Chapter 11
CoSeMed:
Cooperative and Secure Medical Device Sharing

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ABSTRACT

E-health systems need to dynamically integrate heterogeneous types of medical sensors and provide access to streams of sensed medical data in order to properly support patient treatment. Treatment processes usually include several steps and medical departments, which means that sensors could be moved between networks of Care Delivery Operators instead of being reattached every time. Therefore, the authors propose a novel approach that allows sharing medical devices among different operators in this chapter. This means that each operator books a medical device as long as it delivers required data and is present in the operator's network, which the authors call the medical device cloud. Besides cost effectiveness, this approach can extend traditional cloud-based e-health systems, usually designed to share Electronic Health Records, by sharing the devices that emit the data. This mitigates judicial constraints because only the data sources and not the data itself are shared, and allows for more real-time access to mission-critical data.

INTRODUCTION

The evolution of Information and Communication Technology (ICT) in the healthcare domain is heavily influenced by upcoming distributed architectures that integrate and facilitate medical sensors in a ubiquitous fashion (Varshney, 2007). Streams of medical data emitted by integrated medical devices can support physicians in their decision-making process. However, a huge variety of heterogeneous sensors has to be considered in order to get a meaningful survey of a patient's condition. Treatment decisions often have to be made under time constraints, which require an aggregated view of the available data streams. Each stream utilized may differ regarding its specific characteristics, which might include real time requirements, used data formats and nomenclatures or, the communication protocol used by the medical device that provides the stream.

The resulting device integration and data aggregation problems often lead to proprietary

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solutions. Medical device vendors gain flexibility in handling specific hardware requirements, protecting innovations or optimizing their products towards their design preferences. Additionally, market exclusivity can be achieved, which often forces Care Delivery Operators (CDOs) to be dependent on a vendor (i.e. vendor lock-in). However, proprietary solutions hinder the development of open and fully integrated e-health systems, which are required to efficiently deliver cost-effective health services. Moreover, the vendor lock-in problem is intensified, if the movement of medical devices is considered. Since each operator might rely on different solutions, interoperability cannot be achieved. Due to the aforementioned variety, interoperability in the e-health domain can only be achieved, if medical devices can be integrated at any required location regardless of the protocol (proprietary or standard-based) they are based on.

This leads to two options to design medical device integration systems. Either, try to implement all required protocols into one system or rely on standardization. Both options underlie serious obstacles. Although appropriate standards like ISO/IEEE 11073 (ISO/IEEE, 2004) or the Bluetooth Health Device Profile (Bluetooth SIG [BSIG], 2013) exist, the variety of medical devices and regarding requirements makes it difficult to achieve a widespread standardization in a reasonable time span (Buxmann, Weitzel, von Westarp & König, 1999). Moreover, even a lot of standards allow for vendor defined extensions, which again introduces proprietary parts. And, most standards rely on the definition of device profiles to express functionality needed for a certain kind of device. Due to the decreasing time to market, these profiles are changed or added rapidly, which requires to adapt the device integration system too. Implementing all required protocols into one system does not scale, since compute nodes, like smartphones or other embedded systems that are usually used as medical device integration systems underlie resource constraints and often do not allow to implement several protocol stacks in parallel. This raises the question, how a middleware for medical device integration systems can be designed, to achieve interoperability among several protocols, to fit to the rapidly changing requirements and, to be deployable on mobile embedded systems.

Apart from integrating medical devices, data availability has to be considered. Nowadays, treatment processes usually include several steps and institutions (i.e. CDOs), ranging from monitoring at home, emergency transportation or different hospitals, whereat each location might be managed by a different operator. If we assume that a patient is already equipped with a set of wearable medical devices that are organized in a Body Area Network (BAN), real time access to the emitted data could provide better knowledge to physicians. At each location the BAN can grow or shrink (i.e. new medical devices are integrated), in order to fit the set of medical devices to the current treatment situation. However, to prevent reattachment or replacement of the already given medical devices, it is required that the data streams can be accessed by every CDO that is involved in the treatment process. This means that handover processes and some kind of device access management have to be introduced, in order to share the medical devices among different networks and operators.

Based on these problem definitions, the major challenges for middleware architectures in the e-health domain are:

- **Medical Device Integration:** The process of medical device integration shall be organized in an autonomous and dynamic way. In order to integrate unknown or new medical devices in a Plug and Play fashion, the middleware shall allow for reconfiguration at runtime and hide the heterogeneity and complexity of transport protocols from the application layer.
- **Data Aggregation:** Proper data aggregation heavily depends on the characteristics and the semantic interoperability of the incoming data streams. Therefore, the