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Towards an integrated emergency medical care using 5G networks

Abstract: The Interoperability of medical devices and IT systems using various technologies in clinics and the preclinical area is still a research topic. The MOMENTUM project deals with the new 5G mobile technology and explores how they contribute to an improvement in emergency care. Different applications, as well as various technical and clinical aspects, including IT security, are considered. Integrated emergency care seems sensible, particularly for emergencies outside of metropolitan areas and for particularly critical cases.

Keywords: 5G, Medical Device Interoperability, Emergency Care, Emergency Medical Service, Trauma Team, IT Security

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1 Current Situation and Research Focus

The emergency medical care for patients inside and outside the hospital bases on a complex system of interlocking processes with the participation of a large number of different actors such as doctors, paramedics, nursing staff and a large number of different medical devices and IT systems. Treatment outside of specialized medical facilities, among hospitals, medical centers, and doctor's offices, requires the quick and easy availability of medical technology resources,

smooth access to information, and the presence of medical expert knowledge. The supply processes mainly base on the availability of medical technology resources, such as imaging units, vital monitoring, and breath monitoring, and equipment for emergency interventions. Currently, these services cannot be made available nationwide for emergency medical care. Due to their complexity and size, many of these modalities are not suitable for mobile use. This results in the need to design strategic and technical concepts to implement the fastest possible emergency medical care and thus improve the treatment processes from the accident site to the clinic.

With the introduction of 5G as a new option for wireless communication and the possibility of using private campus networks (at least in Germany), additional options for networking and data transmission are emerging. 5G combines a high bandwidth (eMBB – enhanced Mobile Broadband) with the opportunity of low latencies (URLLC – Ultra Reliable and Low Latency Communications) and supports many concurrent communication participants (mMTC – Massive Machine Type Communication). A more detailed overview of the technologies and an assignment to the use cases addressed by MOMENTUM can be found in the paper from GAEBEL et.al.

In recent years, intensive research has been carried out on inter-device communication and, above all, standardization, so that today the IEEE11073-SDC standard family offers a possibility for manufacturer-independent inter-device communication [1], [2]. The MOMENTUM project aims to explore the advantages and challenges of 5G communication in emergency care. The focus is on supporting the rescue chain in a trauma emergency but is not limited to this.

There is an already well-established project in emergency care, particularly in the area of telemedical support for non-medical staff with the “Telenotarzt” [3], [4]. In addition to sound and video information, ECG signals are also transmitted to enable the remote emergency doctor to assess the patient better. The MedDV NIDA system, in turn, focuses on the clinical pre-registration of patients with severe clinical pictures (stroke, heart problems, trauma) [5], [6]. With this system, too, individual medical devices can be connected via a proprietary interface, and the data can be transferred accordingly. Various studies have shown that timely information of clinics can improve the outcome [7] [8]:

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The support by the MOMENTUM can be divided into the following concepts:

Medical information

Distribution of information about the patient across institutional boundaries and merging of information. Integration of the emergency data set and provision at the point of care, for example via augmented reality

Monitoring and reporting

Transmission of the examination results and medical device data both within the ambulance and to the clinic to be treated later. Allow a better assessment of the patient by the trauma Leader and his team. Generate a consistent record of the entire emergency treatment based on the transmitted device data and the manually entered information.

Emergency medical diagnostics

Support for new examination methods (e.g. mobile ultrasound). Due to the possibility of transferring large amounts of data with low latency, the sensors on-site can be separated from the complex calculation. This also opens up opportunities to use methods of image analysis and to implement intelligent control systems.

Emergency medical therapy in the clinic

Continuation of the treatment in the clinic and the combination of various information entities about the entire course of the treatment from emergency admission to discharge

There are several scientific-methodological and medical-technical innovations across the four application areas that are addressed in the project:

1. Development and evaluation of suitable technical methods for networking emergency medical treatment along the process chain from the place of use to the hospital
2. The first provision of location and time-independent medical technology functionalities
3. Development of a common communication infrastructure for the integration of patient data, information, video, and audio data as well as the establishment of an emergency medical telemedicine connection with a focus on device data via heterogeneous communication technologies
4. Use of imaging diagnostic procedures and direct evaluation using state-of-the-art analysis methods already during initial care and patient transport
5. Connection of the medical devices to a 5G network and integration of a drone-based repeater infrastructure
6. Creation of requirement profiles for communication technologies for mobile medical applications based on generally strict requirements for medical devices and comparison of these with the 5G requirement profiles discussed in the 3GPP
7. Mapping of the requirement profiles on 5G services and implementation of selected medical services using 5G technologies
8. Development and technical specification of strategies e.g. for network slicing for medical technology applications in the context of 5G data communication
9. Performance analysis for 5G Release 15 technologies of the physical and medium access layer
10. Development of communication technologies of the physical layer for Release 16 and beyond for the transmission of data of different medical applications using the 5G services (eMBB, URLLC, mMTC)

2 Basic concept

To achieve an integrated communication infrastructure, sufficient mobile radio reception, and access to communication networks or the internet is the main prerequisite. This can be ensured for the building of critical infrastructure, where emergency command centers and ambulance vehicles might have to operate in areas with little to no reception. First, MOMENTUM will create an ambulance vehicle equipped with its own radio cell. In an area with bad reception, the ambulance will itself be able to establish a radio connection and therefore connect all parts of the critical infrastructure.

Second, the same radio technology will be used to interconnect all medical and data-generating devices. Relying on 3GPP releases 15 (and above) allows data to be communicated fulfilling medical as well as technical requirements. Data from medical devices, e.g. ECG or respirator, can be collected with required frequency and tolerable latency. Inside the ambulance, all medical (and technical/non-medical/ organizational) data will be bundled to present a comprehensive electronic emergency record anytime data is needed. This comprises of organizational aspects that describe operational information that might concern the emergency command center, technical aspects (e.g. metadata from medical devices), and, of course, medical aspects and the aggregation of every information entity that is created or might be requested from users. The transparent

logging of treatment data is the basis for further use, e.g. for quality assurance.

Since this sophisticated system involves multiple communication partners from different organizational entities, an elaborate security concept is needed to ensure that device connections are safe, encrypted and access-controlled.

IT security concept

The cybersecurity concept aims to ensure cybersecurity protection goals such as the often-cited confidentiality, integrity, and availability but also authenticity, transparency, and non-repudiation. It guides beginning with the design phase right through to the technical implementation and phrases particular cybersecurity requirements based on functional requirements and a detailed system model and architectural design.

Figure 1: Abstract model of the communication system designed in project MOMENTUM including the trust areas

In this model, where all components, as well as their communication relationships, are represented, trust boundaries and areas are determined. Trust boundaries are

interfaces between communication flows of different areas of trust. Therefore, a communication flow spanning various areas of trust crosses at least one trust boundary. Examples concerning trust boundaries and areas are processes on an operating system, apps on mobile platforms, network interfaces, but also organizational limits and areas with different privileges within one application. Any data crossing a boundary must be validated, and measures to preserve the cybersecurity protection goals must be implemented. The diagram in figure 1 shows an early stage of an abstract model of the communication system designed in project MOMENTUM showing respective trust areas and trust boundaries as well as appropriate checkpoints.

The concept's measures bases on the seven security best practices of access control, segmentation, isolation, hardening, encryption, visibility, and secure management. As a consequence, this framework allows a definition of specific and extensive but feasible functional, as well as non-functional security requirements. Furthermore, a step-by-step refinement and concretization of the system design without specifying far-reaching limits is possible. The technical realization is verified by penetration tests and code reviews to close the feedback loop.

3 Conclusion

The MOMENTUM project is dedicated to data acquisition, forwarding, and processing in emergency treatment. It evaluates the extent to which 5G communication inside the ambulance vehicle and emergency room, as well as between these functional units, can contribute to better data processing/integration and safer treatment of the patient.

Possible fields of application for an integrated, 5G-based system are in development with specialists from emergency care. The results of the requirements analysis are considered during the architectural planning and the designing of the overall system. Besides, the mentioned requirements regarding IT security also deal with regulatory aspects. From the regulatory point of view, there is currently no bandwidth allocated to private mobile networks or emergency services in general. A private band similar to the campus networks in the 3.7-3.8 GHz range, which are now available in Germany, would be ideal. Furthermore, the ongoing discussion about the spectrum in the 450 MHz range does not address the discussed private networks and offers rather small bandwidth, probably insufficient for the required services. In consequence, there must be agreements/arrangements with the network operators and network agencies to equip ambulances with a local and mobile 5G small cell.

The previous discussions also showed that a system like the one presented in this paper could also be of great interest to the nursing sector, especially in rural areas outside of the metropolitan regions. Nursing staff, e.g. working in a retirement home, would greatly benefit from telemedical support and the ability to have remote physicians help them in case of emergency. Overall, supporting medical examinations and emergency treatments with sophisticated, integrated information systems shows its strengths where operation distances are long and the availability of emergency doctors poor as well as the occurrence of a large number of injuries and the associated need for prioritization.

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