Mobile health systems: A brief overview

S. Voskarides[1,2], C.S. Pattichis[3], R. Istepanian[2],
E. Kyriacou[3], M.S. Pattichis[4], C.N. Schizas[3]

[1]Department of Electrical Engineering, Higher Technical Institute,
P.O. Box 20423, 2152 Nicosia, Cyprus   Email: boss@spidernet.com.cy

[2]Department of Electronic and Computer Engineering, Brunel University,
Uxbridge, Middlesex, UB8 3PH, U.K.   Email: Robert.Istepanian@brunel.ac.uk

[3]Department of Computer Science, University of Cyprus,
75 Kallipoleos str., P.O.Box 20537, CY 1678, Nicosia, Cyprus   Email: (pattichi, ekyriac, schizas)@ucy.ac.cy

[4]Dep. of Electrical and Computer Engineering, University of New Mexico,
Albuquerque, NM87131-1356, USA   Email: pattichis@eece.unm.edu

ABSTRACT

Rapid advances in information technology and telecommunications, and more specifically wireless and mobile communications, and their convergence (telematics) are leading to the emergence of a new type of information infrastructure that has the potential of supporting an array of advanced services for healthcare. The objective of this paper is to provide a snapshot of the applications of mobile technology in healthcare. A brief review of the spectrum of these applications and the potential benefits of these efforts will be presented, followed by success case studies in electronic patient record, emergency telemedicine, teleradiology, and home monitoring. It is anticipated that the progress carried out in these efforts, and the potential benefits of emerging mobile technologies will trigger the development of more applications, thus enabling the offering of a better service to the citizen.

Keywords: Telemedicine, health systems, mobile, wireless, GSM

1. INTRODUCTION

Telemedicine can be defined as the delivery of health care and sharing of medical knowledge over a distance using telecommunication means. It aims to the provision of expert based medical care to any place that health care is needed. Telemedicine as a concept was introduced about 30 years ago where telephone and fax machines were the first telecommunication means used. In recent years, several telemedicine applications have been successfully implemented over wired communication technologies like POTS, and ISDN. However, nowadays, modern wireless telecommunication means like the GSM and GPRS and the forthcoming UMTS mobile telephony standards, as well as satellite communications, allow the operation of wireless telemedicine systems freeing the medical personnel and / or the subject monitored bounded to a fixed location. The objective of this paper is to present a short review of wireless health systems.

Telemedicine applications, including those based on wireless technologies span the areas of emergency health care, telecardiology, teleradiology, telepathology, teledermatology, teleophtlalmology, teleoncology, and telepsychiatry. In addition, health telematics applications enabling the availability of prompt and expert medical care have been exploited

for the provision of health care services at understaffed areas like rural health centers, ambulance vehicles, ships, trains, airplanes, and patient home monitoring. Through this study we try to give an overview of wireless telemedicine systems documented through published conference or journal papers (see section 3). Selected case studies of these systems are presented in section 4, followed by section 5 on concluding remarks.

2. WIRELESS TECHNOLOGIES

In this section we briefly describe the main wireless technologies that have been used in wireless telemedicine systems, namely GSM, GPRS, satellite, and wireless LAN.

GSM is a system currently in use, and it belongs to the second generation (2G) of the mobile communication networks. GSM when used in the standard operation mode is able to provide data transfer speeds up to 9.6 Kbps. Through the years a new technique was introduced in the GSM standard called High Speed Circuit Switched Data HSCSD; this technology makes it possible to use several time slots simultaneously when sending or receiving data, so the user can increase the data transmission to 14.4 Kbps (an increase of 50%) or even triple 43.3 Kbps the transmission speed.

The evolution of mobile telecommunication systems from second generation (2G) to 2.5G (iDEN 64 Kbps, GPRS 171 Kbps, EDGE 384 Kbps) and 3G (W-CDMA, CDMA2000, TD-CDMA) systems will be able to provide much faster data transfer rates thus enabling the development of telemedicine systems that require high data transfer rates that are currently only applicable on wired communication networks.

Satellite systems are able to provide a variety data transfer rates starting from 2.4 Kbps and moving to high-speed data rates of up to 2x64 Kbps and even more. Satellite links also have the advantage of operating all over the world.

A wireless local area network (WLAN) is a flexible data communications system implemented as an extension to or as an alternative for, a wired LAN. Using radio frequency (RF) technology, wireless LANs transmit and receive data over the air, minimizing the need for wired connections. Thus, wireless LANs combine data connectivity with user mobility. Wireless LANs have gained strong popularity in a number of vertical markets, including the health-care, retail, manufacturing, warehousing, and academia. These industries have profited from the productivity gains of using hand-held terminals and notebook computers to transmit real-time information to centralized hosts for processing. Today wireless LANs are becoming more widely recognized as a general-purpose connectivity alternative for a broad range of applications.

3. WIRELESS TELEMEDICINE SYSTEMS

The INSPEC and Medline databases were searched with keywords telemedicine and mobile or telemedicine and GSM or telemedicine and GPRS. The number of papers (including both conference and journal papers) published under these categories in the years 1979 to 2001 were 132.

A total of 29 selected applications out of these wireless telemedicine systems published are briefly summarized in Table 1. These systems were grouped under the wireless technologies of GSM and satellite, whereas radio, and wireless LAN health systems are briefly outlined at the end of this section. The systems presented in Table 1 were grouped into the areas of emergency (health care), telecardiology, teleradiology, telepsycology, teleopthalmology, and remote monitoring. In addition, in Table 1, the data transmitted were coded under the following columns: signals for biosignals, IMG for medical imaging or video, EPR for electronic patient record, and AIV for audio (A), or image (I) or video (V) teleconferencing. The last column of Table 1 gives some comments characterizing the system described.

Most of the applications were using the GSM network and were published between the years 1999 and 2001. Most of the applications over GSM were for Emergency telemedicine, remote monitoring and telecardiology.

Table 1. Selected applications of wireless telemedicine systems for GSM and Satellite

Authors	Year	Area	Data Transmitted				Comments
			Signals[1]	IMG[2]	EPR[3]	AIV[4]	
GSM							
Schðchinger *et al.* [1]	99	Emergency					Early hospital admission
Karlsten *et al.* [2]	00	Emergency	ECG				Ambulance triage support
Yan Xiao *et al.* [3]	00	Emergency	BIO			V	Ambulance neurological examination support
Anantharaman *et al.* [4]	01	Emergency	ECG				Pre-hospital support
Rodrvguez *et al.* [5]	01	Emergency	ECG				Cardiac arrest treatment
Istepanian *et al.* [6,7]	01	Emergency	ECG				Wavelet ECG compression
Pavlopoulos *et al.* [8]	01	Emergency	ECG,BP, Temp, S_PO_2,CO_2			A, I	Portable teleconsultation medical device
Reifart *et al.* [9]	97	Telecardiology	ECG				12- lead ECG transmission
Istepanian *et al.* [10]	99	Telecardiology	ECG, PPG				IS-54&GSM cellular telephone standards
Scalvini *et al.* [11]	00	Telecardiology	ECG				Massive evaluation of an emergency ECG service
Reponen *et al.* [12]	00	Teleradiology		CT			PDA based CT teleconsultation
Schulze *et al.* [13]	00	Telepsychology					Support of patients with brain disturbances
Yogesan *et al.* [14]	00	Teleophthalmology		ODI			Glaucoma screening
Hofman *et al.* [15]	96	Remote monitoring	BIO				General purpose telemedicine system
Butera *et al.* [16]	97	Remote monitoring					Support in disaster situations
Bukhers *et al.* [17]	97	Remote monitoring			•		Real time patient-soldier battlefield monitoring
Pitsillides *et al.* [18]	99	Remote monitoring			•	V	Monitoring of cancer patients
Woodward *et al.* [19]	01	Remote monitoring	ECG				Mobile telephony ECG transmission
SATELLITE							
Murakami *et al.* [20]	94	Emergency	ECG, BP			A, I	Telemedicine support in aircraft & ship
Kyriacou *et al.* [21]	01	Emergency, Remote monitoring	ECG,BP			A, I	Portable teleconsultation medical device
Stewart *et al.* [22]	99	Tele-radiology		US		V	Ultra Sound image compression
Takizawa *et al.* [23]	01	Tele-radiology		CT			Spiral CT mobile van (lung cancer screening)
Yogesan *et al.* [14]	00	Teleophthalmology		ODI			Glaucoma screening
Otto *et al.* [24]	97	Remote monitoring	ECG, BP			V	Disaster situations
Anogianakis *et al.* [25]	97	Remote monitoring			•		Maritime telemedicine
Samiotakis *et al.* [26]	97	Remote monitoring			•		Basic telemedicine services
Navein *et al.* [27]	98	Remote monitoring				V	US army portable telemedicine system
Lamminen *et al.* [28]	99	Remote monitoring				A	Travellers and educators suport
Harnett *et al.* [29]	00	Remote monitoring					climbers' hypoxia monitoring

[1]Signals: ECG: Electrocardiograph, BIO: Biosignals, BP: Blood Pressure, Temp: Temperature, SpO_2: Oxygen saturation, CO_2: Carbon dioxide measurement, PPG: PhotoPlythiSmography, FVC: Forced Vital Capacity.

[2]IMG: Medical imaging, US: Ultrasound, CT: Computer Tomography, ODI: Optical Disc Image

[3]EPR: Electronic Patient Record

[4]AIV: Teleconferencing mode, A: Audio communication, I: Image communication (non medical), V: Video communication (non medical)

Satellite links were also used in many applications. Satellite systems have the advantages of worldwide coverage and a variety of data transfer speeds, even though satellite links have the disadvantage of the high cost needed in order to operate a telemedicine system.

Moreover, radio based health systems were developed for the remote monitoring of isolated areas as early as 1979 by Fuchs *et al*. [30], whereas Schimizu *et al*. [31] developed a system for emergency telemedicine support in aircraft and ships.

In recent years, the application of health systems based on the wireless LAN technology is becoming more and more popular. Systems in the areas of emergency telematics [8,21,32], teleradiology [33], and remote monitoring [34], [35] have recently been developed.

4. CASE STUDIES

In this section, case studies of electronic patient record, emergency health care, teleradiology, and home monitoring are given.

4.1 Electronic patient record: (MOMEDA) Mobile medical Data [12,33, 36]

The MOMEDA HC4015 project was partially funded from the European Commission / DGXIII TELEMATICS APPLICATION PROGRAMME. Concerning the wireless telemedicine area; the main objective of the project was the development of a demonstrator that allows the consulting physician to access electronic patient record data from outside the hospital, using a hand held companion device connected to GSM network. A module based on the NOKIA communicator 9110 was developed and tested through the project. The user of this module was able to connect to the hospital main server and receive electronic record and medical images (MRI) of a patient. The project was successfully tested in three European countries (Finland, Italy and Greece).

4.2 A Medical System for Emergency Telemedicine: the Ambulance and Emergency-112 Projects [21,8,37]

The objective of AMBULANCE and EMERGENCY-112, two projects sponsored by the EU and in which Cyprus actively participated, were the development and testing of a portable device allowing emergency telemedicine services between ambulance vehicles and distanced expert physicians via wireless communication. The ultimate goal was to produce a marketable system that will significantly enhance pre-hospital care.

The emergency telemedicine system consists of two separate modules [21: (i) the mobile unit (ambulance site), and (ii) the consultation unit (hospital site). Diagnostically important data, like ECG, blood pressure, heart rate, oxymetry, temperature, etc., are collected via a biosignal monitor connected to a portable computer at the mobile site and are transmitted through the GSM mobile telephony network to the hospital site. Still images of the patient's position and state are captured through a small camera and transmitted. The specialist at the hospital site can observe the signals in real-time, view the images of the patient and mark some interesting areas (whiteboadring), a marking that appears simultaneously at the mobile screen. Thus, he is able to assess the severity of the emergency and through a bidirectional GSM voice communication can instruct the paramedic how to handle the case. The system is supported by a multimedia database, which stores all information available from the time the system is initialized until the arrival of the patient at the hospital. Apart from the GSM communication link, the system supports satellite links, and normal telephone lines communications, as well as operation in Local Area Networks.

The system addresses multiple user needs including: ongoing integration of pre-hospital and in-hospital emergency care systems, new and better therapies available for medical emergencies, demands for cost efficient health programs, integration of emergency handling records into modern computer files, and higher public demands for medical emergency systems. The potential fields of use for the system can be summarised as follows: assessing the severity of multiple trauma, directing handling of major bleeding and life threatening cardiac arrhythmia's, directing on-scene

thrombolytic therapy in acute myocardial infarction, directing use of CPAP-ventilation on scene, directing analgesia for stacked victims, and directing priorities in cases of multiple victims.

The system was evaluated and verified in Cyprus, Greece, Italy and Sweden. Each pilot recorded certain time indicators, such as time-to-transportation, time-to-start-treatment, time-to-stabilization, etc., in a total of 100 cases in which the system was used and in another 100 cases without using the system, in order for comparative results to be deduced. It was shown that the system provides significant support to the early and specialized pre-hospital patient management and to emergency case survival. The diagnosis at the scene of an emergency, as well as the handling of the case, was substantially improved through on-line access to medical specialists, which decreased the time to make the first diagnosis and start the appropriate treatment. Severe or multiple trauma patients were better assessed, while the electronic registration of the patient's data freed the ambulance personnel of any paper work and helped devoting more time on real emergency care. The system can be further used in directing the management of stacked victims and setting priorities in cases of major incidents (TRIAGE). It can also contribute to directing the transport of victims, thus reducing the time of arrival at the hospital.

4.3 Teleradiology: A Teleradiology System Using a Mobile CT van and High Speed Satellite Communication [23]

In this system, a mobile van that houses a whole body spiral computed-tomography (CT) scanner and a second van that houses the satellite communications equipment was used for CT scanning, and on line two way transfer of image data and teleconferencing to a consultation center with various specialists. The personnel of the system consist of two drivers and a radiology technician who operates the CT scanner and the telecommunications unit. The mobile CT van is 12m long and is equipped with a whole body CT scanner, designed for lung disease screening. In addition, the van houses a PC for CT data transmission, teleconferencing equipment, image printer, facsimile machine, and resuscitation equipment. The stationery diagnostic center is equipped with a Sparc 1000, SUN Microsystems, Palo Alto, CA, server equipped with a disk array of 209GB, RAID 7, an image observer station with two units of 1728x2304, 21in monochrome monitor, and 1280x1600 color monitor. The mobile and the stationary stations are communicating at 155 Mb/s asynchronous transmission mode (ATM) via satellite or ISDN. The protocol used for image communication is DICOM 3.0 and for online diagnosis of CT screening of images it takes 10min. for the transmission of 16.5MB. The system was applied for the screening of 19117 residents of 29 districts in Japan that resulted in the identification of 75 cases of early lung cancer that were treated subsequently by partial pneumonectomy. In addition, the system was applied to provide medical services in rural areas, sport events, and home monitoring. The usefulness of the proposed system is limited by the high initial cost for building the system (8 000 000 U.S. dollars), the number of subjects scanned, as well as by the satellite communications fee. These costs can significantly be lowered via the manufacture of 10 similar CT vans, doubling the number of subjects examined, and transmitting the images via the use of multiport format and in compressed format.

4.4 DITIS: Collaborative Virtual Medical Team for Home Healthcare of Cancer Patients [18,38]

Complex and chronic illnesses, such as cancer demand the use of specialized treatment protocols, administered and monitored by a co-ordinated team of professionals. Home based care of chronic illnesses (e.g. cancer patients) by a team of professionals is often a necessity, due to the protracted length of the illness, whereas hospital based treatment is limited, often demand based for short periods of time. As it is not possible for the health care team to be physically present by the patient at all times, or at any time physically together, whilst the patient is undergoing treatment, a principal aim of the current project is to overcome this problem, through DITIS (ΔΙΤΗΣ, in Greek, stands for: Network for Medical Collaboration). DITIS is a system that supports Virtual Medical Teams dealing with the home-healthcare of cancer patients in Cyprus. It aims to support the creation, management and co-ordination of virtual medical teams, for the continuous treatment of the patient at home, and if needed for periodic visits to places of specialized treatment and back home.

The design and development of DITIS tele-cooperation system is based on internet and GSM/WAP connectivity, and includes the following five modules: (i) *Mobile agents* e.g. IBM's aglets workbench, Mitsubishi's Concordia, and Voyager, for the implementation of flexible communication infrastructure for the support of mobile users. The mobile agents may be extended to offer intelligence and co-operation. (ii) *Web based database* for the storage and processing

of the *Electronic Medical Record*. (iii) *Telecooperation system* for sharing of information, team communication, coordination of team activities, and (iv) *Adaptive intelligent interface* for database access from a variety of access units, such as mobile computing units with GSM internet connectivity, and fixed units with internet access supporting tele-cooperation.

5. CONCLUDING REMARKS

This paper attempted to give a snapshot of completed, ongoing and emerging applications of wireless information technology applications in health systems. Wireless telemedicine technology, linked with emerging technological trends like pervasive computing (enabling the seamless human-computer interactions with multimedia databases, "smart" cards), intelligent agent technology, electronic commerce applications in the healthcare sector, high-bandwidth Web, and citizen-centered services provide promising solutions for forthcoming healthcare applications [39]. These trends, together with, more work and efforts needed in the areas of interoperability, standards, security and legal issues at both, national, and international levels will facilitate the wider application of healthcare telematics [40] including wireless for the whole of the health care sector thus enabling the offering of a better service to the citizen.

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