Cost-Effective Health Services for Interactive Continuous Monitoring of Vital Signs Parameters – The e-Vital concept

A Prentza[1], P Angelidis[2], L Leondaridis[3], E Sakka[1], D Koutsouris[1]

[1]ICCS-NTUA, Biomedical Engineering Laboratory, Athens, Greece, [2]INA, Thessaloniki, Greece, [3]NetSmart, Athens, Greece

Abstract

An integrated home care and telemonitoring service chain, the e-Vital service, is presented aimed at large sensitive parts of the European population, the "at-risk" citizens, who are usually patients with a stable medical condition that allow a near normal life but may suddenly deteriorate and put life at risk. This service will increase their quality of life and their feeling of safety concerning their health. The e-Vital project focuses on the implementation and exploitation of a modular and ambulatory secure telemedicine platform, which is using easily wearable vital signs monitoring devices, causing minimal discomfort to patients, and which transfer in real time and on-line critical vital parameters to doctors and/or medical experts/consultants, regardless of their location, while getting feedback to increase their feeling of comfort or in case of alarm.

1. Introduction

European health care systems are facing a period of unprecedented changes prompted by a confluence of events. From the patients' side, the health care demands are in continuous evolution since the demographics structure is evolving. Europe is the area of the world, which faces the fastest ageing of the population, considerably higher than in the United States. This fact, together with a high prevalence of concurrent chronic disorders is generating an extensive use of health care and social services. The advances in information and communication technologies and the recent improvements in genomics are foreseen to have substantial impact on health care

The aforementioned factors together with the exploding health expenses are fostering governmental health agendas to develop new ways to deliver effective health care, rather than addressing traditional medico-social structures.

New models are being proposed that promote patient's active participation, redefine physician's tasks and enhance nurses' roles. For the first time, the health care sector is becoming a significant driving force in the technology evolution process. In this new scenario, integrated delivery systems based on patient-centred care, supported by an intensive use of information technologies, will facilitate the most efficient use of the existing resources in the health care system.

Several points are very important in the definition of a new health model. First, it must be noted that the different patient's conditions should be treated from a holistic approach, not each one of them separately. Secondly, the patient must be active (as well as his/her family or carers) in the control and treatment of the illness. Thirdly, the co-ordination among the different health actors must be enhanced to ensure a better decision making process.

Therefore, patient centered care, including home care as a main component, is seen as an efficient alternative to conventional institutional care for chronic patients. The use of remote monitoring of vital signs can help to extend the range of patients that can benefit from home care and provide further confidence in both patients and health professionals. Additionally, successful involvement of the patients and careers in the process requires increasing their understanding of the illness, which, in turn, promotes self-management skills.

The e-Vital project [1] focuses on the implementation and exploitation of a modular and ambulatory secure telemedicine platform, which is using easily wearable vital signs monitoring devices, causing minimal discomfort to patients, and which transfer in real time and on-line critical vital parameters to doctors and/or medical experts/consultants, regardless of their location, while getting feedback to increase their feeling of comfort or in case of alarm. It also helps physicians to determine a better care strategy, collecting data previously only available in Intensive Care Units (ICU). The interactive continuous monitoring, as proposed, promises cost effective health services, more active involvement of patients in their own care, and a new sense of realism in making a diagnosis.

The tests and validation tasks will take place in a wide geographical area, namely: Greece, UK, Spain, and Italy. These countries constitute samples of different cultures

and healthcare systems, and this will help to assess the validity of the chosen market approach. The benefits of the e-Vital services will be assessed both for patients and physicians. Assessment will include reliability, usability, effectiveness, conformance with requirements and specifications, and user acceptance and satisfaction.

2. The e-Vital service

The e-Vital service consists of the following subsystems:

1) The *patient's module* consists of the monitoring devices and the patient's phone. The patient or a nurse, following the care protocol created by the physician, takes the measurements. The data are then sent to the e-Vital server via the phone. In case of emergency and supplemental to the program, measurements can be taken and sent to the server.

2) The *e-Vital server* is the core of the e-Vital service. Here the physician is able to design the personalised care protocol of each patient, to monitor the application of the protocol and the measurements already taken by the patient. In case of emergency, when the measurements are out of limits, an alarm message is generated and is sent to the physician, who in turn is able to inform the patient and rearrange the schedule of the programmed measurements. The e-Vital server collects the data from the monitoring devices, compares the measurements with the given limits and if there is a problem sends the appropriate messages.

3) The *hospital module* consists of the hospital server and the hospital database. The interconnection with the hospital module is used to retrieve patient's medical record, when it is necessary.

Each monitoring device is connected to the phone, which sends the collected data to the e-Vital server. The e-Vital server establishes a communication with the phone, in an emergency or non-emergency situation, and the data are sent to the e-Vital server via GPRS and TCP/IP. The received data are then transformed in an XML file in order to be compatible to the format of the DB and are forwarded to the database centre.

Since the monitoring devices are different due to the various manufactures, the formats of the data files that are sent to the e-Vital server will be different from each other. For that reason different applications will run in the e-Vital server, to transform the incoming data files to the format compatible to the DB.

Physicians and patients will have access to the service from PC, PDAs or mobile phones connected to the Internet.

Two different scenarios are provided by the e-Vital Service.

a) Routine operation

The first scenario is the programmed one where the measurements are made according to the specific care protocol of the patient. After the accomplishment of the measurements the patient or an accompanying person (nurse, relative of the patient etc.) is calling the e-Vital server in order to send the data. Then, after a connection is established, the appropriate application runs. The task of this application is to validate if the patient is registered in the system, to identify the type of the monitoring device, which sends the data and to collect the data. This information will be available either in the header of the data message, which will be sent to the e-Vital server or will be sent in an individual message after the establishment of the connection. After that the input data are transformed to an XML file that is compatible to the DB of the database server, and the data are stored in the DB.

In the application server the data are processed and checked if they are out of range. In the DB existing medical information about alarming parameter combinations are stored. It has also access to patients' medical records, which are stored in the hospital module. It then combines these two sources of information with the received patient's data and defined decision flowcharts, it appreciates the patient's condition (excellent, good, average, warning /reason, alarming /reason, or death/reason). If the condition is warning or alarming the notification services will be activated to send an alarm message to the patient, to the physician who attends the patient and to the associated people (that is personal GP, relatives, special requested experts in their respective language) of the patient. These messages maybe SMS or e-mail messages and are also stored in the DB.

b) Emergency operation

The second scenario concerns the emergency or alarm events. In this scenario in case of emergency, where the patient doesn't feel well, he/she takes some measurements, supplemental to the programmed ones, and sends them to the web server. After the validation and transformation of the data, the web server sends the data to the DB of the service centre, which by turn sends the alarm messages to the physician and to the associated people.

The e-Vital server will be able to communicate with the HIS of the collaborator clinic. In that case the e-Vital web server will be able to ask only for some patient data (mainly the patient medical history) in order to present the data in the physician or patient's web page. The web server will not restore data to the hospital DB. The e-Vital server and HIS will communicate through web services, which will be located in the web server. The data from the web server will be then transferred to the web pages through services centre as an XML file.

In the case of the e-Vital server, two possible architectures have been proposed that the pilot sites can follow.

In the following section the different subsystems' architectures are described.

2.1. The e-Vital components

The patient's module

The patient module consists of the following components:

- *Monitoring Devices*

The monitoring devices are recording data, processing them and sending them at regular intervals, or at alarming situations, when the patient does not feel well, with or without patient intervention.

- *The Mobile Phone Application*

The mobile phone application is software residing into a mobile phone. The application has two basic tasks: to manage the transmission of data to the server and to interact with the Service Management Applications (residing at the e-Vital server) as requested by the protocol. Some manufacturers offer phone/device combinations but these are only now appearing in the market and have not been tested.

-*The Signal Reception and Transmission Application*

This application is necessary when devices communicate only their signals and not to a mobile phone or directly with a server. It is also necessary in home-based and not mobile scenarios.

The hospital module

The hospital module consists of the Hospital Server and the Hospital Database System. The hospital module has been implemented independently to the e-Vital project. It already exists in the hospital or the private clinic that each pilot site will cooperate with.

The e-Vital server

There are two existing architecture possibilities proposed for the e-Vital server:

1) .NET-based architecture

The first one is based on .NET framework and is shown in Figure 1.

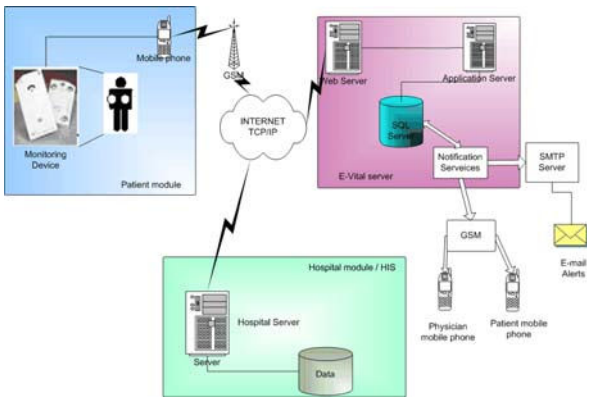

Figure 1. .NET-based architecture of the e-Vital server.

The e-Vital server consists of:

(a) The *Web Server* hosting the ASP.NET web pages that expose the e-Vital functionality over the Internet to the Web Clients (browsers) of both Physicians and Patients. The web server also is responsible for the communication between the application server and the HIS (Hospital Information System) of the collaborating hospital or clinic.

(b) The *Application Server* exposing Web Services that are consumed by the ASP.NET web pages on the Web Server and are responsible for the communication with the Database Server.

(c) The *Database Server* (MS SQL Server 2000). All data for the e-Vital service are stored in the central database server, which is a Microsoft SQL Server 2000 database. The Web Services façade and the desktop applications access the database server through .NET OLE DB driver technology. Additional data can be retrieved from existing HIS databases by adding appropriate web services on the Application Server tier (bridge modules). The tables that are essential for the e-Vital database server are:

- Patient Demographic Data
- Emergency Assistance Contact Information
- Emergency Medical Contact Information
- Registered Doctor Information
- Patient Monitor Plan, and
- Registered Equipment.

(d) The *Notification Services* module that is responsible for notifying physicians or other subscribers whenever an event that a subscriber is interested in occurs (by distributing e-mail notifications to an SMTP server).

2) J2EE-based architecture

The second architecture proposed for the e-Vital server is is a J2EE architecture and is shown in Figure 2. It is based on the PANACEIA-ITV back-end architecture [2].

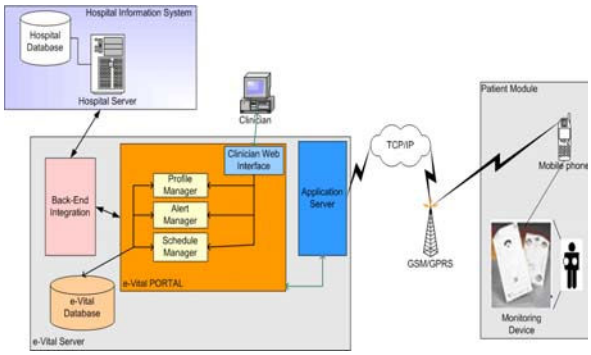

Figure 2. J2EE-based architecture of the e-Vital server.

The e-Vital server consists of:

(a) The *Application Server* which provides the communication links among the different participants of

the e-Vital system (i.e. patient-clinicians), and controls and regulates the data flow among the technical components of the platform.

(b) The *e-Vital Portal* which is responsible for the aggregation of content and service modules, for providing multiple modality access to users, for front-end integration for linking to the e-Vital application server and back-end integration.

(c) The *Back-end Integration* for links to the Hospital Information System - HIS, which access medical records and other data/knowledge repositories.

(d) The *Multi Agent System* for providing additional intelligence and advanced functionality to the system and guaranteeing a high level of quality of services

(e) The *Database Server* which contains information about patients registered with e-Vital Service, along with details about the services provided to each patient and the medical data transferred through the system to the contact centre.

3. Discussion

The proposed services will provide both the patient population and doctors with complete mobile management of their diseases and a monitoring mechanism and management system that delivers benefits to patients, clinicians and payers. Some of the key features include:

Patient Empowering – The services put patients in control of their own healthcare and support them in working with their clinical team. The technology is easy to use, and portable.

Real-Time Communications – The service will also provide a patient with confidence, knowing that their clinician is reviewing their data and can provide meaningful advice, based on quality data, when it is needed.

Clinical Guidelines – The system can help operationalize clinical standards and guidelines so patients are managed in a consistent manner.

Better Health Outcomes and benefits to patients – Through a strong feedback loop that includes regular reporting, data analysis and clinical intervention, the network provides better compliance to care guidelines. The results are reduced complications, reduced costs, and better data for clinical intervention, research and policy development.

Patient awareness – It has been shown that better patient education and self-management on heart failure and other chronic diseases may increase the mean time to re-admission and decrease the number of days in hospital and the annual health care cost per patient [3].

Financial Benefits – A British study indicated that about 15% of home visits could be replaced by telecare because of the absence of hands-on procedures (estimated as high as 45% in the USA) [4]. This implies that the utilisation of the e-Vital service can significantly reduce the cost of treatment as it is expected that it reduce the number of home visits required for chronically ill patients.

The proposed architecture takes advantage of recent technological advances in computing, networking and mobile wireless telemedicine to provide an integrated platform for continuous patient monitoring. Further, the system helps patients to be informed about their clinical condition, participate actively, in close collaboration with their health care provider, to their on-going care, and respond to risk factors through lifestyle changes or other appropriate means. Thus, the proposed platform enhances the effectiveness of health care and improves health standards and in the same time will help patient to continue to some normal and work activities in order to be an 'active' citizen.

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Address for correspondence.

Name: Andriana Prentza
Full postal address: 9 Iroon Polytechniou St., Biomedical Engineering Laboratory, ICCS-NTUA, Computer Building, Office 115, Zografou Campus, 15773 Athens, Greece
E-mail address: aprentza@biomed.ntua.gr