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Smartphone, PDA and Embedded devices as mobile monitoring stations of Biotelemetric System

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Abstract: - Existence of software platform, which will allow us to monitor the patients' bio-parameters and provide us with services which help with full health care, is more than relevant these days. The aim of our project is to provide solution which can be used in different spheres of health care and which will be available through PDA (Personal Digital Assistant), web or desktop clients. Practically developing system works with an ECG sensor connected to mobile equipment, such as PDA/Embedded, based on Microsoft Windows Mobile operating system. The whole system is based on the architecture of .NET Compact Framework, and SQL Server. The project was tested in real environment in cryogenic room (-136^{O}C).

Key-Words: - Smartphone, PDA, Embedded device, biotelemetry, SQL CE Database

1 Introduction

In our world society exist widely spectrum of middle-aged people like businessmen, CEOs, managers and other have very hectic lives with much stress and without good ways of living. Sometimes these people have a collapse, breakdown or heart attack and must be in hospitals or health resorts for a long time to regenerate their bodies. The time that they spend in these institutions, is nonutilisable and very long for them. Possibilities of today physics are restricted by many of prescripts so patients cannot use some of the newest techniques (like hyperbaric or arctic chambers), which make it possible to reduce the regeneration time by weeks or months. For example, these chambers are restricted to patients in the first six months after heart attack due to no information about patients' conditions during the procedure. Here is the main area of utilization of our telemetric system. Of course the use of our system is not limited only to businessmen, but it is targeted to middle-aged people with some knowledge about new technology like mobile phones. The price of client devices of our system is not low, so we suppose people who can invest to these sorts of assistants.

Aim of the platform for patients bio-parameters monitoring is to offer a solution providing services which help and make full health care more efficient without limitations for specific country. Doctors and other medical staff will not be forced to make difficult and manual work including unending paperwork, but they will be able to focus on the patients and their problems. It helps to better psychological condition of both sides. All data will be accessible almost anytime anywhere through special applications designated for portable devices web browser or desktop clients and any made changes will be immediately at disposal to medical staff based on the security clearance. Nurses will be able to find out prescribed procedure of patient treatment which was written down by doctor during regular round. Doctors will have immediate access to the patients newest results of accomplished examinations. In the case that the ambulance have to go to some accident, rescue team can due to portable devices send information about patient health condition directly to hospital where responsible doctors and staff will have information needed to execute immediate operation without delaying by preparation of necessary equipment. Patients who need not hospitalization will be able to be treated at home due to the system capable of remote transmission of information about patients bio-signals, so patients will be constantly under medical supervision and doctors will be able to make necessary measure if needed. All bio-signals data will be stored and automatically analyzed by neuronal network. System will evaluate presence of critical values which could be the sign of worse medical condition of a patient. In the moment of crossing the border of monitored bio-signals values inserted by doctor, system will inform responsible medical staff and provides all information which could help to determine the cause and seriousness of the problem.

The basic idea is to create a system that controls important information about the state of a wheelchair-bound person (monitoring of ECG and pulse in early phases, then other optional values like temperature or oxidation of blood ...), his situation in time and place (GPS) and an axis tilt of his body or wheelchair (2axis

accelerometer). Values are measured with the existing equipment, which communicates with the module for processing via Bluetooth wireless communication technology. Most of the data (according to heftiness) is processed directly in PDA or Embedded equipment to a form that is acceptable for simple visualization. Two variants are possible in case of embedded equipment – with visualization and without visualization (entity with/without LCD display). Data is continually sent by means of GPRS or WiFi to a server, where it is being processed and evaluated in detail. Processing and evaluating on the server consists of - receiving data, saving data to data storage, visualization in an advanced form (possibility to recur to the older graph, zoom on a histogram (graph with historical trend), copying from the graphs, printing graphs), automatic evaluation of the critical states with the help of advanced technologies (algorithms) that use Artificial intelligence to notify the operator about the critical state and its archiving. Application in PDA, Embedded equipment is comfortable, with minimum time - the first configuration, but also configuration after downfall of application. The level of visualization will be lower. The described system can be used with small modifications for monitoring of patients in hospitals or people working in extremely hard conditions. The biggest limitation is the availability of measuring devices in acceptable and adaptable sizes or comfortable enough to have one around.

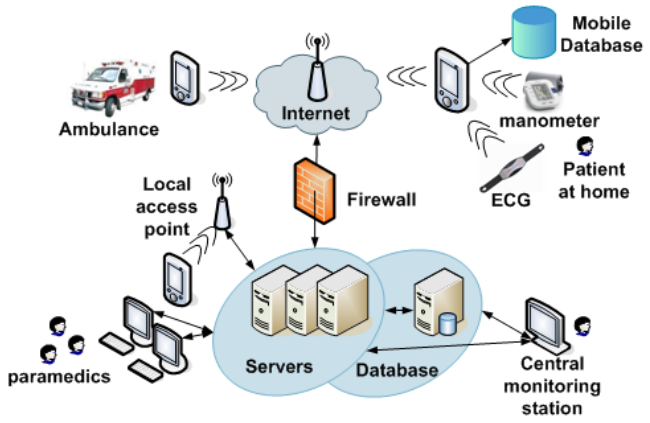

Figure 1 Architecture of platform

2 Developed Parts of Platform

Complete proposition of solution and implementation of the platform for patients bio-parameters monitoring as it was described in previous chapter requires determination and teamwork. Every single part of the architecture have to be designed for easy application and connectivity without user extra effort, but user must be able to use given solution easily and effectively. Crucial parts of whole architecture are network servers, database servers and client applications. Due to these crucial parts development is focused particularly on proposition and implementation of desktop client application, database structure and some other important web services.

Scenario for communication among desktop client, web services and Microsoft SQL Server is: desktop client runs on user´s computer and connects to web services on remote application server. After the desktop client is connected, web services connect to remote database server. Web services provide methods for users so users are capable to work with different data stored in database.

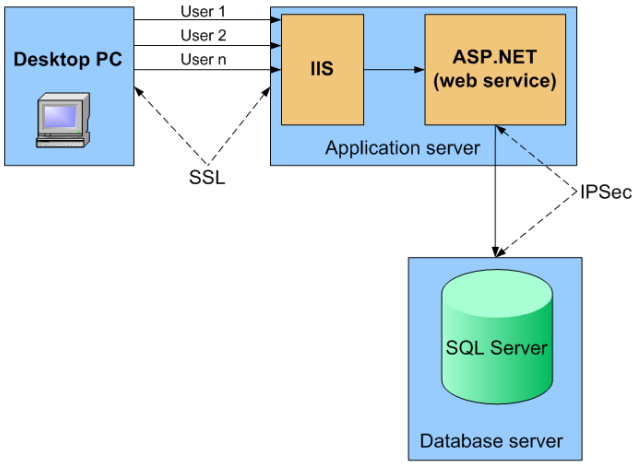

Figure 2 Desktop Client connections to database

2.1 Mobile part

The main part of the whole system is an Embedded or PDA device. The difference in applications for measurement units is the possibility to visualize the measured data in both Real-time Graph and Historical Trend Graph, which can be omitted on an embedded device.

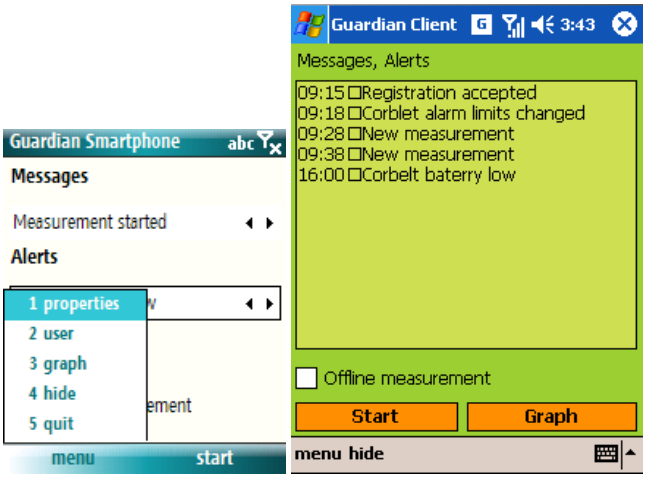

Figure 3 Smartphone and PDA/MDA visualization

PDA is a much better choice for Personal Healthcare, where the patient is already healthy and needs to review

his condition, or for multiple person usage. Embedded devices can be designed for one user, with the option to use an external display used for settings or with the possibility of usage in extreme conditions.
As measurement device is possible to connect several device with Bluetooth communication possibility:

- ECG – electrocardiogram
  - electric hearth activity
  - Corscience CorBELT device (bipolar)
- Blood pressure
  - informations about hearth activity and blood vessels
  - pressure gage measurements
- Spirometry
  - lungs capacity
  - measurement using spirometrs
- Oximetry
  - haemoglobine saturation measurement
  - oximeters measurements

In our application we use an ECG Measurement Unit (Corbelt or BlueECG [Figure 4]) through a virtual serial port using wireless Bluetooth technology. Then, after pushing a button, all necessary parameters are set and the communication may begin. Measured data is stored on a SD Memory Card in a database in MS SQL Server 2005 Mobile Edition.

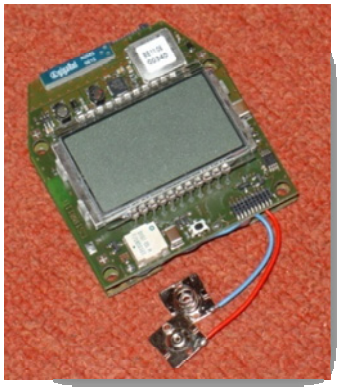

Figure 4 12 channel ECG bluetooth module BlueECG

The performance of available devices seems insufficient for sequential access; parsing of incoming packets is heavily time-consuming. Pseudo paralleling is required. If Windows Mobile OS versions 2003 to 5.0 are used, the processing of data from a professional EKG is not realizable due to thread count limitations. A newer operating system (Windows Mobile 6) can be used to solve this.

Current application is highly specialized and written to accommodate specific hardware. Usage of any other hardware is not possible. This is due to different methods of packet folding, which are unique on each device. This is partly caused by the length of the Telemedicine branch. Operating of the device is simplified as much as possible with the least possible number of steps regarding user registration, measurement device connection and the measurement itself. The informations about user, as ID, name, surname, address and application properties are stored in the system registry (HKEY_CURRENT_USER / Software / Guardian). Working (saving, reading, finding) with registry is easier and faster as saving this informations in file. User registry values are crypted with simple algorithm (shifting char ASCII value).

2.2 Server part

In order to run a server, an operating system supporting IIS is needed. IIS is an Internet Information Server application allowing users to connect to the web server by the well-known HTTP protocol. The web service transfers data between the server and PDA/Embedded devices. It reads the data, sends acknowledgments, stores the data in the database and reads it from there. The service is built upon ASP.NET 2.0 technology. The SOAP protocol is used for the transport of data, which is in XML format. That is an advantage since it allows communication of multiple different technologies and platforms.

The Wireless ECG approaches a real professional ECG with data rate as high as 800 records per second [1]. That makes 48,000 records per minute and 2,880,000 per hour. Considering 100 patients, the value gets to 288,000,000 records per hour. Even if the server accepted only 50 records per second, the sum of records for 100 patients per hour would be 18 million. That is an extreme load for both the server and the database system; hence a better way of storing data is needed. Methods that devices communicating with the web service can use include: receiving measured data, receiving patient data, deleting a patient, patient data sending. To observe measured data effectively, visualization is needed. A type of graph as used in professional solutions is an ideal solution. To achieve this in a server application, a freeware Zed Graph library can be used. For data analysis, neural nets are a convenient solution. However, there are problems in the automatic detection of critical states. Every person has a specific ECG pattern. What is completely normal for one person can indicate crisis for another. The Neural net has to learn to distinguish critical states of each patient separately. To make the specialist's or operator's intervention possible, the system must be provided with a user-friendly interface, possibly imitating those on

medical appliances. This area of development is described in next chapter.

2.3 Embedded mobile device

Devices based on PDA type have a several limitations such as low CPU performance, low battery life or small display. These limitations are possible to solve by embedded version of such mobile clients. We create a special windows mobile based embedded device (see [Figure 5]).

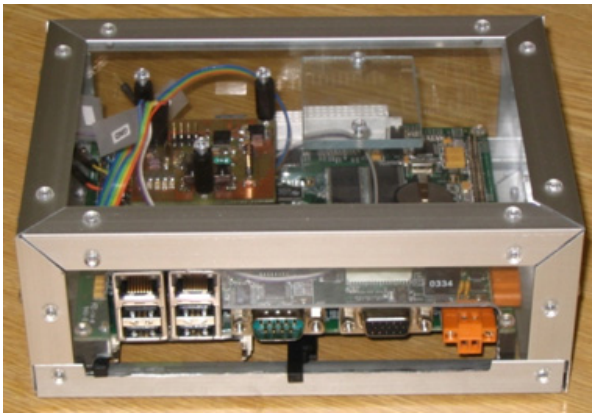

Figure 5 Embedded device Guardian Client

During the development process of this Embedded device the several problems occurred. One of them and the most important was the need of a new operation system creation for our special architectural and device needs. We used the Microsoft PlatformBuilder for Windows CE 4.2 tools (Figure 6). The created operation system based on standard windows mobile has several drivers which we need to operate with communication devices and measurement devices.

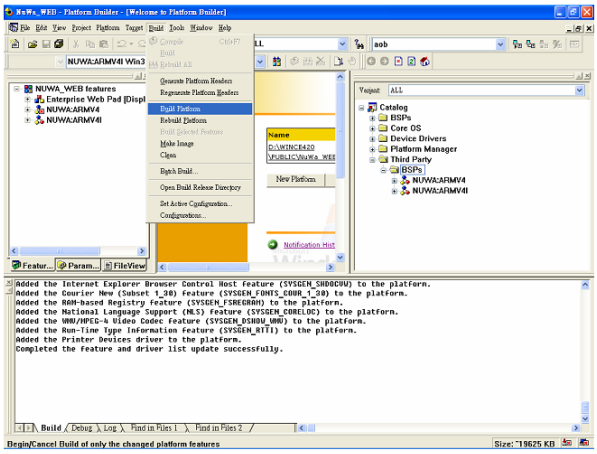

Figure 6 PlatformBuilder for Windows CE 4.2

2.4 Web services

Next important parts of the platform are web services, which allow us effectively work with medical records or other data.

Guardian web services are:

- User management – complete patients management. Provides interface that allows deleting, editing and creating records about new patients.
- Data management – operations with measured data gained from different devices such as personal ECG, manometer or oxymeter.
- Configuration management - provides information about users roles and functions which belong to these roles.
- User management – users = doctors, nurses, other medical staff.

Each web service deals with common security module, which provides methods for one-way encryption and also implementation of methods for authorization and other security components is planned.

2.5 Database

Important part of Guardian is central database. There are stored all data of medical staff and patients. Data of patients include different records such as diagnosis, treatment progress or data which are results of measuring by small portable devices designated to home care. These data represent the greatest problem, because amount of these data rapidly increase with increasing amount of patients. Due to this fact database servers are very loaded.

Current version contains 12 database tables. Database design is made with Microsoft SQL Server Management Studio – graphical application, which provides set of quality and powerful tools for Microsoft SQL Server administration. There are some interesting tables:

- Patient – table which is used to save information about each patient.
- User – this table is used to save information about each user (user = member of medical personnel).
- Role – information about user roles.
- Diagnosis – information about patient diagnosis.
- Treatment – treatments associated with related diagnosis.
- File – all user files.
- EcgRecord – the measured values of ECG. All measured values are saved as byte array.

Figure 7 Infracamera picture from Cryogenic room

Acknowledgement

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3 Conclusion

The measuring device (ECG, plethysmograph) and Guardian PDA client was tested in extreme conditions in a cryogen room in Teplice (-136°C), where the final system will be installed [Figure 7]. Implementation of the data transmission security was not solved. The whole system is classified as „work in progress“ system and it is in a testing phase where we found mistakes and repaired them.

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