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The role of a mobile device in a home monitoring healthcare system

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***Abstract*—In the present study, a home monitoring healthcare system for elderly and chronic patients has been proposed. The system was developed for three types of users: assisted person, doctor and guardian. It analyzes the collected information (e.g. biomedical signals) and in case of detection of dangerous events informs physician and guardian. A mobile device has a key role in the system. It allows exchange and visualization of data to the users. This paper describes the design and implementation of a tablet in the home monitoring healthcare system, with specially developed data exchange protocol Additionally special security features to protect data exchange were introduced. Software part of the system was made using modern technologies such as JavaFX for central unit and Android for mobile devices.**

I. Introduction

RECENTLY healthcare for elderly people has been an important research topic. The increase in life expectancy due to improvements in living standards, and medical treatments, has resulted in an aging population diseases in the last few years [1], [2]. Therefore, the modern health care system aims to enhance the safety and comfort of the patient's life while managing chronic diseases. This creates the need to develop home e-health system, which will integrate various wireless sensors for long-term monitoring and vital signs extraction of the patients. The rapid development of information and telecommunication technology has brought great revolutions in that field [3]. New features of mobile devices (smart-phones, tablets), create new opportunities to use them as devices for the management and presentation of medical data.

There are many promising systems implementing the selected function or the complex monitoring of the patient. One of the first approaches proposed a wearable patient monitoring system, which integrates current personal digital assistant (PDA) technology and wireless local area network (WLAN) technology [4], [5]. A wireless PDA-based monitor is used to continuously acquire the patient's vital signs, including heart rate and SpO_2. The patient's bio-signals are transmitted in real-time, through the WLAN to a remote central management unit

In another approach a mobile phone was proposed as a client-side part that communicates with the central device by the GSM network [6], [7]. An alert management mechanism has been included in back-end healthcare center to enable various strategies for emergency alerts triggered by automatically recognized situations.

A Bluetooth-enabled in-home patient monitoring system, facilitating early detection of Alzheimer's disease was proposed in [9]. The location and hence the movement of a patient is tracked and reported to a local database, with the use of short-range Bluetooth communications. The collected data is then transmitted via the Internet to a decision engine (on a remote site). "Electronic Doctor's Bag" [8] is another approach to medical system with mobile communication. The main idea of this system is that a nurse instead of a doctor, carries the Electronic Doctor's Bag and visits a patient. Than an equivalent to face-to-face communication between the doctor and the patient is realized remotely.

Data security and optimization of wireless communication between devices of the system [10], [11] are very important aspects of the functioning of the patient in-home monitoring systems.

The purpose of this study is to develop a system of comprehensive and continuous monitoring of the patient at home. The functionality of the various parts of the system was optimized for a user. System that is adapted for continuous measurement of biomedical signals, depending on the patient's disease. System that analyzes the collected information and in the case of detection of dangerous events informs physician and guardian. The purpose of this study is to increase the amount of information that can be acquired from patient at home and exchanging them with doctors.

II. System structure

Home monitoring of patients is a wide term and different applications are possible. Some users are highly immobilized others are free to move but suffer dementia. The platform design requires creating a multi-modular system. Proposed by us the Domestic system structure is presented in Fig 1. Our system consists of the following components:

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A. Users

- An assisted person (AP) – person supported with the system. Communicates with the Domestic system using HCI, various sensors and possibly an Android device.
- A physician - A person in charge of AP health. It should be either doctor or otherwise qualified person. Physician communicates with the system only by tablet.
- A guardian - A person who cares for the patient (eg family member, social service person), communicates with the system using tablet or other Android device.

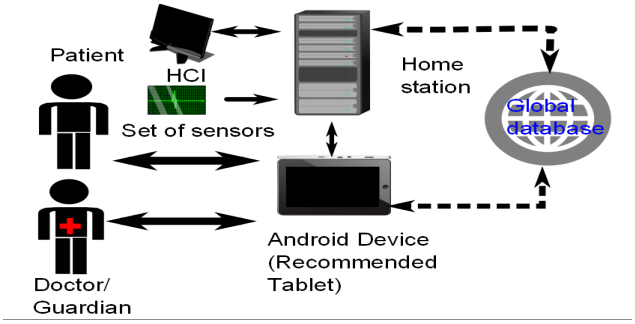

Fig. 1 Domestic system structure (details are given in the text)

B. HCI

The human-computer interface is one of the most important elements of the platform. The acceptance of the entire system depends highly on the way it can be used by older/immobilized users. Three elementary modes of the HCI are being designed: interface based on touch screen; visually guided interface; audio guided interface.

C. Home station – central unit

Central computer around which whole system revolves. Home station is a Domestic device consisting of computer with Bluetooth adapter and HCI software. It should manage databases, synchronize with global database, collect and process sensor data, process and dispatch events, integrate data, manage communication, support mental training, etc.

D. Set of sensors

Set of devices collecting data relevant to patients health state. Different categories of sensors are currently prepared to measure: heart pulse, temperature, body composition parameters, glucose concentration, blood pressure, electric heart activity, and posture activity. Another group of sensors consists of those related to monitor user environment parameters. This is especially important for older people deciding to live independently at home.

E. Mobile device - tablet

A device with Android operating system, used by users of the system. It allows to communicate with Home station and access to functions such as real-time medical measurements or AP information. Features and details of such device are described in the next paragraph.

III. Mobile device

This work is focused on use of a mobile device for exchange and visualization of data in home monitoring. Portable device used in Domestic system must have Android operating system. This type of device is going to be used by all system users. In the case of the patient and guardian device can be either mobile or tablet, while in the case of a physician use of tablet is recommended (due to the improved readability of medical data presented). Special software was prepared for each user type, which enables, among other things, communication with the central unit and carrying out the appropriate function for the role.

In case of the AP it must fulfill three basic functions: communication with the AP (surveys), monitoring of the AP when not within range of the central unit and notification of some activities. Guardian using a mobile device will be alerted about the dangerous events occurring on the side of the patient and, additionally, when he is in the patient's home will be able to view basic data about the patient's condition (e.g., the last activity of the patient or test results).

Application that was prepared for a doctor is the most expanded. It has been prepared mainly to carry out visits in the patient's home. When the device is within the range of the patient's central station the device will automatically connect to it and update current basic information about the patient. Additionally, there is possibility to browse offline basic medical data, which are stored in the internal database. If the device is equipped with a GSM module, it will be served alerts notifications emitted from the patient central unit as well. During home visits physician has access to personal, electronic healthcare records, which contain the list of actual diseases and prescribed medications, information about recent events and a physician's personal notes about the patient. Additionally, physician can access the archived data or add new data if needed. An example of the patient chart with some test data is presented in Fig. 2. Another feature allows the physician to access the list of measurements which suits the patient's condition. After selecting a particular type of test, information specific to this measurement is presented, both in text and a graphics. The physician has the opportunity to view the entire history of examination, that are automatically downloaded from the central station. There is also a possibility to carry out test directly from the application. Monitoring of patient basic vital signs (ECG, pulse, blood pressure, temperature) which is an example of real time measurement, is shown in Fig. 3.

Interface design for medical applications is the result of consultation with prospective users of the system. It imposed the emphasis on maximizing the clarity of the information presented and intuitive interface. In addition, particular attention was paid to issues of communication and the security of transmitted data between the mobile device and a central unit. These issues are described more specifically in the following paragraphs.

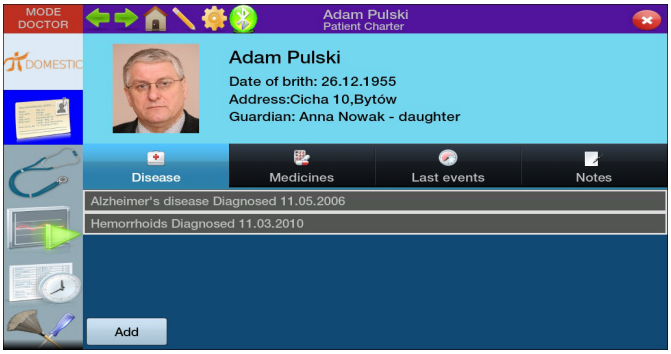

Fig. 2 Patient panel view

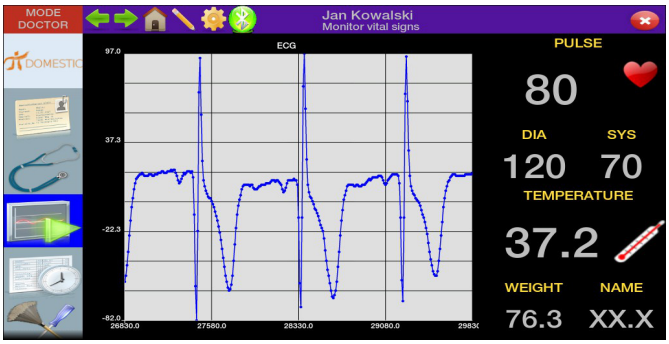

Fig. 3 Real time monitoring of patient vital signs

IV Communication

When two of domestic devices get in detection range of each other and at least one of them is a server, communication begins. After connection is established devices start to exchange protocol defined communicates as shown in Fig. 4. At the beginning, message containing information about the sender device type (Initial request), is sent by a server device (e.g. medical tablet). In response, if client device recognized type of server it sends its own type (Initial response), otherwise error message is sent and the connection broken. Server then analyzes information it has been given, to recognize client device. If recognition was negative connection is broken and error message is sent, otherwise communication continues. What happens next depends on what devices are connected. In case of Home Station - Medical Tablet connection conversation will go as follows. Server device requests list of assisted persons associated with connected device (Request list of AP). Client responds by sending *ids* of users stored in its database (Send list of AP). Medical tablet presents received data to the physician and wait for him to take action. During this time, if the entire system is not set to be synchronized externally (e.g. through the internet), devices update each others databases (DB synchronization). Further steps are results of user actions. For each action server device sends a request (Request AP data) to which client responds accordingly (Send AP data).

V Security

Bluetooth offers some security mechanisms to prevent unauthorized access to transmitted data and device functions. Two most important of them are pairing and data encryption.

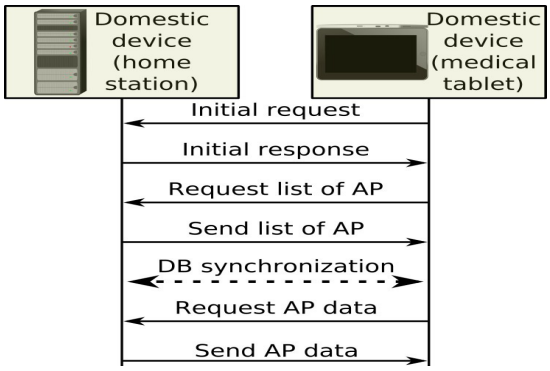

Fig. 4 Data exchange protocol (details are given in the text)

This security measures are not perfect however. To further increase safety of medical data, additional mechanisms were implemented: registering devices; additional data encryption; specially designed system structure. Domestic applications respond only to devices that has been specifically registered to work with them. Registration of device's Bluetooth address is done through applications user interface and not remotely to reduce possibility of registering unauthorized device as much as possible. To prevent data leakage in case of hijacking of Bluetooth connection, domestic applications encrypt all communicates before sending them through Bluetooth adapter (in addition to Bluetooths encryption). Domestic system structure is designed to enhance all security mechanisms mentioned above. Data storing devices such as home stations act as clients for purpose of establishing Bluetooth connections so it is impossible to scan them for services. Part of the data transmitted between domestic devices is in form of unique IDs. To interpret it a device must have access to the Domestic database, otherwise it would only get meaningless strings of characters.

VI Discussion

This paper has presented a comprehensive system of home monitoring of elderly and chronic patients. Previously these types of systems were designed primarily for one group of users. Our system assumes the existence of three types of active members: an assisted person, a guardian and a physician. In the design phase of the system main purpose was to achive maximum benefit for its individual members. In the case of th AP the goal was to ensure the maximum possible convenience of the system that will, at the same time, provide the highest possible level of control over his condition. For a doctor, it is necessary to provide a solution that will allow the correct interpretation of medical data. We used a tablet with Android system and our software, which is prepared to acquire, process and manage medical data and communicate with other devices, using readable and easy to use graphical user interface. In case of a guardian it was important to obtain basic information about patient condition and alert messages via a GSM network

It is usually necessary to monitor and record multiple physiological parameters of patient with chronic disease as the base data to analyze and track patient's condition and to

provide medical treatment. Currently, the majority of the proposed systems of this type is characterized by large size or limited working area, which reduces the desire to use it and quality of everyday life of the patient. We offer a complete system with modular structure, which allows to choose a set of wireless sensors individually for each patient depending on his condition. It provides integration of multiple physiological parameters extracted from all devices. The main component of the system is the central unit, which communicates directly with other devices, systems and processes and stores all data related to patient. The system has three main strengths: good expandability, highly flexible architecture, simple to design hardware and software.

The software of central unit was developed in Java/JavaFX environment. It offers rich graphical user interface creation combined with all the advantages of Java language. This allows the creation of visually pleasing, cross platform applications with minimal effort. On top of that JavaFX is meant to be able to run on many mobile devices, in browsers and possibly even on TV sets. A trait that might prove useful during development of further Domestic devices.

For Domestic mobile devices Android OS was chosen. This is one of the most popular systems (next to the Apple OS's) used in mobile devices, characterized by the following advantages. Open source platform based on Java, with multitasking and wide hardware support. A large variety of available devices, including wide range of tablets with the version of Android 3.0 which is suited to this type of devices. Personal mobile devices with Android system are powerful and flexible in use. It reduces both the time and cost needed for system development.

Both Wi-Fi and Bluetooth provide enough range and transfer rate to fulfill Domestic goals. Advantages Bluetooth has over Wi-Fi are security and ease of use. Bluetooth has two level password protection and getting access to one point of Bluetooth network does not grant access to any other part of it, as opposed to Wi-Fi networks. It is also easier, both software and hardware wise, to establish Bluetooth connection. Another possible choice is ZigBee, however it is inconvenient to send large amounts of data over ZigBee, besides hardly any popular mobile device has built-in ZigBee module, which make it practically useless in out system.

VII Conclusion

The concept of full care service is to prevent interference with patients daily life and still be able to provide long-term health monitoring services. Achieving this goal is attempted by: flexibility and modularity of the system that makes its presence less noticeable; easy-to-use, intuitive interfaces that are enhancing every day usage of the system; deployment of devices that are well suited for their functions, open and accessible which reduces both development and installation time; usage of modern technologies that allow less devices do more. All of that makes Domestic system as close to provide full care services as close as possible.

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