BlueMedica – Wireless Medical Data Access Appliance*

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Abstract. In health-care, it is very important to have simultaneous access to different data on the patient, such as his/her case history, medical history or undergone surgeries. The data is usually stored in the hospital information system. This paper describes design of a system called BlueMedica, which provides the mobile access to data stored in the hospital information system. It is connected to an existing hospital information system by the means of a translation server. A mobile device called TabletPC enables visualization and modification of the data by the user. A part of the system is the a device for patients – a wristlet designed for measuring body conditions. The acquired data can be transferred wirelessly into the information system. The Bluetooth technology provides the mobility of the data connection. As information on patients includes very sensitive personal data, we discuss information security issues as well.

Keywords: wireless data transfer, Bluetooth, access point, translation server, security.

1 Introduction

Mobile collection, access and manipulation of data in local networks is today an emerging issue that involves wireless network connectivity. Wireless local networks can be effectivelly used in different domains. The environment of a hospital is very suited for such applications.

We describe the BlueMedica system, which provides doctors and nurses with mobile access to and collection of data within a hospital. They have access to the latest information on patients from any place. The BlueMedica also enables to modify the data stored in the hospital information system (HIS). A part of the BlueMedica is a wristlet for patients that provides measurement and collecting of data on patient's health and scheduling of examinations and medicaments intake.

Our primary goal was to design a local network for mobile and universal access to data stored in an information system. We decided to use the Bluetooth technology to reach this goal. The Bluetooth technology offers a unified interface to interconnect devices and to replace wires and connectors [6]. The advantages of the Bluetooth technology are: low energy consumption, low electromagnetic radiation and a simple realization. These advantages make it ideal to use in a medical institution setting.

The BlueMedica works with sensitive data, therefore security precautions had to be taken. The data must be protected when it is transferred and when it is stored in various parts of our system. Also, the user access to components of the system must be controlled.

The paper is organized as follows. In Section 2 we give an overview of the BlueMedica. Subsections present design of the BlueMedica's components. Security issues are discussed in the Section 3. We conclude the paper with our conclusions and give some proposals for the future work.

2 System Overview

The BlueMedica system consists from the following components (see Figure 1):

- *TabletPC* - a mobile device for a doctor or a nurse used for mobile data access;

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- *Wristlet for patients* - device for measurement and storing data on health conditions, it serves also as a scheduler;
- *Translation server* - provides universal access to data stored in the hospital information system;
- *Access point* - enables a wireless connection for mobile parts of the system, the TabletPC and the wristlet.

2.1 TabletPC

The doctor or nurse use the portable TabletPC to access and work with the hospital's data. We employed the thin-client architecture, to make the device simple. This makes possible to use thinner and lighter devices than a standard notebook, which can be held in hands like a clipboard.

The TabletPC must be provided with an operating system that allows communication using the TCP/IP protocol suite, and be capable to use the Bluetooth module. It also has to be capable of running a web browser with SSL data encryption support (see Section 3) and a scripting language support.

2.2 Access point

The access point provides wireless network connectivity for the TabletPC devices. This objective can be achieved in various ways. The ways partly differ in terms of the wireless technology used, as well as in the terms of transparency for the application layer. We use the Bluetooth technology. Wireless connections can be transparent to applications, if a complete TCP/IP connection is created. If only selected protocols are transferred, the connection might not be transparent to applications, but requires less resources.

We decided to transfer only the protocols required by our application over the Bluetooth connection, mainly the HTTPS. This solution (often called a HTTPS tunnel) is easier to implement, even though it is not completely transparent for applications. The tunnel consists of two parts, a client part in the TabletPC and a server part in the access point. The client program opens a predefined TCP port. All incoming requests to this port are sent through the Bluetooth connection to the access point. The access point sends this data through a TCP/IP connection to the translation server. The translation server's response is communicated back to the TabletPC in the same way. The connection is always initiated by the TabletPC. For each request, a new virtual connection has to be created over the tunnel. The tunnel must be able to serialize the requests, therefore a simple protocol (called 'link protocol') was implemented.

2.3 Translation server

We expect today's hospitals to have an information system for storing their data on patients, medicaments, etc. The idea of the translation server is to make the client side preferably independent from the HIS.

The translation server provides access to data stored in the HIS. The most important requirements put on the design were simple transformation of data from the HIS, effective presentation of this data on the TabletPC, adaptability to, as well as independence from existing information systems. To reach listed requirements we employed the web server technology. An application running on that server provides access to data. Such design allows using standard products without the need to develop new ones and using existing software on the client side.

Another important issue is data representation. Data representation must provide a universal and flexible access to data and a simple modification of the data. We rejected a binary representation, due to complicated manipulation and difficult modification. The eXtensible Markup Language (XML) [2, 8], which in connection with the eXtensible Stylesheet Language (XSL) [9] used for data transformation provides and ideal solution that fits our requirements. It allows simple data transformation into the standard format used for presentation – the eXtensible HyperText Markup Language (XHTML). We chose the XHTML language for data presentation, because we use a standard web browser to display the data.

The translation server consists of three parts: a part accessing data in the HIS, a part processing the requirements and commands, and a data transformation part. We used the concept of forms to present the data from

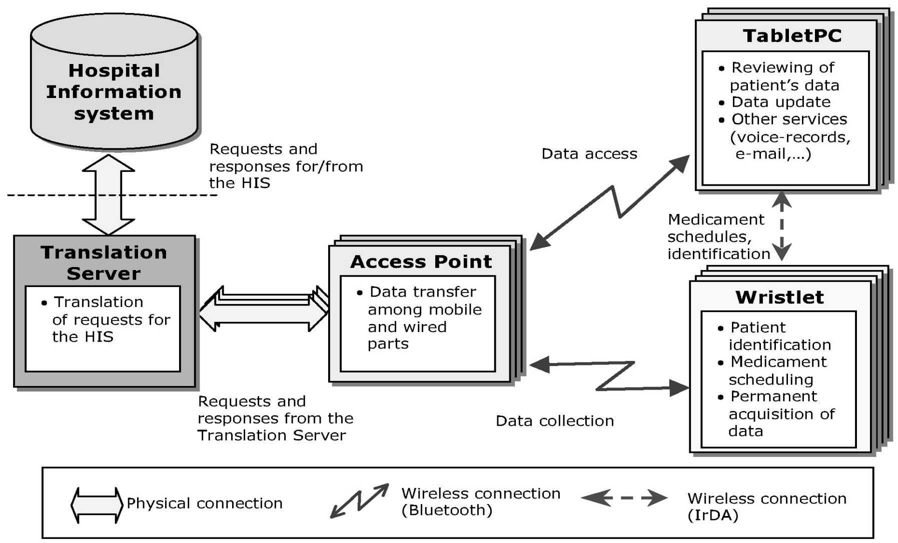

Figure 1: The BlueMedica overview.

the information system to the user. Each form consists of several components like command buttons or textboxes. These components allow forming the user interface.

The operation of the server is based on transforming requests from clients into commands of the HIS, processing the response from the HIS and communicating this processed response back to the client. XSLT sheets are used to produce the resulting layout of the document.

2.4 Wristlet

Each patient is given a wristlet, which he/she will carry all the time spent in the hospital, and optionally at home. The wristlet consists of four functional parts: a scheduler, a measurement module, a communication module and the user interface (see Figure 2).

The *intelligent scheduling system* notifies the patient of both repeating and non-repeating events. It also regularly starts the measurements, as set by the doctor or nurse. Non-repeating events are used mostly during the patient's stay in the hospital, and notify the user for example to visit the doctor in order to have an examination. In such case the wristlet alerts the patient. The patient utilizes functions based on regular events mainly at home (the wristlet notifies him/her of taking a medicament).

The *measurement module* is capable of doing various measurements and transmitting this data to a TabletPC through a Bluetooth connection. We designed temperature and pulse sensors. A dedicated microcontroller collects values from these sensors and translates them into real physical values (beats per minute, degree of Celsius or Fahrenheit).

The *communication module* provides communication services for both the scheduling and measurement part. The communication module is capable of creating a connection with additional devices on patient's body and transfer their measurements into the wristlet, or control their operation (e.g., ECG appliance, EEG appliance, intelligent insulin dosing appliance, blood pressure meter [3], pulse oximetry appliance, stomach Phmetry, plethysmography appliances).

The wristlet communicates with the doctor's TabletPC through a Bluetooth connection, it drives the scheduling system, communicates with the measuring system and stores the measured values. The wrist-

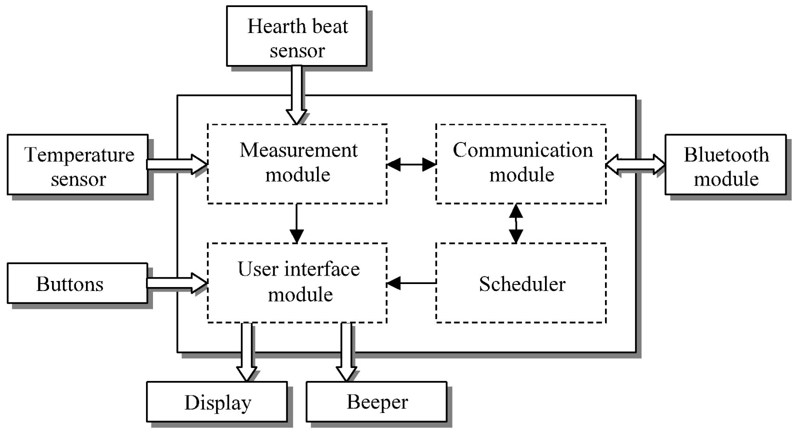

Figure 2: Wristlet block scheme.

let's memory features the identification of the patient (name), important information such as blood type, known allergies, measured values, and scheduling data.

We designed a way to implement Bluetooth connectivity in the wristlet. The Bluetooth protocol stack in the wristlet has to be simple and small in size, due to the performance of the wristlet hardware. Using only the HCI layer [1] of the Bluetooth protocol stack is satisfactory for our needs.

The *user interface* of the wristlet is menu driven. The menu is very simple and easy to use. Besides of checking and confirming the scheduling entries, the user can read the values acquired by the measuring system and check the patient's temperature or pulse.

2.4.1 Temperature measurements

The body thermometer is in direct contact with the patient's skin. It is placed on the inner side of the wristlet, thereby touching the patient's arm. The ambient thermometer is positioned on the top of the wristlet.

The body thermometer range of measurement was determined experimentally, in order to be able to measure the body temperature on the patient's wrist. We tested different types of sensors and transducing methods. We used a simulation program implemented in the Matlab environment to identify measurement errors caused mainly by the non- linear conversion characteristics of the considered sensor. Interpreting the results of this testing, we chose the RTD (resistive temperature detector) sensor KTY84-130 powered with a 2.5V voltage through a serial 4.7kΩ resistor for measuring body temperature. In this case, the measurement error is ca. 0.035C.

For measuring the ambient temperature, a different method of temperature sensing has been chosen, compared to the body temperature measurement, for a better performance in a larger temperature range. We used a similar RTD to deliver defined measurement parameters (precision and resolution).

2.4.2 Pulse measurement

The patients pulse measurement may be based on the plethysmography principle [4, 5], which measures changes in the volume of the entire body or part of it. We considered two types of plethysmography: impedance plethysmography and photoelectric plethysmography.

Impedance plethysmatographs indirectly detect blood volume changes within a limb segment by measuring variations in the electric impedance of skin tissue, which corresponds to heartbeats. Such measurement requires a four-electrode system with a current source. The electrodes must be placed on the arm or the foot, in a 20 to 30 centimeter distance. Such placement of electrode would boldly affect the compactness of the wristlet.

The second choice is to use photoelectric plethysmography. This method is not a true plethysmography, because it does not measure volume changes, as described above. Instead, it detects changes in the blood content in capillaries underneath the skin by means of photoelectric cells. The pulse contours obtained by this technique, however, are quite similar to those recorded by other methods.

3 Security concerns

We have identified three security concerns that have to be solved in the design of a system for mobile collection and manipulation data in the hospital: the security of data stored and manipulated within the system, security of the transferred data and the security of the mobile parts of the system.

Data stored in the patient's wristlet is secured by checking all requests for access to this data. Every device requesting access to data stored in the wristlet has to authenticate itself. The authentication method used is the method provided by the Bluetooth technology. The Bluetooth technology offers an authentication method based on PIN codes. The device (user) requesting access to data must have knowledge of the PIN code. Due to the performance of the wristlet hardware (memory size and computing power), data is stored in the wristlet's memory in a clear-text form. The wristlet does not encrypt the data during transfer. The data is however, encrypted by the Bluetooth modules of the communicating sides.

Though the HIS is not an immediate part of our system, access to the data stored within must be secured. To access data stored in the HIS, the user must first authenticate to the TabletPC device. The user's access rights are defined on the level of individual forms.

Data transferred between the TabletPC and the translation server is protected by the HTTPS. The HTTPS is a widely used and accepted transfer protocol for secured data transmissions [7]. It utilizes the SSL technology to encrypt the transferred data. The SSL technology is based on a combination of asymmetric and symmetric encryption algorithms.

To secure the system as a whole, all parts of the system have to be secured, especially the mobile parts of the system. The BlueMedica system includes two types of mobile devices: the wristlet and the TabletPC. Every wristlet is uniquely identified by the hardware address of its Bluetooth module. This address serves as an identification of the patient, which is carrying the wristlet. Pairing between the patient and his/her wristlet is done by the system. The wristlet also features identification of being unfastened. This function shall alert the hospital personnel that the person carrying the once-unfastened wristlet might not be the person with which the wristlet has been coupled.

To be able to operate the TabletPC, the user has to authenticate to the device. The authentication method should be both reliable and easy to use, in order not to limit the user. The standard login and password scheme cannot be fully trusted. People tend to use short and/or easy-to- guess passwords to remember them. It is also complicated to implement password-input on a keyboard-less device such as the TabletPC. A biometric authentication method such as fingerprint reading fulfills both requirements. Optionally, if the hospital uses token authentication such as smartcards, this method could be extended to authenticate the users to the TabletPC device.

4 Conclusions

We described in this paper the BlueMedica system, which provides mobile and universal access to data, as well as a simple way of remote data collection. Such system enables instant access to the data in the moment when it is required, from the place where it is required. Therefore, the access to data is faster, which lets the hospital staff work more effectively, focusing on helping the patient and not on searching the required information. The system was designed with modularity and universality in mind. The design is based on standard protocols and software.

We created a prototype implementation of the BlueMedica system. The prototype system is capable of secure data transfer between the TabletPC and the Translation server. This enables complete access to the hospital information system. The prototype implementation of the wristlet is able to measure and display both ambient and body temperature. The measured data can be transferred into the TabletPC, and from there stored in the HIS.

In the future, the BlueMedica could be extended to collect more data on patient's health condition, through new sensors. The measured data could be saved directly in the information system, without being transferred to the TabletPC first. This would require a connection to be created between the wristlet and an access point. The wristlet's functionality could be extended to monitor the patient's location (e.g., whether he/she is present in the waiting-room), or to page the patient.

Similar extensions could be applied to the TabletPCs used by hospital staff. Besides of discovering their location and paging them, an advanced version of the BlueMedica could implement a communication feature. This feature would enable two TabletPC users to communicate together wirelessly.

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