A novel system for hemodialysis patients home monitoring

Eleni Sakka[1], Markela Psymarnoy[1] and Pantelis Angelidis[1,2]

[1]Mobihealth Research, 91 Aglandjia Avenue, Diogenes Incubator,1678 Nicosia, Cyprus
[2]University of W. Macedonia, Kozani, 50100, Greece
research@mobi-health.eu

Abstract. Chronic renal patients and patients with end stage renal disease are a distinctive patient group with a serious, chronic and irreversible health condition, which is mainly treated at home. As such they are unique candidates for support via telehealth services. This paper introduces a novel monitoring system for hemodialysis patients. The leading aims of this system are the development of innovative biomedical signals management system and the implementation of integrated model medical signal projection and processing tools. The system is expected to contribute to the increase of the demand in the medical services field as well as to reduce the patient transfer abroad for recovery.

Keywords: home care telematics, renal telematics, telemonitoring, patient management

1 Introduction

Hemodialysis has been a common medical treatment for the people with chronic renal failure. In Cyprus, every year 67 - 77 new incidents of final renal disease appear and though this number remains the same the last 10 - 15 years, the synthesis of patients has changed. The number of young persons with chronic renal disease has reduced, whereas the number of citizens over 60 years old and renal disease citizens due to diabetes has increased [1]. According to the statistics, 60 to 70 thousand people in Cyprus suffer from diabetes and it is anticipated that the number will increase. It has been noticed that the diabetic nephropathy is a complication of 30% of the diabetic patients.

The hemodialysis taking place in a hospital requires the transfer of the patient to the medical centre three times a week. It should be noted that between two visits for hemodialysis, the maintenance of the required quality of life as well as the restriction of side effects for the patient is a big challenge, depending on the ability of biosignal monitoring at home. These signals can be the weight of the patient, heart pulses, temperature and blood pressure and in some cases electrocardiogram and blood glucose (for patients with heart condition and diabetes respectively).

Identifying this problem, we have implemented a novel system for hemodialysis patients home monitoring. The basic scenario of system function is described below: the patient after being registered to the system during the scheduled visit in the

Hemodialysis Centre, he/she is equipped with the portable and useful device. This device communicates automatically with the, essential for the monitor of patient's health condition, digital medical devices, that record the biosignals. Measurements and other data concerning parameters of monitoring procedure can be added manually in the portable device, together with information regarding the general patient's situation. Data, that are collected either manually or automatically from the patient, are transmitted automatically to server during fixed time periods (at least once a day, depending on physicians directions). In the server the measurements are received and stored and are subjected to basic and advanced processing and analysis for the extraction of notifications/ alarms. The medical personnel during scheduled time periods e.g. daily, or after an alarm, reviews the patient's health condition, the patient's compliance to the physicians recommendations and the patient's response to the treatment. According to the processed data, the treatment plan can be revised and the physician is able to communicate with the patient in order to get more information, to refer the patient immediately to the closest medical centre or to modify the treatment.

2 Telemonitoring Service - Overview

The aim of this system is to monitor and manage renal disease patients that undergo hemodialysis. It is based on the recording of all essential biosignals for patient monitoring. The utilization of these signals optimizes the monitoring of these patients, whilst physicians can manage on time the possible complications between two hemodialysis sessions.

The system was based on the fact that patients undergoing hemodialysis every other day need to be monitored between the hospital visits. The system includes the functional units below:

- Patients' device for the collection of medical data that will be transferred telemetrically to the central hospital. The device, which is a PDA, is connected to the appropriate medical devices so as to wirelessly receive the patient medical data (i.e. vital signs), while it gives the option to the patient to add manually further information. The data are sent to the hospital unit via GPRS.
- Telemetry data collection unit, which receives the biosignals as well as all the information that are transferred from the patient unit. It manages them in order to provide basic and advanced services of processing, analyzing and file storing as well as giving the ability to the user to create notifications and alarms. The collection unit has been implemented with open interface so as to give the opportunity to third parties to integrate it with existing systems.
- Database with personal, medical and biomedical patients' data.
- Database with administrative data (user data, roles etc)
- Central system administrative unit (server) and basic communication centre between users (medical personnel, patients, administrators), which undertakes the medical data presentation to the medical personnel and supports the administration of system and of users (new patient registration, new medical personnel registration, roles management etc). The server is implemented with web services

in order to facilitate the convenient and universal access, ensuring the essential security together with interoperability.

These basic functional units and their interconnection can be seen in Fig.1.

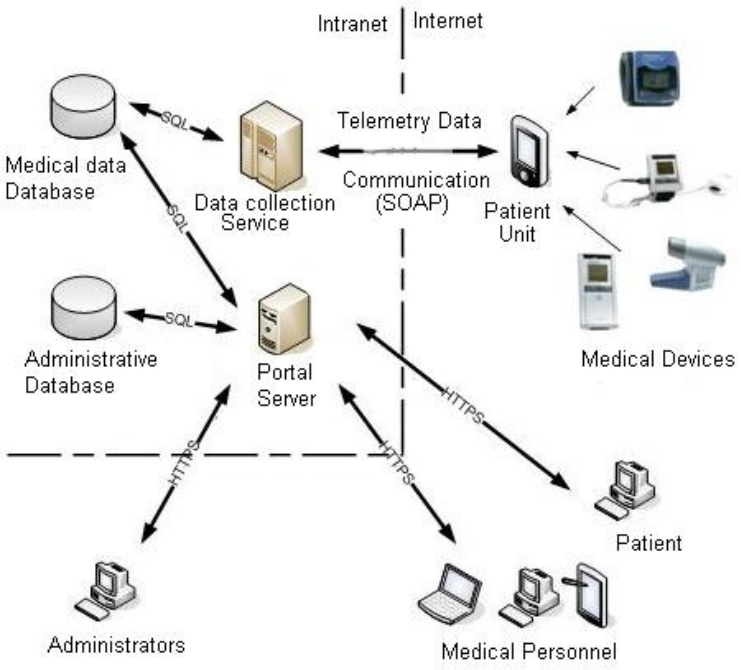

Fig. 1. Functional units of the system.

2.1 Implementation

2.1.1 Patient Unit

The implementation of the patient unit was made on .NET Visual Studio 2008 [2] together with Windows Mobile 5.0 pocket pc SDK [3] and Microsoft SQL CE 3.5 [4] for the local storage of medical data and scheduled measurements program.

The patient after opening the application can choose to download the new plan of scheduled measurements, specified by his/her physician or to proceed in the performance of a new emergency measurement in case he/she doesn't feel well. The patient unit communicates with the server and gets the configuration of the scheduled measurements as well as the monitoring plan that the attendant physician has defined. After that the unit displays the sequence of the scheduled measurement(s) that need to be taken by the patient. The appropriate medical devices (according to the scheduled measurement) are connected via Bluetooth and send the biosignals to the PDA. At the end of each session, the patient is asked whether to send the measurements to the

server or not. Upon successful transfer, a confirmation message is shown to the patient. Alternatively, the patient is notified in case of transfer failure, in order to re-send the data.

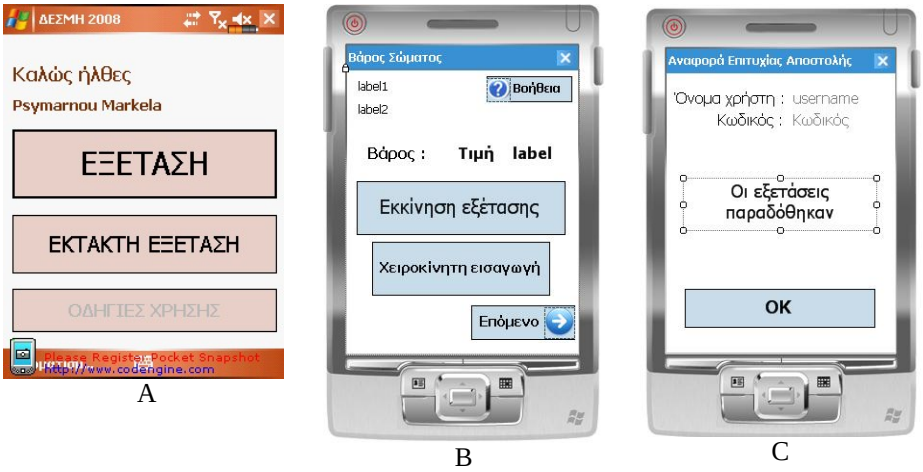

Fig. 2. Screenshots from patient unit. A) Welcome screen, b) Weight measurement insertion form and c) Successful data transmission message screen.

2.1.2 Telemetry Data Collection Service

The Telemetry data collection unit is basically an XML web service, developed in .Net Visual Studio 2008, using standard Internet based protocol SOAP. This gives the option to third party manufacturers to integrate their patient units to the system.

The web service enables the communication between the patient unit and the server. It encapsulates all the essential functions regarding the measurements configuration download, the programmed measurements download, the upload of the performed measurements as well as the upload of the errors that have potentially occurred during the execution of the patient application.

In the web service the check for the generation of notifications/alarms is performed. After the recording of the biosignals a control is performed whether the measurements, that were uploaded, where accomplished on time according to the schedule or not and in the latter case a notification is created to the attendant physician. Secondly a test is carried out whether the value of the measurement is between the physiological range of values. If it is above or below the normal values, and according to the criteria the physician has specified, either a notification or an alarm is created and the physician is informed. Finally the web service checks and creates the corresponding notification in case there are any measurements not performed (or sent) by the patient.

2.1.3 Personal and Medical Data Database and Administrative Database

Both databases are designed and implemented in MySQL server version 5.1 [5].

The personal and medical data database was implemented according to the system requirements for the regular function of the server. It includes all the necessary data

tables for the patient management, the control of the measurements' plan, the administration of the necessary measurements required for the patient monitoring as well as the definition of the notifications/alarms.

The administrative database is generated by ASP.NET membership control system and it includes the fundamental data tables for the management of users, roles as well as information about the users' activity as long as they are logged in to the system.

2.1.4 Central System Administrative Unit (Server)

The central system server is the core of the system. It is implemented in ASP.Net Visual Studio 2008. It is mainly the portal where the physicians and the administrators of the system are able to view, control and process the patient information.

The system allows access to the portal only to authorized users. Once the credentials of the user are correct and the user is authenticated, the system redirects the user to the appropriate page. If the role of the user is administrative then he/she is redirected to the administrator's page, whereas if he/she is medical personnel he/she is redirected to the first page where the list of the monitored patients is shown (Fig 4).

Fig. 3. Login page to the portal of the system

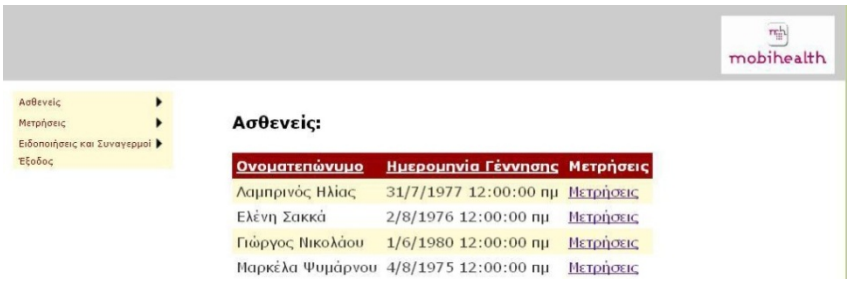

Fig. 4. Patients list for the logged in physician

The physician can view the scheduled measurements of his/hers patients, the measurement results of the patients, as well as the measurements that have not been carried out (Fig. 5). The system gives the ability to the physician to define special notifications that contribute to the patient monitoring and shows the alarms that were created according to these notifications' definitions. The physician can also add new patients to the system and he/she can define the program of measurements that patient needs to follow.

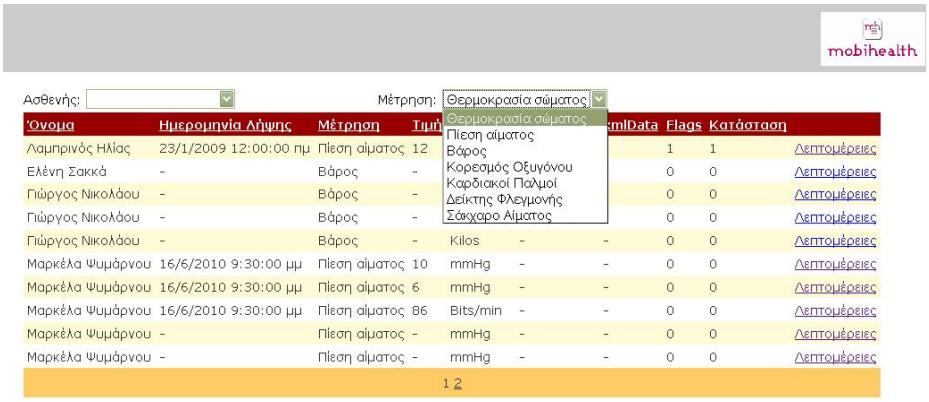

Fig. 5. Measurements list

The administrator on the other hand has the ability to add, edit and delete users and assign roles to the system, as well as view the log information about the activity of users in the system.

Fig. 6. Add new user to the system

Fig. 7. Create new role to the system.

3. Conclusion

Chronic renal patients and patients with end stage renal disease are a distinctive patient group with a serious, chronic and irreversible health condition which is mainly treated at home. As such they are unique candidates for support via telehealth services. Early detection and treatment can often maintain renal function before chronic kidney disease deteriorates to end stage renal disease and renal failure. However, this is not always possible and the disease progression may eventually lead to kidney failure and the fact is that the number of end-stage renal disease patients tends to increase. It is therefore becoming all the more imperative to take measures for the prevention and the better management of end stage renal disease. Close monitoring may prove a good measure for early diagnosis, treatment adjustment and rehabilitation.

The above described system has been implemented in order to help the aforementioned problem. Aim of this system is to contribute to the increase of the demand in the medical services field as well as to reduce the patient unnecessary transfer. It is a novel system for hemodialysis patients home monitoring, where medical personnel is able to monitor renal patients at home between hemodialysis session which take place in to the hospital.

Patient's satisfaction and self-esteem increases as a result of not being forced to visit hospital daily and therefore enjoys a better quality of life. From physician's point of view, the described system gives the opportunity for a better patient management, integrated support and increased prestige duo to the fact that he/she is able to put into practice novel and pioneer methods in everyday patients' treatment. Finally, concerning the healthcare system, the aforementioned solution not only ameliorates the quality of provided services but also reduces the cost of the hemodialysis services provided, and helps for the optimal resources usage (human, technical, and financial).

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