Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

Delivery of healthcare services over mobile phones: e-Vital and CHS paradigms

A. Prentza[1], S. Maglavera[2], L. Leondaridis[3]

[1]ICCS-NTUA, Biomedical Engineering Laboratory, Dept of Electrical and Computer Engineering, NTUA, Athens, Greece
[2] Pouliadis Associates Corporation, Dept of Research and Development, Thessaloniki, Thessaloniki, Greece
[3] NETSMART S.A., Athens, Greece

Abstract - **Health delivery practices are shifting towards home care, since there are better possibilities for managing chronic care, controlling health delivery costs, increasing quality of life and quality of health services and the distinct possibility of predicting and thus avoiding serious complications. Mobility brings a totally new dimension to the healthcare domain and to the whole interdisciplinary provision of regional healthcare. Healthcare services can be provided in virtually any location, where access to a mobile communications system is available. Mobile tele-health systems apply mobility as a potential means in order to bring significant improvements to emergency, treatment, routine check-ups and medical consultation. e-Vital project (eTen) and CHS project (IST) worked towards m-health applications.[1]**

I. Introduction

In the early 90s, the success of mobile telephony in Europe in terms of common infrastructures and market penetration created considerable interest within the research community on mobile systems. Cellular telephony, in particular, formed the basis for work investigating appropriate architectures for the provision of information services delivered to mobile telephone users. As a consequence, between 1998 and today, the European Commission (EC) Information Society Technology research program funded dozens of projects that developed mobile applications in different fields. A common thread throughout this work is the desire to develop universal information services delivered over ubiquitous, high-speed wireless networks.

Development of information services for mobile telephones shares several of the challenges of ubiquitous computing: the very small form factor makes user interaction hard, devices may operate in an environment that may not be secure or may even be hostile and last but not least, in addition to network connectivity there is a clear need for infrastructures that support service delivery. Some of the techniques useful for the delivery of services on the small form factor of mobile telephones or PDA type smart-phones currently available should also be useful for similar devices often used in pervasive systems. It is also worth noting that the use of voice as the interaction modality is rather extensively explored in work on the provision of mobile information services. Results in this area should also be useful to the designer of ubiquitous computing systems, however reporting on this area is beyond the scope of this article. Further, the fact that mobile telephones are frequently carried by a person offers distinct opportunities for personal and activity data harvesting as well as for the timely delivery of information services to individuals. Finally, a significant proportion of mobile telephones currently feature wireless local networking capabilities that allow them to interact with other devices in their immediate environment.

II. m-Health Applications

Mobility brings a totally new dimension to the healthcare domain and to the whole interdisciplinary provision of regional healthcare. Medical services can be provided in virtually any location, where access to a mobile communications system is available. Mobile tele-health systems apply mobility as a potential means in order to bring significant improvements to emergency, treatment, routine check-ups and medical consultation. Specifically, wireless technology enables seamless access to healthcare services wherever they are needed; at home, at work or on the move. Mobile networks provide an ideal platform for deploying effective monitoring and treatment mechanisms, guaranteeing continuity of care and bringing sizeable cost savings and flexibility without compromising the values of healthcare: full confidentiality, total privacy and high reliability.

Among the various advantages of the adoption of mobile services in healthcare provisioning are:

- improved access to medical information and data
- continuous health monitoring independent of the location of patients and physicians

Manuscript received April 3, 2006. This work was supported in part by the European Commission under the eTen and the IST Programme (contract numbers C27979 and IST-1999-13352 respectively).

A. Prentza is with the Institute of Communication and Computer Systems, Biomedical Engineering Laboratory, National Technical University of Athens, Athens, 15773, Greece (tel: +30-210-7722429, fax: +30-210-7722431, e-mail: aprentza@biomed.ntua.gr).

S. Maglavera is with Pouliadis Associates Corporation, Dept of Research and Development, Thessaloniki, Greece (e-mail: stavmag@the.forthnet.gr).

L. Leondaridis is with NetSmart S.A., 15554, Athens, Greece (e-mail: lld@netsmart.gr).

1-4244-0033-3/06/$20.00 ©2006 IEEE.

- o reduced bed stay in hospitals resulting in cost savings and reduced costs, since patients clinical condition may be monitored continuously
- o better specialist care and enhanced medical productivity
- o service provision in regions that cannot be covered by traditional healthcare systems, e.g. obscure islands or villages
- o supporting the transmission of patients' biosignals through mobile networks
- o provision of educational services and psychological support in a more frequent base than the one between patients' hospital visits
- o more efficient preventative treatment
- o a modern approach of traditional face-to-face appointments between patients and healthcare providers, through establishment of remote sessions between counterparts, freeing the patient from unnecessary travelling and visits by moving patients from hospital to their home:
  1. improvement of recovery rates (statistically proved)
  2. avoiding the risk of infection when treated in a hospital
  3. less delay in diagnosis and treatment

The increased availability, miniaturization, performance and enhanced data rates of future mobile communication systems will have an increasing impact and accelerate the deployment of m-health systems and services within the next decade. M-Health can be defined as 'emerging mobile communications and network technologies for healthcare' [1].

Of course, existing healthcare is a very complex industry and difficult to change and organizational changes are often required for healthcare institutions to benefit from e-health and m-health services. This paper presents some of the current m-health systems.

III. Mobile Healthcare Applications

e-Vital Application

The e-Vital concept is based on the supply of homecare and telemonitoring and 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 [2].

The elements, the Integrated Homecare and Telemonitoring Service Chain (Figure 1) consists of, are the: (1) Devices and/or sensors connected to the patient, (2) Service Enabling Applications at the e-Vital patient module, (3) Service Management Applications at the e-Vital server module, (4) Service Facilities and Operations, (5) Technical and organisational support, (6) Organisational models.

The e-Vital service consists of the following subsystems:

- The *patient's module* consists of the monitoring devices and the patient's phone. Each patient follows a personalised care protocol, designed by a healthcare provider, according to which s/he or a nurse takes appropriate measurements by using appropriate monitoring devices. The data are then sent to the e-Vital server via the patient's mobile phone or PDA.
- The *e-Vital server* is the core of the e-Vital service. The physician is able to design the personalised care protocol of a patient, to monitor the application of the protocol and evaluate the patient's measurements and overall health condition.
- 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.

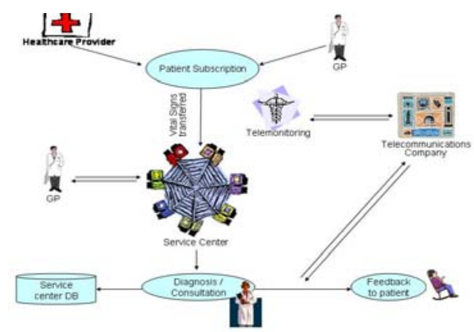

Figure 1. e-Vital Service Chain

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 transformed in an XML file in order to be compatible to the format of the DB and are forwarded to the DB centre. Physicians and patients have access to the service from PC, PDAs or mobile phones connected to the Internet.

As depicted in Figure 2, the e-Vital architecture consists of the following modules:

1) The Patient module, which includes (a) The monitoring devices, which record, process and send the data at regular time intervals or at alarming situations with or without patient intervention. (b) The Mobile Phone or PDA Application that is software residing into a mobile phone and has two basic tasks: to manage the transmission of data to the server and to interact with the Service Management Applications as requested by the protocol. (c) The Signal Reception and Transmission Application that is necessary when devices communicate only their signals and not to a mobile phone or directly with a server.

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

3) The e-Vital server is the core of the e-Vital service and holds the whole functionality of the service. The e-Vital server architecture consists of:

a) The Application Server which provides the communication links among the different participants of the e-Vital system, and controls and regulates the data flow among the technical components of the platform.

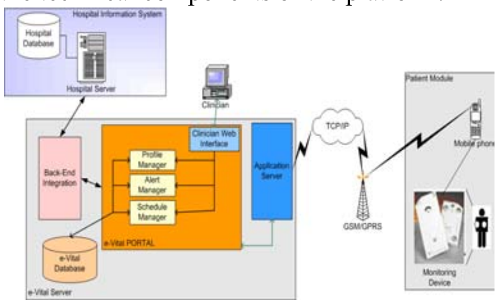

Figure 2. e-Vital System Architecture

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 HIS, which access medical records or 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.

CHS Application

CHS project's [3] main goal is to develop a generic contact centre which in its pilot stage can be used in the monitoring, treatment and management of chronically ill patients at home in Greece, Spain and Germany. CHS was conceived to meet home health care needs of chronic disease patients suffering for example from diabetes, congestive heart failure and post trauma in culturally diverse countries. The system consists of two units. The clinical centre unit that is going to be deployed in the contact centre unit, which can reside in the hospital, specialty clinic, or ambulatory care centre, where home care is coordinated. The home care unit is deployed at the patients' home. The modularity of the system, where all modules can be developed and implemented independently is an important asset of the CHS concept [4], [5]. As can be seen in Figure 3, the CHS contact center model comprises of modules dealing with the following: (1) Interfaces between the user and the database, (2) Decision support tools, (3) Medical signals archive, (4) Clinical data processing, (5) Reference library, (6) Customer/patient agent interface, (7) Medical devices interface.

The CHS system can be linked with hospital information systems as well as with already existing external specialized applications. In CHS a generic system was developed aiming at the management of chronic disease patients such as CHF, and Diabetes/Obesity patients. Pivotal to this purpose is the development of a Contact Centre, which acts as mediator between the medical staff and the citizens seeking advice and/or therapy. The CHS System, the Contact Centre offers the means for gathering medical data submitted by the patients and makes available for them educational procedures. Mechanisms for patient administration and reviewing of patients' data are also among the functionalities offered by the Contact Centre (Figure 3).

The CHS system consists of several modules designed to serve the Contact Centre functionality. These modules are used to transmit and authenticate information, filter received data, process and manage queries from both patients and doctors and provide decision support and intervention tools at the clinician's site for quality and timely health delivery.

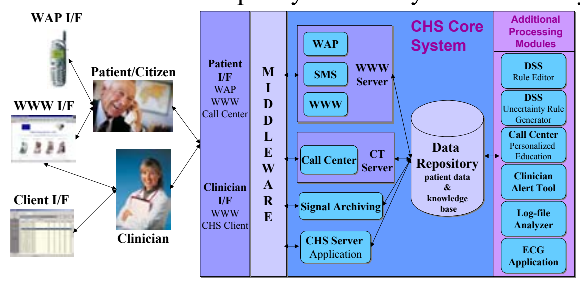

Figure 3. The overall architecture of the CHS system.

One of the basic concepts of the CHS system design was the need for a parametric and customisable patient data model, which would facilitate personalised procedures and treatments. Different communication means, suitable to different patient lifestyles and adaptation to technology were available and different kinds of information were accordingly included. Thus, a middle-tier architecture, able to communicate with different interfaces, had to be implemented.

The application scenario for a patient: The patient who can be a diabetes obese patient or a congestive heart failure (CHF) patient can run a session with the choices depicted in Figure 4. The CHS contact center is manned by nurses. Training of the patient on how to use the contact center is done once by nurses at the contact center site, following a doctor's visit and it takes 2 hours to complete this task. The services provided via the home care system are:

- Measurements. Each patient may send measurements like blood pressure, glucose, pulse or weight. These measurements are taken at home using simple devices. Complementary to the measurements are a number of questions asked to the patients, since the corresponding answers may be explanatory of their condition. The values are keyed in using the selected technology (WAP, WEB or regular phone). The set of required values and questions may be personalised for each patient. Vital signs like ECG may also be transmitted to the system by use of transtelephonic devices. Figure 5 shows sample screens of a typical WAP based session.
- Education. Each patient can attend educational sessions, either on demand, when he/she needs some information on a specific subject, or scheduled ones where the system calls automatically the patient for more detailed educational sessions on subjects that are of importance. All educational messages are also available in text form, so Internet can be used alternatively for educational

purposes. Besides, a pool of Websites with useful information for disease management is available as a reference library.

- Communication with the medical personnel. Depending on the communication media, written or voice messages can be exchanged between patient and the medical personnel.

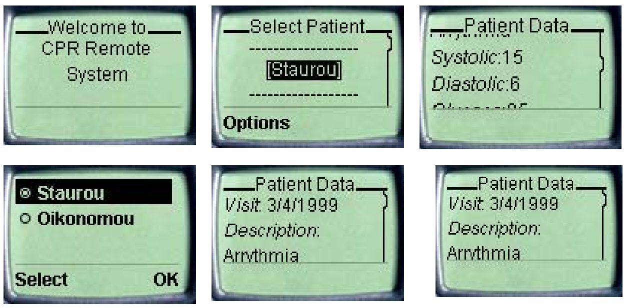

Figure 5. Screen sequences for a patient session using WAP.

Mobile telephony is used in the settings of the CHS clinical trials, where patients are using a Motorola mobile telephone, and have contact with the CHS contact center in order to send in vital parameters (e.g. body weight, arterial blood pressure (ABP), blood glucose and ECGs), something that constitutes the measurement session, answer simple Yes/No questions, listen or browse educational material related to their disease, and finally leave a voice message to their doctor. While browsing capabilities of mobile telephones are limited, the patient can still enter alphanumeric data easily, and browse through short messages sent by their attending physician.

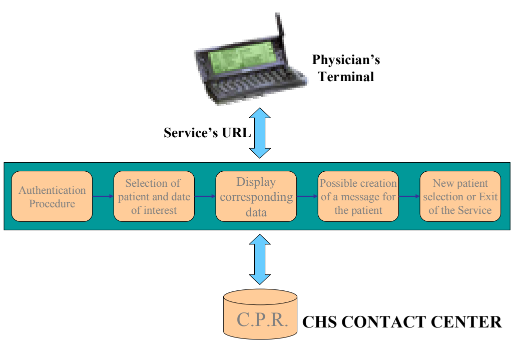

Figure 6. The block diagram that is implemented for a doctor contacting the CHS contact center through the mobile telephone network.

These short messages can be an integral part of a typical contact session, usually appearing in the beginning or at the end of the session, or they can be programmed to be sent via the contact center as SMSs to the patient's mobile telephone. Each session is saved as a LOG file, in for future analysis, or possible error detection which result in higher health service quality. Each contact session lasts at the most 3 min, and on the average about 1 min. The physician can have ubiquitous access to the contact center data linked with his/her patients also via the mobile telephone. Figure 6 depicts a block diagram with a menu of the functions that a physician can accomplish through the CHS contact center. Figure 7 shows a number of sample screens from the clinician interface.

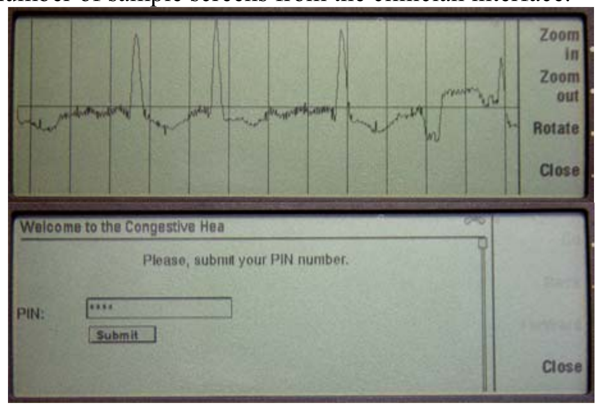

Figure 7. Screen sequences from the clinician interface.

Conclusion

The recent research relevant to m-health such as advances in nano-technologies, compact biosensors, wearable, pervasive and ubiquitous computing systems will all lead the successful launch of next generation m-health systems within the next decade. They will encompass all these technologies for future healthcare delivery services with the vision of 'empowered healthcare on the move'.

IV. Acknowledgements

The authors would like to thank the European Commission for the financial support provided to CHS project (IST-1999-13352) and e-Vital project (C27979) under the IST and eTen Programmes respectively.

V. References

[1] M.F. Collen, "Historical evolution of preventive medical informatics in the USA", *Meth Inform Med*, vol. 39, no. 3, pp. 204-207, 2000.
[2] S.M. Borowitz and J.C. Wyatt JC, "The origin, content, and workload of e-mail consultations", *JAMA*, vol. 280, pp. 1321-1324, 1998.
[3] E.A. Balas and I. Iakovidis I, "Distance technologies for patient monitoring", *BMJ*, vol. 319, no. 7220, pp. 1309-1311, 1999.
[4] E. Rosenblatt, "Telephone triage. A common sense approach", *RN*, vol. 64, no. 3:suppl, pp.2-3, 2001.
[5] M.L. Stricklin, S. Jones and S.A. Niles, "Home Talk/Healthy Talk: improving patient's health status with telephone technology", *Home Healthc Nurse*, vol. 18, no. 1, pp. 53-61, 2000.
[6] J.C. Cherry, T.P. Moffatt, C. Rodriguez and K. Dryden, "Diabetes disease management program for an indigent population empowered by telemedicine technology", *Diabetes Technology & Therapeutics*, vol. 4, no. 6, pp. 783-791, 2002.
[7] e-Vital Technical Annex, e-Vital Project, Contract number C 27979 project, 2002.
[8] V. Koutkias, I. Chouvarda and N. Maglaveras, "Agent-based Monitoring and Alert Generation for a Home Care Telemedicine System", in *Proc AMIA Annual Conference*, 2002.
[9] PANACEIA-iTV Technical Annex, Citizen Citizen Centered Health and Lifestyle Management via Interactive TV: The PANACEIA Health System – Contract number IST-2001-33369, 2001.
[10] C.M.J. Cline, B.Y.A. Israelsson, R.B. Willenheimer, K. Broms, L.R. Erhardt, "Cost effective management programme for heart failure reduces hospitalisation", *Heart*, pp. 80, pp. 442-446, 1998.
[11] Delloite & Touche, "*The Emerging European Health Telematics Industry*", Market Analysis. Health Information Society Technology based Industry Study - Reference C13 25533. On assignment of EC-DG Information Society. 25/04/2000.