Making advanced Telemedicine affordable

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Introduction

Telemedicine becomes increasingly important, especially in rural areas or for rare diseases requiring an expert's opinion. Due to the widespread use of proprietary communication protocols, existing telemedicine approaches can only incorporate a subset of relevant medical devices. Thus, the remote physician is dependent on on-site colleagues and video-based reading of the device and medical parameters. According to Ackerman et al. [1] vendor-independent medical device interoperability and plug-and-play functionality as well as the lack of standardization are key problem that have to be solved for future telemedicine systems. Therefore, we state that an open standard for medical device communication does not only enable locally interconnected medical systems but is also vital for creating comprehensive telemedicine systems.

In this paper we describe a system for local device interoperability based on a service-oriented architecture (SOA) that is proposed for standardization in the IEEE 11073 family. Because the new architecture is designed mainly for hospitals, we focus on telemedicine for this environment. We introduce a comprehensive telemedicine system, which enables remote monitoring and control, based on this architecture. The whole system extension for telemedicine is comprised of cost-efficient of-the-shelf components. This will build the basis for affordable telemedicine.

State of the Art

Multiple studies have shown the benefit of telemedicine for the patient's health and the costs, especially for intensive care units (ICUs): [2]–[5].

Information and communication technologies for telemedicine applications in ICU and inpatient treatment context have been investigated in several research projects and thoroughly technically documented. The projects Maryland eCare [6], THALEA [7] and Tele-Intensivmedizin [8] focus on telemedical ward round of the ICU where hospitals in rural areas work together with the university medical centers.

At the commercial market there are several proprietary, vendor-dependent, and closed solutions for telemedicine available from the major manufacturers. All mentioned projects and (commercial) solutions have one problem in common. Only a (small) subset of medical devices can take part in the telemedical environment. In case of the vendor-dependent solutions only the vendor ecosystem can be used. However, to enable proper care, all medical devices that are associated with the patient need to be directly accessible. To the best of our knowledge there are no solutions that can provide these features yet. Hence, reading device parameters via video stream is necessary or only potentially outdated information that is available at the clinical information systems (CIS) can be used.

Interoperable Communication for Distributed Medical Devices

Following a SOA-based framework for medical device communication that meets the requirements for a comprehensive telemedicine system is presented. It enables both interoperable plug-and-play communication among medical devices and between the medical devices and the CIS. This architecture is going to be standardized in various sub-standards as part of the IEEE 11073 family.

The central part of Fig. I shows a schematic representation of a loosely coupled, non-centralized service-oriented device communication. Multiple medical devices are interconnected. Information about the patient like demographic data or order information from the CIS is accessible via the information system connector. A detailed view into the structure of a device that participates in the communication is shown in the left part of Fig. I. The Devices Profile for Web Services (DPWS) [9] is used as basic communication technology. IEEE P11073-20702 extends DPWS to the Medical DPWS (MDPWS). It introduces some modifications in discovery, messaging and event propagation to allow utilization for Point-of-Care medical devices. This includes the following three major points: Firstly, the safe remote control of medical devices including single-fault safety via dual channel transmission over one medium. Secondly, the *SafetyContext* that enables the ability to define the requirement for transmitting safety-relevant contextual information for a message in the message header. A concrete example is the requirement to send the last power value of an ultrasonic dissector within the header of the command to change the power output. Thirdly, the possibility of data-stream transmissions (e.g. for waveforms) has been extended.

The information- and service-model for distributed medical systems are defined in the IEEE P11073-10207 "Standard for Domain Information & Service Model for service-oriented Point-of-Care medical device

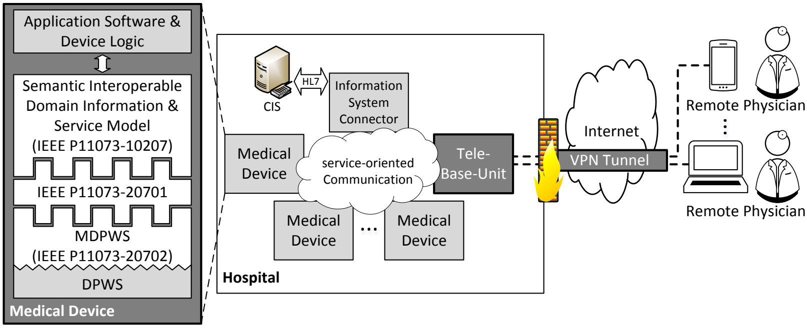

Figure I: Schematic overview service-oriented device communication and proposed telemedicine infrastructure

communication". The information model that is derived from the 11073 Domain Information Model (DIM) (IEEE 11073-10201) allows a semantic interoperable representation of the capability description as well as the current state of the medical device. The semantic description is done via codes and corresponding coding systems (e.g. code: 18442; coding system: IEEE 11073-10101; meaning: pulse rate). The medical device is accessible via the service-oriented communication model (or service model). There are services to retrieve information about the device capabilities and the current state, set parameters, and get event reports. IEEE P11073-20701 defines the binding between MDPWS and the Domain Information & Service Model.

Telemedicine Infrastructure

Based on the service-oriented device communication for medical devices introduced in the previous section we present our telemedicine solution. We developed a dashboard that dynamically composes all available medical information at one place. It consolidates virtual panels of distributed medical devices, vital parameters, pictures, and video streams. The Tele-Base-Unit (TBU) is part of the hospital's distributed medical device system. It collects all the information and provides read access as well as remote control access if possible with respect to medical risk management. The dashboard can be accessed by a common web browser. Due to security aspects the corresponding web server will only be accessible via a Virtual Private Network (VPN). Fig. I shows the proposed infrastructure: Medical device network of the hospital including the TBU and the remote physicians having access to the medical devices by using the dashboard via a VPN connection and a firewall due to security issues (dashed line).

Our solution has several advantages. The whole system is comprised of cost-efficient of-the-shelf components. The web browser based approach

Figure II: Demonstrator

requires no configuration effort and no special hardware from the remote physician, even mobile devices can be used. Physicians can access exactly the information they need for diagnostic purposes or treatment.

Demonstrator Implementation

We developed a demonstrator to showcase the described telemedicine infrastructure. It is shown that the solution is able to provide the whole range of device accessibility that is necessary to provide a comprehensive telemedicine system. An endoscopic camera and light source (right part of Fig. II) as well as a pulse oximeter (Fig. II bottom left corner) that implement the described communication infrastructure are included as medical devices. The TBU is located in the device stack at the right part of Fig. II. The left part shows several devices, also mobile ones, which access the dashboard. Reading and setting parameters and showing pictures and video streams is possible.

Conclusion

In this paper we have shown that a comprehensive telemedicine system can be built based on an interoperable service-oriented communication architecture for locally distributed medical device systems. The described solution comprises cost-efficient of-the-shelf components and is easy to use for remote physicians. This will make advanced telemedicine affordable.

Acknowledgment

This work has been partially funded by the German Federal Ministry of Education and Research (BMBF) under reference number 16KT1238, and by the German Research Foundation (DFG) within the graduate school MuSAMA (GRK 1424). We thank KARL STORZ GmbH & Co. KG (Tuttlingen, Germany) for the support on prototype development.

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