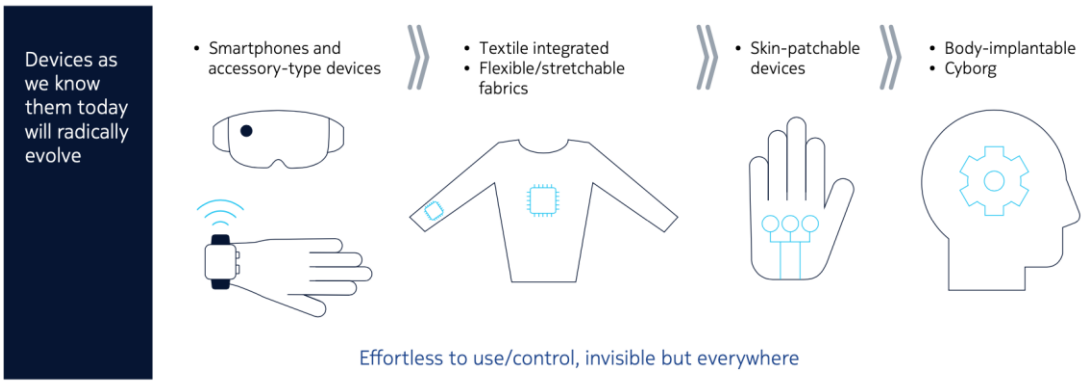

Figure 10. Likely evolution in devices

(Image source : 6G White Paper by Nokia Bell Labs - https://onestore.nokia.com/asset/207766)

4.2.4 Fusion of Digital and Physical World

When XR experience enabled by hyper-speed and connectivity become available to the mass of society, a fusion of digital, or cyber world and physical world is expected to considerable advance. Ericsson (2020) pushes the idea one step further and proclaims the new concept of "Internet of Senses", IoS. Their large-scale survey revealed consumer expectations on the future of online experiences, in which digital technologies will allow humans to experience the world in a new way, by using all of our senses. Most of the survey respondents believe that the advanced VR and AR technologies would make our physical and virtual realities interchangeable. For example, by 2030, more lightweight wearables will become a new norm and allow users to place digital objects into real spaces at such high quality that they would look like real objects. Other senses such as smell and taste are expected to be experienced digitally. Around 2030 and later when 6G emerges, technologies would evolve to the point where people can smell scents in films or advertisements, and experience tastes through devices that digitally replicate the taste of food someone is eating. If achieved, IoS may impact businesses in various sectors significantly. For example, e-commerce experience with multiple senses such as smell, taste, texture

may have a chance to eliminate shopping at brick and wall shops if online purchases can offer the same or even convenient experience than physical stores.

Not only digital experiences at an individual user level, manufacturing and various industries may embrace drastic progress of digital fusion. From the dawn of the 21st century, we are in the midst of the fourth industrial revolution, or "Industry 4.0", where the digital transformation of the business world is explicit (Ghobakhloo 2020). Digital twin, a virtual representation of a physical object or process that works as a digital counterpart, is a key feature of Industry 4.0. It emulates realistic models and behaviour of the target object and enables the interaction with their environment in the real world. Digital twin has a high expectation to revolutionize the design and maintenance processes in many industries, however, it requires a massive amount of capacity at low latency to instantly provide a complete representation of the physical world at any place (Viswanathan - Mogensen 2020).

Another example of integrating the digital experience into the physical world is a high-fidelity mobile hologram. Hologram is "a next generation media technology that can present gestures and facial expressions by means of a holographic display. The content to display can be obtained by means of real-time capture, transmission, and 3D rendering techniques" (Samsung Research 2020). The adoption of 3D holograms has many opportunities from innovative entertainment and enterprise services for gaming, sports, live watching (NTT Docomo, Inc. 2021), to telepresence for both work and social interaction (Viswanathan - Mogensen 2020). It has the potential to heavily impact commercial aspects and social aspects such as human to human interaction. At the same time, hologram display over a mobile device (Figure11 below) is estimated to require an extremely large volume of data, therefore the connectivity and speed of mobile services in the future is the key to provide sufficient and robust services for seamless integration of the digital and physical world.

Figure 11. Hologram displays over mobile devices

(Image source : 6G White Paper by Samsung Research - https://cdn.codeground.org/nsr/downloads/researchareas/20201201_6G_Vision_web.pdf)

4.2.5 Adoption of Artificial Intelligence

The utilisation of Artificial Intelligence (AI) is progressing in many industries, and the mobile wireless world is no exception. To construct mobile wireless networks, mathematical modelling is indispensable to calculate the locations to install base stations to effectively extend the coverage of mobile services. Additionally, continued optimization is required to maintain the coverage whenever new base stations are in place. The current mathematical models are expected to fall short of improving the capacity and performance of mobile networks in the time of 6G, thus machine learning capability of AI will play a crucial role in building and maintaining 6G mobile networks (Samad et al. 2020). Furthermore, machine intelligence is anticipated to be imperative to provide real-time XR experiences. In the future mobile networks, machine intelligence may be placed in every aspect of networks and provide data-oriented, real-time services, which in result may reduce the necessary workforce in the mobile wireless industry.

4.2.6 Network Topology

Along with the introduction of AI, the network architecture of mobile networks may face a radical change in the 6G era. As discussed in the previous chapter, cloudification and virtualization are bringing new changes in the network architecture. Decoupling of hardware and software are progressing, and many of network functionalities are being run on virtualized environments. This trend is expected to continue in the era of 6G, blurring the boundary between conventional Radio Access Network (RAN) and Core Network (Core) instead, edge computing, where computing functionalities are being shifted from centralized servers to edge devices is expected to be mainstream in 6G. To support the ultrafast speed and low latency network, communications going through centralized servers may become a bottleneck. Core functionalities may be merged into RAN elements, and simplified network architecture may emerge (Viswanathan - Mogensen 2020). The reduced number of elements (servers, functions) in mobile networks may likely impact

the profit model of existing network infrastructure vendors. MNOs may welcome this trend as their investment in network facilities may see the reduction.

4.2.7 Social issues

A remarkable point in 6G white papers published by various organizations is the heightened interest in social issues. One of the white papers published by the 6G Flagship collaboration, “White Paper on 6G Drivers and the UN SDGs “ (Matinmikko-Blue et al. 2020) is dedicated specifically to the perspective of how advanced mobile communications could solve the United Nation’s Sustainable Development Goals (SDGs). They address that the mobile communications in 6G shall contribute to achieving SDGs via hyper-connectivity, elimination of digital divide, access to virtual resources. In the white paper by Docomo (2020), mobile communication is expected to bring a wide range of solutions such as telework, remote control, telemedicine, distance education, and autonomous operation of various equipment such as cars. Samsung (2020) also mentions that differences in regional and social infrastructure and economic opportunities may be reduced when 6G networks are widely deployed. Expectations are high in these researches that unprecedented networks in the time of 6G shall be the answer to social issues and tremendously contribute to the quality of human life.

At the same time, it is necessary for the mobile wireless industry itself to consider sustainability when developing future technologies. Climate change is expected to continue to be a global agenda by the 2030s, and the energy consumption of mobile networks and devices will be greatly scrutinized (Viswanathan - Mogensen 2020). Network equipment and devices with lower energy consumption and less impact on environments are critical in the future as well.

Considerations on SDGs shall play a more important role than ever in the coming 6G era.

5 METHODOLOGY, DATA COLLECTION AND ANALYSIS

In this chapter, the research methodology adopted for this Master's Thesis is discussed. To explore new business operations of stakeholders in the mobile wireless industry in the 6G era, a scenario building method is chosen. Heger and Rohrbeck (2012) argue that creating new business fields are characterised by a "multi-dimensional uncertainty", and the following four steps are indispensable to effectively develop new business fields to ensure long-term competitiveness. "(1) integrate multiple perspectives, (2) ensure a high level of participation of the major stakeholders and decision-makers, (3) function despite a high level of uncertainty, and (4) take into account interdependencies between the influencing factors." In their work, a comprehensive framework to integrate multiple corporate foresight methods strategically and cover these four points are proposed.

Scenarios provide answers to these challenging steps, as the major characteristic of scenarios is that they provide a plurality of plausible alternative futures (Yrjölä et al. 2020). For this disposition of scenarios, point (1) in the framework of Heger and Rohrbeck meets the requirement to have multiple perspectives. For point (2), Moqaddamerad et al. (2017.a) suggest that scenario thinking fosters "the organizational learning loop where sharing ideas regarding the emerging trends, building consensus, planning, and acting take place collectively", as the scenario building process involves the direct participation of stakeholders. Furthermore, Schwarz et al. (2019) adopt scenario building to business wargaming to cope with disruptions and uncertainty caused by competitors. They summarize that scenario building enables "the anticipation of less predictable future".

Based on these arguments, this Master's Thesis aims to create scenarios for exploring new business fields, uncertainty, and discontinuities of existing business operations of stakeholders in the mobile wireless industry.

5.1 Data Collection

Three approaches were taken as the data collection for this Master's thesis. The first collection method is the literature review of published 6G white papers, academic articles focusing on technological changes in 6G, and empirical data sources such as company websites of MVNOs or network infrastructure vendors. The second is environment scanning to detect strengthening trends, weak signals, and wild cards to potentially affect the pathways of future development of the mobile wireless industry. Last but the most critical

data collection method is expert interviews to gather the real-time, live opinions from experts who are the forerunners of researches for 6G.

5.1.1 Environment scanning

As preliminary data collection, environment scanning was conducted. Gordon and Glenn (2009) define environmental scanning as the central input to futures research, and futurists perform it in one way or another in their work. Scanning the environment is crucial to identify new events of symptoms that can impact the development of issues of interest in the future. Detection of early warning of important changes in the form of weak signals is indispensable in corporate or strategic foresight work, as it enables organizations to gain lead-time to prepare for any possible important changes in the future. Not only early and weak signals, detection of wild cards is also another indispensable task in futures work. Wild cars are events or developments with a low probability of occurrence, but with high impacts (Peterson et al. 2009). Wild cards can bring catastrophic damages to the pathways of organizations if not properly detected. On the other hand, early identification of wild cards can enable decision-makers to better prepare for disruptions and consider countermeasures ahead of their competitors. Nikolova (2017) states that scanning of wild cards can expand our visibility on futures.

In the research of this Master's Thesis, the first and the most important sources referred is 6G white papers published by organizations. Furthermore, scanning is performed to collect information on megatrends, trends, and emerging technologies that can have impacts or relativity on the development of 6G. Sources used for scanning is publicly available information from reputable research institutions, consultancies, national and international governmental bodies. A few examples of such sources are Organization for Economic Co-operation and Development (OECD), NATO, Defense Advanced Research Projects Agency (DARPA), Sitra (Finland), VTT (Finland), Gartner Inc (USA), and so on.

5.1.2 Expert Interviews

The primary data collection method of this Master's thesis is expert interviews. As the research question aims to question the possibility of new business development in the 6G era, data gathering from stakeholders in the current mobile wireless industry was indispensable. As the development of 6G has not started yet and there has not been a shared,

common understanding on businesses in 6G, qualitative interviews to gather free input were chosen over more structured inquiries such as survey or Delphi.

However, the interview sessions for this Master's thesis are divided into two categories. The first category is the preliminary interviews to research "7G", as mentioned in the previous section "1.2.2 Preliminary expert interviews". The purpose of the interview sessions for this category was to mainly explore the possibility of future advancement of mobile wireless technologies after 6G – which will probably be called "7G" if it follows the tradition. In the interviews belong to this first category, the main questions asked were about the triggers of the development of 7G mobile wireless technologies. Additionally, the trigger of the 6G development and possible changes surrounding the mobile wireless industry including the business aspect were questioned. 4 experts participated in the interviews belong to this first category to explore the possibility of 7G, and they provided insightful opinions both on the 7G and on the 6G development and businesses. The second category of the interviews for this Master's thesis focuses on the business aspects in the 6G era. Another 4 experts participated in the sessions to examine the possible future development of the businesses of the mobile wireless industry.

Regardless of these two categories, the participants of the interview sessions were mainly selected from the participants of two major initiatives of 6G, which are the 6G Flagship project and the 6G Symposium.

Requests for interviews were sent via email. The breakdown of positions of 8 participants in the interviews is listed in the following Table 3.

Table 3. Breakdown of participants

Role	Number of participants	Organizations
MNO	2	Orange, Telefonica
Vendor	5	Nokia (2), Huawei (2), Samsung (1)
6G Initiative Editor	1	6G Symposium

All the interviews were conducted in a semi-structured way. The preliminary questionnaire was sent to interviewees prior to the interview session to give clarity on the research question and the author's interests in the topic. The list of preliminary questions are added in the Appendix section. Sessions were held solely on online platforms, either

Zoom by Zoom Video Corporations, Inc or WebEx by Cisco Systems, Inc as most of the participants were located in distant places outside Finland. The interviews were conducted based on the predefined questionnaire, however, additional ad hoc questions were asked depending on the contents of answers by interviewees. The duration of each interview session was from 45 minutes to 60 minutes depending on the availability of interviewees. The languages used for interviews were English and Japanese. 7 out of 8 interviews were conducted in English, and only 1 interview with a Japanese expert was done in Japanese language. As this particular participant and the author share the same native language (Japanese), it was decided that having an interview in Japanese language would facilitate a more active discussion.

All the participants have deep knowledge and insider views as incumbent players in the mobile wireless industry. They are especially visionary in 6G researches, and 7 out of 8 participants are being actively engaged in forums of 6G, such as 6G Flagship and 6G Symposium. For example, two participants are key authors of white papers of organizations they belong to. For more detail, their names and job titles are listed in the Appendix section of this Master's thesis.

However, the disclaimer is that their opinions shared in the interview do not necessarily reflect the official position of corporations or organizations they belong to. To gather unbridled input to freely explore the future, the author specifically requested interviewees to provide free opinions from the personal perspective of the interviewee, not bounded by the official position of their organisation.

The answers given in the interviews are added in the Appendix section. The script from one interview conducted in Japanese language is translated to English by the author. The permission was given by each participant to cite their names in this Master's thesis. However, upon the request of one participant, the linkage between the participant's names and responses is intentionally hidden. Readers are not able to know which participant gave which statement.

5.2 Data Analysis

The collected data through interviews and environmental scanning are organised through scenario building steps. The steps followed in this research is loosely based on the following eight steps proposed by Schwarz (1996).

- Step1 : Identify Focal Issue or Decision

- Step2 : Key Forces in the Local Environment
- Step3 : Driving Forces
- Step4 : Rank by Importance and Uncertainty
- Step 5 : Selecting Scenario Logics
- Step 6 : Fleshing Out the Scenarios
- Step 7 : Implications
- Step 8 : Selection of Leading Indicators and Signposts

This process is thorough and suitable for organizations to perform scenario creation, most likely with the selected participants to scenario workshop. Especially, from Step two to Step four above shall be conducted most optimally by a team, rather than by a solo individual. Furthermore, Step 7 and 8 above are about the verification of built scenarios. Schwarz recommends monitoring changes in the environment where the focal issue resides after scenario building is completed so that any indication of deviation from the expected scenarios can be detected at an early stage. However, the research question of this Master's thesis is aimed at exploring possible future development of the mobile wireless business in the 6G era and their drivers. It does not target actual decision-making or accurate prediction of the future of a certain organization.

Therefore the eight steps by Schwarz are modified, to be simplified to suit the purpose of this Master's thesis. As the result, the following simplified steps are taken to create scenarios in this thesis.

- Step1 : Identify Focal Issue or Decision

  In this Master's thesis, the research questions described in the first chapter serves as the focal issue. Namely, seeking alternative and multiple futures of the business development of key players in the mobile wireless industry in the 6G era.

- Step 2 : Identify Driving Forces

  The second step is to identify driving forces surrounding the focal issue. Driving forces are factors that influence the development of the focal point. This step is performed first by data collection, which is environmental scanning and expert interviews. As the first step, global megatrends, trends, and emerging technologies in ICT are examined in environment scanning. Collected

information is gathered to cover PESTEC (Political, Economic, Social, Technological, Environmental, Cultural) categories, so that non-technology related drivers are also gathered. Then the second step, expert interviews are conducted. The collected data are examined by the author. Information and keywords relevant to the focal issue are selected solely based on the decision of authors, with the order of the following priorities.

Priority 1 - Information or keywords detected both in environmental scanning and expert interviews have the highest importance. Priority 2 - Information or keywords mentioned in expert interviews alone. Priority 3 – Information found in environmental scanning but not mentioned in expert interviews

- Step 3 : Analysis of Driving Forces

  Driving forces identified in the previous step are organized in the impact-uncertainty matrix to weigh the relevance of each driver.

- Step 4 : Selecting Scenario Logics

  In this step, the logic to be a backbone of scenario creation is examined and selected. This is a critical step in scenario building to determine the scenario narrative and differentiates scenarios from one another. To create multiple scenarios for alternative futures, a matrix with the use of two axes are adopted, which are the X-axis and the Y-axis. The general matrix of a quadrant is in Figure 12 below. The actual value of the X and Y axis are explained in the next chapter.

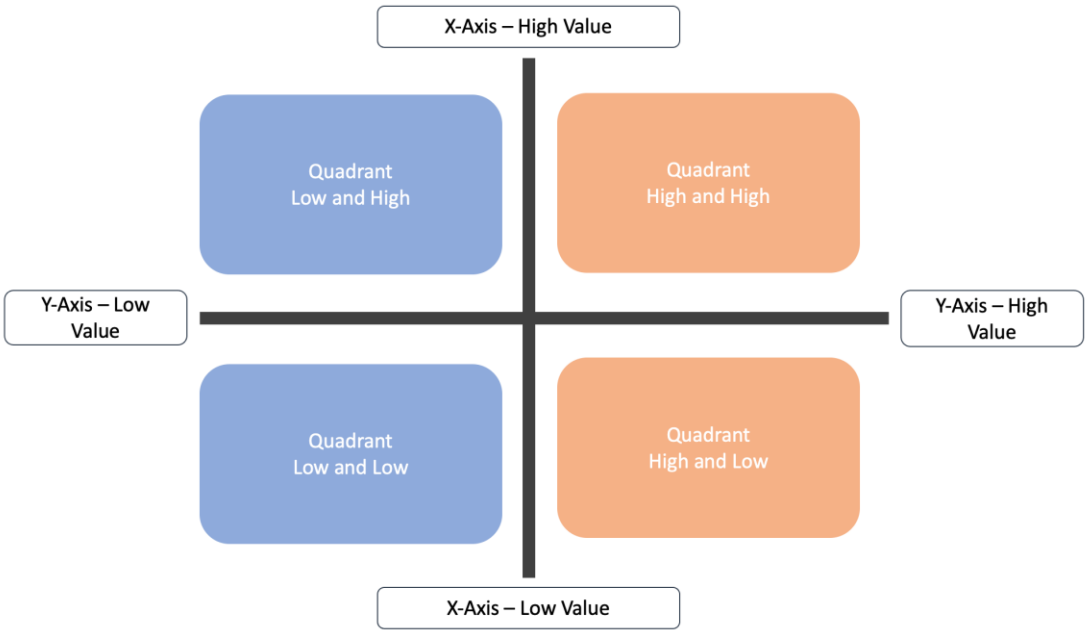

Figure 12. Quadrant to create scenarios

- Step 5 : Fleshing Out the Scenarios

  The last step is finalizing scenarios. Four scenario narratives corresponding to each area in the quadrant are generated. In the following chapter, identified forces and the scenarios as a result of this research are described.

6 RESULT - BUILT SCENARIOS

In this chapter, data gathered from environmental scanning and expert interviews are analysed, and driving forces relevant to the development of 6G technologies and business are identified. Drivers are collected to cover PESTEC categories. Subsequently, important items are laid out in the impact-uncertainty matrix to examine the most relevant drivers to affect the future of businesses in the mobile wireless world. Based on the outcome of the impact-uncertainty analysis, scenario axes are decided. Finally, scenario narratives are fleshed out based on drivers.

6.1 Drivers of changes

The following are driving forces that are likely to impact the development of future businesses in the mobile wireless industry. Driving forces are categorized per PESTEC. For clarification, the source of information of each driver is categorised into two types. The one is information suggested in expert interviews, marked as (I) at the top of the sentence. The other is type (E), meaning the information is searched through environmental scanning. The marking (I,E) represents that the information is found at environmental scanning, and also mentioned by experts in interviews.

- **Political Drivers**
- (E) Governmental policies to invigorate the mobile wireless market is strengthening
- (E) Regulation of spectrum licensing may be loosened
- (I) Rise of India, Latin America, Eastern Europe in mobile technology development
- (I) Regional standard may strengthen, weakening global standardization
- (E) Laws against cybersecurity may strengthen
- (I) The US retreats from the world stage, China becoming the new world leader

- **Economic Drivers**
- (I) Desire for scalable, dynamic, fluid, ad-hoc network architecture
- (I) Emergence of smaller operators to cater to niche markets
- (I,E) Aspiration for new services utilising AR and VR technologies

- (E) Thirst for new content, new applications over mobile devices
- (I) Price for data is becoming zero. Unlimited use of data is taken for granted.
- (I) Demand for private, super-local, customized networks for different industries – satellite, smart factories, automobiles, and so forth.
- (I) Giant IT companies such as Google, Amazon, Facebook, Apple enter the mobile wireless market
- (I) Over The Top (OTT) media players such as Netflix, Amazon Prime and so on enter the mobile wireless market to provide media contents
- (I) Vertical integration with different industries such as the auto industry progresses
- (I,E) Sharing Economy
- (E) Motivation of MNO to lessen the burden of nationwide wireless network development and maintenance

- **Social Drivers**

- (I,E) Sustainable Development Goals (SDGs) by United Nations has gained world popularity
- (I,E) Ageing society is explicit in many developed countries
- (E) Declining birth rate in many developed countries
- (I,E) Social inclusion as a global agenda
- (I,E) Equal opportunities for all populations regardless of regions they inhabit (Elimination of digital divide)
- (I,E) Empowerment of people brought by ubiquitous connectivity
- (I,E) A more open attitude toward a fusion of machine and human intelligence
- (I,E) Human to machine collaboration
- (I,E) Education via digital platforms
- (I,E) Healthcare via digital platforms, telemedicine
- (I,E) Rising Concern about privacy and cybersecurity
- (E) Concentration of wealth, widening gap between the rich and the poor
- (E) Urbanization continues for the next several decades
- (I,E) Agriculture revolution to feed the growing world population

- **Technological Drivers**

- (I,E) New forms of devices emerge. Smaller and wearable, such as VR glasses
- (I,E) Advancement of Artificial Intelligence (AI) technology development
- (I,E) Advancement of Augmented Reality (AR) technology development
- (I,E) Advancement of Virtual Reality (VR) technology development
- (I,E) The emergence of 3D haptic holograms
- (I,E) Fusion of digital and physical world - Digital twins for industrial use and personalised use
- (I,E) Virtualization, cloud solution on general hardware have become common. Bare-metal based solution becomes obsolete
- (I) Software oriented network, software decoupled from dedicated hardware. Off the shelf hardware is commonly in use
- (I) Common use of eSIM. Users can more flexibly change operators.
- (I,E) Smart technologies such as smart homes, smart cities, etc
- (E) Wave of robotics and automation seen in Industry 4.0
- (I,E) Massive deployment of advanced sensor devices
- (I,E) Open RAN. Standardization of open interfaces is progressing.
- (E) Use of higher spectrum band and advanced radio head technologies
- (I,E) Edge computing, decentralization
- (I) Biodevices with nano-level granularity
- (I) Warehouses or unused buildings in cities become new data centres
- (I,E) Evolution of network architecture. The boundary between RAN and Core become blur, context-aware network by machine intelligence is desired
- (I,E) Network slicing and tailored performance for each client
- (I,E) Quantum computing
- (I,E) Space development, cellular network on the moon

- **Environmental Drivers**

- (I,E) Overarching concern on environmental impacts, especially climate change
- (I,E) Sustainability, UN SDGs as a global agenda
- (I) New requirement for future technologies - reduced energy consumption, prolonged battery life, use of recyclable materials
- (I) Cost of renewable energy production may decrease in the future

- **Cultural Drivers**
- (I,E) Aspiration of the general public for a fusion of digital and physical world
- (E) Constant thirst for new experiences
- (E) Access to data, digital platforms is becoming basic human right
- (E) Telepresence, telework is widely accepted after the COVID-19 pandemic
- (E) Growing positive attitude toward sharing economy and open source development
- (E) Not owning a smartphone can be regarded as a personal statement
- (I,E) Concern about data privacy is rising
- (E) Organizations failing to meet Corporate Social Responsibility (CSR) are shunned by consumers

6.2 Analysis of drivers

To elicit the impactful driving forces among collected information, the impact-uncertainty matrix is used. The identified forces are sorted on the impact-uncertainty matrix by assessing each item based on these two points. (1) How large is the impact of the driving force on the future development of the mobile wireless industry. (2) What is the probability of occurrence of each driving force.

The result is shown in Figure 13 illustrating the placement of driving forces on the matrix. The vertical axis is impact assessment. The larger the impact of the driver is, the driver is placed in the upper end in the quadrants, and vice versa. The horizontal axis is uncertainty assessment. The more uncertain the occurrence of the driver is, the more on the right the driver is set and vice versa. The layout, i.e., the assessment is solely done by the judgement by the author, speculating the future impact on the mobile wireless businesses. The judgement is inspired by information brought through expert interviews and environment scanning. For example, A force named “Entry of OTT into the mobile market” is placed at the upper left of the matrix, indicating that this item has less uncertainty and high impact. This is because several experts mentioned the new entry, especially big ICT and media companies. Information acknowledged by several experts is considered to be with less uncertainty. Also, experts emphasized its impact on incumbent companies, thus the assessment of the impact of this driver is high. The rest of the drivers are analyzed similarly, according to information gathered.

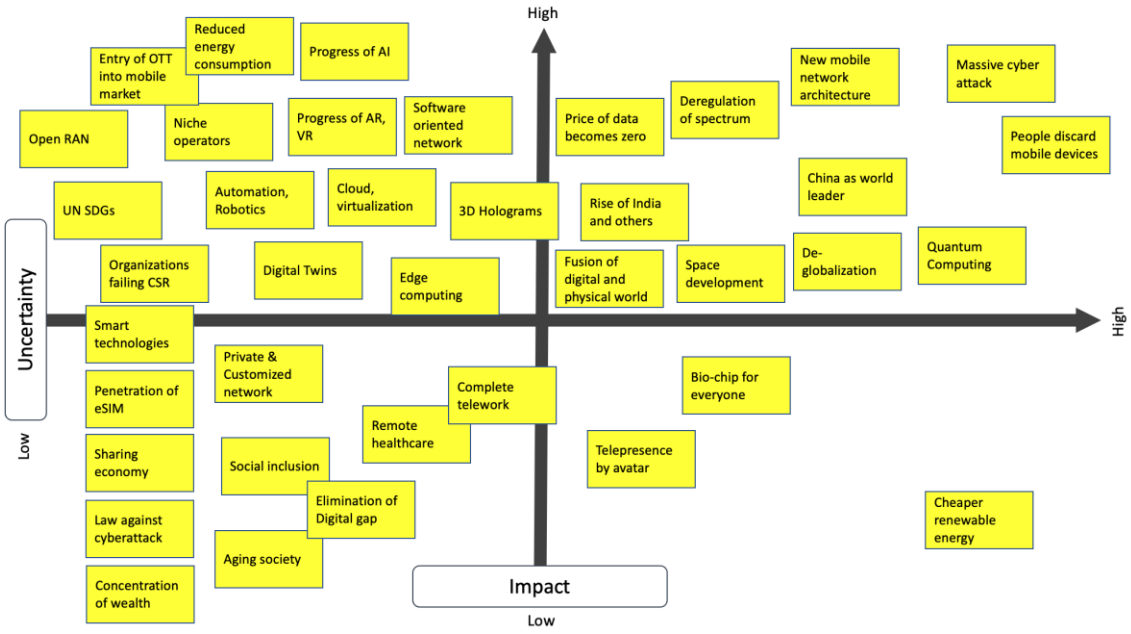

Figure 13. Impact-Uncertainty Matrix

6.3 Scenario matrix

From the process of organizing drivers, key items which can impact the business development in the 6G era are identified. In addition, most of the experts emphasized in interviews that the following features are indispensable when considering the future of the mobile wireless world.

- New entrants into the market are inevitable
- Mega IT companies and OTT is most likely to enter the market
- Meaningful collaboration with new competitors and different industries is imperative
- New contents, new applications based on AR, VR, holograms are awaited
- Sustainability goals need to be incorporated in the development of 6G
- Network architecture will be changed from today

For these points, all the interviewee shared the same view and there were no divergent opinions raised. Based on these key points, the scenario axis are determined. For the attribute used for X0axis, two values as “transformative” and “conservative” is selected, as this Master’s thesis focuses on how the current businesses in the mobile wireless industry

would change in the 6G era. Opinions gained from expert interview sustains this view, as most of the experts suggested that the current mobile wireless industry is rigid, and it will be imperative for it to renew itself.

"Transformative" means that business operations conducted by MNOs or network infrastructure vendors in 6G are different from the ones we know up to the time of 5G. For example, new and revolutionary business models are hatched and become dominant in the industry. On the other hand, "conservative" indicates that key players in the industry maintain the current business operations and do not see many of novelties.

The attribute chosen for Y-axis is "Fall" and "Rise". The reason why these values are adopted is to examine how alternative futures will look like if the mobile wireless industry intentionally chooses to keep the current structure and avoid renewing itself. The current industry landscape is dominated by the oligopoly of a few players and maturing market, as explained in the earlier sections in this thesis. "Rise" signify that the current players in the market shall continue to dominate the market, further strengthen their positions. The opposite value, "Fall" suggests that incumbent major players shall lose their strength seen in today's market, gradually giving up their seats to new entrants.

As the result of marking quadrants with these values, a matrix in the following Figure 14 is created.

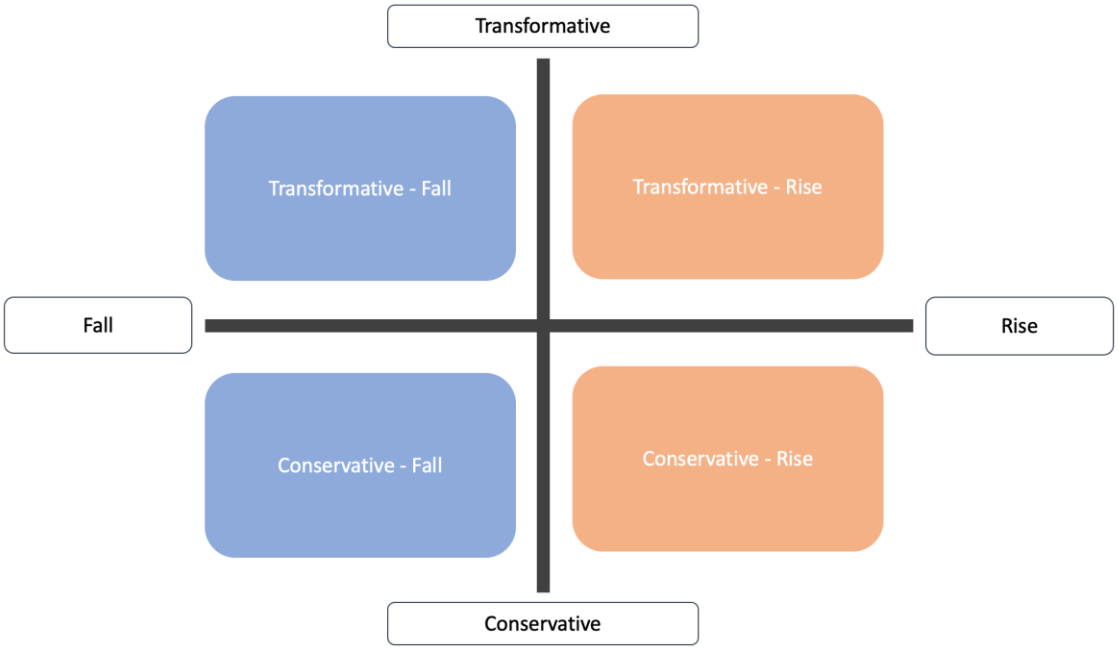

Figure 14. Scenario axes

Subsequently, the storyline of scenarios differentiating each other is generated. In Figure 15 below, the key elements of each scenario is outlined.

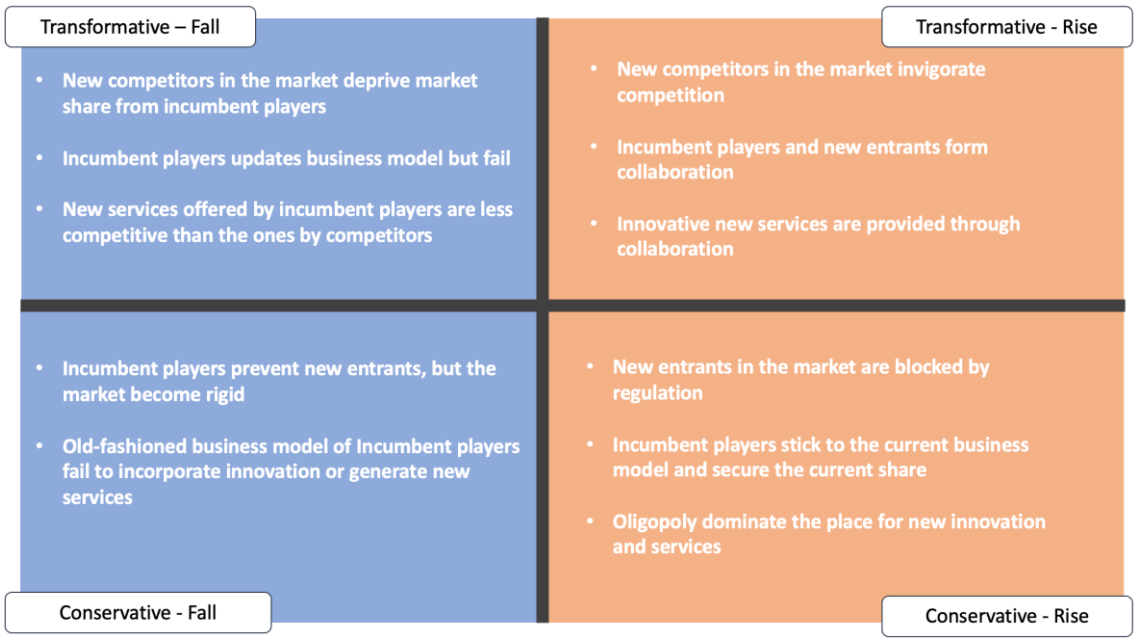

Figure 15. Key elements in scenarios

The viewpoint to determine these elements is whether incumbent players in the market, who are responsible for the current rigid and oligopolistic structure, may keep the current mode of operations or not. Based on these elements, finally, the scenario narrative of each quadrant is generated. The titles and narratives of each scenario are found in the next section.

6.4 Scenario narratives

6.4.1 Target year of scenario narratives

The target year of four scenarios is set to be 2035. This is determined based on the pattern of researches, development, mass commercial deployment of the past generations of mobile wireless technologies up to 5G. For example, 5G was targeted to be commercialized around the year 2020, and the first commercial deployment was done in the year 2019. However, at the initial stage, 5G service was available only in a very limited number of countries. Generally, it takes several years for a new generation of mobile wireless technologies to be widely deployed and reaches a wide range of end-users.

For this reasoning, the target year of scenarios is selected to be 2035, assuming that 6G commercial services would already be commonly available and the landscape surrounding the industry is taking a clear shape.

6.4.2 Titles and PESTEC clarification of scenarios

Scenario names are given to four scenarios considering the key elements of each scenario

- For "Transformative – Fall" quarter
  - Title – "Good ideas. Actions don't follow along"
- For "Transformative – Rise" quarter
  - Title – "Fluid, dynamic, and collaborative"
- For "Conservative – Fall" quarter
  - Title – "Thus passes the glory of the world"
- For "Conservative- Rise" quarter
  - Title – "Leave it to the professional"

Furthermore, to elaborate the difference between each scenario, the main characteristics of each one are picked up and organized per PESTEC fields. The following Table 4 shows the summary of distinctive flavours of each scenario per PESTEC categories.

Table 4. PESTEC for each scenario

	"Good ideas. Actions don't follow along"	**"Fluid, dynamic, and collaborative"**	**"Thus passes the glory of the world"**	**"Leave it to the professional"**
X-Axis: Transformative/Conservative	Transformative	Transformative	Conservative	Conservative
Y-Axis: Rise/Fall	Fall	Rise	Fall	Rise
Political:	Spectrum regulations loosened, new entrants are favored by governments	Spectrum regulations loosened, but fair competition is secured by policies	Spectrum regulations unchanged, the current players keep the majority of spectrum	Spectrum regulations unchanged, the current players keep the majority of spectrum

Economic:	ICT companies and OTT and smaller players enter the market	Collaboration with a variety of industries progress	No new frontiers are to be developed. Market is locked	Status quo - new entrants are not arriving in the market
Social:	ICT companies and OTT are the main solution provider to social issues	Social inclusion is achieved with ubiquitous connectivity achieved by collaborations	Unable to provide solutions to digital divide	Social inclusion is achieved with ubiquitous connectivity achieved solely by incumbents
Technology:	Unable to efficiently integrate emerging technologies after many attempts	Collaboration with new players generate more optimized service and innovation	Incumbents stick to current technologies, ignore emerging technologies	Incumbents evolve existing networks by leveraging AI and past track record
Environment:	Too much weight on sustainability goals decrease the profit of incumbents	Collaboration with new companies to aim for greener solutions	Profit for incumbents is prioritized over sustainability goals	Successfully incorporate UN SDGs into the development of 6G
Culture:	End-users aggressively seek new experiences, AR/VR/Holograms become a norm	End-users aggressively seek new experiences, AR/VR/Holograms become a norm	Rebound from too much digitalized world is seen	End-users aggressively seek new experiences, AR/VR/Holograms become a norm

Although each scenario has different characteristics, several assumptions are common in all of these scenarios. By the year 2035, it is expected that 6G commercial deployments are steadily progressing and users are expecting versatile services through 6G. For example, end-users are enjoying hyper-fast, novel experiences empowered by emerging technologies such as AR, VR, 3D Holograms. Enterprise sectors desire flexible and customized networks catering to different business demands.

Such shared assumptions are summarized in the next subsection, followed by different, dedicated narratives for each of scenario.

6.4.3 A shared narrative of assumptions – base background of each scenario

The world has seen the initial commercial network launch of 6G in the year 2029, about six months earlier than the year 2030 which the industry had aimed as the start year of 6G service. At first, the deployment of the 6G networks was not straightforward, as the new performance and reliability requirement in 6G had forced the network architecture

to be progressive and network architecture was drastically updated than the ones of earlier generations in 4G and 5G. By the year 2035, the industry has successfully deployed 6G networks in mass and they are able to provide stable 6G commercial services to end-users.

Emerging technologies, such as AR, VR, and 3D Holograms are widely available due to the technological advancement in the past 15 years. Nowadays most digital contents are featuring these mixed realities functionalities to offer novel user experiences which are almost indistinguishable from than physical, real world. Social Network Service (SNS) are still commonly used, and users upload their posts to the SNS platform from anywhere, anytime. Viewers enjoy such posts on their mobile devices featuring AR and hologram functionalities as if the experiences shared by other people are happening in front of them. These high data-intensive contents are exchanged instantly thanks to the ultra-fast network enabled by 6G mobile networks.

These technologies are not only entertaining end-users but also various industries are reliant on the super-fast connectivity in the time of 6G. For example, autonomous driving cars are now occupying half of the fleet worldwide. Vehicles for personal use and commercial fleet such as buses are driven autonomously empowered by AI and mobility of 6G with the highest reliability. Remote health treatment and education based on digital platforms are common. People living in remote areas are able to have the same quality of service as city inhabitants, which lead to the lesser digital divide in society.

In such a rapidly digitalizing society, the demands from users for mobility and mobile services are becoming more and more diverse. Although the majority of end-users desire networks fast enough to fully enjoy content featured with AR, VR, Hologram functionalities, the rest, the minority of users are not seeking drastic fast networks. On the enterprise side, each organization is in the need to have private and customized mobile services for their businesses. Some require faster networks with higher capacity, while others request bare minimum networks with lower subscription costs. The performance requirement differs per organization.

In the era of 6G, networks need to be more flexible and dynamic compared to the previous generations. 6G visions and targets aim to expect networks to be built on completely virtualized environments except for radio antennas. Furthermore, computing functions are offset to peripheral, edge devices rather than at the cluster of central servers located in the centralized network centres.

6.4.4 Narrative for scenario 1 – “Good ideas, Actions don’t follow along”

Before the first 6G commercial service was launched, governments in many countries loosened the regulation of spectrum assignment to invite new competitors into the market. This movement devasted the businesses of existing major companies in the mobile wireless industry. In 6G, new frequency bands are in use to support the 6G requirement, however, they are allocated to new competitors in the market as well. The allocated band per company becomes smaller and the competition has become fierce among conventional players and new players.

Mega ICT companies such as Google or Amazon, along with Over The Top (OTT) media companies acquired frequency bands and embarked upon the mobile wireless business. With massive computing power at their existing cloud and virtualization platform, they are succeeding in managing 6G mobile networks at virtualized platforms efficiently. Furthermore, with AI-empowered algorithms combined with their past database about user behaviours, they are now providing flexible, customized, and competitive data subscription plans catering to each mobile user.

Smaller companies are also actively entering the market, aiming to fulfil the niche demands of small enterprises. Some are excelling at providing super small edge computing servers which can be installed in limited spaces.

In such a rapidly changing industry, the conventional major companies of MNOs and network infrastructure vendors who used to dominate the mobile wireless industry are finding it hard to cater their services to the various demands of users. Up to the time of 5G, MNOs had built a nationwide network and offered a fixed set of subscription packages for all uses. Such a business model has become obsolete in the 6G era, which make conventional telco companies struggle to adapt to new business requirements. Conventional MNOs still provide nationwide networks for 4G and 5G to keep the backward compatibility for users who still use services of older generations. However such legacy assets are becoming a major burden to them as the maintenance cost and effort are becoming enormous compared to the revenue gained by loyal 4G and 5G customers. Network infrastructure vendors are also struggling as the revenue of selling dedicated hardware has decreased significantly. As 6G networks are more fluid and modular, the differentiation of RAN and Core networks in the backbone networks has diminished. The type and kind of network elements consisting 6G networks have decreased significantly, which has led to the decreased profit to network infrastructure vendors.

To address this situation, conventional companies try to metamorphose themselves into new business entities in the market, to no avail. To compete with OTT companies, MNOs try to offer content over AR, VR, and holograms dedicated only to their subscribers. However, they cannot beat OTTs as such giant ICT companies have already acquired most of the promising start-ups specializing in media contents creation. They create and offer innovative content all the time utilising their massive, accumulated knowledge on user behaviour. Then, to support more private and customized networks for enterprises, MNOs try to adopt new, lower priced subscription systems. However, they are not profitable enough to secure the maintenance cost of old networks of 4G and 5G, and also new networks for 6G. Then they attempt to fully utilise MVNO system to collect the cost of maintaining old networks and invite new competitors as MVNO partners. However, as a result, many end-users leave the existing major MNOs and become new users of new MVNOs, attracted by lower subscriptions costs and novel services provided by them. The churn rate of subscription users is too high so that the existing MNOs cannot earn enough profit to keep their services. As a result, many major MNOs fall apart, unable to maintain profitability. They break their companies up into smaller pieces of business entities and sell them to new competitors.

Looking at the network infrastructure vendors, they have also failed to adjust themselves to the new era of 6G. Requirements of 6G force infrastructure vendors to produce versatile products. Any network elements need to be environmentally friendly with minimum energy consumption, and they need to function as edge devices. It is necessary for the existing network infrastructure vendors to stop their old product lines and start new lines to produce new products only applicable for 6G. In addition, many network infrastructure vendors also attempt to compensate for their loss caused by the decrease in hardware sales. For example, they produce new forms of mobile devices, mostly in the form of wearable glasses or accessories. However, the time to come up with a revolutionary device is too short, and they end up losing to more sophisticated devices offered by giant companies such as Apple. After distributing a lot of effort and capital into several products line, they found that none of them is novel or competitive enough to beat their new competitors.

In this scenario, the successful players in the mobile wireless industry up to the 5G era shall fall in the time of 6G. They are being unable to adapt to new business environments in 6G although they attempted to try out new business ideas.

6.4.5 Narrative of scenario 2 – "Fluid, dynamic, and collaborative"

The visions of 6G proclaiming ultra-fast, reliable, capable networks have attracted governments in many countries, and they have had high expectations that 6G shall provide solutions to social issues especially the digital divide between urban and rural inhabitants. Prior to the 6G commercial launch, governments loosened regulations on spectrum use so that more new competitors could enter the mobile wireless market.

The major players of MNOs and network infrastructure vendors in the mobile wireless industry had long anticipated that barrier of entry in the market will be lowered, even while 6G specifications had been determined from around the year 2021. MNOs and network infrastructure vendors were leaders in finalizing technical specifications of 6G, thus they are able to grasp the coming changes and had time to review their business models before the commercial launch of 6G. The requirements of ultra-fast and reliable networks in 6G require computing functionalities performed at the edge rather than centralized servers seen in past networks up to 5G. Furthermore, elastic and easily scalable networks is a mandatory condition to serve various demands from enterprise users.

First, existing network infrastructure vendors proactively approached top ICT companies who own and provide general cloud services. Virtualization and cloud are mandatory requirements to achieve flexible networks. Up to 5G, network infrastructure vendors either developed their special hardware for the radio network or reused generic hardware provided by third-party vendors. For virtualization and cloud services as well, most network infrastructure vendors purchased licenses of virtualization technologies and run their own specific software on top of it. To mitigate R&D costs for the infrastructure of the virtualization layer, they proposed a collaboration with OTT companies to develop a new set of virtualization infrastructure best suitable for mobile networks. For example, Ericsson has co-founded a new subsidiary company with Amazon. The joint company reuse the technologies and knowledge-based on Amazon Web Service (AWS) and developed new virtualization middleware capable to run radio network software to achieve dynamic and reliant networks with ultra-low latency. Furthermore, the utilisation of artificial intelligence (AI) is a key enabler of 6G. To achieve fluid and flexible networks based on virtualized platforms, optimization by AI has become common. Antenna locations and performance of networks are autonomously controlled by AI. Major network infrastructure vendors are the first ones to have teamed up with companies providing AI algorithms to have better-optimized network, ahead of any new competitors in the market.

The businesses of mobile networks are more and more software-oriented in the 6G era. Traditionally, telecom operators own centralized network centres and locate their Core network elements there. In many cases, hundreds of servers were being run in a network centre, which incurred a massive cost for electricity and maintenance personnel. With the network architecture of 6G being more reliant on virtualization and edge computing, the necessity of centralized servers are becoming less. To support the requirement of 6G of ultra-fast, low-latency networks, computing functionalities are offset to smaller-scaled edge servers. This new network architecture has worked out in favour of both MNOs and their valuable enterprise customers. MNOs have set up a new business model in the joint effort with network infrastructure vendors to bring "network centres" to the premises of enterprise users. Vendors migrated mobile network functionalities previously burdened by dedicated network element servers into software only elements. As they do not require dedicated hardware, the software can be directly installed at computing devices owned by customers. They are flexible and scalable according to each user's demand on performance. MNOs lease a set of software and radio antennas to enterprise users, and most mobile network functionalities are being operated in such customer's office buildings. With this model, MNOs have reduced the running cost of network centres significantly.

In the time of 6G, a large effort to diminish the digital divide has been visible, with the aim to cover all the surface of the earth with mobile services. It is the era of extreme coverage with the idea that no matter where a user is, mobile services should be provided. To achieve this target, energy-efficient radio antenna has been an important key. Radio antennas in 6G must be enormously efficient in energy consumption or capable of self-generating energy from natural resources such as wind and solar power. Network infrastructure vendors have acquired start-up companies specializing in novel renewable energy production. For example, Samsung has set up a joint venture with one of the start-ups that focuses on the technology to create electricity out of thin air. Also, radio antennas made of new materials such as algae and fungi are gaining attention for several years now. Space development is also becoming an important source of new business development. In the year 2023, Nokia had installed the first-ever 4G cellular network on the moon in the collaboration with NASA. The moon cellular network was upgraded to 5G after several years, and now it is being upgraded to a 6G network. Upon this success of Nokia, Nokia has set up a new subsidiary company with SpaceX, an American aerospace

manufacturer, to specifically develop a new cellular system to be deployed on Mars in near future.

In this scenario, the collaboration with new competitors and different industries than the mobile wireless industry is the key to success. Most likely, new entrants into the market would be inevitable in the time of 6G. Rather than competing with them squarely, the effort to find meaningful collaborations would be critical for incumbent MNOs and vendors to survive. In this scenario, existing mobile wireless companies need to make their organizations as fluid and flexible as possible, as the network architecture and demands from end-users in the 6G era would also be fluid.

6.4.6 Narrative of scenario 3 – "Thus passes the glory of the world"

In 2035, the commercial deployment of 6G networks has been progressing. MNOs are investing a large amount of money into the advertisement of their services in the 6G era, in an attempt to steal subscribers from rival MNOs. Despite the desperate effort of MNO companies to increase end-users, the new subscriptions are just growing at a sluggish pace.

Until today, governments in most countries have been hesitant to update the regulation of spectrum use due to the cumbersome management work when the number of spectrum holders increases. Additionally, major corporations of MNOs and network infrastructure companies had vigorously lobbied politicians to block new entrants to the market in the effort to defend their existing market share. The effort paid off, and spectrum regulations remain unchanged for the past 15 years. It means that it is extremely challenging for new competitors to enter the market.

At the same time, incumbent major MNOs have been struggling to renew their business models and increase their revenue. The mobile wireless market has already been mature since the time of 4G or 5G. The share of the pie is limited, and MNOs are unable to find a way to drastically increase their subscription base. As a result, existing MNOs are desperate to increase their subscriptions by robbing users of competitors. MNOs are making much effort to attract users with dedicated media content utilising AR, VR, Hologram displays, but it is hard to make differentiation and get ahead of competitors.

Network infrastructure vendors are also facing a hard time. As the new network architecture of 6G is more and more reliant on software, their previous business models to sell both software and dedicated hardware are no longer profitable in the 6G era. Radio antennas are still hardware-based, thus network infrastructure vendors increase the price

of radio heads gradually. However, at the same time, the movement of Open RAN, which is to make radio interfaces open to new vendors is impacting the existing major infrastructure vendors. New competitors are trying to offer radio antennas with more competitive prices, however, the business is not lucrative either, again as the mobile wireless industry itself is mature.

Both MNOs and network infrastructure vendors have not changed their business models drastically in the past years since 5G. Meaning, they have lived in a closed ecosystem. MNOs are reliant on the subscription fees of end-users and infrastructure vendors are dependent on the revenue earned from MNOs which is decreasing year by year as there have not been major investments done for the development of new coverage areas. Although there had been discussions about eliminating the digital divide per region by extending coverage area, expected small revenue from remote areas has made MNOs reluctant to make a big investment in the exploration of new coverage areas.

The tight financials of existing players have failed to nourish a place for innovations and services. MNOs and vendors are busy with maintaining the current market share and they do not have the affluent energy to invest in emerging technologies. Furthermore, many of such companies are not successful in achieving UN SDGs. Energy consumption of mobile wireless products has not been much improved from the previous generations.

As a result, even in the time of 6G, both MNOs and network infrastructure vendors have not found a way to expand their businesses yet. With such a background, against all the hype and expectations on 6G, the mobile fee in the 6G era has been critically expensive, as MNOs are trying to translate their investment cost onto mobile subscription fees. End-users seeking novel experiences are repelling increasing fees and are now trying to use mobile services less and less. Instead, they enjoy data-heavy content using VR, AR, Holograms under the environment where WiFi service is available. Only industries that require mobility as a mandatory condition, such as auto industries to offer self-driving cars are using the mobile services provided by MNOs. However such valuable customers are also frustrated with critically expensive mobile services.

The backlash against such an ever-continuing oligopoly by a subset of incumbent players is growing significantly. A variety of industries are now aggressively lobbying politicians to change laws to make spectrum use freer and invite new competitors into the market. Upon such requests, governments in many countries are also considering new regulations to cap the growing subscription fees, and more importantly, researches for a new generation of mobile wireless technologies are now strictly controlled by

governmental bodies. Politicians have concluded that the current predicament in the mobile wireless world has come from the fact that the development of specifications of 6G had been dominated by market-leading MNOs and network infrastructure vendors. They target to eliminate a future generation of mobile wireless technologies which are in favour of incumbent major companies.

In this scenario, the players in the mobile wireless market manage to maintain their regimes and continue to dominate the market. However, at the same time, the effort to keep the oligopoly has invited the deadlock of the market without buffer for future growth.

6.4.7 Narrative of scenario 4 – "Leave it to the professional"

In the year 2035, people are fully enjoying experiences through novel technologies of AR, VR, 3D Holograms over their mobile devices. Nowadays mobile phones are less seen among users, but smaller and more sophisticated wearable devices in the form of glasses, bracelets, or small chips attached to the skin are becoming common. Not only entertainment, most of the infrastructure for a living is now built on the ultra-fast, reliable networks of 6G. People have more flexible choices in living and working places, as telework and telemedicine are available almost everywhere on the earth. Work meetings can be conducted remotely as if workers are in the same space thanks to real-life 3D holograms. Health conditions are constantly monitored by the aforementioned wearable devices and the data are managed by doctors in remote hospitals.

The world has now observed the visions of 6G set by leading companies in the mobile wireless industry come true. Until this day, the industry has paid an enormous amount of effort. Major corporations of MNOs and network infrastructure companies had vigorously lobbied to politicians to block new entrants to the market in the effort to defend their existing market share. The effort paid off, and spectrum regulations remain unchanged for the past 15 years. It means that it is extremely challenging for new competitors to enter the market.

In the bubble unthreatened by new competitors, key players in the industry have set out new projects to become a key revenue source in the 6G era - they have determined UN SDGs to be the key enabler of success in the time of the new generation of mobile wireless technologies. As most of the densely populated terrestrial areas are already covered by the existing mobile wireless networks, the industry has decided to feed their way into the excavation of new coverage area. This goes beyond terrestrial areas and expands into the sea, mountains, and spaces. From the early days of 6G researches, network

infrastructure vendors have put massive effort into the development of new radio antennas which can be usable in extreme conditions. Vendors have acquired start-ups and small-scaled companies specializing in new raw materials, nanotechnologies, to develop radio heads with new materials sustainable in areas where frequent maintenance work is challenging. Furthermore, many of MNOs have acquired orders from governmental bodies to enable equal access to data in remote areas in correspondence to one of the goals in SDGs to eliminate the digital gap between urban and rural areas, which has secured a steady revenue stream.

In addition, both MNOs and network infrastructure vendors have made a great investment in the application of artificial intelligence (AI). The networks of 6G are run on virtualized environments to achieve flexibility and scalability. Network functionalities can scale themselves up or down depending on real-time demand by end-users. To manage such a fluid network, the utilisation of AI is indispensable. With the intelligence accumulated by machine learning of AI, network operations are optimized to consume minimum power.

User subscription fees are also dynamic, based on the demands of users. Especially enterprise users have their own requirements in performance and customized network catering to each demand is desired. AI-based, flexible virtual solutions are able to answer the demand for more personalized networks. With the use of AI, companies in the mobile wireless industry have been successful in cutting down human resources and generating profit from flexible network solutions.

In this scenario, the structure of the mobile wireless industry remains unchanged from the time of 5G. The key enabler is the use of AI for optimization, and how companies find a profitable source of revenue in the mature market. The possible areas to be explored are an extreme surface of the earth, space, and how the industry responds to SDGs.

7 DISCUSSION AND CONCLUSION

7.1 Discussions

In the attempt to explore the future development of the mobile wireless business world, four scenario narratives were created in this Master's thesis. The data gathered from environment scanning, the expert interviews, and the scenario building process have clarified several outstanding phenomena to possibly influence the future of businesses in the mobile wireless industry. The notable part found in the research is that most of the experts shared the same view that new market entrants, competitions with new players are anticipated. In addition, the expectations of experts suggested that the demands of customers would be diverse. The current business model of conventional MNOs to provide nationwide networks with fixed-mobile fees for most users would most likely be obsolete. Furthermore, the performance of 6G mobile networks aimed at 6G white papers are raised to a different level than previous generations. Ultra-fast and reliable networks with massive capacity and lowest latency would force the network architecture of mobile networks to be transformed to be more optimized ones. This will directly impact the business models of network infrastructure vendors. All of these insights point out the possibility that the bearer of mobile services in the future, i.e, the mobile wireless industry may be taking a quite different shape than today. The oligopoly we observe in the current market may disperse with the entry of competitors. As mobile services are an integral part of our modern lives, the development of businesses in 6G could affect the future of individual users, and also of the whole society.

This Master's thesis shed a light on the possible future development of the business operations of incumbent giants in the mobile wireless industry through four scenario narratives. However, the research of this Master's thesis has also revealed the limitations and the room for further researches in the future. The limitations are explicit in the following two points. Firstly, there is a possibility that different scenarios may have been sketched out as the result of this Master's thesis. Although the main part of the information utilised for the scenario building came from the real voice of forerunners belonging to the mobile wireless industry, the number of interview participants can be considered small. Due to the limitation of time for the research, only eight people were able to participated in the interviews. While most of the participants shared the same view on the necessity of a change of the industry and surrounding driving forces, there could be a possibility that

driving forces formed from the interviews might have contained different views if there were more participants. Furthermore, the insights provided by the experts is based on their speculations. All the interviewees have long years of working experience in the mobile industry and their insights are sustained by such real-life experiences. However, it must be mentioned that their input is not analyzed or proof-checked quantitatively. In addition to the limited number of the interview participants, the limitation risen by the nature of researches done by a solo researcher is explicit. It is a fact that the work was completely conducted by the author alone. The evaluation of gathered data, the building of scenario logic were solely made by the author's intuition, which may have led to the lack of objectivity in scenario narratives. For example, In the Impact-Uncertainty matrix (in section 6.2) played an important role in the process of scenario building to decide scenario axes. However, most drivers are listed in the quadrants with lower uncertainty. The assessment of each driver was conducted by the author based on the desktop researches and the input from the expert interviews. While the insights from experts are reflecting solid trends and anticipations in the industry, it also suggests the challenge of crossing the boundary of "common senses" in the target industry. Integrating novel, unthinkable, and out-of-the-box views to scenarios helps creating a space for freer and more stimulative future developments, however, it was challenging to integrate audacious views outside the common senses of the chosen experts for this Master's thesis.

The second limitation is about the stage of the researches for 6G. Although active, the discussions and researches for 6G are still in their early phase. The technical requirements define the product designs of network equipment in 6G networks, thus greatly impact the business operations of the companies in the mobile wireless industry. The more concrete the requirements shall be, the more specific scenario buildings will be possible. For example, new requirements of 6G may require new and unconventional product developments. They may reveal weaknesses of the incumbent players and suggest the entrants of new competitors from certain industries. However, at the moment, researches for 6G are still in visioning phase. Thus the scenarios built in this Master's thesis show the characteristic of being the general descriptions of future images. Furthermore, scenarios created for this Master's thesis do not aim to be utilised for strategic foresight of certain organizations, therefore they do not serve the purpose of making immediate strategic decisions based on a focal issue.

However, although being high-level, the scenarios built in this Master's thesis still elicit key drivers of changes and offer hints for the development pathways for future

business operations of the incumbent players in the mobile wireless industry. It is fair to assume that the severe performance requirements of 6G will bring about disruptions to their businesses. Most likely, network architecture will be drastically changed to cater to diverse demands by individual and enterprise customers. The trend of open source and Open RAN already seen today will open a door to invite more competitors in the market. At the same time, sustainable development will become an integral issue when developing new devices and networks as represented by the rise of the UN SDGs. How the incumbent players find a way to incorporate these critical drivers would decide the future pathways of them. For example, one of the four scenarios, "Transformative – Rise" scenario discussed the potential collaboration with diverse industries outside the mobile wireless world. The incumbent players may benefit from the early researches on the possibilities of collaboration with potential competitors, rather than focusing on eliminating new entrants. There is an unlimited space of future researches and strategic foresight while waiting for the year 2030.

7.2 Conclusions

In this Master's thesis, the author attempted to explore alternative futures with an effort to identify driving forces which have influence to reshape the business world of the mobile wireless industry in the future, specifically when the new, sixth generation of mobile wireless technologies are commercially available. While the current industry is looking ahead to the future and shaping visions of mobile technologies in the 6G era, the potential impacts and disruptions brought by 6G on their current business operations have not been strongly emphasized in research papers of 6G. Considering the target year of the commercial service of 6G is being set to be 2030, the industry has an urgent need to prepare itself against upcoming changes in less than a decade. It is imperative for the industry to have a clear view of both known and unknown trends, signals, drivers to affect their business operations. Furthermore, having as diverse and multiple views as possible on possible future pathways is critical in dynamic environments.

To serve this purpose, this Master's thesis adopted scenario building as the method to explore several possible development pathways of the mobile wireless industry. As summarized by Bell (1997), scenarios are a tool commonly used to seek alternative options of future possibilities, thus are applicable to the research questions of this Master's thesis. To create scenarios, literature review, environmental scanning, and expert interviews were conducted. Eight experts who belong to leading companies of either MNOs

or network infrastructure vendors cooperated in interviews. Most of the interview participants are involved in the discussions led by the international 6G forums, 6G Flagship or 6G Symposium. Their opinions are not bound by organizations they belong to, but are free and imaginative based on personal experiences and viewpoints. Data gathered in the interview sessions had become the foundation of scenario building work by the author. As the outcome of the research, this Master's Theis produced four scenario narratives reflecting upon the possible future development of the current leading players in the mobile wireless industry. The scenario axes were determined from the perspective of whether the current industry up to the time of 5G could maintain the current structure of businesses that are described as closed and rigid by the interview participants, or, they would be forced to go through a transformation. The four scenarios differentiate each other based on the parameters of how transformative the industry would be, and how successful their business operations in the future would be.

The produced scenarios suggest that disruptions are awaiting in the pathways of future developments of the incumbent players in the mobile wireless industry. Visions of 6G and the requirements being analysed as of today will most likely invite many new opportunities in the market. At the same time, the scenarios also indicate the opportunities for future business developments for the incumbent players.

This Master's thesis has only scratched the surface of possible, alternative futures of the mobile wireless industry in the 6G era. The continuous foresight effort to deep-dive the pathways of the industry is awaited.

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APPENDICES

In this section of Appendices, the list of the interview participants, the description about semi-structured interview for this Master's Thesis, the scripts of each interview are attached. Regarding the interview scripts, eight scripts from eight interview sessions are attached. However, upon the request from one participant, the relationship between interview script and the identify of participant is not clarified intentionally. Therefore in the following sections from Appendix C, interview script per person is labelled as "Interview script of participant #1,2,3…8".

Appendix A : Interview Participants

The names of interview participants, the organizations they belong to, and their titles are as follows.

Table 5. Details of interview participants

Name	Organization	Title
Seppo Yrjölä	Nokia Corporation / University of Oulu	Principal Engineer at Nokia Enterprise / Professor of Practice
Mérouane Debbah	Huawei Technologies Co., Ltd.	Vice-President of the Huawei France Research Center
Eric Hardouin	Orange S.A.	The director of the "Ambient Connectivity" research
Masao Akata	Huawei Technologies Japan	Chief Technology Officer, Japan office
Alex Lawrence	6GWorld	Managing Editor at 6GWorld
Harish Viswanathan	Nokia Corporation	Head of the Radio Systems Research Group
Juho Lee	Samsung Electronics	Fellow (technical SVP)
Diego R. Lopez	Telefonica S.A.	Senior Technology Expert, in charge of the Technology Exploration activities within the GCTIO Unit

Appendix B : Semi-structured interview

All of the 8 interviews conducted for this Master's Thesis took a form of semi-structured interviews. The author prepared a set of predetermined questions and sent them to the participants before the beginning of each session, two days prior to the interview by average. The interviewees had time to grasp the questions beforehand. Each interview started with the predetermined questions, however, additional and ad-hoc questions were asked depending on the answers made by the participants to the preliminary questionnaire.

As mentioned in the previous sections, "1.2.2 Preliminary expert interviews" and "5.1.2 Expert Interviews", the interview sessions conducted for this Master's thesis are divided into two categories. The first category is the preliminary interviews to explore the possibility of 7G development, and the second is the interviews focusing on the businesses in the 6G era. However, in the interviews belong to the first category as well, potential impacts on the businesses of the mobile wireless industry were also discussed with participants.

The sets of the predetermined questionnaire are as following.

Predetermined questionnaire for category 1 interviews

- Researches of 6G targeting 2030 are becoming active. What do you think were the main drivers to start 6G research ?
- From your own perspective, how 6G will impact our daily lifestyle ?
- Similarly, how 6G will impact our human to human communication ?
- What would be the potential downside on society (human communication, economy, education, sustainability, or anything) brought by 6G ?
- How do you think 6G will change the business models of manufacturers and Mobile Network Operators ?
- Do you think that 6G will impact the current political systems ?
- Do you think new generation of mobile wireless technologies after 6G (temporarily call it "7G") is necessary ?
- If yes, when do you think will be the target year of 7G realization ?
- How do you expect the research / discussion of 7G will start ? Who will be the key players ?
- What do you think would be the megatrends when the research / discussion of 7G starts ? (For example, climate change, etc.)

Predetermined questionnaire for category 2 interviews

- Current ecosystem surrounding the business of mobile wireless industry can be described as rather closed – MNOs with radio frequency licenses given by government, subset of network infrastructure vendors (e.g. Nokia, Huawei, Ericsson), smartphone makers (Apple, Huawei, etc) are dominating the market. Do you think that this existing structure will change in 6G era ?
- If yes, what is what about 6G will be pushing the change ? (Any particular reasons with 6G ?)
- What kind of new market, new service, new product will emerge in 6G ?
- Do you expect new players would emerge in mobile wireless business ecosystem ? If yes, who are they ?
- MNO – Will MNO need to change their business model based on user subscription to different model ?
- MNO – What kind of services can MNO offer to end users in 6G time ?
- MNO - Do you expect any collaboration between MNO and new players in 6G ?
- Vendors - Current network infrastructure vendors raise profit by selling radio, core, OSS systems over dedicated HW or licensed software. In the time of 6G, does this business model need to be changed ?
- If the answer to above question is yes, then how they generate profits in alternative ways ?
- If the existing business models up to 5G need to be changed in 6G era, what would be the drivers in technologies area ? (e.g. Open source, AI, Distributed Ledger Technology, Quantum, etc)
- Similarly, what would be the drivers in cultural area ? (e.g. people's attitude toward technology, lifestyle change, etc)
- What would be the drivers in political area ? (e.g. Legislation about radio frequency, etc)
- What would be the drivers in economic area ? (e.g. platform economy, etc)
- What would be the drivers in societal area ? (e.g. More awareness toward environment, UN SDGs, etc)

Appendix C : Interview Script of Participant #1

- Beginning of changes are already seen in couple of fronts. Biggest change is coming from **private wireless network**. So far we have primarily just a consumer mobile wireless network, which are also used for enterprises, for their connectivity needs. I think the **combination of connectivity and cloud** is making private wireless network very interesting for many different entities. And 5G is the first generation where that is going to be push forward.

- Operators providing these private networks, and then vendors like Nokia are also providing network directly to various entities. The operators may face to **challenge how to scale this**. How companies like Verizon, Vodafone are managing wide range of networks, from private wireless network to large number of entities is the key challenge. Maybe there could be some new models that might be global companies that are focused on managing networks, deploy and manage the networks, spectrum owned by the entities by themselves.

- Or it could be that MNO are **creating franchises**. We might see an **emergence of smaller operators** that are just franchises of some of the larger operators. So larger operators establish in the systematic way of deploying and maintaining networks and then issue franchise to others, then get new revenues from that. That is the potential changes in the non-consumer space, but in business space.

- The issue in consumer space is that biggest changes might come in **new devices**. So far, the smartphones are the dominant device for consumer. However, we are seeing already a trend where more and more devices are coming into the future. Not all these devices are directly connected to the cellular network, but these devices will form versatile **device networks** which then is connected to the cellular network as a whole. It is a concept of **sub networks**. This could be the big change in industry from today. It means that some kind of computing devices next to you are connected to each other, and one of them connects to the network to outer connection. All of these devices operate together, however, one of them such as a smartphone segregate into external network. Such network diagram should impact not only operators but also consumers as well.

- Then, with such new devices, come **new services**. All these experiences such as AR and VR in 5G, will be eventually more established and become more available. Users can experience the whole virtual world as if almost being another place with high resolution, multiple sensing capability, and so on. That is not a service for consumer only but also be useful for businesses, such as **manufacturing partners**. **Collaborative work, education, healthcare**, all of these will benefit from such immersive digital experiences.

- As for **new players** in the industry, we can expect whole **new host of applications**. Which is, applications. They are built on top of entirely new digital world. When we think about how apps are made today, they are all built on top of multimedia. Video, images, web pages, smartphone as UI. Moving forward 10 - 20 years, **new generations of applications will be on top of the foundation of digital world**. It could be **virtual world**, it could be **digital twin** world, and people will create applications on top of that. For example, adding a new object that is specifically built in the digital world. It will provide different types of experiences, on top of some foundations of digital experiences. That is where we are heading. It might not happen in 10 years, but eventually happening in the 6G era. 2030 – 2040. If you think back between 20 in the past, enormous amount of changes are happening in 20 years. We need to expect the same degree of changes in future.

- Furthermore, **the combination of computing and Artificial Intelligence (AI)** are one of biggest drivers. The ability to create **high level solution map**, ability to **automation**, as machines can process enormous amount of data and provide actions so there are different types of machine learnings. And underlying computing power/resource is becoming available. So even though people say that we are approaching the limit of Moore's law, we will find **a new way of optimising computing**. More and more systematic, low power, ASIC, much more computing. They are essential elements for our vision.

- Regarding the new business from MNO's point of view, **new set of applications** are the key. Think about the value of information and applications – currently it's mostly going to Apple or Google. Others are just posting their applications on their

platform. But there's a possibility that **MNO can play a big role in the next round**, where you have **new classes of applications and new classes of devices**. Who takes the lead ? A whole new set of companies who are **start-up companies** may grow to exploit 6G with Augmented Reality as the starting point and then they evolve to bigger. It is not clear who is in the best position to exploit all of that. MNO could also explore and become the main player, not just domain like Google or Apple.

- Business model of MNO – traditionally they first started by charging to voice. In 2G to 3G, they focused on reducing voice capacity but introducing data, eventually **voice became free**. Subsequentially **we only paid for data**. And data was charged according to subscription plan such as 1G plan or 2G plan. However, in the shift to 5G, **the cost of data is becoming zero**. Meaning, we all have subscriptions but **we don't pay for data, because data is unlimited**. So voice is free, data is free, so we are just paying for the basic subscription. This is still a predominant model in 5G. But then there's a whole bunch of new services. Charged on the per-service basis. So I think it will be important **who owns the application**. If MNO introduces some interesting services, for example, mapping of physical world to create digital world. That would be possible to use network just as a tool to communicate, but as a per-haps, sensors. **Network as a sensors**.

- That's a new services, many enterprises may pay for to build apps. Then it can be-come a transaction point for a new generation of applications. These are the new ways to raise profit for them. Voice and data are no longer medium to make profits, as voice and data are unlimited. Subscription is the only base customers pay for, but it will continue to decline, because cost of connectivity is becoming cheaper. **From 5G to 6G, the cost of connectivity will become even less, so you cannot make money just from connectivity. So the point will shift to who provide the ser-vices.**

- MNOs may profit from **private network**. Thus **B2B** will become a dominant source of revenue. B2C may become one fractional of revenue stream.

- For vendors, **software** will be critical. I see a gradual **shift from hardware to cloud**. We may not be providing HW anymore, because they are provided by cloud vendors. But that is only a part of functions. When it comes to the real radio devices (such radio head), we will still be providing HW.

- There could be many more vendors, because of **geopolitical reasons**, and governments are interested in seeing multiple players. We saw in 5G era, even radio vendors are beginning to explode. There are many more players providing radios. Especially as we standardized interfaces as in Open RAN. That is likely to **increase the number of players** in the world. But how good networks would be – sort of matching different vendors is the question. So far, we saw different vendors are offer Radio or Core. But in the future, **operators may mix different vendors for many more pieces to create the network**. We might be more and more expanding market as a whole. It is also possible that more operator types and more opportunities to sell network.

- Regarding drivers to push forward the development of 6G, AI is important one. It can be used in various fields, such as optimisation of the network, orchestration, slicing. Fundamentally different thing from the past is that **network as a sensors will create value for MNOs**. Base stations are not only used for connectivity but used as sensors. **Re-use the same equipment for sensing.**

- Another driver is **cloud based network deployment**. Networks are becoming more disaggregated and more heterogeneous.

- **Quantum computing** is a buzz word, however, it is too early to be utilised in 6G. Maybe in 2040. Because all the design work for 6G is already being done without quantum.

- Network topology of Radio Access Network (RAN) and core network are changing as well. Some functions of RAN are already shifting to **cloud based**, and core is also being implemented as cloud native function. With cloud based infrastructure, it will be **less meaningful to keep separate entities between RAN and Core**. You want to treat them network function, services that are loosely coupled, using services based

interfaces. So that you can add more services. Only needed services are used for particular deployment. It is a change basically exploiting cloud nativity. Movement of RAN into the cloud, distribution of Core toward RAN brings faster, low latency.

Appendix D : Interview Script of Participant #2

- Regarding the necessities to change business operation in mobile industry, even with 5G, there have been new players starting to flourish. They are companies specializing in **satellite, smart factories, automobiles**. Whenever a new generation of mobile wireless technologies is born, there will always be new players. I expect 6G will bring newcomers as well, and they will influence the ecosystem for sure.

- The change drivers for 6G is customer requirement. We are seeing the flourishment of players such as **OTT, Netflix, Facebook**. As you know Netflix is focusing on streaming. Facebook is now having new devices like **VR glasses**. And in 6G timeframe, they will invite new companies who are making new media contents. They may have power to change the overall ecosystem.

- As for new business opportunities for existing network infrastructure vendors, virtual RAN is quite visible these days. Rather than hardware oriented businesses, we will see more companies focusing on software. **Cloud, virtualization** solution will be dominant. **More software oriented business model** or more collaboration between software companies are expected. For example, Amazon is providing cloud service. Core network can be replaced by cloud company and **existing vendors may more focus on Radio components only.**

- MNO - Subscription based current business model probably needs to be changed because there is not much room for expansion. Today we have **eSIM (embedded SIM)** approach. Which means that user information on SIM (Subscriber Identity Module) is embedded in device. With eSIM, you will just be able to flexibly change the operators. eSIM simply chooses new operators digitally. So MNO cannot simply rely on subscriptions because users will be more flexible to change operators any time. Competition among operators to retain customers will be more fierce.

- Drivers to push forward 6G development - There are lot going on in technological area. **Higher spectrum band, MIMO technologies, satellites**. Terrestrial network and satellite network fusion, topology change, machine operation can be expected.

- In the 6G era, new services with **VR** will be more advanced and available. Traditionally people are bound in physical world. But there has been effort to provide people virtual world. In the future the boundary between physical world and digital world becomes blur. People always seek **new media experiences**. Combination of physical and virtual is critical.

- In terms of pure communications, you can't use your phone with the same capability as laptop. People still use laptops, but they are heavy because it has CPU, storage and other components. However, more and more computer powers are burdened by cloud networks, not on the device itself. In the 6G era, **new device which can replace laptop** may be visible.

- Regarding culture, we need to develop technology to convince people there is **no fear in security**. It is like a car. When a car was first developed, people were riding horses. But horses were faster than cars in the beginning. But eventually people realized the potential of cars and cars surpassed horses. I expect similar phenomenon will be seen with 6G as well. With new technologies there always be fear in the history.

- **Geopolitical changes** has potential impact on 6G. Older generation of mobile wireless technologies had **regional standard**, which prevented the global rollout. With 4G and 5G, finally global standard came into the picture. If each region would start to have different standard due to geopolitical reason, it is going to be a problem.

- Society – **SDGs, especially energy consumption** will be a critical factor in 6G. New requirements on environmental impacts will be important. Also **equal opportunities** must be given to people regardless of regions they belong to. 6G can help people by reducing effort of chores, such as driving cars. **Smart technologies, AI, and robotics** may make human society better, if they are used rightfully to assist people.

Appendix E : Interview Script of Participant #3

- Regarding the trigger of 6G researches - Evolution in mobile wireless communication technologies has happened every 10 years since 1G. The researches have continued from 1st generation. For 6G, the background is a little different from 5G. The notable points when considering drivers are increasing concerns over **green deal**. UN SDGs are megatrends. Social, Political aspects are getting stronger. Also compliance toward **security** is becoming more important.

- In 6G, the most interesting and important changes imposed on society is that it is the time for **mixed intelligence**. Meaning, human to machine communications, connected intelligence, augmented intelligences are seen. I would say that 6G is beyond connectivity. **Convergence of different industries** will be seen. Massive number of sensors will be brought in to support AR, digital camera installed everywhere.

- Currently **digital twins** are gaining momentum, but in the future, digital twins of humans will also emerge. I.e. **digital avatar**. It can be utilised in healthcare, namely predictive maintenance of health. Utilisation of digital data are business critical, but it gets more personal.

- Overall, for 6G, I expect more positive effect than negative effect. Still, as digital data will exponentially grow, **privacy and security** will be of critical concern. Who owns the data ? How you use the data ? IT is empowerment, but at the same time, many people are hooked up in digital world such as SNS. How to opt out from them is a big question. **Decision not to use technology** is difficult.

- Next generation of mobile wireless technology after 6G is necessary and the development is unstoppable. The expected data volume in 6G is more than the whole sum of data today provided by all operators in the world. Industrial applications is a key. Trillions of connectivity is required with sensors, HD and 360 cameras, radars, which transmit enormous volume of information. They are used for MR, real-time audio visual, etc. In “7G”, data will be transmitted over high frequency and high bandwidth. Collected data are sent to and processed by AIs. Even in factories today,

safety is ensured by using robots. In the future, **human-machine collaboration** will progress. Low latency and more accuracy are required.

- The next phase of mobile wireless technology may not be called as “7G”. The requirement differ by countries and regions. Different regions need different speed. In 7G, **geo politics, diversity may be key words rather than globalisation**. Also **open source** and **modularity** are critical. When interface becomes open, the development speed may differ. So in the future, networks may evolve **super-locally**.

- UN SDG is the megatrend when we think about 6G and beyond. The difference between 6G and 7G scenarios are how to create value and profit. Value creation is easy, however, profit value is challenging. The current value chain surrounding mobile wireless technology is **rigid**, players are MNO and manufactures. However it will be expected to change during 6G. Open source, **open RAN** may become main stream, and **new start-ups and new players** will emerge. They are disruptions. Data can be run on **general-use clouds** such as AWS (Amazon Web Service). Virtual RAN, vRAN is also possible. Platform eco-system might become dominant. The landscape surrounding MNO and manufactures may significantly change. Disruption to existing players will come.

- Also network topology will also be updated. Currently the backbone of mobile wireless network is separated to be RAN or CORE. This architecture will change. **Decentralisation** will progress and the architecture will be **hyper-local network**. Privacy and trust play key roles. People may not trust MNO anymore. The trend of “I own data” will become mainstream.

- Business in the future will transform itself from conventional telco-business to **software business.** Currently MNO’s business is built on **spectrum licensing**. Spectrum policy is protecting MNO. However spectrum will be re-allocated for factory use. **Decentralisation** is unavoidable.

- Quantum computing and Distributed Ledger Technology (DLT) such as Blockchain may be relevant emerging trends when considering beyond 6G.

Appendix F : Interview Script of Participant #4

- I cannot really answer what changes 6G will bring to society, but I can tell you what are the issue we have today and tomorrow 6G needs to solve. To answer the question how 6G changes the world, we need to know what 6G will be, and we have some ideas, but we don't know yet exactly what it will be. The perspective we have in our organization is that we want to make sure that **6G will help solve the issues that have not been solved today**, and that will be very important. So we need to design 6G, so that we can answer those needs and continue to solve those problems.

- One of social issues is the climate change. For that, there are two aspects that are important. First, 6G needs to be environmentally friendly in a sense that it needs to be **energy efficient**, and **minimum impact on environments**. That includes also thinking in terms of how we will **recycle and reuse** the 6G equipment when it reaches the end of life. It also pays the attention the way we manufacture the equipment. We also think about energy and CO2 emission which is associated to millions, billions of terminals we produce. Probably we need to think about ways to reduce this impact and solutions are not clear today. It is a need for research there, how can we make **terminals more sustainable and less frequently replaced**. It is not only about networks. Terminals also depend on how digital services are provided. Digital platforms such as YouTube. This is a E2E question that all the players in this industry need to answer. Second aspect is how 6G can help all the other sectors to reduce their environmental impact and particularly CO2 emission because CO2 is responsible for the climate change.

- And for that we started already a lot of features to include the efficiency and reduce the waste in assembly line, etc. Also how to reduce gas consumption for vehicles. It is taking the right way. With 6G, we should have new capabilities and new performance that we can certainly offer even more efficient usage in that sense.

- The **resilience and security of the technology** is something we are already seeing today. Mobile networks are essential, it is very clear. Even more essential these days with **remote working**, which leverages communication technology. With 5G,

the critical service 5G ensure in future is even more important, that networks are **secure and robust against failure**. It needs to be able to recover quickly after failure and **cyberattack**. Naturally we expect 6G to be more robust against any issues.

- 6G is also aligning with UN SDGs. We are happy to see that several initiatives in 6G are referring to these UN targets. Our organization is also aligning this policy. There are several important stakes already presented today, but in 6G, low, **more efficient industry, agriculture**, **cities, better health, remote health monitoring**, and so on. For that perspective, it is improving what we do today with further capability and higher performance.

- About possibility of 6G giving negative impact on society - It is always the same. **Technology is neutral. What you do about is the problem**. You can use it for good and also for bad things. If you take the preliminary vision of 6G, which is being formed by 6G Flagship project, you can sum up by saying that 6G will **connect different world – digital to physical world**. **Digital twins** meaning real time control, augmented humanity. Every time you realize something more in digital in general, you also increase the attack surface. Imagine that you have the possibility to enhance the humanity for instance, if the government wants to control and get information about your body. If hackers find a way to attack something device which is responsible for your health, that kind of risk exist. That is why invest a lot in cyber security. In some countries they use massively technology better control population, video, AI, surveillance, facial recognition everywhere. That can be good to protect citizens but it is also bad that government control citizen and restrict their freedom. With more powerful technology, you will have more powerful tool to do so. Either to protect population or control them. That is the same with any technology.

- We will **never stop innovation**, unless we find a way to do teleportation or download terabytes of data instantly. But that is not feasible for the moment. For 6G and beyond, namely 7G, we will always continue to innovate to improve technology. Every time we start new generation, intelligent people will say, do we really need new technology ? We already have so much ? But it continues. I heard from my colleague who was engaged in 3G research. Back then people said, “What do we do

with this new technology? What to do with such 2 MB data ? “ And now you see the data rate today. As technology progresses, first of all we always improve things. And we always find useful ways to use additional power supply by technology. One thing that has changed is the sustainability we talked earlier. The limits of planet in terms delivering resources and energy, the usage is more clear than before. And we cannot ignore that this is something we really need to take into account. Several people opposed to 5G said that drawbacks, impacts on environments would be higher than the benefits we get from 5G, and we should not do it. But personally I was convinced that this is wrong. But we need to make sure that **the value of technology must overcome the impact on the environments**. So the **efficiency and cost of environments** needs to be absolutely considered in the new generation. For 7G, there will be for sure, further technology progress and new researches in 2040 or 2050. We don’t know yet if it is called 7G, but for sure technologies will evolve after 6G.

- If we follow the same pattern, 7G research will start in 10 years from now. There will be fore sure issues, most likely climate change will be an issue. We may have also an issue about **population growth**. So far we can feed everyone but if it continues to exist, maybe at some point we will have food shortage. In that case, how to make even more **efficient agriculture** could become a really central problem. Vital problem. Also it depends a lot how society we evolve, we are seeing in the past about **inequality between rich and poor**, increase dramatically. A lot of extremely poor people. In 6G and any technology, **social inclusion** is critical. If technology wants to be truly valuable and if everyone wants to use it, then of course that we need to ensure that the coverage is affordable. And also we anticipate political problem, low cost devices, low subscription, and so on. For sure, it will still be also very important issue in for 7G or whatever. Environment, population increase, city management, as the population grows we need bigger city, and large cities are more complex to manage than small cities. And robotics. **Robotics** will advance in 20 years. We need to properly manage these robots. Also health. Aging of population in the developed countries. So we will need more services for elderlies than today. Larger fraction of population will be old.

- **Quantum computing**, for example, may be integrated future mobile wireless technology. They are basic researches today which are progressing fast. Probably they are maybe closer to maturity than today by the time we start 7G research. They may play role in the future of telecommunication as well.

- In 6G, we are trying to make sure that technology will be designed for future users, whether they are civil society, normal people like us, or industries, governments or cities, what we regard important in 6G is that in 5G, we did great job **making liaisons with verticals**. For example, **automated sector**. Which has led to the association, gathering both representatives of telecom and representatives of those automotive or manufacturing industries. Those are extremely important in designing technology which answer the need for users in futures. There is a collaborative called MGMN created by association of international operators. MGMN issued white papers of 5G, which is foundation of later 3GPP requirements. MGMN is initiating project in 6G as well, and in this project our organization is proposing to design a questionnaire to ask different organizations across the world, about their expectations in digital services in 2030 – 2035 horizon. And the goal is to collect, expectations and needs from various organizations, regardless if they are industrial or governmental or operators in the different place of the world, and the idea is to take into account their feedback in the design of operator's vision of what 6G answers to their needs.

- About business model of the mobile wireless industry, it should be changed because the world is changing fast. The essence of MNO business is to provide connectivity, by deploying network and necessary infrastructure. One thing we change business model even in the future is the **edge computing**. Because with **edge computing, network operators will also become part of computing platform**. That will be able to host 3rd party application. There must be **partnership and revenue sharing model**. Because in those 3rd parties, installing applications on our network, so that we can get revenue out of it, they will pay the fee to us. That will be profitable for everyone. Then of course we also have new technologies arriving. Particularly satellite, **low orbit satellite**. They will provide the world wide coverage, probably we terrestrial operators make deals with those satellite companies to offer services including worldwide coverage, and there will be need for new partnership.

- Drivers to shape future mobile wireless technologies - equal sharing of resources, probably education is the key. Because when everyone have access to education, people are more having chance to be happy in their lives. Be less aggressive to others, maybe. Education is a critical component to have good future. Good communication can greatly help. **Remote education** is ensured by communication network and internet. Definitely mobile wireless has a role to play to make the education better.

Appendix G : Interview Script of Participant #5

- About the current business model of the mobile wireless industry - **Ecosystem is quite rigid** because technology has been quite monolithic. Specially on Radio side. Not necessarily in the other parts. It has grown on its own way. When first I joined the company I have been working for 10 years, I was surprised. Fixed networks and mobile networks are completely separated. Only at the top level, they are merged. This may be due to the characteristics of mobile wireless itself. Or, it may be organizational, or regulation issue. However, it is true that disaggregation started some time ago, where control plane and data plane become interchangeable, or at least they are required to follow open interfaces. Such movement is happening. When that happens, **the boundary between traditional network segments such as RAN, Core, or transport, packet will become blur**. This will be translated into more fluid network.

- Furthermore, current structure of industry may change. Currently, for example, vendors such as Nokia or Huawei are focusing network while Apple or others are making phones only. **Mixed approach** may pop up.

- **Fluid network and possibility of building ad-hoc network may be the trigger to change busines sin 6G**. Networks in 6G will be much denser than we know today. This means that potential devices connected will be exponentially increase. For example, roses in a garden might be devices to be monitored by attached sensors. Also **security** plays a critical role in 6G. Connected devices everywhere, meaning that personal information such as health info may be threatened. Current

architecture is too much centralized. And such **architecture does not scale easily**. Lack of flexibility of network. **More dynamic, more people oriented, more personal network**s should be built. More customized network would be necessary. Currently there is network slicing, but it is still limited in functionality. Different elements need to collaborate more freely.

- New business possibilities - Mechanisms to make small devices' interactions possible. Smaller means that even smaller scale than IoT. It may be, **nano level**. For example, such small devices may be used for brain interface. Also **interface to facilitate communication between human and non-human**. And **Bio devices** to revolutionize farming. Nano, bio sensors have lots of potential.

- I believe that new competitors such as Google or Apple are going to emerge. Simply because the combination of good idea, little bit of luck, opportunities, new businesses can happen. **Big organizations tend to be more rigid** as if human become less flexible when growing older, which is their weak point. Thus existing big organizations need to find new ways to make a profit. However new player cannot compete with incumbent at the scale of economy. Currently big names such as Amazon provide centralized solutions and it is not wise to challenge them in same solutions.

- Regarding MNOs' business models, **subscription based revenue model** will not necessarily be changed. Subscription may be most natural model, you pay and get the service such as electricity. Some countries which aim to offer **universal connectivity** may be a different story. Government provide connectivity for free, thus subscription may not be required. As additional services for enterprise, ad-hoc network be suitable to be commercially explored. **Dynamic, elastic network** may be new services. Create your own network dynamically. From end-users' point of view, **security and privacy** play even more critical role in the future. Enhanced encryption may become a service. Also, child protection from harmful contents need to be strengthened.

- **Collaboration with new competitors** is necessary, otherwise existing players will be doomed.
- We can think that new players make cake bigger and bring different flavours. There is network sharing already, but in the future the network itself may be built collaboratively with new entrants. Of course, standardization and regulation will require a lot of tasks. But when we think about the past, previously it was unthinkable that everything is connected through the internet. But it happened, and it will continue. Global level collaboration and integration may be seen.

- Telco vendors tend to rely too heavily on patterns of the past, having their own gardens. They **translate costs into high benefits**. This need to be changed. Physical system they are manufactured are **allowed to interconnect with limited partners**, thus MNO need to buy physical devices separately from each vendor. This model may change in the future.

- Drivers for changes in business in 6G may be technologies such as AI. **Data driven autonomous application** which can design network themselves may emerge. Optimized operation of network becomes possible.

- Regarding social driver, **aging society** is one key. As more people get older, more aggressive ways of connectivity is required to monitor them. Development of **bio chips** and their connectivity may be a profitable business.

Appendix H : Interview Script of Participant #6

- Changing business structure of the current mobile wireless industry - that is a fascinating topic. I think it is definitely going to change, as we are already seeing it today. I think there are a few things happening all around us. One of them is **the development of software defined network and their rollout**. When you can basically use **off the shelf hardware** to use your software, you don't necessarily need to own special infrastructure any more. This is we see quite a lot these days in telecom providers that selling off their infrastructure to separate companies and focusing on their services. I think that relates to couple of new changes, for example, **growth in private networks in 4G/5G**. For example, enterprises. Because they can

buy relatively cheap network infrastructure and basically just have the software for the network on top of the platform. We are seeing new kinds of service providers. National operators also wants to capture enterprise customers, they are actually making it easier for new type of competition to come. On the vendor side, at the same time, one of the most obvious phenomenon is **Open RAN.** That again is helping to enable a new kind of vendor in there, rather than having companies like Ericsson or Huawei providing everything from hardware to software, middleware, etc. That's opening up a new kind of competition there as well. Big providers do have certain strength and resilience to this competition because on top of selling hardware and software, they also **supply managing services**. So the challenge is that the issue of having many players may be the service.

- The changes are already happening at the moment, and over the next 10 years, we will see this growing in strength. We will have players such as **Amazon, Alibaba**, and so on. They already have a lot of **data centre infrastructure**. As people are excited about **edge computing** in 5G and 6G, bringing services closer to user, then it means opportunities for them to provide data rather than from centralised data centre to smaller places. There will be competitors between such new players and existing telco companies who own quite a lot of buildings and infrastructure, distributing services. Another players may be **warehouse in a city**. They can be converted to data centres, and that could provide local edge services. So I believe that there will be much more complexity around in architecture and how to different business relationships works within that network.

- Driving forces for business development in 6G - One thing is that the time between 2000 and around 2015, competitions within telecoms environment had mostly decreased. Some players like Nortel, Alcatel Lucent, Siemens and so on. In the end, basic 4 big vendors remained. There is something similar going on in the core networks as well, and even in terms of MNO, many countries saw consolidations. I think on one level there's a **push back against consolidation**, and there's a need for a place to break in the market, and they can see some of the revenue available to focus on the market, they are finding voice to work that. For consumers, it's probably not changing at all. If you don't like operators, you can go to MVNO, something like that. In the enterprise environments, historically, telco is not good at

working with large companies. They know how to provide connections, phones, how to manage them, but that's all. With 5G, what is promised is a revolution. **The ability to work more closely with different industries** too. Create smarter, more intelligent work spaces to, for example different kinds of network services provision, such as ultra-reliant latency, and so on.

- We are already seeing some new emerging technologies which can bring new services in 6G. It's really exciting. Network is only one part of creating these new services. With things like **AI, holograms, AR, VR, built-in machine sensin**g, these things are thought to be building blocks. For example, 6G enabled simple top of the table may offer broadcast hologram on the table, and provide haptics, VR experience. So you can actually have hologram that can be touched and manipulated in 3D. Give feedback to sensing that you are holding an object in your hand. And AI can work the hologram according to what your hands are telling what to do. You could use that for all kinds of things. For example, hotel owners can have virtual hotels, where you open up and can see in real time, what the stage of restaurants. Sci-Fi is becoming reality.

- For MNOs, on one level, if you are talking about business to consumer model, **subscription** is pretty good one, it gives everybody idea what the cost is going to be. The challenge is how to build on that. Because the problem we see in the past, **whenever we had a new generation, we invested tens of millions of dollars in network**. People don't want to pay additional for services.

- And that has been a real challenge to the telcos. I think that's the one reason they want to break into enterprise especially in 5G, as there is no much further area to make money with consumers. The real challenge lies in how to deal with enterprises. Whether they want to go directly with businesses, or build partnership models, some companies are already collaborating with different types of industry, like building, and developing new type of services very closely with them. For example, monitoring the safety of buildings. Having people wearing hats all the time.

- Very interesting is what ZTE did last year. They came up with the service offering to MNO, **Network slicing** as a service. MNO can do the slicing with the very easy interface with enterprises, with particular kinds of, different performance indicator for the needs of business.

- Coverage is shifting to cover universal coverage. However, performance consumers can get at any point of place is very different depending on the area. For example, in some domain such as medical management, a very robust secure connectivity and good performance is required. AI could be helping the distribution of network performance. Universal coverage doesn't get the same level of performance anywhere. **Performance needs to be tailored** based on the demands. And if you have a flexible network, let's say, smart cars, they can carry computing and storage power to where people are, as they are loaded onto the car. And you can have additional drones and coverages as well if you need that. So there will be some flexibility but there will always be opportunities for people selling hardware, because there will be changes in hardware depending on the demand. **Management of devices** will be much more complicated. I see much opportunities in services for managing them.

- **Security and safety service** will be a key feature in 6G. Services will be very depending on location and context. When taking an example of smart cars, security may not be the main focus but safety. It's easy to repair bring back online after the attack. Service to recover the stability. **Service on data privacy**. Such problems will open up new forms of jobs. Different kinds of jobs than today.

- Enter of **OTT** such as GAFA into the mobile market is very real. There could be a possibility that OTT may dominate the telecom industry. However, what we should consider more is meaningful collaboration.

- Interesting about what is happening today is not just about telco network anymore. Things like **AI, quantum computing, blockchains**, all these emerging technologies are coming together in new ways. happening together. Some of them are used to build better networks, performance. They help society as a whole.

- Also geopolitical changes are important. In the past, there was obvious centre of development of new technologies, Europe, the US, Japan and China. But because there are a lot of academic institutions in **India, Latin America, Eastern Europe** are now focusing telcos. There will be opportunities in 6G that some of these late commers will take a seat at the table. And for example talk about the energy reduction in networks. **Sustainable goals**. It could be a good business cases. Renewable, sustainable network, it is very valuable for SDG as well. Telecom industry will be the first one to measure performance for such sustainability goals. Also we see investors focus on **CSR**, responsibility and future of humanity. New way of people individual express idealism through their purchase and investment. Companies are not greenwashing but they have to show more established way of their doing. If we increase IoT, what impact will be done in water energy consumption. On average, it is a positive story that you can save energy. But there are still lots of challenges to be overcome.

Appendix I : Interview Script of Participant #7

- The researches for 6G have started because there is already a forecast that by 2045 there is a more, massive demand for connectivity. It is same when 5G happened. It was driven by massive, ubiquitous deployment such as self-driving car. When we look at the forecasted needs of data rate, for example, autonomous car with cameras will scream for data through cloud such as 4TB of data per day. Then 4TB multiplies by the number of cars. The reason why a car needs camera is that car can monitor the surroundings as if you are seeing Google Maps. Cameras catches real-time the environment where the car and the driver is navigating. The second example is historical recording of our society. Today, wouldn't you be happy to see the happenings in the past in a given place on the earth, as if you see movies. For example, selecting and seeing the Napoleon's attack on a certain place with 3D view, etc. It basically means that we can reproduce the history of humanity with the data we are recording. Another topic is layered traffic, something called "**3D traffic**". Airplanes in certain altitude has such and such network requirements and ones in lower altitude have different performance. Last area to be developed is everything related the sea. We need **cellular system on the sea** of satellite system or combination. All

those things are not achievable in 5G, thus we need 6G. Clean slate, new wireless network for providing all these mentioned services.

- I would say that 4G is mobile to internet, 5G is mobile to things. In 6G, it is mobile to machines. More and more machine intelligence will among us to support us. It is already happening today. For example when you are sending text to someone, computers will automatically spell check your writing. I still do not have clear idea what they will look like, something like wearable glasses or display of information, but there will always be a necessity to rely on information to be able to communicate with somebody.

- Regarding businesses in 6G. The focus that we already see in 5G – today operators do not how to make money out of 5G. Why ? Because classical operators build their network and sell data. I guess it is a big game changer already in 5G. The game change is how to exploit the platform related to 5G or 6G. How to get service by plugging into them. Of course it is not easy thing to do. Today the industries which make money are Amazon, Facebook, all these **companies who are specializing in software than communication base**. So the question is how to find a right balance – for classical operators – in selling pipes (networks) and moving to **selling more and more services**. Either contents, or exploiting data as Amazon or Facebook are doing. Because raw data cannot make money. It is necessary to extract useful information from data. It would be important to come up with **solution to extract value from data** by plugging into the network.

- As for the network infrastructure vendors, they need to understand more that the importance is on **selling services**, in terms of how to operate networks. Also, more and more **diversity** would be seen in what we used to do. For example, the company I work for is basically a telco company. We sell smartphones too, but the focus is being more shifted to **computing**. It means that chip set is becoming more integrated into end to end solutions. The conversion of communication and computing would happen. It means that computing part plays an important role in providing communication service.

- For political aspect, 6G as of today is already a big issue – previous generations had global standards. However, one possible problem could happen in 6G is the decoupling of east and west. Meaning, **divide between China and western countries**. Of course, companies like us are pushing forward global standards.

- As seen in **Open RAN**, the tendency to have open source and open interface is explicit these days, however, they **may play only a partial role** in the future. The concern is that the troubleshooting. When problems happen, who is responsible for the issues happened on open source platform ?

- Emerging technologies surrounding mobile wireless technologies - Although 6G does not have **quantum computing**, the next generation after 6G will be having quantum computing the starting point. Also, **space internet**. By 2040, we expect to build internet on space level. So if there is something called 7G, it will be intertwined with quantum and space.

- **Ethical issue** about future mobile wireless technologies is critical. Companies without ethics will fall. Without ethics, you may conquer the market immediately, but in the long run, they will be diminished. In case of telecom, use of devices with mobility, such as drone and robotics may be strictly examined if they are ethically appropriate or not.

Appendix J : Interview Script of Participant #8

- Before looking into businesses, we need to acknowledge that 6G is nothing special compared to the previous generations. Let's clarify the reason why mobile wireless technologies go through multiple generations of evolutions so far. When the demand for higher capacity of data rises, new technologies have been adopted. For example, higher frequency band is used, or analogue techniques were replaced by digital ones. Whenever technologies to support new demands can no longer maintain the backward compatibility with previous generations, a new technological requirements are consolidated as a new mobile wireless generations. This cycle has been happening once in 10 years so far. In a way, mobile industry is changing according to demands, by developing new requirements and technologies to support them.

Thus, when we think about 6G, there is no unique and particular background only applicable to 6G.

- However, the notable change obvious these days is the **increasing demand for higher capacity of uplink**. For example, in China, deployment of 5G network is quite advancing. During the course, it is already anticipated that the maximum speed of uplink supported by initial 5G may not be sufficient to afford increasing data. Thus, new set of requirements, 5.5G is under consideration. Uplink means the data traffic sent from user end. Before 5G, the use of downlink, the data traffic from antenna/data centre to users, was dominant, such as browsing of internet and videos. However, from 5G, mobile services are being used in industrial setup where video footage shot by multiple cameras are uploaded via uplink. Then, artificial intelligence at the backbone analyzes them. In 6G as well, the use of uplink, along with cloudification would be a key driver.

- One more characteristic is that 6G is regarded as the age of **Connected Intelligence**. In summary, the data uploaded via uplink are analyzed by machine intelligence. For example, especially in China, there are many systems in which video footages are analyzed by AI. In 6G, AI will be fully integrated into the foundations of mobile communications. Even in 5G, AI is partially utilised for network optimization. In 6G, “federated learning” will become mainstream - machine learning functionality will be deployed at edge devices in the networks, and such intelligences will communicate with each other without human intervention. The use of AI should be dominant in 6G.

- The most imminent challenge for 6G is, how telecoms can become **green**. AI consumes enormous amount of energy. And if we use higher spectrum, more energy is required. Low energy consumption and environmental-friendliness have already been a major agenda nowadays, and it will continue to be a key driver in the age of 6G.