WHITEPAPER

5G Health

The need for 5G technologies in the healthcare domain

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(Version 1.0)

Authors of the whitepaper
Clemens Bulitta, Technical University of Applied Sciences Amberg-Weiden, Weiden
Frank Edelmann, Department of Internal Medicine and Cardiology, Campus Virchow-Klinikum, Charité Universitätsmedizin Berlin & German Centre for Cardiovascular Research (DZHK)
Steffen Hamm, Technical University of Applied Sciences Amberg-Weiden, Weiden
Alfons Mittermaier, highstreet technologies GmbH, Berlin
Thomas Neumuth, Universität Leipzig, Innovation Center Computer Assisted Surgery, Leipzig
Max Rockstroh, Universität Leipzig, Innovation Center Computer Assisted Surgery, Leipzig
Ann-Christin Schleser, Technical University of Applied Sciences Amberg-Weiden, Weiden
Christoph Thümmler, Helios Park-Klinikum, Leipzig

Executive Summary

The traditional healthcare systems are going through massive and permanently accelerating change. These changes are driven by improved or newly emerging information and communication technologies (ICT). Upcoming technologies will include advanced digitization concepts and approaches to virtualization, based on principles adopted from industry 4.0 standards.

In turn, the latter will strongly rely on advanced data communication capabilities such as those offered by 5G technology to support future healthcare. The application of these technologies will increase patient access to health services regardless of geographical location while at the same time improving ease of use and comfort and contribute to increased patient convenience, reduced patient risk as well as to increased health efficiency.

5G applications in health must meet essential communication requirements such as reliability, availability, and security for fast and high-volume data transmission. Original features that provide added value for healthcare are network virtualization functions, network slicing, as well as the power to supersede conventional hard-wired networks.

This article discusses tangible and realistic clinical applications and technology implementations that go beyond the current state of the art and draft future applications. The use cases are clustered according to different stakeholder groups such as hospital management, clinical departments, health authorities, and emergency responders, as well as individual users. They comprise a large variety of operational areas such as distant medical services, health facility dynamization as well as mobilization and virtualization of biomedical technology.

We expect the main benefits of 5G for use cases in the field of hospital management, clinical department operations, and emergency response. The implementation timelines are estimated from short- to mid-term after the general roll out of the technology.

Current challenges related to 5G health applications comprise high investments for infrastructure, missing macroeconomic guidelines, and the ongoing discussion about the effects on human health.

5G is a significant enabler for advanced digital health services. From a technical point of view, some technologies concerning intelligent healthcare are currently still in an experimental phase and require a considerable amount of expenses and effort for maintenance and promotion.

Content

1.   Introduction

1.1.   Why do we need 5G for future healthcare?

The traditional healthcare systems are going through massive and permanently accelerating change. These changes are driven by improved or newly emerging information and communication technologies (ICT). With the help of these ICTs, sophisticated healthcare services are ubiquitously available – they can be anywhere at any time for any use case possible, only limited by our imagination.[1]

However, at the same time, the aim needs to focus on the combination of the best available technologies with the best clinical outcome to make healthcare affordable and accessible for everybody anywhere and anytime. This combination eventually could boost efficiency and allow for a personalized approach to medicine while still maintaining the highest quality of patient care.

The development of healthcare will take place synchronously on various levels. Firstly, the patient-care paradigm is already shifting from hospital-focused and disease-specific to a distributed patient-centered care model, also bridging sector-specific hurdles of healthcare providers. Secondly, the generation and processing of health-related data emerge from intra-institutional to regional availability. Also, health management is moving on from general and generic to personalized management. Moreover, the healthcare systems focus is evolving away from the treatment of diseases towards the prevention of illness altogether.

This new approach – referred to as „4P" medicine (personalized, preventive, predictive, participatory) [2] – requires innovative technologies to enable the added value for the patient. Such technologies will include advanced digitization concepts and approaches to virtualization, based on principles adopted from industry 4.0 standards[3]. In turn, the latter will strongly rely on sophisticated data communication capabilities such as those offered by 5G technology to support future healthcare.

Additionally, the application of these technologies will increase patient access to health services regardless of geographical location while at the same time improving ease of use and comfort. It will improve patient care in areas with inadequate medical coverage allowing for location-independent access to knowledge-bases and thus reduce costs for and enhance the quality of health monitoring, diagnostics, and therapeutics, due to using synergies in resource utilization.

1.1.1.   Increasing patient comfort and decreased patient risk

Patients are no longer willing to compromise on their care: They expect immediate and personalized

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1   Weiser M, The Computer for the 21st Century. Scientific American 1991

2   Hood L, Friend SH. Predictive, personalized, preventive, participatory (P4) cancer medicine. Nat Rev Clin Oncol. 2011;8(3):184–7.

3   Thuemmler C, Bai C. Health 4.0: How Virtualization and Big Data are Revolutionizing Healthcare. Springer International Publishing; 2017

attention to the highest standard even in rural areas. New technologies are needed that comply with these requirements. Currently, patients are often frustrated by the hurdles associated with obtaining healthcare services, such as travel time to see a specialist, waiting times for appointments, and delays in getting test results. The availability of suitable technologies could quickly change these dilemmas. According to a study, 39% of chronically ill patients prefer online consultations to direct physical meetings with medical staff.

Additionally, some patients may benefit from telemedical services as they could consult their medical practitioner on the fly and independent from their location. Thus, the goal should be to develop and to deploy technologies that can provide personalized healthcare services directly at the patients' side [4] and to enable virtual patient treatment. This development includes continuous patient monitoring and smart medication administration[5] as well as automatic pattern detection and assessment of global knowledge bases.

Furthermore, all information regarding health needs to become ubiquitously available: Healthcare providers need to cooperate and to network with each other across different sectors and regions to exchange data based on agreed standards. 5G is one of the essential technologies required to implement this transformation of the delivery of health services. Currently, these services are volume-centered, accounted for the number of services provided. We need to evolve this into a value-based model centered on healthcare providers accounted for by the quality of services.

1.1.2. Cutting costs for the provision of health services

Information technology can continue to reduce costs in the health domain by providing distributed, patient-centered care, decentralized health services, distant from hospitals, but personalized and instantly accessible from anywhere. An additional aim is to enhance reliability and trust by achieving higher granularity of patient data and improving the services and their service levels. 5G will allow for instant aggregation of data stored in distributed instead of local repositories. This aggregation will be mandatory to keep patient data safe to highest standards and satisfy the growing requirements for patient confidentiality. Consequently, it will support more effective and efficient patient care.

5G furthermore allows for a shift towards virtualization of services, so that services might be personalized and designed in hospital but delivered in nursing homes or elsewhere. This development makes a direct translation into additional savings highly probable bit most of all boost the quality of life for patients and carers. Within healthcare facilities, such as hospitals, 5G enables more flexibility by offering independence from hard-wiring. Changes in the hospital layout become considerably cheaper as expensive and time-consuming Gigabit data stream infrastructure will not be needed anymore. Thanks

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4   Ericsson ConsumerLab. From Healthcare to homecare. 2017.

5   How 5G Could Transform the Delivery of Healthcare. Available from: http://www.cambridgewireless.co.uk/news/2019/nov/18/how-5g-could-transform-delivery-healthcare/

to 5G transmission of Gigabit streams will be seamlessly possible from any location within hospitals, including operating theatres and radiology departments. More than half of the decision-makers expect that the decentralization of healthcare services to local facilities will help solve resource scarcity and increase the efficiency of care.

1.2.   What makes 5G different from current technologies

5G technology is not a unique, innovative technology but a range of progressive techniques in all relevant areas of mobile communication. 5G includes innovations to the radio access framework (RAT), the core technology, and on network level through the introduction of new strategies such as Software Defined Networks (SDN) and Network Function virtualization (NFV) or Virtual Network Functions (VNF)[6].

Amongst the many advantages of 5G technology are main features such as a high-volume data transmission, low latency, rapid diffusion of information, and the possibility to connect a much higher number of devices than any other mobile technology before (see Figure 1). Please note that we discuss the technical features in more detail in section 3.

High volume data transmission

Fast data transmission   Multiple senders and receivers
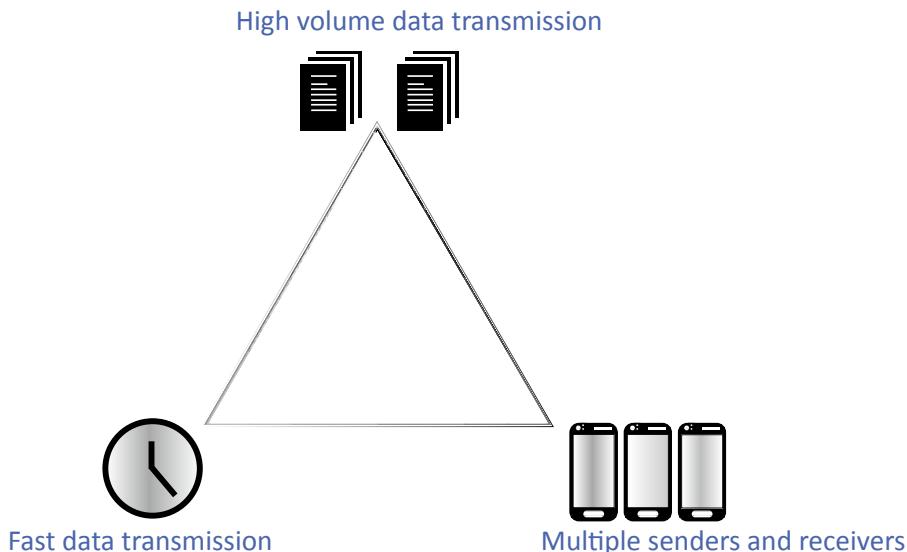
Figure 1: Main features of 5G radio technology

Other network technologies partially cover some of the mentioned technical features. WiFi, for instance, provides high-volume data transmission capabilities but does not guarantee data delivery times. In contrast, field bus communication technologies provide low-delay and extremely reliable communication but often lack high-volume transmission capacities.

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6   5G PPP Architecture Working Group. View on 5G Architecture, Version 3.0. 5G PPP; 2020.

5G combines these features and integrates them to form one core technology. This combination generates vast opportunities for health verticals, which shall be discussed in detail in this white paper. In particular exciting features are that local network limitations do not apply, and health data, independent of the specific volume requirements, may be transmitted with consistent quality and low latency through heterogeneous networks. Network functions and systems will be virtualized. Thus, there will no longer be a need for hard-wiring and Gigabit pipes in hospitals. This fact provides increased flexibility for hospitals as they can quickly adapt to changing markets and requirements.

1.3.   Why yet another whitepaper for the healthcare vertical?

The objective of this paper is to discuss tangible and realistic clinical applications and technology implementations that go beyond the current state of the art and draft future applications. All introduced use cases are driven by current clinical needs in real-world scenarios, thus approaching 5G use cases from the point of view from the practitioner or related professions such as biomedical or medical informatics experts.

In 2015, the 5G Infrastructure Association of the European 5G PPP initiative authored an original whitepaper on the health domain[7]. Afterward, several 5G and health-related papers emerged, put together, for example, by the NGMN Alliance and others[8,9,10]. In the meantime, requirements and specifications became more application related. Thus, a concise assessment of current conditions and specifications is long overdue.

According to the latest Cisco report, 5G will constitute 10% of global mobile connections by 2023[11,12]. It is safe to assume that a significant growing share of this will be health-related as new models to deliver healthcare are emerging with a focus on IoT and virtualization.[13] These developments will be based on 5G as enabling technology and will drive the global uptake of 5G, similarly to the automotive industry. In this context, it is essential to highlight that in Europe, healthcare reflects a more significant share in the GDP than automotive and this trend will continue.

This white paper presents a variety of clinically relevant use cases for 5G applications that go beyond the current instances that 3G PPP TR 22.826[14] specifies

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7   5G Infrastructure Association. 5G and e-Health. 5G PPP; 2015.

8   NGMN Alliance. NGMN 5G White Paper. Next generation mobile networks; 2015

9   Thuemmler C, Rolffs C, Bollmann A, Hindricks G, Buchanan W. Requirements for 5G based telemetric cardiac monitoring. In: 2018 14th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob). 2018. p. 1–4.

10   Thuemmler C, Jefferies N. A New Generation of e-Health Systems Powered by 5G. Wireless World Research Forum. 2016

11   Cisco. New Cisco Annual Internet Report Forecasts 5G to Support More Than 10% of Global Mobile Connections by 2023. 2020. Available from: https://newsroom.cisco.com/press-release-content?type=webcontent&articleId=2055169

12   Cisco. Cisco Annual Internet Report - Cisco Annual Internet Report (2018–2023) White Paper [Internet]. Cisco. 2020.

13   Thuemmler C, Bai C, editors. Health 4.0: How Virtualization and Big Data are Revolutionizing Healthcare. Springer International Publishing; 2017

14   3GPP. Study on communication services for critical medical applications, TR 22.826, Release 17. 2019.

2.   5G for healthcare - How people benefit

This section presents a selection of clinically relevant use cases for 5G applications to highlight the clinical potential of 5G technology. To stratify the use cases, we will group them by user group and applications and pinpoint the relevant aims and objectives, requirements, and estimated times to market. The different categories of users are patients and carers, professionals such as doctors, nurses, therapists, managers, industries, politicians, and legal institutions.

Clinical facilities are integral parts of national health services. 5G technologies will optimize communication for areas such as telemonitoring or telehealth and will fundamentally change the way healthcare will be delivered across the 21st century. We will demonstrate and discuss some practical examples to highlight the upcoming changes in different areas in the health domain.

Hospitals, practitioners, nursing services, and nursing homes, rehabilitation facilities make up our first group. This section includes 5G use cases to manage the hospital and to support the work of specific departments before and after discharge.

Regional decision-makers are institutions that are responsible for enabling, managing, and controlling the healthcare system. Examples are health authorities, ministries of social affairs, as well as emergency first-responder and epidemic management.

Individual users and their family members use technologies for personal reasons. This category includes assisted as well as self-responsible health monitoring. There are applications for ambient assisted living (AAL) and non-medical self-tracking that have no clear-cut separating line to medical applications. Please note that we restrict the use cases in this group to purely medical products.
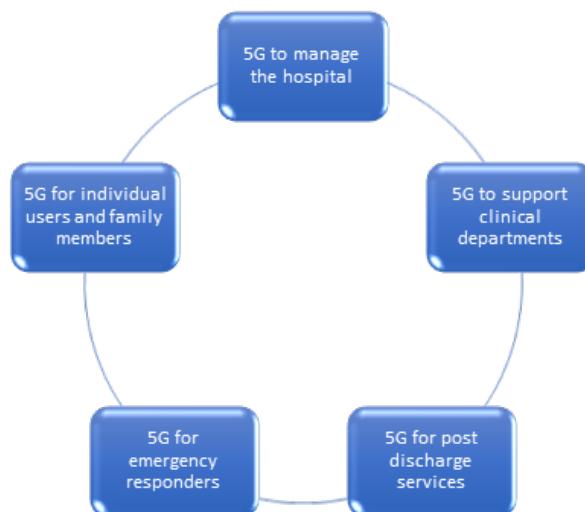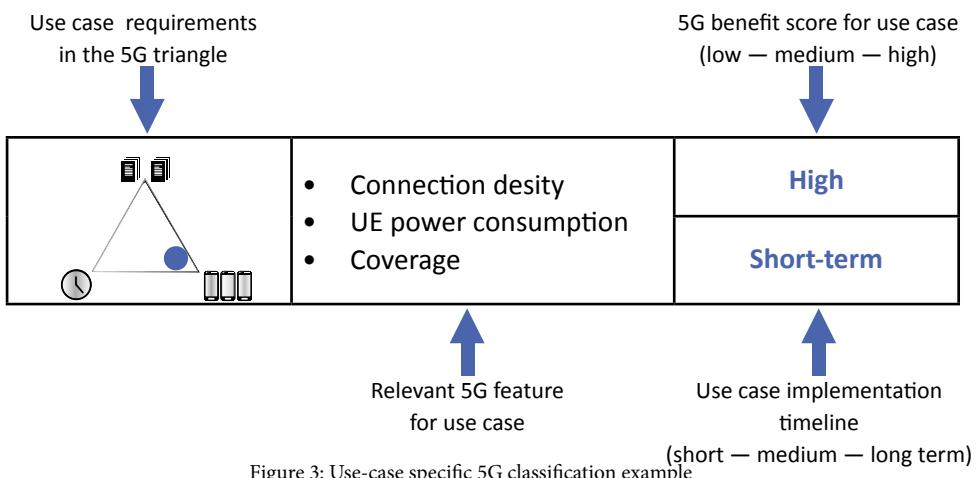

Figure 2: Classification of 5G use cases in the white paper

To increase the readers' identification with the use cases that affect individual patients, we will later introduce personas for some use cases. These provide a more immersive perspective on the use cases and support understanding as well as credibility.

For a proper linking of the clinical use cases to the technology, we support every use case with a technical characterization. This assessment consists of four indicators (see also Figure 3). Firstly, we will present a qualitative evaluation of the use case according to its classifications in the "5G triangle" (requirements for data volume, transfer time constraints, and the number of senders).

Secondly, the authors will present a listing of 5G specific technical features and technical properties that the use case requires.

Lastly, we will introduce two parameters that provide an estimation of how strong an application benefits from 5G. The first parameter is the "5G benefit score". It focuses on 5G-specific features and KPIs and is expressed on an ordinal scale of low, medium, and high. The second parameter estimates the timeline for the implementation of the particular feature from the date of availability of necessary 5G infrastructure (parameter "use case implementation timeline" on an ordinal scale of short-term: <5 years, mid-term: 5-<10 years, long-term: >10 years). Both parameters, the benefit score and the timeline, have been obtained by a Delphi study with seven experts.

Figure 3: Use-case specific 5G classification example
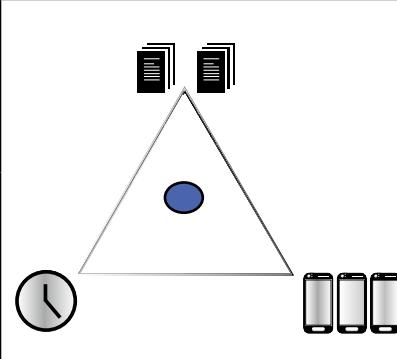
Please note that in the context of the white paper, we understand 5G as an overarching platform technology. This platform technology offers a uniform and technologically consistent basis for the implementation of medically relevant functions. In some cases, individual use cases can already be realized by combining different technologies. However, we expect these different technologies to be replaced by 5G in the medium term.

2.1. 5G to manage the hospital

2.1.1. Hospital retrofitting

A university hospital built in the 20th century needs to modernize its infrastructure. The planners assumed that individual hospital facilities would not change during the lifetime of the building. Thus, the building has highly specialized and custom-made structures. These structures include glass-fiber cables with high-speed data pipelines and hard-wired data outlet points. To continuously adapt to new trends, new technologies, and the ever-changing demands on the health market [15], it is vital for the hospital to adjust its infrastructure to ubiquitous computing [16] and to implement agnostic technology.

Today's rapid changes in hospital-infrastructures, functions, and services need to be almost seamless with as little interruption to services as possible. Alternative structures are not available due to years of hospital bed curbing [17]. 5G enables the hospital to meet new needs without having to undergo rigorous reconstruction measures, interfering less with occupancy, utilization, and service allocation. The technology also supports future extensions without the need to re-wire the hospital environment every time.

	• UE Data Rate • End-to-end latency • Availability • Reliability • Trafic density	**High**
	• Connection density • Coverage • Time error • Security • Network slicing	**Short-term**

2.1.2. Virtualization of clinical services
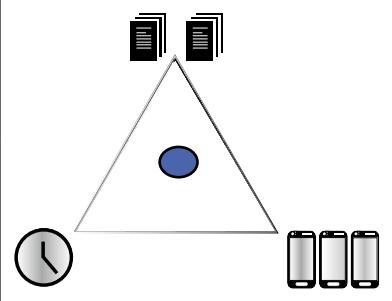
Most mid-sized hospitals don't have a dedicated cranio-maxillo-facial (CMF) surgery department. Let's assume that such a hospital wants to establish a new clinic to provide CMF-related services. Thus, it purchases basic diagnostic and therapeutic CMF device bundles for on-site treatment and licenses advanced functions such as volume reconstruction, personalized implant planning, and patient-specific treatment services from an external CMF service provider.

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15   Luoma Halkola L (2017) Modular Service Concept for Hospital Retrofits, Master Thesis, Aalto University, School of Engineering

16   Weiser M (1991) The Computer for the 21st Century, SciAm, September 1991

17   Eurostat (2020) Hospital beds, https://ec.europa.eu/eurostat/databrowser/view/tps00046/default/table?lang=en
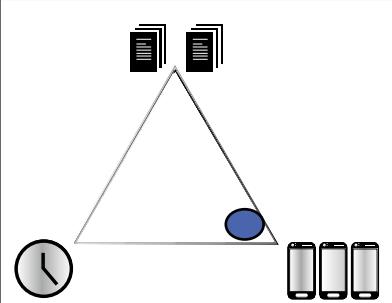
Doctors and other medical staff do the diagnostic and therapeutic parts of the treatment on-site in the hospital. At the same time, advanced processing services are performed on the servers of the service provider and processed in real-time over the 5G network. The private campus network will be able to reconfigure and pass through CMF service bundles according to individual requirements and specifications.

	• Availability • Reliability • Traffic density • Connection density • Coverage • Security • Network slicing	**Medium**
		Mid-term

2.1.3. Hospital equipment management

A mid-sized hospital operates several thousand medical devices – including diagnostic and therapeutic tools – monitoring technology and patient equipment. The management of these various devices presents a significant challenge for the localization, maintenance, and efficient employment of the machines. All appliances, for instance, ultrasound machines, infusion pumps, wearable ECG machines, or hospital beds, provide their current technical status over the hospital 5G campus network.
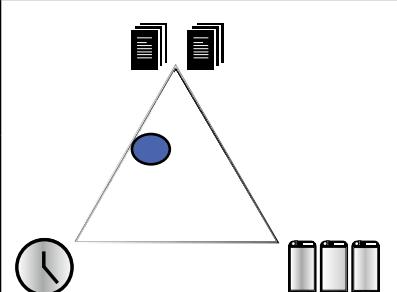
The hospital management can continuously monitor the technology readiness and functional status of the devices, also under mobile operation. Additionally, the hospital equipment management system gathers other parameters such as localization of the tools, intrahospital mobility, and usage rates.

	• Connection density • UE power consumption • Coverage • Network slicing	**High**
		Short-term

2.1.4. Location-independent healthcare staff training

Digitization has found its way into all areas of education and training. In the healthcare sector, at university hospitals and academies for health professions, online platforms convey knowledge. Augmented and virtual reality glasses enhance and deepen theoretical training. Students can use virtual spaces to experience and train various scenarios from everyday practice. They can learn reporting and diagnostic techniques with the help of AI-based diagnostic systems.

5G technology, with its low latency and the secure real-time transmission of large data packages, has become the decisive tool for telerobotics-based operations. Prospective surgeons learn to perform surgery on smart devices with sensory feedback that will enable doctors to treat remote patients – for instance, in rural areas – while remaining on-site. The rapid development of new digital assistants in healthcare and the integration of 5G-based technology make all processes in healthcare and teaching more efficient and save resources.

	• UE Data Rate • End-to-end latency • Trafic density • Connection density • Coverage • Network slicing	**High**
		Mid-term

2.1.5. Parameter overview for hospital management use cases

The parameter aggregation overview (see Figure 4) demonstrates that the hospital management use cases will strongly benefit from 5G technologies. The implementation timeline is estimated between short- and mid-term.
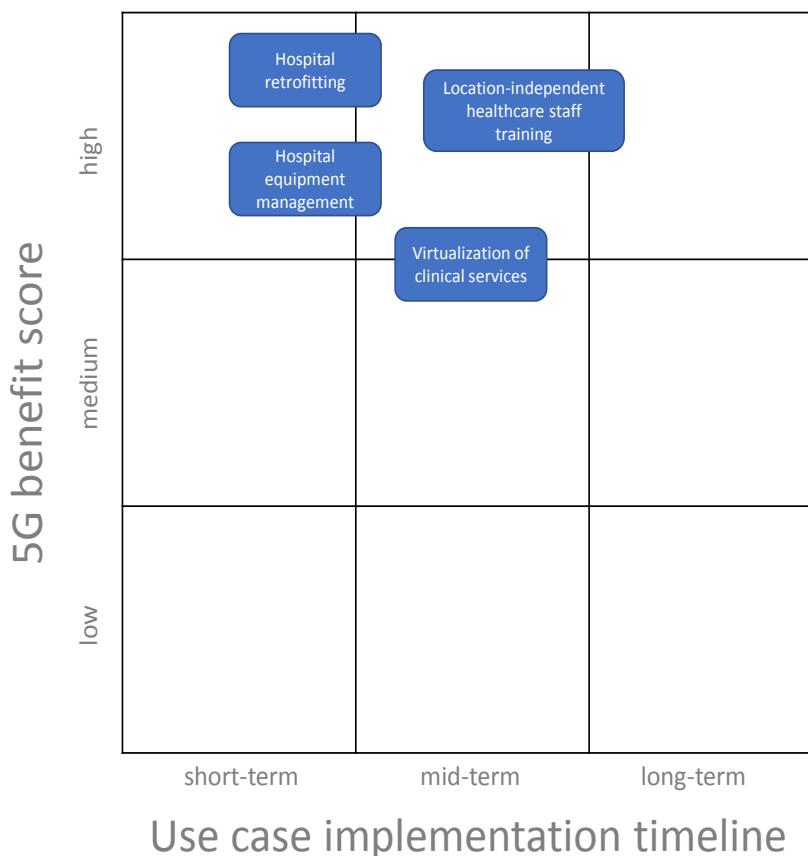
Figure 4: Parameter overview for hospital management use cases
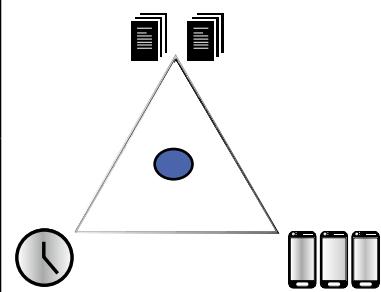
2.2. 5G to support the department

2.2.1. Patient monitoring outside wards

Some patients, for example, after extraction of infected pacemakers, will have to stay in the hospital for several weeks, although they are relatively fit and able to move. Typically, patients are advised by the staff to remain in the ward for monitoring issues at any time to prevent an emergency from happening unnoticed by the medical staff somewhere on the hospital premises.

The dilemma is that these patients feel well and tend to forget their vulnerability. To prevent unnoticed cardiac emergencies, the patient wears a unit that simultaneously monitors ECG and tracks location. However, the infrastructure for person tracking is not yet ideal: The patient moves through different WiFi cells and might even come through areas not covered by radio transmitters. Consequently, there is a risk of signal loss due to poor roaming capabilities.

5G enables the constant monitoring of mobile patients with high risks of cardiac arrhythmia or cardiac arrest across different networks within the hospital. Furthermore, it also allows for an extension of cardio monitoring capabilities beyond wards.
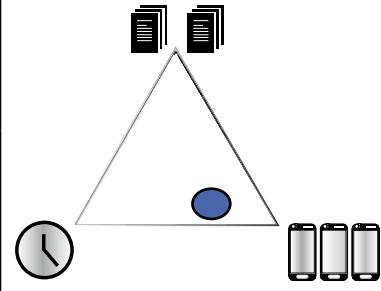
| | • Availability
• Reliability
• Connection density
• Coverage
• Maximum UE velocity
• security | **High** |
| | | **Short-term** |

2.2.2. Patient tracking to execute supervision duties

Apart from psychiatric wards, modern hospitals are typically not designed to restrict the freedom of patients. Especially in the case of elderly patients with dementia, it would be counterproductive to isolate and exclude patients from daily life. Many patients with cognitive deficits are otherwise fully capable adults. Thus, it would be ethically irresponsible to restrict their freedom.
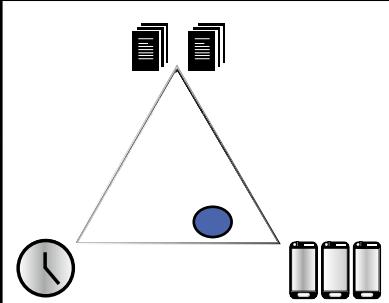
However, this matter is highly complex: The condition of demented patients sometimes prompts them to neglect or underestimate dangers, thus leaving their home or the hospital unattended or stepping outside without appropriate clothing to keep them warm. Also, lack of mental capacity means that some people lose their way or forget where they want to go altogether.

To reduce the associated patient-risks interactive trackers with geofencing functionalities could be piloted. When people with cognitive disorders approach certain defined boundaries, staff or relatives will receive a notification. Thus, patients with milder dementia could be reassured, guided, and kept safe.

| | • Reliability
• Connection density
• UE power consumption
• Coverage
• security | **Medium** |
| | | **Short-term** |

2.2.3. Supporting medication compliance
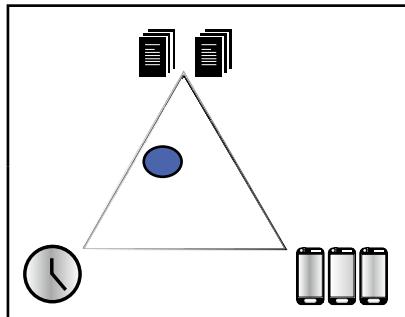
Ward nurses need to check and record medication compliances. Interactive smart pharmaceuticals can support them in the future: Smart inhalers or insulin pens, and similar devices equipped with an embedded subscriber identity module (eSIM) can record their application. Additionally, these devices might implement sensors and algorithmic functions to estimate the medication effect on the patient and consequently predict critical situations. These devices may also support personalized medication dose management and precision medicine.

	• End-to-end latency • Availability • Reliability • Connection density • UE power consumption • Coverage • Maximum UE velocity • Security	**High**
		Mid-term

2.2.4. Interhospital patient handover
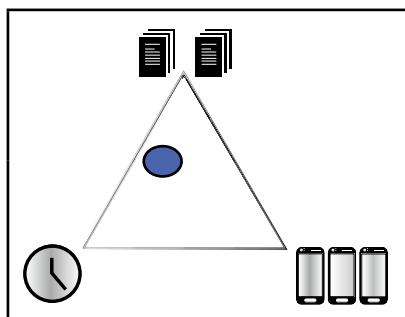
Mr. Hopkins, age 58, suffers an acute heart attack. In the hospital, he undergoes surgery and receives a bypass. In the aftermath of the successful intervention, he is under observation in the cardiological intensive care unit in general intensive care medicine. All parameters of the patient are checked continuously for 24 hours. All intensive care devices store the information, are connected via a 5G network, and analyze the patient's data.

After 48 hours without further incidences, the hospital transfers Mr. Hopkins to a district hospital near his home. Subsequently, also rehabilitation for 3 to 4 weeks in a rehabilitation unit or an ambulatory setting is needed for the patient. The cardiologists can transfer the information concerning the course of the operation to the district hospital via telemonitoring using 5G. Also, his data from the monitoring in the university hospital is accessible by the staff of the district hospital: The doctors can access all findings, radiological images, and the documentation as well as his monitoring data. Based on this, further treatment and medication can be determined to provide the patient with optimal care without delay.

	• UE Data Rate • Availability • Reliability • Time error • Security	**Medium**
		Short-term

2.2.5. Digital twins for location-independent patient assessments

Dr. Smith supports peripheral hospitals in the telemedical assessment of geriatric patients. Additionally, she provides specialized assessments for hospitals without a care of the elderly department, nursing homes, and home environments. For this task, she needs to assess digital twins of the patients with information from different repositories. Her exploration of the patient includes ad hoc retrieval and volume rendering of extensive image volume data and bidirectional communication for dynamic and interactive research of dedicated aspects on remote devices. Thus, she requires effective communication with different sources as well as structuring, displaying, and interacting with patient information in real-time.

	• UE Data Rate • End-to-end latency • Availability • Reliability • UE power consumption • Time error • Security • Network slicing	**High**
		Mid-term

2.2.6. Parameter overview for department support use cases

The parameter aggregation overview (see Figure 5) demonstrates that the use cases for the clinical departments will strongly benefit from 5G technologies. The implementation timeline is estimated between short- and mid-term.

5G benefit score (y-axis: high, medium, low)
Use case implementation timeline (x-axis: short-term, mid-term, long-term)

- Hospital retrofitting
- Hospital equipment management
- Location-independent healthcare staff training
- Virtualization of clinical services
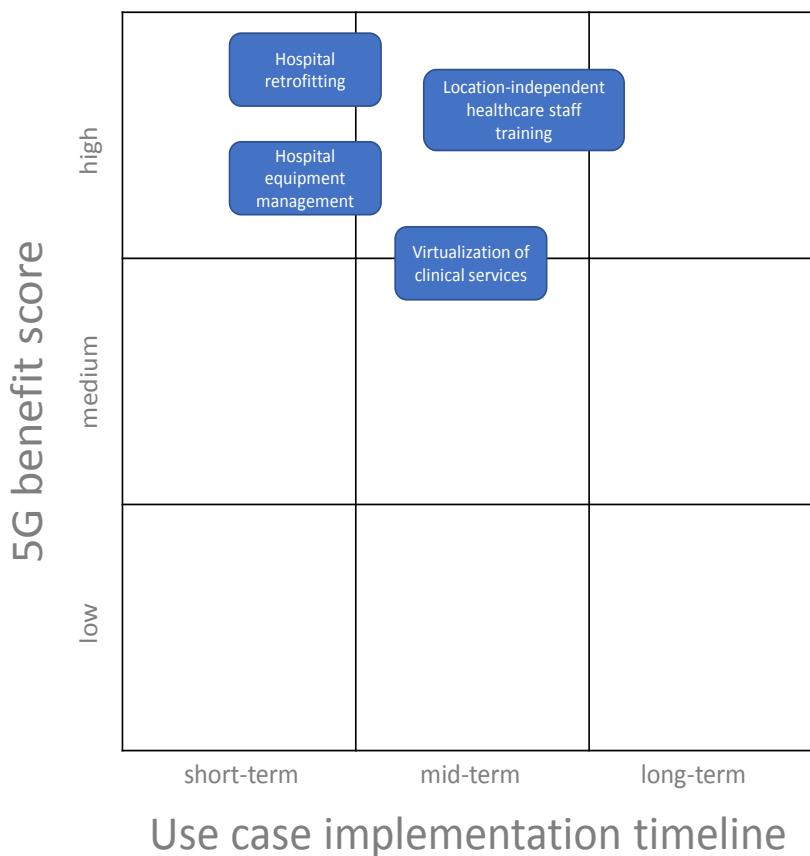
Figure 5: Parameter overview for department support use cases
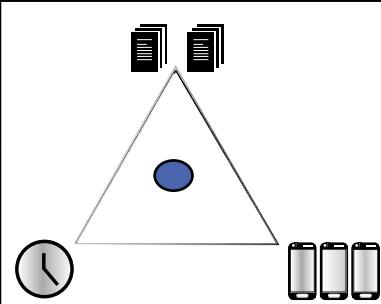
2.3.   5G for post-discharge services

2.3.1. Distributed AI services for personalized medicine

Mrs. Porter, 46, has received a breast cancer diagnosis and is scheduled for chemotherapy. Consequently, she must visit the chemotherapy medical center several times a week. To assess the progress of the therapy, an on-site nurse draws a blood sample at the start of each session. The sample is then analyzed, and the data stored.

Furthermore, the distributed data is sent in real-time to a centralized laboratory in the hospital using 5G technology. An AI algorithm provides recommendations for action based on the patient's blood count. The chemotherapy is then adjusted accordingly, and the therapy can be adapted individually to Mrs. Porter. The benefits, aside from a personalized treatment for Mrs. Porter, are numerous. She

is spared waiting times as the adaptation of the therapy takes place immediately without delays. As a result, the medication, for instance, against nausea or her pain medication, can also be adjusted.
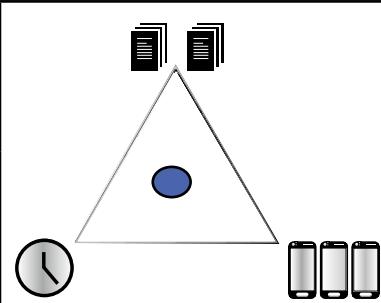
| | • Availability
• Reliability
• Security
• Network slicing | **Medium** |
| | | **Mid-term** |

2.3.2. Predictive monitoring by health service providers

Mr. Mendel suffers from heart-failure induced congestion and shortness of breath. Such acute phases often lead to hospital stays and life-threatening situations. Usual therapies using oral tablets do not work anymore after this point. Thus, Mr. Mendel is admitted, and in-hospital treatment and monitoring are required.
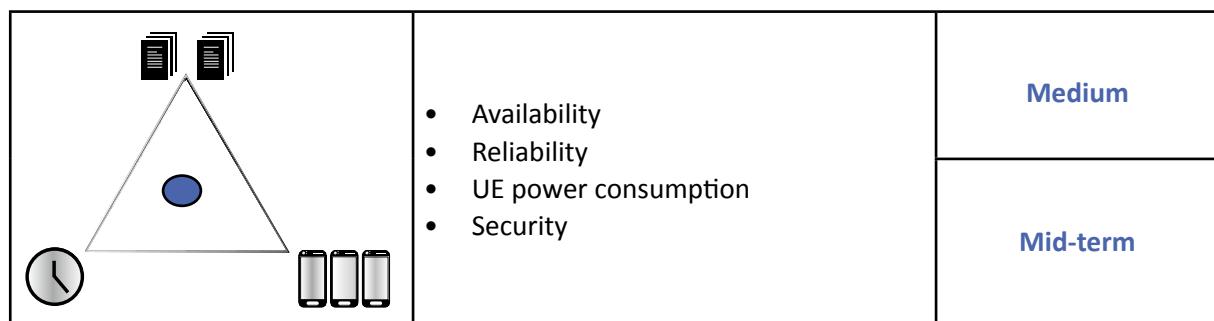
Therefore, early detection of acute phases remains a key to improve patient care. By geotracking wearables, a heart-failure specialist can track the daily distance, speed, and pattern walked in different facilities of the university hospital. From the data, he can deduce a deterioration of Mr. Mendel's condition. A reduction in the walking distance and or speed over days indicates a change in exercise capacities and increased shortness of breath the beginning of a clinical decline. The specialist can then initiate measures even before the patient himself realizes a deterioration.

The physician tracking this information will contact the patient to tell him how to adapt his medication to the current situation. Thus, Mr. Mendel avoids a potential stay in the hospital. The geotracking tool needs to include other information as well, such as blood pressure and heart rate.

| | • Availability
• Reliability
• Security | **Low** |
| | | **Short-term** |

2.3.3. Medical tourism and shared care

After a complicated surgical intervention on her heart in a German specialized cardiological unit, 64-year-old Mrs. Khan from Saudi Arabia returns home. Despite the distance, a team of cardiologists in the German clinic still monitors her heart-functions using various sensors worn by Mrs. Khan. 5G transmits the vital signs in real-time. Utilizing a telemedical platform, the Saudi Arabian doctors who continue the treatment also have access to this data. Furthermore, they can use the platform for teleconsultation and exchange information with their German colleagues. Also, an alarm system integrated into the wearables on Mrs. Khan can alert her treating doctors or emergency services should her vitals deteriorate.

	- Availability - Reliability - UE power consumption - Security	**Medium**
		Mid-term

2.3.4. Parameter overview for post-discharge service cases

The parameter aggregation overview (see Figure 6) demonstrates that the use cases for the clinical departments will strongly benefit from 5G technologies. The implementation timeline is estimated between short- and mid-term.
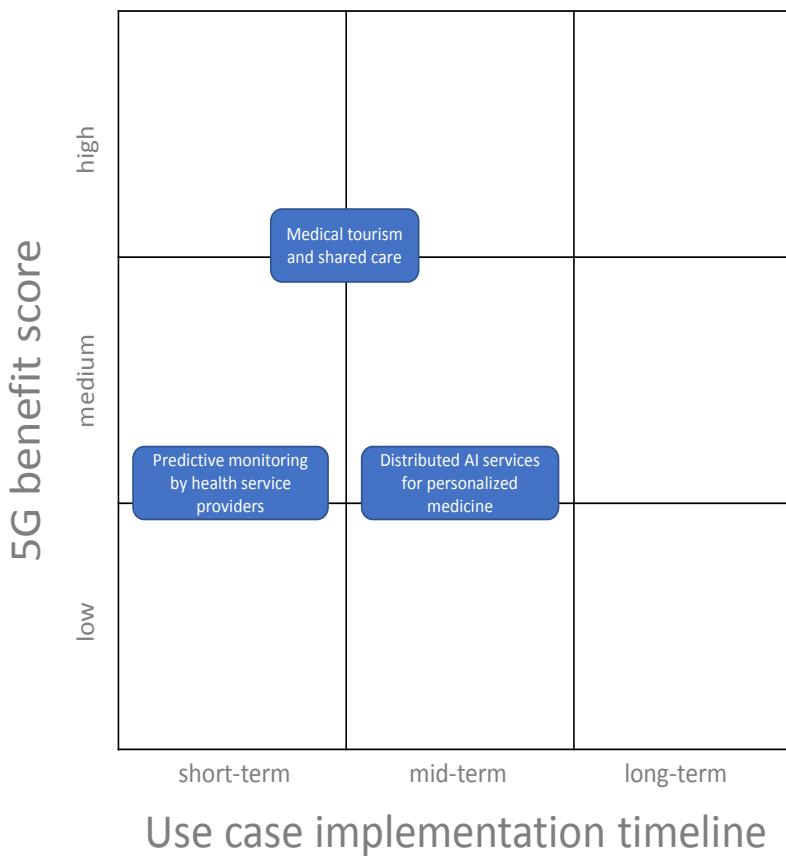
Figure 6: Parameter overview for post-discharge service use cases

2.4.   5G for emergency responders
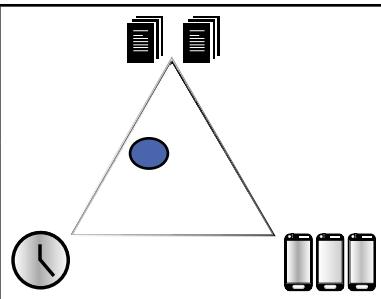
2.4.1. Emergency medical services

Mr. Marin, 34, married, car courier, and a new father, has had an accident on the freeway between Berlin and Magdeburg due to lack of sleep. As a result, he is injured and trapped in the driver's seat. Upon impact, however, his car's integrated emergency call system dispatched a message to emergency services via 5G.

Upon arriving at the scene of the accident, the arriving rescue forces realize that they need a cutting tool owned by the fire brigade to free Mr. Marin. They also notice that the victim of the accident fell unconscious and shows signs of shallow breathing. Due to heavy traffic, the emergency physician on duty will not arrive for another couple of minutes. Thus, the rescue team decides that they need to act quickly because of the life-threatening situation. They need to gather additional information concerning the state of Mr. Marin to be able to help him.

Using the ambulance's technological infrastructure, a local 5G mobile communication cell is established. Gathered data, such as video and sound, is then transmitted to an available, experienced emergency physician via a telemedical application. This physician can then review the data and help the on-site team make time-sensitive decisions. Additionally, a rescue assistant can gather more data by fastening a belt to Mr. Marin's chest to measure lung function through electric impedance. This information is also transmitted via 5G to the remotely assisting emergency physician.

After a review of all available data, the doctor assumes that the patient is suffering from a collapsed lung. As a precaution, he asks the assistant to make an ultrasound of Mr. Marin's chest. Via a telemedical application, he can aid the assistant during the recording by projecting supportive data on the rescue teams' augmented reality glasses. When the initial diagnosis is confirmed, the doctor dispatches a rescue helicopter that will fly Mr. Marin to the nearest trauma center. When the fire brigade finally arrives, the remotely acting doctor can continue to monitor the patient during his extraction from the vehicle. He can then transfer all necessary information to the trauma center so that the treatment of Mr. Marin can continue seamlessly.
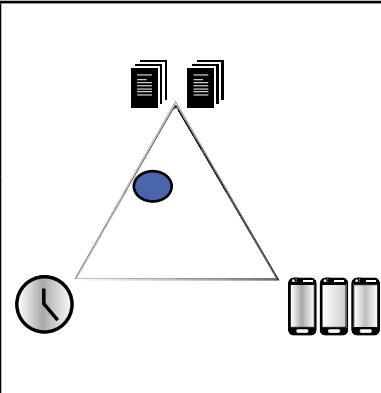
	• UE Data Rate • End-to-end latency • Availability	**High**
	• Reliability • Coverage • Maximum UE velocity • Security • Network slicing	**Mid-term**

2.4.2. Medical device fragmentation

Mr. Marin, the casualty from the previous use case, arrives at the trauma center in the hospital. The sensors remain at the patient's body, but the processing is handed over from the ambulance to the hospital governance.

With the option of 5G high data rates with low latency, devices can be broken down into their sub-components and used wirelessly, e.g., wireless ultrasound probes and distant imaging processing units. Consequently, the actual sensors can remain for continuous monitoring on the patient. The raw data are transferred to a processing unit via 5G and processed there for use by the personnel.

Medical device fragmentation enables high-performance devices, for example, for video data preparation, to be kept available without the tools having to provide these capabilities on site. In addition to high bandwidth, the bidirectional connection with direct feedback to the medical staff also requires very low latency in both the transmission and the processing.

	• UE Data Rate • End-to-end latency • Availability • Reliability • Trafic density	**High**
	• Connection density • UE power consumption • Coverage • Time error • Security • Network slicing	**Mid-term**
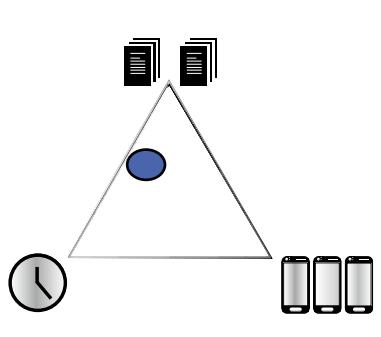
2.4.3. Management of pandemics through virtualization and mobilization of health resources

Pandemics, sudden-onset natural or human-made disasters, such as pandemics, bioterrorism, or refugee camp scenarios, require a timely response of regional health services to a suddenly increasing number of patients. However, if the current health service cannot repurpose its resources to meet the changed requirements, an easy-to-install mobile infrastructure such as an Emergency Medical Team[18] [19], needs to be set up rapidly. An example of such a situation is if a hospital-external quarantine area, as currently discussed in the background of COVID19, that needs to be established for a few days or

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18   World Health Organization. Emergency Medical Teams Initiative. 2020

19   EUMFH consortium. European Modular Field Hospital. 2018.

weeks. These mobile hospitals need sufficient medical equipment and communication infrastructures [20] to provide dedicated services to different expert groups such as medical staff, task forces, or researchers. The communication infrastructures and the offered services need to be mobile and adaptable to the current needs. These needs can be met using 5G technologies.

| | • UE Data Rate
• End-to-end latency
• Availability
• Reliability
• Traffic density
• Connection density
• Coverage
• Time error
• Security
• Network slicing | **High** |
| | | **Short-term** |
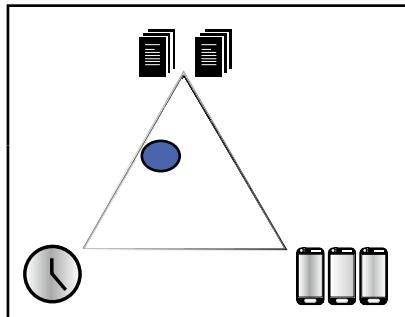
2.4.4. Situational intelligence

Following a massive accident involving a coach bus and a tank truck on the freeway between Munich and Berlin, the dispatched head of the relevant operations center, Mrs. Walther, has to assess the hazards. For her appraisal, she needs to take into consideration factors such as the number and dispersion of injured or affected persons, their general state, the severeness of the injuries as well as possible dangers to victims and rescue services.

Even before the arrival of the first responders, Mrs. Walther can gather data using a drone. The drone's aerial perspective provides her with a better understanding of the surroundings and the damage. The drone, using light detection and ranging (LIDAR) technology, camera systems, and spectroscopes, can give her information she usually would not be able to use. Thus, a comprehensive assessment of the situation and the measures to be taken is made possible.

5G can transmit high-resolution image and sensor data to the operations center. Due to the very low latency, real-time control of the drone is possible from a considerable distance. Using the accumulated data, Mrs. Walther can redirect the rescue forces to avoid leaking petrol and direct them primarily to the persons requiring immediate help. Also, the extra information can help her with updates on the current situation and thus ameliorate here understanding of the overall condition.

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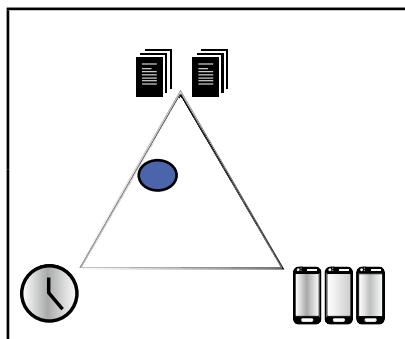
20   Neumuth T. European Modular Field Hospital - Electronic patient record and biomedical information technology concepts. 2018

| | • UE Data Rate
• End-to-end latency
• Availability
• Reliability
• Coverage
• Time error
• Security
• Network slicing | **High** |
| | | **Mid-term** |

2.4.5. Ground-based and aerial healthcare logistics

Due to their flexibility, ground-based automated guided vehicles (AGV) systems and unmanned aerial vehicle (UAV) systems are one of the most crucial supply solutions to ensure high logistics availability and performance in hospitals and homes for the elderly. Aside from the support of logistic tasks between locally distributed clinic sites, for instance, to transport blood samples from clinics to a central laboratory, these systems can also support private logistic tasks such as the delivery of drugs from pharmacies to patient homes.

While AGVs are currently in daily use in clinics, UAVs are still at a very early stage for civil applications. They are fitted with information technologies such as beacons, 3D cameras, or real-time location technologies for localization, navigation, environment recognition, and collision avoidance. The multiple vehicle sensors send their data, mainly images, via 5G mobile networks in near real-time. The information is then analyzed, translated to instructions on the servers, and returned to the vehicles.

| | • UE Data Rate
• End-to-end latency
• Availability
• Reliability
• Coverage
• Maximum UE velocity
• Security
• Network slicing | **High** |
| | | **Mid-term** |

2.4.6. Parameter overview for emergency responder use cases

The parameter aggregation overview (see Figure 7) demonstrates that the use cases for the emergency responder use cases will strongly benefit from 5G technologies. The implementation timeline is estimated at mid-term.
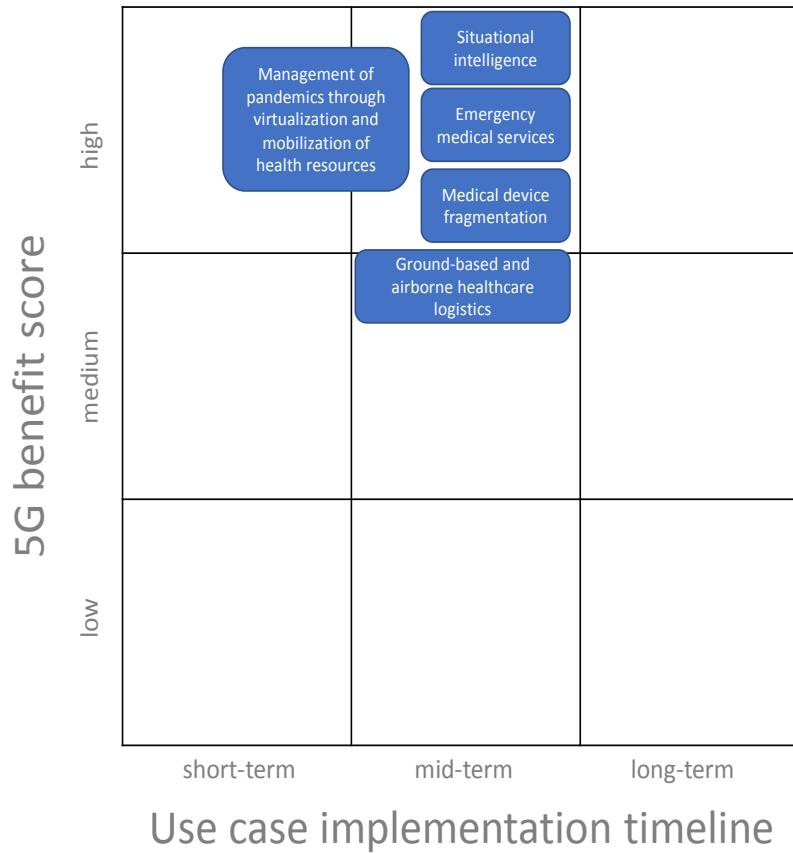
Figure 7: Parameter overview for emergency responder use cases
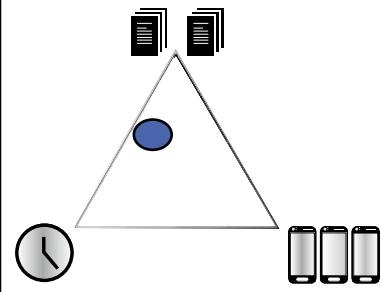
2.5.   5G for individual users and family members

2.5.1. Tele-assistance and telecare in rural areas

The provision of healthcare to individuals is becoming increasingly difficult, particularly in rural areas. It represents a significant logistic challenge, which is the result of geographic and demographic factors. 5G-based, hands-free augmented reality technology has a strong potential for remote medical consultations in real-time under hygienic requirements. Also, it can enhance the experience and communication between nursing services and healthcare professionals in different locations.
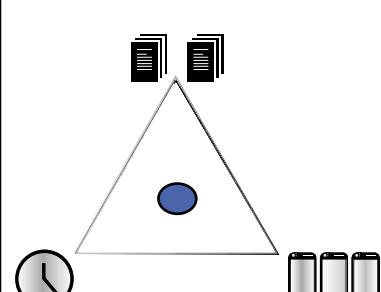
The use of AR glasses provides an opportunity for medical services supporting wound healing in remote areas where specialists are scarce. For instance, a nurse might focus her AR-glasses precisely on the area to be analyzed and transfer the imagery of the wound to the wound expert's screen via a built-in camera.

The images enable the expert to provide a remote diagnosis of the wound in real-time and to instruct care.

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	• UE Data Rate • End-to-end latency • Availability • Time error • Security	**High**
		Mid-term

2.5.2. Family in-touch

Mr. and Mrs. Green are new parents to a baby girl named Sophia. She was born prematurely and needed constant ventilation during her first days of life. Additionally, doctors are monitoring her heart-rate using a monitoring system. The neonatology department of the hospital provides real-time transmission of Sophias's monitor to family members outside of the hospital via 5G. Thus, her parents can stay in touch with their daughter 24/7 from home.
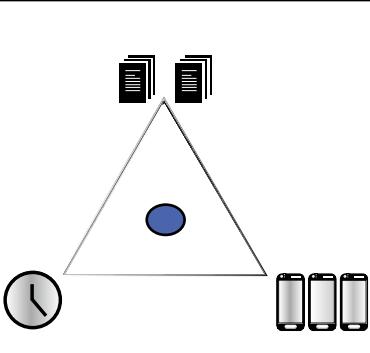
	• Availability • Reliability • Security	**Low**
		Short-term

#

2.5.3. Rehabilitation support

Mr. Hariot, 46 and head of a family of 4, comes home after six weeks of rehabilitation after a severe stroke. The left side of his body is paralyzed, his gait pattern is unsteady, and he is in constant danger of falling. Thus, Mr. Hariot still needs support for food intake and physical hygiene due to the immobility of his guide arm. His family and nursing service support him with everyday tasks.

His wife has already adapted their home: She commissioned a constructor to convert it into a smart living home. All household appliances, entertainment, and wearable monitoring systems communicate with each other and can be controlled via voice, tablet, or smartphone. The latter even works location-independently.

The 5G-based communication takes place with close to zero latency, a high data transfer rate, and high reliability. The system used by the patient to monitor vital signs also transmits the acquired data to the medical staff on a 5G basis for online analysis. The family doctor can evaluate the gathered data and, via television, determine the future course of treatment of Mr. Hariot in cooperation with his family. The omission of traveling distances is very time-saving for the patient, his relatives, and medical staff. Also, the family and the health services save resources, and the environment is relieved.

	• UE Data Rate • End-to-end latency • Availability • Reliability • UE power consumption	**High**
	• Coverage • Maximum UE velocity • Time error • Security • Network slicing	**Mid-term**

2.5.4. Parameter overview for patient indivudal use cases

The parameter aggregation overview (see Figure 8) demonstrates that the use cases for the patient individual and family member use cases show distributed benefit scores. While the delivery of health services to rural areas and as rehabilitation support is rated as a great benefit, the remote monitoring functions for family members show a low gain. The implementation timeline is estimated short- to mid-term.
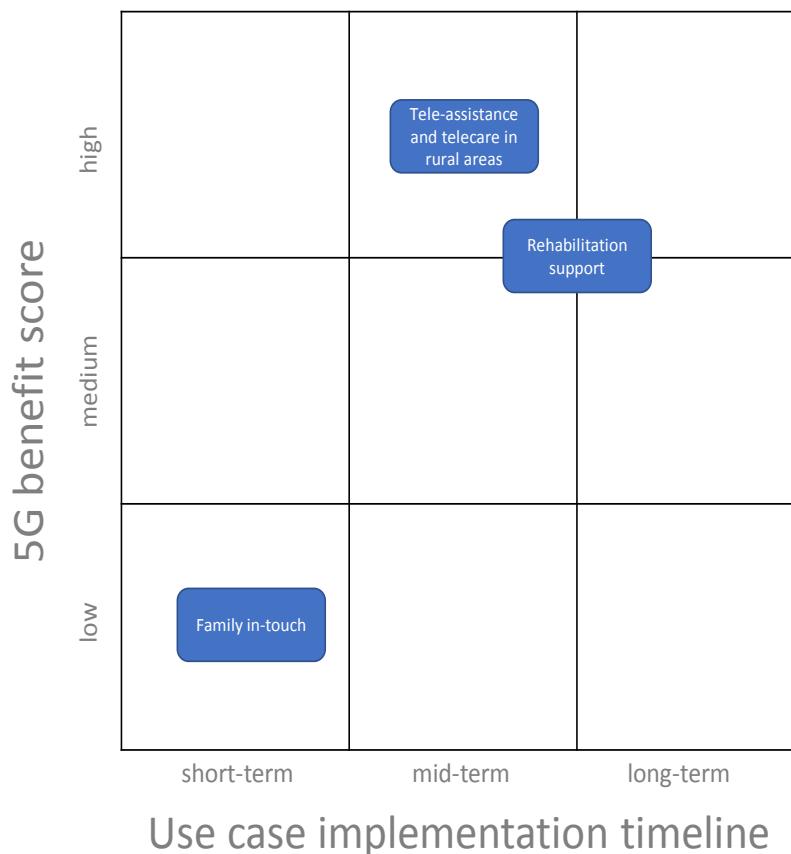
Figure 8: Parameter overview for patient individual use cases

3.   5G for health services -How it works

3.1.   5G technical key performance indicators

The new generation of 5G mobile devices includes more and more applications from a professional background. Examples of possible usage areas are industry, autonomous vehicles, internet of things (IoT), and healthcare. The new technology supports higher bandwidth, very low latencies, and a high number of up to 1 million synchronous users per km2.

The advantages of 5G technologies fall into three groups. However, they cannot be used at once by the developed applications. Firstly, 5G enables a very high bandwidth for data transmission (eMBB – enhanced mobile broadband). Thus, high-resolution images and videos can be transmitted and down-loaded wirelessly. Mobile broadband addresses the human-centric use cases for access to multi-media content, services, and data.

Another possible advantage is communication with a very low latency during transmission (URLCC – ultra-reliable and low latency communications). This is mainly relevant for automated applications and the remote controlling of systems over a wireless network.

The last group comprises the synchronous communication of a vast number of sensors within a wire-less network (mMTC – massive machine-type communications). 5G in this context is characterized by a deficient use of energy and minimal data rates; thus, a vast number of connected devices transmitting low volumes of non-delay sensitive data. The connected devices are required to be low cost and have a long battery life. Examples in this context are biosensors or wearables, for instance.
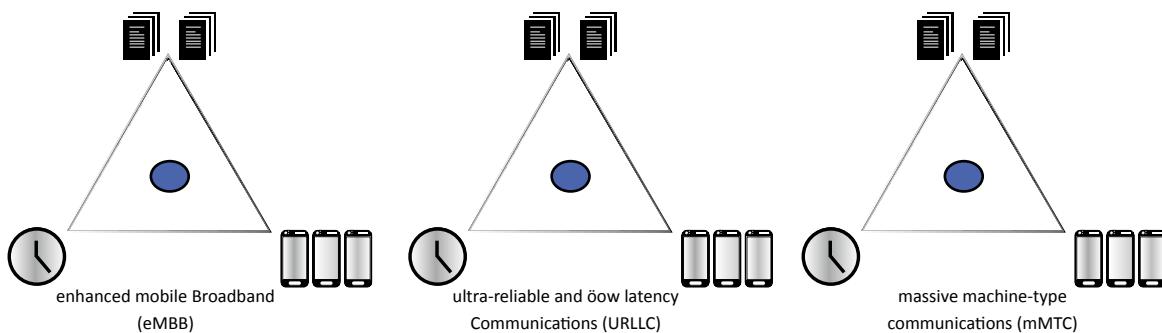
Figure 9: General 5G usage scenarios

The usage scenarios for eMBB, uRLLC, and mMTC translate into a set of key performance indicators (KPIs). Firstly, the **user experienced data rate** is the uplink (UL), respectively downlink (DL) data rate provided to the end-user. Catchwords in this context are peak, average, and guaranteed data rate. The maximum peak DL data rate can reach up to 10 GBit/s, whereas the guaranteed DL data rate will be in the range of 1 GBit/s.

Secondly, the **end-to-end latency** is the time it takes to transfer an application layer packet from the user equipment (UE), through the 5G network, to the application processing the user data on a server, or, respectively, on another UE. With proper network design and configuration, the maximum end-to-end latency is 10 ms.

A third performance indicator is **availability**. This indicator refers to the percentage of time the 5G network provides its services without any severe degradation. With proper network design and configuration, the availability can be as high as >99.99999%.

A fourth indicator is **reliability**. This factor indicates the trustworthiness of the network to provide its services. In contrast to availability, it is characterized by network design and operation rather than by the average percentage of availability. By connecting the UE to two or more disjoint, highly available networks based on different technologies and processes, a maximum of reliability can be achieved.

Traffic density is the aggregated data rate provided within a given area and can be as high as 1 TBit/s per km2. Connection density, on the other hand, is the number of simultaneously active 5G connections within a limited area. Up to 100,000 devices per km2 can connect to a 5G network. Also, the UE power consumption directly translates into the battery lifetime of the UE under average usage. The battery lifetime of 5G devices with low data volume can reach up to 10 years.

Coverage refers to the area on the ground and above at which 5G services are provided concerning the given KPIs. Moreover, indoor and outdoor coverage can be distinguished. The **Maximum UE velocity** is the speed at which the UE may move without adversely affecting the KPIs of the 5G connection. 5G will support speeds of up to 300 km/h so that high-speed trains and helicopters are covered.

Position accuracy refers to the deviation of the position of a UE measured by the 5G network from its actual one. The target of 5G is a maximum deviation of fewer than 10 m. At the same time, **time error** is the deviation of the time-of-day provided to the UE by the 5G network from the universal time coordinated (UTC). The target of 5G is a deviation of less than 10 ms.

Two more KPIs in this context are security and network slicing. The first, **security**, refers to defense against malicious attacks to protect operation and data privacy. However, the problem here is that security has no real measurement, as it cannot be quantified. **Network Slicing** is a new concept in 5G. It means splitting up the resources of the network into slices to create virtual networks. These virtual networks can be dedicated to specific services or tenants. The impact on a network slice by the use of another network slice of the same physical system is minimized.

The standardization process within 3GPP, an organization responsible for mobile communication standards, subdivides standards into releases. A generation of mobile communication, such as 5 G, is thus divided into versions that focus on particular aspects. The most recent release is 16, 17 will be pub-

lished by December 2021. The latter will also center around 5G. We would like to point out that at this point, not all planned features of 5G are available.

Excursus 1: How KPIs are achieved

These stringent KPI values are hard to achieve. Only a properly designed network, a robust configuration, sensible operation, and rigorous maintenance can attain good ratings. One method is **the regional area network (RAN) configuration for low latency, guaranteed data rate, and low packet loss by 5G QoS identifiers (5Qis)**. Consistently configured, the end-to-end network, the mobile core and the transport network connecting these two ???. (xHaul). Each of these components has to be tuned for uRLLC.

- **Network design for low latency by Mobile Edge Computing (MEC):** MEC is a key component for providing uRLLC services. On the one hand processing of user data has to be moved close to the end devices to reduce the propagation delay on the fibers. A fiber run of 200 km to a centralized data center would already consume 2 ms of the tight delay budget. In addition, the hard- and software architecture of the MEC platform has to support near real time computing.

- **Network design for high data rates by mmW small cells:** mmW technology promises extremely high data rates. Due to range limitations, coverage will be limited to campus networks. Antenna location needs to be well planned in order to cover the spots with highest data rate demands. For getting the needed reliability, redundant antenna and radio mounting will be needed.

- **Network reliability by campus networks:** So far, mobile networks were under the sole control of mobile network operators (MNO). Thanks to the decision of the German and other governments to license part of the spectrum to local networks a new breed of so-called campus network operators is popping up. In contrast to public mobile networks providing primarily country-wide eMBB services, campus network operators are much more customer-focus providing precisely the services hospitals need. Moreover, they can be expected to integrate the local 5G network with the existing wired or WiFi communications infrastructure of hospitals resulting in a much more reliable network.

- **Network reliability by network slicing:** The aforementioned campus networks can provide reliable 5G coverage on the hospital campus. For emergency use cases, however, country-wide coverage is required. Public MNOs can play a role here. They can provide a slice of their mobile networks to first responder organizations like BDBOS in Germany. By procuring uRLLC slices from two or more MNOs the overall reliability can be improved.

- **High network coverage by 450 MHz spectrum:** As another fallback option, first responder organizations may use purpose built 5G networks in the 450 MHz spectrum. In this frequency band country-wide coverage can be achieved more easily. The available data rates, however, will not exceed a few MBit/s.

- **Satellite networks:** There are several satellite network initiatives with the most prominent being SpaceX' Starlink network. These networks will provide global 4G coverage with upgrade to 5G later on. Combined with network slices from public MNOs extremely high service reliability should be achievable.

Excursus 2: 5G and other network types

- **Public Land Mobile Networks**
  Public Land Mobile Networks (PLMN) are terrestrial, typically country-wide mobile networks offering services to individuals, companies, and public authorities. In Germany, for instance, Deutsche Telekom, Vodafone, and Telefonica operate 2G, 3G, 4G, and most recently 5G PLMNs.
  Technologies: 2G, 3G, 4G, 5G

- **Campus Networks**
  In contrast to PLMNs, the coverage area of Campus Networks is confined to small, precisely confined areas. Typically, the coverage area is owned or managed by a single authority, e.g. a production plant or a farming cooperation. Please note that the assignment of dedicated frequencies for 5G campus networks is currently only available in Germany
  Technologies: WiFi, 4G, 5G

- **Public Safety Networks**
  Public safety organizations like BDBOS in Germany operate own country-wide mobile networks. These networks meet the highest security standards. Their usage is limited to public safety organizations like police, fire brigades, and ambulances.
  Technologies: TETRA, 5G in 450 MHz spectrum

- **Satellite networks**
  As of today, Iridium Satellite LLC is the only operator of a worldwide satellite communications network. The peak DL data rate is 1.4 Mbit/s, and the peak UL data rate is 568 kbit/s. Such low data rates do not provide any advantage over TETRA networks. Moreover, the coverage is not as good as it might seem at first glance. Since there must be clear line-of-sight above an angle of 8.2 degrees above the horizon, the satellite link may be disrupted at many locations.
  The future SpaceX' satellite communications network Starlink is expected to provide DL and UL data rates will be in the range of Earth-to-sat latency between 25 to 35 ms.

## 3.2.	Which KPIs are relevant for medical applications?

Based on the clinical use cases from the previous section, we analyzed the need for 5G KPIs across medical applications in an initial assessment. Although our use case selection is by far not complete, we tried to include use cases that are complementary to each other. By assigning KPIs to the use cases and analyzing the probability of KPIs across medical use cases, we get a hint which KPIs are most relevant for medical use cases (see Table 1).

Following this initial analysis, we can conclude that the KPIs with the highest relevance for medical use cases are availability, reliability, and security (see Table 2).

Table 1: 5G KPI analysis for medical use cases

KPI	UE Data Rate	End-to-end latency	Availability	Reliability	Traffic density	Connection density	UE power consumption	Coverage	Maximum UE velocity	Time error	Security	Network slicing
KPI in subset of 20 use cases	11	11	16	16	4	8	7	12	5	8	17	13
KPI in use cases [%]	55%	55%	80%	80%	20%	40%	35%	60%	25%	40%	85%	65%
KPI Relevance group	B	B	A	A	C	C	C	B	C	B	A	B

Table 2: Results of KPI analysis for medical use cases

KPIs required in >80% of the use cases	KPIs required in 50% to <80% of the use cases	KPIs required in <50% of the use cases
Availability Reliability Security	UE data rate End-to-end latency Coverage Time error Network slicing	Traffic density Connection density UE power consumption Maximum UE velocity

4.   Current technical and societal challenges

5G also presents us with some new challenges. The implementation of this new technology sets new standards for infrastructural components. Even though 5G is sometimes heralded as a novelty, some aspects of these technologies have been in use for years. Most notably, the radio-access technology (RAT) is pretty similar to the existing and far spread 3G and 4G technology. The frequencies between 450 MHz and 3.8 GHz used by 5G handsets have been in operation since the beginning of mobile phone technology in the early 90s.

The innovation and added value consist of a combination of existing technologies in different sections of the network. For instance, "network slicing" as one of the most innovative features of the core network uses existing frequencies to create new business services by virtualized communication channels. Even though some of these technologies have been in use for decades, the requirements on the infrastructures have grown. Many of the newer features have a growing need for computational power that cannot be met by current structures. Thus, further investments in 5G infrastructure need to be made. On the one hand, we need to invest in an innovative transmitter infrastructure. On the other hand, many of the existing communication systems are not up to par for 5G applications. We conclude that high investment costs and inconvenient conversion measures hinder the advancement of 5G technology.

All medical devices, including software connected via 5G and transmitting patient data, will have to be licensed by the governments and will have to follow the relevant legislation for medical devices and data privacy. Patients can thus rest assured that their data kept safe. More specifically, the hospital sector faces a high demand for data safety and security. Critical application scenarios, such as indoor transmission within hospitals, are heavily regulated and monitored.

The manufacturer-independent, functional interconnection of medical devices currently presents great difficulties. 5G, as a high-performance communication link between medical devices, enables new use cases and application scenarios (see section 2). These new applications need to be scientifically and technically explored and evaluated before they can be employed for the benefit of patients.

Another current challenge is the discussion about the effects of electromagnetic radiation on human health. Nonionizing electromagnetic waves, such as radio waves used in any mobile phone technology, maybe pose a health hazard if misused. An example would be exceeding the legal limits of output energy levels during transmission or relaying on unauthorized frequencies. Due to these hazards, the application of radio transmissions is heavily regulated, licensed, and monitored by state agencies in every country. These agencies make sure that all installed transmission devices and the relevant operations are permitted and follow the legal requirements.

The impact of electromagnetic waves on human health was investigated heavily in the last few years

by national and international organizations. The World Health Organization (WHO) concludes, "A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use". [21]

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21   World Health Organization. Factsheet No. 193, Electromagnetic fields and Public Health. World Health Organization; 2014

5.   Outlook

The mobile communication technology of the latest generation is promising. It has the potential to advance the digitization process in medical care considerably. Table 3 gives a list of the opportunities and risks of 5G concerning medical or related usage. As a comprehensive communication infrastructure, 5G challenges sectors and limits of transmission[22]. It has the power to supersede conventional, hard-wired networks. Furthermore, it will outmode the current wireless networks. The latter is limited by single cells, while 5G seamlessly transitions between cells.

The employment of 5G will lead to a homogenization of existing network and communication technology. At the same time, it will comply with many highly heterogenous requirements regarding bandwidth, time requirements for the transmission of data, as well as connecting a vast number of users simultaneously. It is noticeable that all of these highly diverse challenges can be addressed by only one novel technology: 5G.

Hospitals and other health-service will have the possibility to establish their own, non-public networks. Thus, they can react appropriately to demands on the safety and security of health data. By creating their communication infrastructure, they are independent of common standards. Thus, these communication infrastructures meet the high standards set for medical devices.

At the same time, the implementation of 5G might speed up the conversion of standard biomedical technologies and medical information systems. This speed-up is due to the fact that nearly all of the applications are realizable only as compound structures of medical devices in a bounded communication infrastructure. 5G technology supports the demands of patients for the freedom of choice and more comfort regarding access to health services. Also, they will be able to reduce the "blank spots" regarding preventive care, treatment, and follow-up care.

Based on the expert assessments, the main benefits are expected for use cases in the field of hospital management, clinical department operations, and emergency response. The implementation timelines are estimated from short- to mid-term after the availability of the technology.

Currently, regional health structures are missing macroeconomic guidelines and programmatic documents for the employment of 5G[23]. These missing guidelines result directly to a lost focus regarding development goals and, thus, to a waste of funds and resources.

Furthermore, medical facilities require a uniform standard over different regions and organizations. In this regard, a guarantee and amelioration of data integrity are of the highest importance. Medical data is often complicated and comes in large volumes. This can lead to difficulties concerning data transfer

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22   Verdict Medical Devices. Separating the fact from fiction of 5G in healthcare. Verdict Medical Devices. 2019.

23   Ericsson ConsumerLab. From Healthcare to homecare. 2017.

and communication. Also, compatibility between various platforms and devices is not always guaranteed.

5G is a significant enabler for the provision and use of digital health services. From a technical point of view, some technologies concerning intelligent healthcare are currently still in an experimental phase. Thus, they require a considerable amount of expenses and effort for maintenance and promotion.

Table 3: Opportunities and risks of 5G application in medicine

Opportunities	Homogenization of wireless network technologies	It is no longer necessary to switch between WiFi and mobile networks
	Replacement of wired communication networks	The complicated and expensive Ethernet cabling of clinics is no longer necessary
	Fulfillment of previously conflicting data communication requirements	High bandwidths, data delivery with guaranteed delivery times and the connection of a large number of transmitters are possible with the same technology
	Relocation of health services and infrastructures	Flexibility by supporting the retrofitting of health infrastructures
	Increased flexibility for patients when choosing healthcare providers	technology enables advanced telemedical services and location-independent patient monitoring
	Enables continuous patient monitoring, "white spots" in the monitoring are closed	consistent, uniform and constant connectivity
	Increased resource efficiency	The use of resources can be better coordinated because services are independent of location
	More convenient access for patients to healthcare providers	Patients use healthcare services with less effort by digital access
	Enabler for distributed real-time AI applications	By accessing and transmitting high-volume data in real-time, the cross-facility use of artificial intelligence applications are made possible
Risks	Decline of inter-human interaction	Risk of dehumanizing the patient. A patient can become a mere record in the database, which means that the doctor cannot establish an emotional connection with the patient.
	Missing macroeconomic guidelines	Currently still unclear positioning of governments and health market participants on the topic of 5G in medicine
	High investment needs in the technical infrastructure	Very high investment requirements for adaptation of the existing mobile radio infrastructures.
	In-depth social discussion about the health effects of technology	There is still a lack of social consensus on the health effects of 5G technology

6.   About the expert group 5G in healthcare

The fifth-generation (5G) mobile communications standard is a new technology that enables a multitude of innovative applications in all areas of daily life. One of the essential areas for citizens is the health sector.

The objective of the 5G Health Association (5g-health.org) is the assessment, development, and evaluation of 5G applications in the health technology sector. The working group matches the capability of 5G technology with the clinical needs and general conditions of biomedical and medical informatics technologies.

The members of the expert group are currently involved in the following projects interfacing 5G and healthcare:
- 5G4Healthcare Link
- 5G_eHealthSax Link
- Health5G - Future eHealth powered by 5G Link
- MOMENTUM - [Mobile medical technology for integrated emergency care and accident medicine] Link