A Telematic Support System for Emergency Medical Services

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ABSTRACT

The presented system is part of the research project Med-on-@ix for the safe application of information technology in preclinical emergency health care. It aims at supporting members of the emergency medical services (EMS) at the incident location from a remote Competence Centre.

In this paper cases in which a telematic support system can be used will be outlined. This includes the assistance of medical and non-medical staff in emergency incidents. The functional and non-functional requirements for the on site medical devices, the documentation system and the medical decision support system in the Competence Centre will be outlined. This paper also presents a possible hardware and software system architecture approach to a telematic support system.

Keywords: Telematic Support, System Architecture, Competence Centre, Emergency Medical Services, Vital Parameter Transmission.

1. MOTIVATION

The number of missions handled by the German emergency medical services (EMS) has increased by about 50 % in the last 19 years. In 2004 German EMS handled about 3.6 million incidents. The number of incidents in which an emergency physician was involved on site has increased from 33 % to approximately half of the operations in the same period [1]. These figures - as well as the number of false incidents - increased continuously over the last years. One major reason for dramatic growth of this problem is the demographic change [2].

The problem is intensified by a shortage of physicians in German public health care. The German EMS envisions the attendance of an emergency physician in the event of severe indications. The need for increased treatment quality and higher cost efficiency is a pan-European phenomenon.

Figures presented by Gries/Helm/Martin [3] on the percentages of different procedures in emergency cases suggest that in a maximum of only 15 % of all incidents, the manual abilities of physicians are needed, this being determined by the invasive character of the procedure. In contrast, non-medical staff could handle at least 85 % of all missions with only basic abilities for manual invasive interventions, if a physician could transfer his decision competence to the incident location via a Competence Centre.

2. SUPPORT SCENARIO

A virtual presence of the specialized physician in the Competence Centre is achieved by the transfer of incident and medically relevant data such as vital signs, auscultation and video material by the telematic support system, as shown in Figure 1. The physician in the Competence Centre supports the staff on site with medical decisions and treatment proposals.

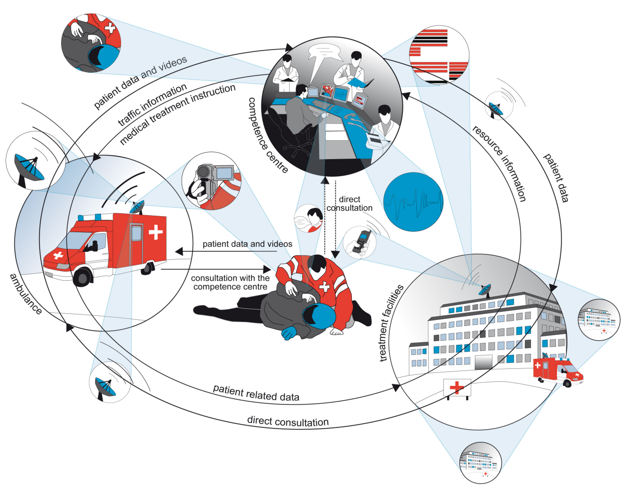

Figure 1. Telematic support scenarion for EMS

Another task of the Competence Centre is to optimise workflow by arranging communication with the health care facilities to which patients will subsequently be sent. The physician in the Competence Centre is supported by a software system that leads the user through treatment algorithms, facilitates documentation and provides all relevant information in an easily useable fashion. An important step towards better quality control for the emergency medical services through Med-on-@ix is the introduction of electronic documentation of the incidents on site. Especially, the transfer and the hand-over of the patient to treatment facilities is improved by the early availability of data forwarded from the Competence Centre.

3. GENERAL CONDITIONS AND REQUIREMENTS

General Conditions

The sustainable implementation of a telematic support system into emergency medical services must respect opinions from a number of stakeholders. The functional and non-functional requirements concerning the system design were found in two expert workshops with physicians and paramedic staff. Apart from the medical and technical requirements a number of judicial parameters such as the directive authority of the physician in the Competence Centre and the privacy of patients and staff must be taken into account. The same applies for the economic and the social feasibility as well as aspects for usability and acceptance.

Most of these aspects like the judicial boundaries must be evaluated in detail according to the laws in the country where the implementation is planned. For the area of the trial operation of the project Med-on-@ix all judicial doubts were cleared. The results may not be conferrable to other countries. As for the economic analysis the cost calculation for implementation and operation of the system is adaptable to other emergency medical services. Furthermore the benefit is strongly dependant on the established emergency system and the characteristics of its major problems.

Usability requirements are observed during the development phase by the means of iterative processes and a stringent participation of the users. This is not as challenging as the aspects of the user's acceptance which are not only influenced by usability but amongst others by the fact that users on site may feel observed or controlled by the Competence Centre. Every mistake on site could potentially be logged and antagonized against the user. Having such a user bias on the one hand and the benefits for the patients and users on the other, it is important to attend the introduction of the system with an appropriate change management concept.

The expert workshop results for the functional und non-functional requirements were validated and detailed in simulator studies at the full-scale patient simulator at the RWTH Aachen University Hospital. 24 teams consisting of one emergency physician and two paramedics could test the specificated functionality of the system without having the concrete system implementation. Thus they assured the validity of the functional requirements. Each team handled two simulated emergency cases (an acute coronar syndrom and a craniocerebral injury) with and without the attendance of a physician in the Competence Centre. The most crucial resulting requirements are presented in the next sections.

Functional Requirements

The software and hardware architecure is mainly ascertained by the functional requirements of the communication between the emergency site and the Competence Centre. Table I shows the different necessary signals to be transmitted from the emergency site and their priority with a classification into continuous or intermittent transmission and the priority for transmission. The specifics for some of the signals to be transferred such as the ECG leads shall be configurable by the Competence Centre. The experts did not identify a need for a more dynamic prioritisation or a control of these priorities.

All vital parameters shown in Table I must be measured by one single monitor/defibrillator device with the ability for a real-time export of all signals except the 12-lead ECG. Additionally an electronic stethoscope must allow the wireless live transmission of auscultation sounds.

Table I
SIGNALS TO BE TRANSFERRED FROM SITE AND THEIR PRIORITIES

Signal	Continuous / Intermittent Transmission	Priority
12-Lead-ECG	intermittant (every 5-30 min)	1A
Voice Communication	continuous	1B
Rhythmn ECG	continuous	2
Non-Invasive Blood Pressure	(every 1-5 min) intermittant	3
Pulse Oximetry	intermittant	4
	continuous	10
Kapnometry	intermittant	5
	continuous	8
Defibrillator	intermittant	6
Invasive Blood Pressure	intermittant	7
	continuous	9
Central Venous Pressure	continuous	11
High Resolution Pictures	intermittant	12
≈30 sec Video Sequences	intermittant	13
Video	continuous	14
Stethoscope	intermittant	15

Video and high quality pictures complete the impression from the situation on site. Thus, the ambulance car must be equipped with one remote control camera, allowing live transmission. A portable camera must provide a video live stream and high resolution steady pictures from the place of emergency.

For the voice communication with the Competence Centre and the listening to auscultation sounds, three wireless headsets are needed at the place of emergency. The microphones can be muted by a central control device on site. Every team member is able to listen to the voice communication at any time. The quality of the headsets must be of diagnostic quality for auscultation.

As an important step towards better quality control, the system must feature the documentation of medical and mission tactical data by a software on site and in the Competence Centre software. The documented data from the place of emergency must be displayed in real-time in the Competence Centre. The documentation software must receive and display textual commands from the Competence Centre and allow automatic online plausibility checks of the entered data. It must also allow an automatic data import of vital parameters from the medical devices.

For later evaluation and quality management all transmitted data from the place of emergency must be archived. The latter access to (anonymized) archive data must be restricted by an appropriate authentication system.

It is necessary to develop a system architecture allowing the integration of multiple ressources of the domains emergency site, Competence Centre and server site.

The system must ensure quick access to treatment algorithms for the physician in the Competence Centre. The software to be designed for that purpose must provide help in differential diagnosis and link diagnosis results directly to treatment algorithm documents.

The system must provide an initial estimation of the network coverage at the place of emergency to the EMS control centre by a web-service.

Non-functional Requirements

To be easily adaptable to the heavily varying local conditions of EMS, the system must be configurable in a modular way to ensure extensibility and adaptability. This applies especially to medical devices and to mobile communication technologies. The main issues concerning safety, security and reliabilty that have to be ensured in the system design are

- the health protection for staff and patient,
- the safety from interception of patient related data,
- the prevention of unauthorized access to the system and
- the data privacy of staff and patient related data.

Commercial mobile radio networks are well established and available at reasonable prices in most countries. They shall be utilised even for the safety critical application to take advantage of the huge capabilities in data transfer compared to Professional Mobile Radio Standards such as Terrestrial Trunked Radio (TETRA). GSM and TETRA may be used for voice communication where they can still deploy their advantage of high availability. Although partly based on commercial networks the system must ensure the data security.

A mobile device such as a Tablet PC must be used as the central control unit and for the documentation software on site. The Tablet PC software must allow the on site user to authenticate against the telematic support system. The method used must be a tradeoff between system security and usability. Delays at that point may affect the patients safety.

The audio transmission of auscultation from the stethoscope must be of diagnostic quality. The video cameras must feature resolutions and frame rates of diagnostic quality. A change of the frame rate must be possible during online operation. For energy and weight efficiency reasons the fixed camera in the ambulance vehicle, as well as the portable camera, must feature a hardware compression of the video stream. For usability reasons the portable camera must either be mounted on a small telescope tripod that is fixed to one of the other units or be a head mounted model.

The system must reestablish lost connections due to problems on the underlying communication channels. The system must integrate active and passive signal sources by receiving actively pushed data or polling data from its signal sources. The system must ensure the synchronicity of signals.

The system must support the use of Professional Mobile Radio services (PMR), such as TETRA and a Circuit Switched GSM mode for voice communication. Common mobile network technologies such as GPRS with EDGE and UMTS with HSPA must be supported through a generic interface for the IP based communication.

4. System Architecture

Fulfilling the demands on a telematic support system is for the most part possible with currently available standard hardware. The same applies to many of the required functions which can be realized by already available (open source) software solutions. Challenges to overcome include the integration of already existing services and the diverging standards for the real-time transmission of vital parameters. Another research area is the utilization of wireless consumer telecommunication networks to establish cheap, secure and reliable communication between the Competence Centre and the staff on site. ([4], [5])

To implement a proliferate solution, a suitable system architecture must take these conditions into account, integrate existing partial solutions and provide generic concepts to overcome local conditions.

Hardware Architecture and Component Distribution

Figure 2 shows the planned hardware arrangement for the domains of the ambulance vehicle, the server site and the Competence Centre. The data traffic within the system is transported over the internet to which all parts are connected. Although voice communication may also be realized by Voice over IP solutions the Public Switched Telephone Network (PSTN) is foreseen as a fallback solution in case of insufficient bandwidth. The domains differ in the way they access these networks.

For the stationary system domains (Competence Centre and server site) a reliable connection can be achived by common access technologies such as an ethernet and ISDN connections to one or multiple network providers. The technical solution for the mobile domains (ambulance vehicle and on site) is much more complex. For that purpose multiple connections to both multiple commercial and professional mobile radio network access points are used in parallel. They are established by the mobile communication units. Being an endpoint of the virtual private network (VPN) this unit also secures the data connections.

Although both communication units in the ambulance vehicle and on site may directly establish these connections, a wireless LAN connection (IEEE 802.11) between the units is foreseen as a fallback solution. Peripherial devices on site are the medical devices such the ECG/defibrillator device and the electronical stethoscope as well as a Tablet PC for system control and documentation purposes, headsets for the voice communication and a head mounted video camera. Additionally a printer and a remotely controllable video camera are available in the ambulance vehicle. The communication units serve as hubs for the peripherial devices by connecting them using different wired and wireless standards. They also host parts of the middleware solution to abstract vendor specific details of the peripherial devices and to organize communication.

The server site hosts the server applications and the archive in which all data from the missions is stored. For reasons of the data privacy protection, parts of the data must be anonymized before beeing stored in the archive.

In the Competence Centre the physician only works with a standard PC running client software. In detail the clients are live and archive viewers for the vital parameters, a support software for the quick access to treatment algorithms and collaboration software for the communication with the EMS control centre and hospitals.

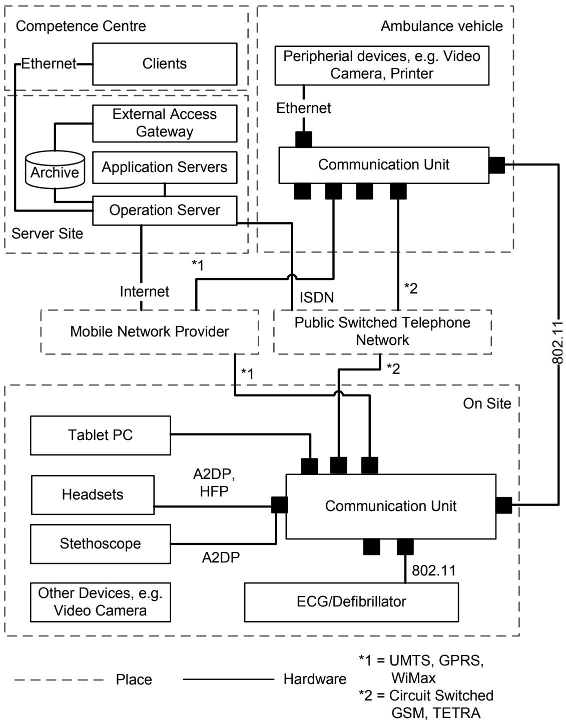

Figure 2. Hardware arrangement and Network Architecture Overview

Software Architecture

Figure 3 shows the software architecture layers of the telematic support system. All the software clients, servers and medical devices are on the Application Layer. The middleware software on the session layer is connected to the components on the upper Application Layer. It utilizes drivers to abstract from the vendor specific details. Another task of the middleware is to prioritize the different data types according to the bandwidth that was announced from the Network Layer according to Table I. The prioritized signals are packed into frames of equal length to ensure the synchronicity of all signals during transfer. Dependant on the type of signal and the available bandwidth they are then compressed with lossless or lossy compression algorithms. The connections between the middleware parts in the different domains are established through the VPN.

The network connections in the system are always established in the direction to the server site. All communicating components in the domains Competence Centre and Emergency Site are clients connected to the corresponding server in the server site. An operation server in the Server Site organizes the ressources and assigns incoming client request to servers. That way it is possible to have multiple instances of the different domains. Typically the ressources will be organized in areas where one area will have one Server Site and one Competence Centre but multiple emergency sites. In the case of a high mission appearance, the described system allows to forward

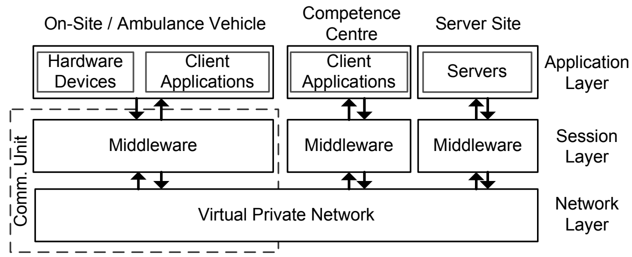

Figure 3. Logic layers in the support system

missions to another area by assigning clients to server ressources of a neighbor area.

The correct choice of an adequate middleware technology is of high importance for the implementation of the system. Object orientation helps overwhelming problems at high system complexities by allowing high levels of abstraction. Thus, the implementation of the middleware should make use of an object-oriented middleware technology. Another important boundary condition for the middleware technology is the types of licenses under which the technology is available. ZeroC's Internet Communication Engine (ICE) is an object oriented middleware framework available both under the GPL and a commercial license.

5. Outlook and Conclusion

Telematic assistance in the safety critical field of EMS must not only take medical and technical requirements into account. It can be achived with already established solutions. The parallel use of multiple communication links adds reliability and can be secured by using VPN mechanisms. A middleware architecture must offer an integration for partial solutions and must be to a high degree extensible. For the future collateral organizational concepts have to be developed and the practical feasibility of the described approach has to be evaluated in trial operations.

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