FUTURE 6G NETWORK SERVICES

Discussion Paper 6G & Human Capital

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Table of contents

1. Introduction

During the development of 6G, it is important to timely consider the need for human capital required to optimally utilize the opportunities that 6G offers. This is especially true during a tight labor market. This exploration looked at the following knowledge question: What is needed in terms of human capital to optimally utilize the opportunities that 6G offers? We look at potential changes in existing task packages, potential new tasks that may arise, and the scope of employment. We want to emphasize that this is a first exploration of very limited scope and that further research is necessary to obtain a more complete and detailed picture of the changing skills needs. For this exploration, nine experts were interviewed, and three work sessions were organized as part of the Human Capital working group of FNS. Appendix 1 shows the interviewed persons and the participants of the working group.

2. General Observations regarding impact 6G

It is still very uncertain what 6G will look like. Therefore, it is also very difficult to estimate the impact on human capital. With such a high degree of uncertainty, it is also very challenging to make quantitative estimates of the need for human capital.

There is still a lot of uncertainty and there are different opinions about the impact that 6G will have.

The form that 6G will take is still unclear. In the discussions, it emerged that new antennas will be needed for 6G. Whether more antennas and how many more antennas are needed will be influenced by the frequency, how directed a signal can be transmitted, and whether antennas will be shared between providers. The opinions of the experts varied from a similar number of antennas to ten times as many or even a hundred times as many.

Additionally, the adoption of 6G is uncertain. For the consumer, 6G itself will have little added value, according to various experts. However, the applications that 6G enables can have added value for consumers. Which applications will be possible is unknown and difficult to predict, but one can think of self-driving cars, large-scale deployment of drones, 'internet of everything', social XR and VR, etc.

Furthermore, there was even resistance from consumers during the introduction of 5G. It is also unclear who will produce what and where. Software development, for example, is progressing very quickly and new parties are emerging that focus on it. Although the Netherlands does not currently play a major role in this, that could change in the future.

Finally, the timeline is uncertain. The transition from 5G to 6G will be gradual and not a hard transition. The networks will coexist, just as 3G and 4G are still in use. So the question is when adjustments in the infrastructure will occur, and work will actually change.

Possibly a lot of indirect impact through the development of new applications

6G is an enabling technology. As mentioned above, the difference between 5G and 6G will mainly lie in the applications of 6G. These applications can be directly aimed at the consumer, such as new applications or self-driving vehicles, but also at companies and factories, such as deploying 6G in a factory hall, which allows for more flexibility in the production process and more automation. Think of a cookie factory where the recipe and machine settings can be stored in the cloud instead of on the machine, making it easier to adjust a new recipe from a customer. This also shows that 6G increasingly enables the transition from human-machine interaction to machine-machine interaction (internet of everything).

We focus this exploration on the direct effects of the development, installation, and management of 6G, but it is important to keep in mind that there can also be many indirect consequences of 6G for human capital. Especially the (new) applications enabled by 6G may have a significant impact. This aspect will be briefly addressed in Section 3.7.

3. Impact components of 6G op human capital

To get an understanding of the impact of 6G developments on human capital, various components of the 6G development process were examined. The research phase, to which the FNS program contributes, was skipped. The components addressed in the interviews are:

- Production of components (cables, antennas, data centers, computer chips, etc.).
- Installation of infrastructure (physical).
- Maintenance of network infrastructure (physical).
- Software development (for use and management).
- Network management.
- Marketing of 6G.

3.1. Production

Antennas

For a 6G network, various components are needed. New antennas, computer chips, data centers, cables, etc., are required. We will focus on the changes that have the most impact on human capital.

In the discussions, it emerged that new antennas will be needed for 6G, and there will likely be more of them because higher frequencies are being used. On the other hand, more precise targeting of the signal or sharing antennas between providers could limit the need for antennas. Expert opinions varied from a similar number of antennas to ten times as many or even a hundred times as many (compared to 5G).

Additionally, the question is how these antennas can be integrated into the physical environment. Smart lampposts with built-in antennas are an option. These lampposts would need to be produced on a large scale for new residential areas or places where lampposts need to be replaced. Where lampposts do not need to be replaced, an antenna could possibly be mounted on an existing pole. It was mentioned that a smart lamppost could be placed every 100-300 meters. These can be produced in the Netherlands, which will significantly impact the amount of work in this specific sector.

Furthermore, it was mentioned that network parties that currently have their own antennas could share antennas, as it otherwise seems unfeasible. This raises a new issue of ownership and responsibility. On the other hand, it was noted that different network parties having their own antennas ensures (politically) desirable competition, making antenna sharing limited.

The number of computer chips needed for 6G will increase significantly. Chips are needed in antennas (which will likely increase in number) and in devices connected to the internet (which are also expected to increase; internet of everything). In interviews, it was estimated that the number of required chips could increase by a factor of 10 to 100. All interviewees agreed that the demand for chips will grow exponentially. Chips and chip components are made in the Netherlands (think of NXP), but the question is whether we can produce enough in the Netherlands. Producing as much as possible in the Netherlands or Europe is important for strategic autonomy and is therefore (currently) politically desirable. Employment

could increase significantly, and the required skills will not differ greatly from what is currently needed for chip development.

If smart antennas and new antennas are introduced, fiber optics will also be an important product. According to one of the interviewees, this remains the backbone of the connections between antennas. If more antennas are placed, more fiber optic cables will be needed. There are Dutch cable companies (Twentse Kabelfabriek [TKF] and Draka).

Production and Human Capital: All experts indicated that new antennas are needed, and most expect more antennas. This means more work for antenna manufacturers (think of Antennex), and the work will also change due to the demand for smart, small antennas. The production work itself will not change significantly (requiring entirely different skills), but the amount of work is expected to increase significantly. When working with smart lampposts, organizations like Signify and VDL will see a significant increase in work. Additionally, more fiber optics will be needed for the installation of the 6G network, and an increasing demand is also expected here without a significant change in the type of skills required. Finally, more chips are needed, and employment in this area will also increase significantly. Although different chips will be developed, it is not expected to lead to a fundamentally different need for production skills. More specifically, increased employment in the development of antennas, smart lampposts, fiber optics, and computer chips is likely to primarily drive demand for workers with vocational (MBO-level) education, particularly in electrical engineering, process technology, and mechanical engineering. To a lesser extent, it will also increase the need for highly educated professionals with backgrounds in electrical engineering, telecommunications, and mechanical engineering.

3.2. Installation of Physical Infrastructure

As described above, more antennas and cables will be needed, and all of these will have to be installed. Installing and mounting antennas is a significant task, especially if one needs to be installed every 100-300 meters. The installation of both individual antennas and lampposts is not complex; the antennas are likely plug & play. Additionally, these antennas will probably need to be connected to the fiber optic network in many places. If an antenna is to be placed every 100-300 meters and these indeed need to be connected via fiber optic cables, this will generate a lot of work.

More data centers and/or more efficient data centers will also be needed. An operator reported experiencing a 30% increase in data traffic per year. The construction of data centers and the production of components also creates a continuous demand for human capital, which can be boosted by 6G. The production of data centers requires above all construction workers (VET), as well as electrical and mechanical engineers, most of whom are trained at the vocational education and training (VET) level. The physical and digital security of the digital infrastructure also plays a role. This probably leads to a demand of skills of vocational educated security personnel and higher educated IT personnel. Much of this is left to the market, but the government could also take on a role here if this is considered vital infrastructure.

Installation of Physical Infrastructure and Human Capital: A significant increase in work is expected here. The work does not seem to become more complex. Especially the installation and connection of antennas and cables can become a very large task. Most of the work is suited for (lower educated) employees with a general technical background, construction workers and for workers with vocational training in electrical engineering. Additionally, these actions take place in the physical environment, involving municipalities, the government, and residents.

3.3. Maintenance of the network

The expectation is that network maintenance will become simpler. Smarter systems can monitor themselves, thus requiring less work. Much more will be done remotely. Despite the possibility of more antennas, it is not expected to generate more work.

Maintenance of the Network and Human Capital: Little change is expected in this area.

3.4. Software Development

Software is becoming increasingly important, especially in the context of 6G. Major players like Nokia and Ericsson employ their own software developers (often high educated personnel with a background in Software Engineering, IT or Computer Science) and offer a wide range of software for network management and optimization. Additionally, there are many small organizations developing software, including in the Netherlands. AI is playing an increasingly significant role in software development. Part of the development can be taken over by AI, but it will become increasingly important to have developers who understand AI well and can oversee complex systems. Overall, the work for software developers is expected to increase and become more complex. Additionally, a shift from intelligence in machines to intelligence in the cloud is expected. Besides developers, there will also be an increasing need for system integrators. These are often highly educated employees with backgrounds in IT, which need to bring systems together into a working whole for the providers.

Software and Human Capital: There is consensus among the interviewees that both software developers and system integrators will have more work. Additionally, the work will also become more complex. It is worth noting that developers are already accustomed to adapting and working with innovative systems (as they have to do now).

3.5. Network Management

The management of the 6G network will increasingly use AI-supported software. For example, more intelligent troubleshooters will be used to identify bottlenecks in the network. Optimizing network utilization will also be an important task. It is expected that AI support will lead to a limited increase in work.

Additionally, there will be more data streams to monitor. This is because many more systems are connected to the internet (internet of everything), and data centers are expected to be used more flexibly, requiring insight into which application runs on which server. The amount of data and flexible use also brings additional complexity in terms of security. More (high educated) data analysts and data scientists may be needed to work with this data.

The physical infrastructure can be monitored remotely. Although there will be more to manage (more antennas, more cables, etc.), AI will support this to the extent that employment does not change significantly.

Network Management and Human Capital: The work will become more complex and the task more extensive. At the same time, more tools, such as intelligent troubleshooters, will help manage complexity and make work processes more efficient. The expectation of several interviewees is that the network will not become much more complex and that the people currently working in this area are already accustomed to dealing with such changes. An increase in work is expected, but relatively few people in the Netherlands work in this area. One interviewee estimated that at KPN, Odido, and Vodafone, it would

involve hundreds of additional people in network management and security. However, this is a scarce group in the labor market.

3.6. Market for 6G

The market for 6G will mainly focus on new applications enabled by 6G and companies seeking customized solutions (think of port companies, agricultural businesses, or factories). There will likely be no direct market for consumers, as respondents currently do not expect changes in how consumers use the network, and 6G would have limited added value. The commercial departments of providers will need to sell more customized solutions. They will need to collaborate more with companies (ports, factories) to develop solutions together with customers.

Marketing and Human Capital: Overall, the challenge of marketing 6G currently seems significant. It is expected that the nature of the work will change as more company-specific knowledge will be needed to deliver customized services. This will increase the demand for business developers, account managers and sales engineers.

3.7. Applications

This exploration focuses on the impact of network technology on human capital. However, network technology enables various new applications. Thus, 6G indirectly influences this. New or improved services such as drone package delivery, better-regulated traffic flows, or increasingly complex digital twins (e.g., of a city) can be developed. VR headsets may also find new applications. No one has a clear view of the 'killer app,' and past killer apps have often been surprises. Nonetheless, a significant relationship between 6G and employment is expected.

Applications and Human Capital: There will be more work for app developers, and the work may become more complex due to the more intensive interaction between the network and devices. This is a profession that is already accustomed to dealing with change and can adapt to it.

4. Conclusions and recommendations for follow-up

6G is expected to have significant implications for human capital, according to the respondents. The extent of this impact remains unclear as there is still much uncertainty about what 6G will look like. There is expected to be considerable employment in the production of components and the installation of infrastructure. The development of AI-supported software to optimize and manage the network is also a significant task. Although this is not currently done in the Netherlands, it could be in the future. The respondents mainly see implications for employment and expect that the demand for different skills within professions will not pose significant bottlenecks. Our experience shows that the changing skills needs become more apparent when research activities are more specifically focused on certain work processes and tasks.

The working group has a need to quantify the results presented here as much as possible. It is possible to develop one or more scenarios based on assumptions about the form 6G will take (e.g., ten times as many antennas) and attach figures to them. The uncertainty is very high, so the range of these estimates will also be wide. The question is whether it is worth the cost to quantify all components at this stage of 6G development.

Another option is to delve deeper into specific components and provide qualitative and quantitative depth on those specific components. Given the limited budgets for the human capital issue within FNS, this seems like an obvious option. Criteria for choosing a component could include expected impact (how many workers are affected and to what extent), the most critical functions needed to make 6G a success, the labor market scarcity of functions related to 6G, the desirability of attracting certain employment or industries, etc. Activities undertaken at the 'testbeds' can also be aligned with this.

At the same time, we do not need to sit still and wait for 6G to be fully developed. The dialogue with key stakeholders such as educational institutions and sector organizations can continue regarding the potential implications and how to prepare for them. The developments of 6G must also continue to be monitored, and the discussion about the impact on human capital must be held at various times. This way, a choice for a particular direction can be influenced by also considering the availability of human capital in the business case.

Appendix 1: Participants interviews and working group

The interviews were conducted with:

- Floris Drijver, Senior Scientist at TNO and the Technical Lead of WP 4.1 (FNS).
- Eric Smeitink, Senior Manager, Technology at Koninklijke KPN NV.
- Paul Wijngaard, Senior Business Development Manager TNO and Alliance Director 6G Future Network Services.
- Andreas Daun, Account CTO Vodafone/Ziggo, Ericsson.
- Jeroen Zaalberg, Technology Program Manager, Vodafone/Ziggo.
- Robbin Hof, (formerly) Head of Audit & Compliance, Gomibo Group.
- Jos Berière, Program Lead 6G Applications, TNO.
- Bart Smolders, Full Professor and Chair of the Electromagnetics (EM) group, TU Eindhoven.
- Ben Kokkeler, Lecturer of the Digitalization and Security research group at Avans University of Applied Sciences, Senior Consultant at the European Technopolis Group.

Participants in the Human Capital working group within FNS included:

- John Herfkens (PTvT).
- Linso van der Burg (PTvT).
- Jan Henk Kamps (Sabic).
- Jelle Post (TU Delft).
- Roland Klarenbeek (Hanze).
- Lenneke de Voogd (TU Delft).
- Ties Dammers (RDI).
- Elke Spiessens (TU Delft).
- Rob van der Maarel (TNO).
- Jeroen Zaalberg (Vodafone/Ziggo).
- Cas Damen (Saxion).