TEEM: A Mobile App for Technology-Enhanced Emergency Management

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Abstract. In this paper we describe a mobile app for *Technology-Enhanced Emergency Management* (TEEM), designed for supporting data recording and transmission during patient transportation by ambulance. TEEM allows the travelling personnel to record the most significant patient data, and to send them to the destination center, where the specialist physician will be notified and allowed to inspect the data themselves, possibly providing immediate advice. The exploitation of TEEM also allows to maintain the transportation data over time, for medico-legal purposes, or to perform a-posteriori analyses. The app is currently under evaluation at the Neonatal Intensive Care Unit of Alessandria Children Hospital, Italy.

Keywords: Mobile app · Mobile cloud computing · Data recording · Data transmission · Emergency patient management

1 Introduction

Patients experiencing a medical emergency (e.g., stroke patients, pre-term born babies, or accident victims) are normally taken to the closest hospital structure, which might be insufficiently equipped, in terms of human or instrumental resources, to address their needs. In these situations, the patient has to be stabilized, and then carried to a larger and more suitable health care center, where specialized physicians and all necessary diagnostic/therapeutic devices are available.

During patient transportation by ambulance, a specialist physician (e.g., a neurologist) is typically not present; assistance is usually provided by paramedics and/or emergency medicine doctors. The patient is continuously monitored by means of proper devices available on the ambulance (such as ECG or blood pressure monitor). However, the monitored data, at least in Italy, are not automatically recorded. Therefore, they cannot be inspected/analyzed a posteriori. Moreover, they are not accessible in real time by the specialist physician at the destination reference center.

In this paper, we propose a mobile app for *Technology-Enhanced Emergency Management* (TEEM), specifically studied for patient transportation by ambulance.

M.U. Ahmed et al. (Eds.): HealthyIoT 2016, LNICST 187, pp. 101–106, 2016.
DOI: 10.1007/978-3-319-51234-1_16

TEEM allows the physician or paramedic personnel to record the most significant patient data (generated by monitoring devices or directly measured), and to immediately send them to the destination center, where the specialist physician will be notified and allowed to inspect the data themselves, thus having a more complete understanding of the patient's situation already during transportation. In case of need, the physician will also be able to communicate with the ambulance personnel and supervise the management of possible critical needs in real time.

TEEM has been designed to be secure, but also extremely user friendly in its design, since the travelling personnel must not be distracted from more critical tasks (i.e., patient management).

The exploitation of TEEM will not only support real-time communication, but will also allow to record the most significant data, maintaining them for medico-legal purposes, or to perform a-posteriori intra and inter-patient analyses (e.g., for a more complete patient characterization, or for quality assessment of the medical center).

TEEM has been specifically designed for pre-term born baby transportation, but could be easily be extended to different application domains as well.

2 Technology-Enhanced Emergency Management in the Ambulance

The TEEM mobile app, in its current version, has been realized to monitor the transportation of pre-term born babies. The application domain specificities will be quickly illustrated in Sect. 2.1. Section 2.2 will then provide the details of the technical and methodological choices. Section 2.3 will illustrate the main characteristics of the client side interface, to be used by the ambulance personnel on a smartphone, and Sect. 2.4 will provide a description of the server side interface, to be used by the specialist physician at the hospital.

2.1 Pre-term Born Baby Transportation

Pre-term born babies are very often critical patients, who need intensive care. If a baby is born at an insufficiently equipped hospital, s/he has to be moved to a hospital equipped with a *Neonatal Intensive Care Unit* (NICU) [1]. Transportation may also be required if the baby, possibly already cared at the NICU, needs a specific intervention, that can be performed only at a larger or more specialized clinical center.

The clinical conditions of the baby to be transported may require ventilation assistance during the journey. Three different types of mechanical ventilations exist, each of them requiring specific parameter settings. Different transportation types must therefore be considered.

2.2 Related Work

Recently, architectures for storing and analyzing medical data in cloud computing [2] have been proposed in combination with the usage of mobile devices, which allow to send/receive data in real time without any particular equipment and/or knowledge. This new computing paradigm is called *Mobile Cloud Computing* (MCC) [3]. MCC integrates the cloud computing into the mobile environment and overcomes obstacles related to the performance (e.g., battery life, storage, and bandwidth), environment (e.g., heterogeneity, scalability, and availability), and security (e.g., reliability and privacy) discussed in mobile computing. When adopting MCC, low bandwidth issues from the mobile communication side, and security, confidentiality and integrity issues from the cloud computing side have often to be considered. Bandwidth issues have been dealt with in the approaches in [4, 5], which propose solutions to share the limited bandwidth among mobile users. As for security/integrity/confidentiality issues, a classical solution [6] consists of three main components: a mobile device, a web and storage service and a trusted third party. This third party is in charge of running a trusted crypto coprocessor which generates a *Message Authentication Code* (MAC). Thanks to the MAC, every request from the user to read/write data on cloud storage is properly authenticated and, at any time, it is possible to validate the integrity of any file, collection of files or the whole file system stored in the cloud.

2.3 System Architecture

In our system, we have adopted the MCC paradigm. To adopt MCC in our scenario, we had to address both low bandwidth issues from the mobile communication side, and security/integrity/confidentiality issues on storing medical data from the cloud computing side. To address bandwidth issues we have resorted on the already cited approaches in [4, 5], while for security/integrity/confidentiality issues, we have resorted to the three component architecture described in [6]. The overall system architecture is illustrated in Fig. 1.

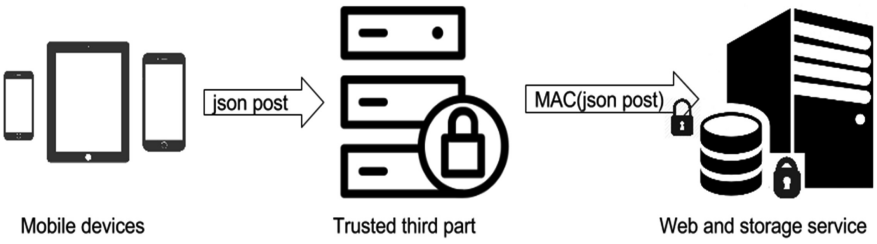


Fig. 1. System architecture.

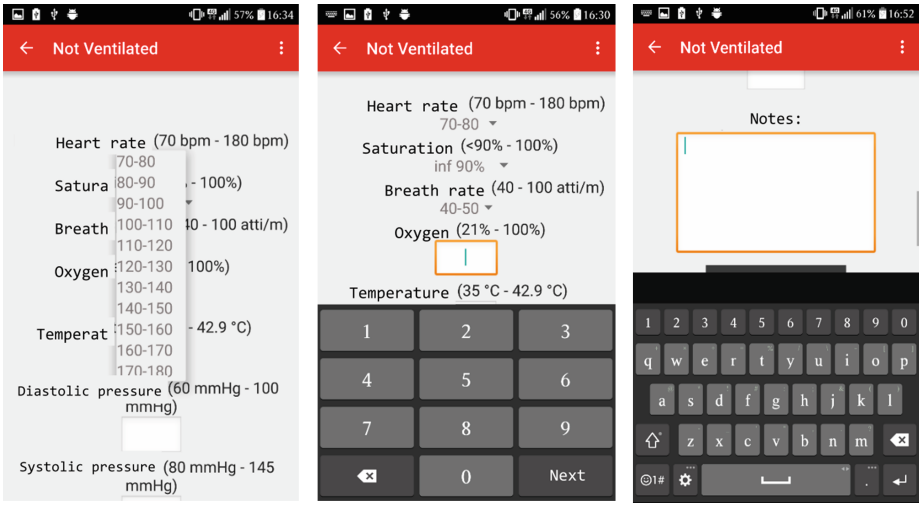
2.4 The TEEM App: Client Side

The TEEM app is meant to be exploited in very critical situations, where the user has higher priorities with respect to data entry. At the same time, key transportation data are extremely useful for the specialist, and of course need to be correct. Given these goals, the mobile app has been designed to be very user friendly, very clear, and essential in its graphical design.

As observed in Sect. 2.1, different types of patients may be transported: those requiring mechanical ventilation, and those who are able to breathe autonomously. In order to minimize the number of data to be inserted, and to avoid mistakes, TEEM immediately asks to select whether the patient has to be ventilated or not. In case of ventilation, the user will further set the correct ventilation type. In this way, instrumental setting data will be required only in the appropriate cases.

Overall, the parameters to be inputted have been selected by our medical collaborators, on the basis of domain knowledge.

Every data entry operation has been customized on the basis of the type of data being inputted, in order to make it as fast and simple as possible, as illustrated in Fig. 2. The figure presents three different activities of the TEEM app, that allow the user to input some data for a non-ventilated transportation.



(a) (b) (c)

Fig. 2. Snapshots of 3 activities in TEEM.

In Fig. 2(a), heart frequency is being inputted. In our application domain, the exact value of heart frequency is not of interest: only the range needs to be specified. To this end, a set of pre-defined ranges are shown to the user, who will just have to choose one of them without digitizing any number. Pre-defined ranges have been defined on the basis of medical knowledge as well.

In the second activity (Fig. 2(b)), oxygen saturation has to be inserted. The admissibility range (21%–100%) is reminded to the user, but s/he has then to insert a specific numeric value. To this end, a numeric keyboard is activated.

It is worth noting that consistency controls are also executed in this case, since, as observed above, transportation data always need to be correct. If the digitized number is outside the admissibility range, an error message will appear, in order to allow the user to introduce the correct value.

Finally, in the third case (Fig. 2(c)), additional textual notes can be inserted. In this case, an alpha-numeric keyboard with auto-completion is activated.

When data have been sent to the server, the user is notified by a toast message, i.e., a notification message that shows for a few seconds and then fades away.

2.5 Server Side

The data inputted by the user through the mobile app interface are then serialized as a JSON string, which is posted to the server (see Fig. 1). At the server side, data have to be de-serialized, stored in a database, and shown to the user through a web interface.

The web page is automatically refreshed every five seconds, in order to always show the most recent data during transportation. Indeed, an updated measurement can be send several times during the journey.

Data are stored in a database, which maintains all the measured information, for medico-legal purpose, and constitutes an important knowledge source for the hospital. Indeed, historical data can also be queried, and shown to the user through the web interface, for further investigation, or for comparison with different patient cases.

3 Conclusions and Future Work

In this paper we have described TEEM, a mobile app studied to support data communication during patient transportation by ambulance. TEEM allows the ambulance personnel to insert the most significant patient monitoring data, and immediately send them to the destination center, thus substituting the extremely incomplete paper log that is currently deployed. TEEM has been designed to be user-friendly, but also to guarantee data entry correctness. Interestingly, we are not aware of any other similar approach in the field of emergency patient transportation.

TEEM is currently being made available to the personnel of the NICU of Alessandria Children Hospital, Italy. The NICU has 7 beds, and usually performs more than 80 transportations a year. After a testing period, TEEM will be revised/enhanced as needed, and then made available for routine adoption.

In parallel, we are working at the implementation of a second mobile app, directly interfaced to the monitoring devices of the ambulance. This second app is meant to automatically send to the hospital server all the data measured by the devices, in real time. It will complement TEEM (which will still be used to insert non-instrumental data), and will allow the specialist physician to receive a significant amount of information during transportation. This will enable her/him to have a very clear picture of

the patient's situation as soon as s/he arrives at the hospital, and thus to immediately start the proper treatment, without having to re-asses the patient condition, as it currently happens.

Acknowledgments. We acknowledge Dr. D. Gazzolo and Dr. M.C. Strozzi for providing their knowledge about pre-term neonatal care, and about the specifics of the service we have designed.

This research is original and has a financial support of the University of Piemonte Orientale.

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