ASTER - Acute Stroke Care
Telematics for Ambulance Vehicles

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Abstract: In the collaboration project ASTER secure communication structures for ambulance vehicles are developed in order to optimize care processes for paramedics in cases of stroke. Ambulance vehicles will be equipped with various communication devices and technologies in order to enhance the care procedures in the pre-clinical phase. IT-security and communication availability are the essential aspects of high-sensitive and mobile communications developed for this case, because wireless transfer of sensitive data such as patient and case related data will be involved. The structure and communication networks is designed and validated using different scenarios of acute stroke care in order to answer the requirements towards the new communication structure needed for security demands. In order to secure this high level data the project is using certificated encrypted connections and a central communication node, which will be presented in detail. The upcoming demonstrator of the ASTER project, a full applicable ambulance vehicle will be equipped with the proposed technologies and systems in order to enhance the emergency procedures for paramedics and patients suffering stroke.

1 INTRODUCTION

Stroke is one of the leading causes of death in Germany, responsible for permanent disability and dependencies (Heuschmann et al., 2010).

In 81% of strokes immediate medical intervention can potentially offer a better success of treatment. But for now only about 3% of all stroke patens can benefit from this special treatment due to a therapeutic timeslot of only about 4 hours after the occurrence of symptoms. Furthermore special diagnosis is required including CT scans of the head by experienced doctors best performed in a stroke specialist unit (stroke unit).

This is why especially rural regions such as the north of Saxony-Anhalt suffer from the disastrous consequences of strokes today. Because of the demographic change it is expected that the direct treatment costs will even rise, covering over 100 billion EUR in 2030 (Klebingat et al., 2010). An acceleration of the procedures in cases of emergency could increase this rate significantly, in all regions (Kwon et al., 2008) As a consequence the enhancement of preclinical emergency care structures, especially for stroke patients are of particular importance: Especially reliable detection of strokes, a semi-automatic selection of the best available hospitals and an early involvement of the hospital staffs have a high potential of enhancing the care procedures. The German research project ASTER - Acute Stroke

care -Telematical platform for ambulance vehicles - is a two year project which aims to develop solutions for the optimization of stroke care within the rescue chain. For this purpose a communication platform is being developed, connecting all kinds of stakeholders - ambulance vehicles, control centres, paramedics, hospitals, experts, external data sources such as traffic information centres - to one another in order to enhance the communication flow in the pre-clinical field. The ambulance vehicle shall furthermore be connected to traffic infrastructures e.g. for active prioritisation at traffic light systems

(Kwon et al., 2008) and (Wolf et al., 2008). Based on different radio standards, the information exchange between target hospitals, paramedics and other external data sources is designed to achieve both: Optimal communication availability and IT-security. In the following the actors of the ASTER

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system are described along with the needed data communication structures.

The use cases will lead to the functional requirements derived. The concept of secure communication architecture and its modules are presented. Furthermore the design of the full functional emergency vehicles which is currently being equipped with all devices is shown.

1.1 Aims of the ASTER Project

The goal of the ASTER project is to develop a telemedical platform for ambulance vehicles in order to optimize the emergency care with the focus on stroke emergencies.

The focus of the development is the establishment of a digital mobile assistant for paramedics (DIMAP), which assists the rescue staff in order to enhance quality of diagnosis concerning the type and severity of strokes. The DIMAP will be used to collect data concerning patient and the rescue case, to give assistance in choosing the best hospital and in order to gain necessary support of a stroke specialist in a stroke unit using a bi-directional multimedia telemedical connection (video conference). Here a camera and microphone shall connect the paramedics on the case, which can be the house or

flat of the patient or on-track during the trip to the hospital, with the data sources they currently need. The consultation of the expert can help in various situations in order to assess the severity of the stroke. Apart from the staff assistance the DIMAP shall provide intelligent traffic telematics to the ambulance vehicles in order to choose an optimized route to the best hospital for the special case of emergency. Factors of the different accessible destinations like the occupancy rate, specialization and availability of emergency rooms and doctors will be taken into account. Then the choice of route is actively made based on online traffic data such as traffic, distances and further more.

Active acceleration on-trip is realized by activating a priority route through a sequence of traffic lights (Pohlmann, 2010). These prioritisation-routes are especially marked in the DIMAP in order to choose the best route in order to assure the optimal response time, one of the main optimisation characteristics for operating procedures for paramedics (Pons et al., 2005). The traffic telematics module combines this information and generates a route to the destination hospital optimized in way and time for the diagnosed kind of emergency. Then, the collected information is transmitted to the destination hospital in order to make the necessary preparations. The telemedical platform developed for ambulance vehicles provides a link from mobile emergency medical services to hospitals and transport telematics. A practical use and a comprehensive diagnosis will be possible wherever needed. Therefore a real and full functional ambulance vehicle will be equipped with different modules of telematics as a prototype for demonstrations and tests. The planned modular design of the telemedical platform allows to be extended for other emergencies such as heart attack or polytrauma and highly integrates into the workflows of other entities such as emergency departments, emergency management and logistics.

2 ACTORS AND USE CASES

A use case defines the interactions between external actors and the system under consideration to accomplish a goal. The actors of the ASTER system are mainly from the medical field. As stakeholders they are interested in the enhancement of care procedures, but not necessarily depending on such a new system. Therefore the analysis of the current working and caring procedures are essential in order to integrate the ASTER system and it's usage into the normal working procedures of paramedics and their infrastructure.

2.1 Actors of the ASTER System

The following actors interact with the ASTER system:

Control Centre - it provides information on the emergency situation and communication to the paramedics via established radio systems (POCSAG, etc.) and maintains contact to the hospitals and the available emergency vehicles.

Paramedics and Ambulance - The paramedics often are the first actors on the scene of emergency. They are therefore the most important source of information for the ASTER system. Here the data of the case and the patients are collected.

The Medical Expert - The medical expert (stroke, cardiac, trauma, etc.) is positioned in a specialised hospital, such as a stroke unit. He or she provides the paramedics medical and logistical help with a video conference based of telemedical monitoring stations.

The Target Hospital - The target hospital and the doctors on duty need information about the emergency case of stroke and the initial diagnosis of the patients arriving in the emergency room in order to prepare the emergency rooms specifically.

2.2 Actors of the ASTER System

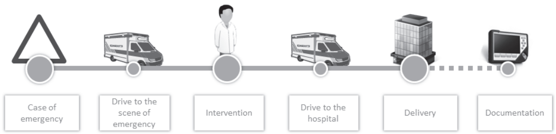

Figure 1: ASTER use cases.

According to the formally described actors following use cases or applications are identified for the ASTER system. Listed in chronological order the following use cases of the Aster system are:

1. **Case of Emergency** - A case of emergency with a suspected stroke occurs and the control centre is informed. In the ASTER system potentially applicable ambulances are displayed on a digital map and appropriate notifications are given to the ambulance vehicle and the paramedics using the DIMAP.
2. **Drive to the Scene of Emergency** - The ASTER system gives the optimal driving route to the paramedics. This optimal route consists of current traffic and route conditions. Furthermore active prioritisations at traffic lights could lead to an acceleration of the ambulance vehicle along the res-cue route.
3. **Intervention at the Scene of Emergency** - It is taken care of the and the relevant data such as medical background of the patient and his/her personal data is collected using a mobile device the DIMAP. A specific decision support system installed on the DIMAP enhances the estimation of the severity of the stroke. If any doubts remain a medical expert in a special stroke unit can be consulted via a video conference.
4. **Drive to the Best Hospital** - Like the drive to the scene of emergency the drive to the hospital will be based on an optimized route. Furthermore a prioritised selection of reachable hospitals will be provided by the system, depending on the hospitals current treatment capacities (available doctors and CTs), specializations and current journey times to the destination. When selected, the emergency case and basic data of the patient will be presented at the emergency room using an arrival board.
5. **At the Hospital** - The patient is given to the hospital staff. Through an automated data transfer and authorization during the transport the hospital is al-ready informed about the case.
6. **Documentation -** The processing of the case is finished by the paramedics and the control centre. The documentation and billing can be done quickly based on digital, matched data. According to the formally described actors following use cases or applications are identified for the ASTER system.

3 REQUIREMENTS OF COMMUNICATIONS ARCHITECTURE – DESIGN OF A SECURE NETWORK

Each of the actors and use cases of the ASTER system requires a specific data collection, processing technology, and above all a secure data communication. Especially the interoperability and harmonization of the different data types, devices and connections have to be integrated into existing security concepts. Here, a continuous redundancy of the infrastructure is necessary in order to provide an availability of 99% or more.

Furthermore Aster has special requirements for availability and reliability, particularly for the mobile applications of ambulances on their way to the scenes of emergency or the target hospitals. Therefore the design has to involve dynamically the best available connections such as GPRS, UMTS, LTE, Wi-Fi and Ethernet.

A main interest of the Aster communication is the secure transfer of particularly sensitive case-related and personal data. They are classified as the most sensitive data (Level E) of the Federal Office for Information Security in Germany (BSI), because they are directly linked to information about health, life and economic existence of the patient, including real name. Therefore, it is essential that this class of data is only stored temporarily on the mobile devices DIMAP in the ambulance vehicle. After completion of the transport of the patient the data is immediately archived, locked or freed of sensitive personal data. A long-term storage of personal data shall not take place on the DIMAP. The data communication itself is to be certified. Therefore established encryption protocols (IPSEC), primarily EAL 4 + certified technology shall be used.

Furthermore the authentication of all users of the ASTER system is set as mandatory. This is because of both: privacy reasons and for legal and liability reasons.

4 IT SECURITY AND MOBILE DATA COMMUNICATIONS

In order to answer the challenges of the communication system and the system architecture in ASTER concerning the mobile IT security (Stumpf et al., 2007) a communication concept is presented based on a centralized and scalable instance. The developed system design is based on the interaction of major functional blocks, their spatial distribution and organization (hardware and software units inside the ambulance vehicle and their connections to the outside world) as well as basic applications (including external data). Especially the essential high security requirements are regarded along the requirements of the BSI.

One of the basic requirements of security in the project is the transmission restriction towards sensitive or privacy relevant data which assures a solely encrypted transmission in order to ensure the end-to-end security within the communication architecture. Because it is not feasible to distinguish the different levels of sensitivity of the data during the normal operational process, the general encryption of all data is required. Therefore the IPSEC protocol suite (Elkeelany et al., 2008) shall be used for encryption, because it.

- transfers all IP packets
- is already certified in Router systems as Common Criteria EAL 4 +
- provides strong encryption algorithms
- is already in use for similar applications in the medical field,
- is a multi-vendor industry standard and
- is subject to a constant process of development.

4.1 The Central Communication Unit Intermediary

An intermediary (Latin intermedius ”intermediary”) is a mediating between the individual data sources and subsystems of the ASTER system. The type of placement can range from simple forwarding of IP packets for individual services (e.g. voice and video) over the caching of messages and data, to the provision of supportive applications for paramedics or other project partners. For the application to the intermediary the requirements of the terms of availability of the operation must be very high (99.95%), also concerning the confidentiality and privacy (category D + E BSI), same is true for the software and hardware clients of the ambulance vehicle. The system concept provides a strict encapsulation of the data flows within the intermediary and to the connected modules. Is can be also used to for monitoring incoming and outgoing data streams in real time in order to detect attacks and viruses (IDS / IPS). The intermediary and its communication structure is designed modular and expandable and is based solely on currently available device types and operating systems. Only hardware and software components are considered that are already certified according to Common Criteria EAL4. The intermediary has to be stored in a secure data centre providing a broadband internet connection and the availability of official IP addresses. The use of cloud technologies is possible, providing that the strict protection of privacy and confidentiality can be guaranteed, e.g. by having already audited standards according to ISO27001 of the BSI Protection Certificate.

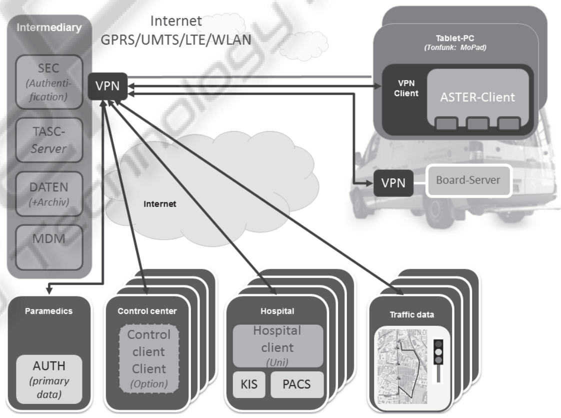

Figure 2: The communications and modules of the intermediary.

4.2 Basic Structure of the Intermediary and the Communication Interfaces

The intermediary currently consists of the following components:

– **VPN:** This VPN router performs the centralized handling of all encrypted connections to all ambulance clients and external data sources. It also realizes the routing of data traffic (IP traffic) from clients to external data and vice versa. The VPN realizes the distribution of data streams (routing), the implementation of IP addresses (NAT) and the protection of security and confidentiality. Furthermore, the individual network structures (such as private IP addresses) of the connected partner and external data sources will not be affected. The network traffic from and to the intermediary is encapsulated by the firewall rules restrictively configured and verified by the proposed IDS / IPS functionality permanently concerning malware and attacks.

- **SEC:** The security application handles the authentication of users and the rights issues. In addition, at the SEC component all the necessary services are localized. This relates to the time synchronization (NTP), the internal name resolution (DNS), the self-monitoring (SNMP) and logging (syslog) of the system components of the intermediary.
- **DATA:** This component serves as data storage and archiving. It thus provides a backup and configuration management of the MDM (see below) and for the provision of information of navigation and traffic control systems.
- **MDM Mobile Device Management:** This component implements the management of mobile devices (e.g., configuration, maintenance, backup, and update).With this component, the operator is able to keep the mobile devices available and secure. These include condition monitoring Smart File Sync, File Push, backup, restore, device management, software updates and device localization (GPS). Necessary maintenance actions are predictable and thus can be realized automatically and unattended at appropriate times.
- **Central Hospital Node:** It is to be examined in the project, whether the existing functions of hospital systems can be implemented in the intermediary.
- **VER:** A Traffic Telematics Server, which contains all the current traffic data and also the communication with the light systems [11] can be integrated via a secure connection or alternatively installed as a separate instance.

The proposed communications architecture has been designed based on the requirement analysis and the use cases, focussing particularly on the security requirements. A crucial factor was the seamless communication of the backbone databases to time-specific traffic data, clinic characteristics and stroke characteristics in order to support all modules of the ASTER-system: the software systems of the DIMAP (medical and traffic modules) and the components of the backbone systems. The goal of the overall system design is a generic clinical supply management, which opens the communication components of emergency vehicles as preclinical systems and passes through interfaces to hospitals, centres and transport infrastructure. For every rescue case, every control centre, every hospital and every other external data source an encrypted connection must be realised. For the external data sources, this connection can be terminated on existing security systems (firewalls and routers). Such a procedure is already used widely by hospitals and industry partners. But for the ambulance vehicles, the connection must be held available as long it is needed. This shall be automatically performed on the best available internet technology (GSM, UMTS, WLAN, etc.) using VIPRI net as an automatic device.

5 SUMMARY AND FUTURE STEPS

Each Stroke is the third leading cause of death in Germany and often leads to permanent disability.
A quick consultation of experts on the case and diagnosis of the patient based on his case data are necessary to achieve rapid treatment and thus recovery of the patient.

However, such time-optimized transportation plans and treatment strategies are due to lacks of communication infrastructures in the pre-clinical environment.

Nevertheless they are essential in order to improve chances of treatment, especially for stroke patients. As the main objective of the project ASTER a special secure IT communication architecture has been set up in order to satisfy various requirements of a mobile communication of emergency vehicles on their way to the patients and the hospitals.

Based on the requirements analysis and use cases presented here, high secure communication architecture has been realised. A crucial factor has been the seamless communication of the backbone databases (offering on-time traffic data; hospital characteristics and stroke related knowledge to support the decision support system) and the mobile components of the emergency. This integrated telematics platform will enable paramedics in the future an accelerated, efficient and safe patient transport.

For now the communication system is integrated in a real ambulance vehicle with connection to the intermediary. Therefore a cable and communication plan has been set up, which will be built in till summer of 2013.

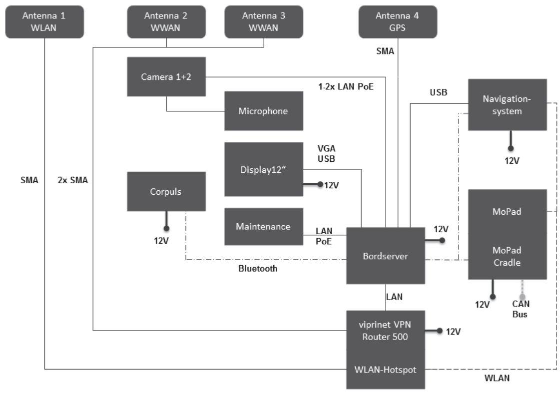

Figure 3: Communication infrastructures in the ambulance vehicle demonstrator.

Other services that may be incorporated into the ASTER system in future in order to expand the medical rescue scenarios on other application scenarios are:

- Chat / Instant Messaging application. The implementation could be realized by a freeware server in the intermediary. The protocol XMPP protocol (Jabber) is favoured.
- Governikus. Optionally, the usability of certified services (e.g. Gouvernikus) to the qualified delivery of information is to be examined. This service is based on the OSCI protocol. The aim of the overall system design is the design of a generic pre-clinical supply management, which opens the communications components of emergency vehicles as a preclinical system via interfaces to hospitals, command centres and transport infrastructure. The sentence must end with a period.

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