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Continuous Real-Time Monitoring of Patient's Vital Signs Based Onzigbee Standard

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ABSTRACT

This paper gives an understanding of what possibilities Wireless Body Area Network (WBAN) have when using shortrange wireless communications protocols. There advantages are used to facilitate versatility in the movements of health care patients. The paper investigates the feasibility of using the ZigBee protocol, givean analysis of methods for collection of received data from multi sensor environment, and mechanisms for privacy and data protection by using encryption techniques. This characteristics are applied on previously developed collaborative healthcare system model (COHESY).COHESY is aimed at continuous real time remote patients' health monitoring.

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1. INTRODUCTION

Pervasive health care takes steps to design, develop and evaluate computer technologies that help citizens participate more closely in their own healthcare, on one hand, and on the other to provide flexibility in the life of patients [1]. By including collaborative value in these systems patients are enabled to exchange experience in terms of therapy and rehabilitation by using the experience of the activities that have been taken by other patients. System model COHESY uses mobile, web and broadband technologies, so the citizens have ubiquity of support services where ever they may be, rather than becoming bound to their homes or health centers [2].

The work presented in this paper attempts to probe into the applicability and practicality of using WSN based on ZigBee protocol. The focus is given on ways of processing the sensor data; meaning setting strategy for their frequency of loading, determining the noise that can occur in sensor data and proposing algorithms that can be applied for their removal. In this way compression algorithm that gives the best results is proposed, so the volume of data that would be transferred for a further calculation can be reduce. These processing techniques also have contribution in reducing the energy consumption. Related work is presented in the next section. System Architecture - general overview including implementation details is discussed in third section, in fourth section data processing is described, while the fifth section concludes this paper.

2. RELATED WORK

Recent improvements in low-power wireless communications have motivated great interest in the development and application of wireless technology in healthcare and biomedical research, including Wireless Body Area Networks (WBAN). As result of this, various systems that demonstrated the successful transmission of bio signals are created.

C-SMART [3] is a platform for a continuous real time remote patient monitoring, it uses Bluetooth for transmitting signals from sensors to mobile devices. Application sends the raw data continuously via e-mail or SMS to a remote computer for monitoring and analysis. After data analysis, medical records are updated and the result is send back to mobile device.

Wireless Sensor Network based Health Care Management Platform for Long-Term Care Institution [4] proposes a safety monitoring system for health care management that incorporates ZigBee humidity sensors. Electronic humidity sensors help to provide appropriate care to disabled and incontinent elders.

Digital Fitness Connector (DFC): Smart Wearable System [5] allows users to monitor physical activity either in real-time or post workout using ANT+ sensors. DFC gives user flexibility to carry smartphone only if they wish to monitor physical activity in real-time, otherwise users can just carry DFC to capture and store data from health and fitness sensors.

In [6], a prototype on RFID and sensor networks for elder healthcare is presented. The RFID system, including a reader and one or more tags are used to track the elder patient who needs the medicines. The patient wears a UHF tag that may be detected by the associated RFID reader within 3-6 meters. Thus, the system is able to determine that the patient is in the vicinity, and alerts the patient to take the required medicines via a beep sound or a blinking light.

This paper presents a solution for data acquisition and processing techniques implemented in the system model COHESY, which is designed for continuous healthcare of patients. COHESYallows users to perform their daily obligations (work, walks etc.), so wide range of patients like: working capable people, children and elderly patients can use it with ease. This system model offers connection to social network consists of patients with similar diagnosis, uses collaborative techniques for filtering data from information systems and social network, and sendsnotifications, suggestions and proposals to users. These characteristics distinguish COHESY and make it more comprehensive than other systems.

3. SYSTEM ARCHITECTURE – GENERAL OVERVIEW

Collaborative Health Care System Model (COHESY) [7] allows continuous real time monitoring of the patient's conditions without restriction of movement and their daily activities. Its platform is designed to allow detection of unwanted results and irregularity in patient movements, and to use experience from other patients for giving appropriate recommendation to the new ones. The system consists of a WBAN, mobile device, information systems, and social network. The general architecture is shown in Figure 1.

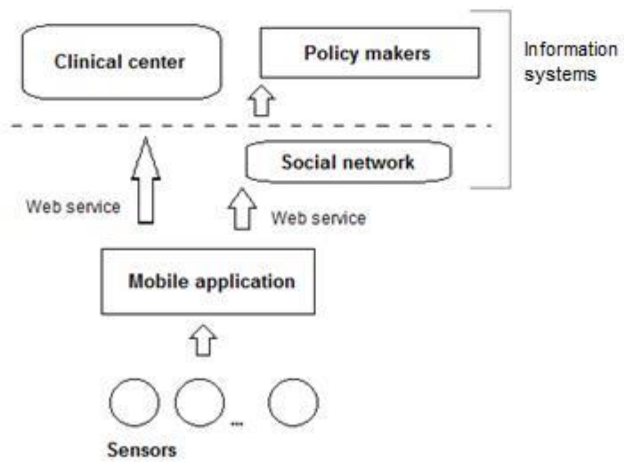

Figure 1.General architecture of COHESY

The WBAN comprises a number of wireless sensor nodes and mobile device. The sensors are distributed over the users' body. The sensor layer consists of a set of sensors that measure the patients' vital conditions and any related conditions, like motion and temperature. Although the current system model only incorporates these sensors, other types of sensors like EEG, EMG or blood sugar level can easily be added to the system. The motion sensor can be used for monitoring body motions and gesture recognition, whilst the temperature sensor can be used to monitor body temperature or the temperature of the ambient surrounding the body. This layer receives signals from patient sensors (transforms analog into digital), and sends data to the network, which forward measured data to the mobile device.

Network layer is based on ZigBee. The main criteria why we choose ZigBee protocol [8] in COHESY are: (1) the wide range of activity (100 m) makes it possible to receive data from the sensors in case when the mobile device is not close to the user; (2) the amount of data that is read from the sensors is small, but a high-speed transmission (250 kbit/s) allows timely calculations without delay; (3) battery life lasts for months (4-6 mounts), which is acceptable for medical applications.

The mobile application monitors the condition of patient. Its function is divided into two sub layers: aggregator layer and local calculator layer. The aggregator layer is divided to three processes:

a. Collection: collects data from sensors, including sensors for physiological signs and any related sensors like temperature, position etc.;
b. Filtering: filters previously collected data from any unused (noise) received information;
c. Data should be prepared for processing; they are settled in previous defined format and forwarded to the calculation layer.

Local calculator layer analyzes the data and reaches conclusions based on predefined rules. If there are unsatisfactory results, the patient will be informed by notification/warning message on mobile device and he/she will receive explanation information (the reason for notification or recommendation). If the result is emergent then an emergency signal will be send (mobile call or SMS) to related care or medical personnel to deal with the event. In case where local calculations are not enough, data is sent to a clinical center for additional calculations. After determining procedures for the patient, his/her data is updated and the result is sent to patients' mobile device. In the process of sending, data is previously encrypted which produce smaller data size and energy efficiency impact. To protect the privacy and confidentiality of the users' information data is sent though secured protocols.

The information system performs calculationson received data from mobile application, including find dependency between measured sensor data, (e.g. heart rate and patient movements) and functions that require more resources like memory or processor power. Some of these operations use collaborative filtering techniquesa, in order to give recommendation based on knowledge from other patients, cases and medical experience. The aim of the recommendation algorithm is to discover which activities affect change in the value of each health parameter individually [2].

The clinical center can be virtually anywhere in the world as long as it is reachable from the Internet, providing the following purposes:

a. To communicate with the remote entities and to collect the data generated by theWBAN sensor nodes;
b. Once the data collected, it can be stored in a database or file system with a certainformat, or it can be visualized and displayed in a graphical user interface, ordisplayed as web content;
c. In The case where the data is stored in a database/file system, the data can be retrievedlater and processed further to be used by authorized users (such as doctors,clinicians, physicians, researchers, etc.) for purposes of diagnosis,research, statistics and so forth.

The social network consists of patients with different diagnosis; each of them has a profile with information about their personal characteristics, diagnosis, treatments, experience, and habits. The social network enables collaboration between patients based on collaborative filtering techniques, thus connecting users with the same or similar diagnoses, sharing their results and exchanging their opinions about performed activities or received therapy. The users can also receive average results from the other patients that share same conditions in the form of notifications. These notifications can vary from the average levels of certain bio data calculated for certain geographical region, age, sex to the recommendation for certain activity based on the activities of other users. Collaborative filtering can be used to achieve different recommendations in these contexts [2]. Recommendation from social network is considered as the second level of recommendation; the first level is from medical personnel.

Policy makers receive data from social network based on filter critera. Policy makers analyze data and make programs and strategies for prevention of specifichealth condition.

COHESY system model choose layer architecture pattern [9], for this reason it is decomposed into groups of subtasks in which each of them is at a particular level of abstraction.

Sensor Layer uses sensors for reading vital signals and any additional signals. Network layer is based on ZigBee protocol for receiving data from sensors and propagates them to the mobile device. This layer is a mobile application which will support most of mobile platforms at server side; client side could be implemented on (HTML5 + JavaScript) so it can be used by majority of smartphones. Received data from sensors could be converted in JSON (JavaScript Object Notation) format. We proposed this format because it is compact, simple and has faster transmission (transfer less data). It has predefined template where some of data will be mandatory while other will be optional, allows uniformity and consistency.

The security aspects include using 128 bit hash encryption function for sending encrypted data to the clinical centers and social networks. This type of encryption takes less time than other encryption functions, encryption level is satisfied, and by the nature of data it is sufficient. Information systems may use PostgreSQL database for storing all patient data, including settings, medical history and diagnosis and daily activities. This database is an open source and based on features and satisfied requirements of this system model. Data stored in this database is used for further analysis by researches. Data flow diagram is presented in next Figure2.

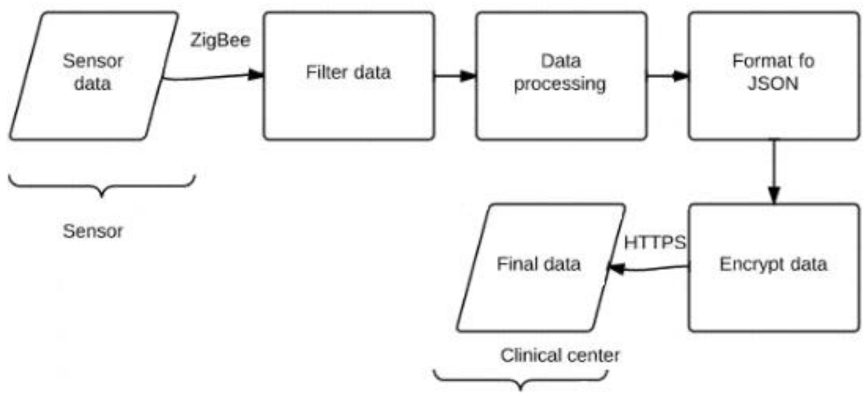

Figure 2. Data flow diagram

4. DATA PROCESSING

The first step of data processing is data preprocessing. This phase includes checking whether the received data is from the right sensor BAN network and if thay are sent to - filtering. The results of this phase are still considered as raw sensor data and the data is sent to the following calculations. The next step is data filtering, meaning removing the noise from the received signals. Removing the noise present in the signals requires different techniques, depending on their nature. For this purpose, can be applied two types of filtering:

1. Frequency - domain filtering is appropriate when the signals are static and stationary noise is a process that appears randomly regardless of the signal.
2. Adaptive filtering the other hand is a good choice when you need to remove noise caused by movement [10].

Which filter to be chosen basically dependson filters' suitability for its application. Particularly filters' impact on the removal of all unnecessary signals that affect the originality of the signal.

Since there is a possibility of noise, withinthe proposed system model, caused by movement of the patient, the goal is to ensure the smooth execution of daily physical activities of the patient (e.g.running, driving). One way to eliminate this type of noise is the use of an adaptive filter.For example, can be used Normalized Least mean square algorithm, which gives better results for the performance of Least mean square algorithm [11]. While removing the noise caused by the external environment, such as wind, can be used band-reject filter [11]. Otherfilters for noise removal that can be used are the techuques from neural networks, such as: moving average filtering, local regression filtering, Savitzky-Golay filter and Hamming window filtering [12]. The comparation of the time of execution of the previouslymentioned algotihtms and neural network techniques has shown that the most time consuming is local regression filter [12]. Another approach for systems that have a fusion of different sensor data is to useother methods and algorithms including: Kalman filter, Bayesian networks, and Dempster-Shafer [13]. The implementation of filtering algorithms at the mobile device is important because of the way the data is sent over the network. The send data are smaller in size, so when the compression algorithm is aplied, it is completely minimized in their size

[14]. The following Figure3 represents the process of receiving data from sensors, processing and transfer to external systems.

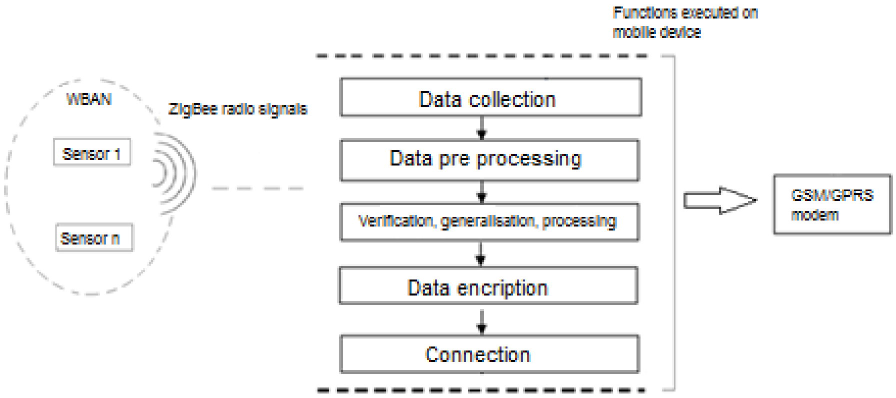

Figure 3. Display of processes running on sensor data

The next stage is data verification, generalization and additional data calculations. This phase is the final phase of the local processing of data [15]. The state of data processing level aims to formalize and give conclusion about the real situation of the patient. If the resultsare outside the allowable range for patient reports, the patient receives instructions for the next steps he/she should take. In case where the results are critical then information message is sent to the responsible medical staff and the patient. If the results are right then the patient gets a positive message about his condition and can resume previous activities, diet and life.

Important aspects in this kind of systems are timely transmission of data and type of data that should be transferred, which has a very important role in determining the strategy to be used in case of delay. According to whether the nature of the signals is a continuous transmission or not, they can be divided into:

1. Wavy - dependent data requires non continuous data transfer. As a result, the transmission of data can lead only when data is requested from the side or periodic monitoring.
2. Wavy - independent datarequire continuous transmission of data for long periods of time, especially in critical and emergency situations [16].

Depending on the frequency of data transfer, proportional is the energy consumption of the mobile device. These are some prominent causes of energy wastage in wireless networks: retransmission of lost packets, reload (overhearing), idle listening (idle listening) and re- broadcast (over emitting). In medical applications, however, recovery of lost packets through retransmission is not necessary, because health data must be in real time. Any packet loss must be replaced with the latest update on the situation. Retransmission of packets also requires more memory to store nodes, which is usually limited in size. Data received from the sensors may have been damage, so the following approaches can be executed:

to accept the fact,
remove and wait for the next load,
seek to reload.

Which strategy to use depends on the type of the loaded data. If the data is irrelevant as temperature or position of the patient, and such type of data loads often then the second option is acceptable. If measurements are for more sensitive data, than the third option should be applied. Energy consumption also needs to be carefully analyzed to make an informed decision. Sensor nodes consume energy during the apprehension of changes, processing and transmission of data. The energy consumed to transmit data is greater than the energy for processing. One approach to saving energy is the application of efficient compression scheme. This method achieves a reduction of the amount of information that will be transmitted [15]. Following algorithms are used in WSN: Lempel-Ziv 77 (LZ77) and Lempel-Ziv-Welch (LZW), thay are based on the methods of prediction by partial matching based on statistical methods, while Burrows-Wheeler Transform (BWT) reduces the amount of information andoptimize data compression. Benchmark tests done on these algorithms show that the algorithm LZ77 has maximum speed and minimum memory used [17]. Made improvements to these algorithms are tailored to provide the optimal solution for a particular problem. For example, in systems intended for medical protection different types and format of data arereceivedand send. So, a dynamic compression that will adjust depending on the type of data should be implemented. This type of algorithm divides the data sequence into blocks and for each block is used an optimal scheme. Compared with previous algorithms this one gives the best results [15]. In the system model proposed in this paper is selected LZ77 algorithm to be used. If tests show high utilized resources and energy, then we will make improvements of this algorithm.

5. CONCLUSION

This paper presents implementation of ZigBee standard for a continuous real time monitoring of patient's vital signs in the COHESY system model. The low-power nature of ZigBee sensors offers great potential in creating a wireless body area network for data collection within the body area. Its battery life of few months eliminates the need for even infrequent battery replacements or recharges. These characteristics allow the patient flexibility in movement and everyday activities. The main aid is timely detection of adverse outcomes in order to take preventive measures.

In this paper are presented two ways of energy efficiencies: using the mechanisms to reduce the traffic and data encryption before sending through Internet. For reducing the traffic between the sensors and the mobile device is necessary to make an analysis of the nature of the proposed bio signals. If the signal is vital then the frequency of reading is very common and on another case of signals readings are performed at regular intervals that are predefined. To reduce traffic between the mobile device and remote (clinical) centers filtering algorithms are proposed. These algorihms reduce and eliminate unnecessary information, use compression techniques that affect the result of the reduction of traffic congestion and thus minimize energy consumption on mobile devices and sensors.

The model represents a successful first step towards the improvement of the quality of patient care. Future aim of COHESY will be to make practical tests in different environments and cases. These results could be used for improving the design, performance and optimization, so that COHESY can be expanded to become efficient monitor and control health care system in the future.

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