A brief overview of m-Health e-Emergency Systems

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Abstract— **Rapid advances in wireless communications and networking technologies, linked with advances in computing and medical technologies facilitate the development and offering of emerging mobile systems and services in the healthcare sector. The objective of this paper is to provide an overview of the current status and challenges of mobile health systems (m-health) in emergency healthcare systems and services (e-emergency).**

I. Introduction

M-Health can be defined as 'emerging mobile communications and network technologies for healthcare' [1]. This concept represents the evolution of 'traditional' e-health systems from desktop platforms and wired connections to the use of more compact devices and wireless connections in e-health systems. The emerging development of m-health systems in the last decade was made possible due to the recent advances in wireless and network technologies, linked with recent advances in nano-technologies, compact biosensors, wearable devices and clothing, pervasive and ubiquitous computing systems. These advances will have a powerful impact on some of the existing healthcare services and will reshape the workflow and practices in the delivery of these services [1].

A brief review of the spectrum of m-health systems and applications and the potential benefits of these efforts was presented in a recent paper by our group [2]. Moreover, an edited volume was published [1], covering a number of areas in mobile m-health systems. The objective of this paper is to provide an overview of the status and challenges of m-health in emergency healthcare systems and services (e-emergency).

A longer version of this paper was also published by our group [3]. The paper reviews recent e-emergency systems, including the wireless technologies used, as well as the data transmitted (electronic patient record, biosignals, medical images, video and other).

The structure of the paper is as follows. Section II covers an introduction to wireless transmission technologies. In section III, a short overview of m-health e-emergency systems is documented based on published journal, conference papers, and book chapters. Section IV addresses the future challenges and section V the concluding remarks.

II. Wireless Transmission Technologies

In this section we briefly describe the main wireless technologies that are used in wireless telemedicine systems, namely GSM, 3G (W-CDMA, CDMA2000, TD-CDMA), satellite, and wireless LAN (WLAN). Emerging wireless technologies such as Wi-Max, and ad-hoc networks are also described.

GSM is a cellular system currently in use, and is the second generation (2G) of the mobile communication networks. In the standard mode of operation, it provides data transfer speeds of up to 9.6 kbps, whereas the enhanced technique High Speed Circuit Switched Data (HSCSD) makes possible data transmissions of up to a maximum of 115 kbps [4]. The evolution of mobile telecommunication systems from 2G to 2.5G (iDEN 64 kbps, GPRS 171 kbps, EDGE 384 kbps) and subsequently to 3G (W-CDMA, CDMA2000, TD-CDMA) systems facilitates both an always-on model (as compared with the circuit-switched mode of GSM), as well as the provision of faster data transfer rates, thus enabling the development of more responsive telemedicine systems. High Speed Downlink Packet Access (HSDPA) [5] is the latest system enhancement of W-CDMA networks. With a theoretical peak of 14.4 Mbps (typically around 1 Mbps), telemedicine systems can benefit from data transfer speeds currently only feasible on wired communication networks [4], [6].

Satellite systems are able to provide a variety of data transfer rates starting from 2.4 kbps and moving to high-speed data rates of up to 2x64 kbps and beyond [7] .

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, WLANs transmit and receive data over the air, minimizing the need for wired connections. To extend coverage over large distances, wireless mesh networks are also being considered.

WiMax is a wireless digital communications system defined by the IEEE 802.16 standard. Its advantage over WLANs lies in the fact that WiMax can provide broadband wireless access up to 50 km for fixed stations and 5 km-15 km for mobile stations, thus intended for wireless "metropolitan area networks" (WMANs) [8]. It is anticipated that utilization of this attractive feature will lead in a vast deployment of WiMax systems.

Mobile ad-hoc networks or MANETs are a collection of geographically distributed mobile nodes that interact 'on the

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Table 1a. Selected applications of m-**health e-emergency** systems that use GSP/GPRS and 3G networks [3]

Commun. Technol.	Author	Year	Data Transmitted: ECG and/or other signals	Data Transmitted: IMG	Data Transmitted: EPR/ DATA	Data Transmitted: Video	Web application	Comments
GSM/GPRS	Karlsten *et al.* [11]	00	√					Ambulance triage support
	Yan Xiao *et al.* [12]	00	√			√		Ambulance neurological examination support
	Anantharaman *et al.* [13]	01	√					Pre-hospital support
	Rodriguez *et al.* [14]	01	√					Cardiac arrest treatment
	Istepanian *et al.* [15][16]	01	√	√				Transmission of ECG data and still images for emergency use. Compression of ECG using a wavelet compression method
	Pavlopoulos *et al.* [17]	01	√	√				Portable teleconsultation medical device
	Chiarugi *et al.* [18] & Kouroubali [19]	03 05	√					Transmission of 12-lead ECG in order to support ambulance and rural health centers emergencies (HygeiaNet)
	Kyriacou *et al.* [20]	03	√	√				Wireless transmission of biosignals and images from a Rural Health Center and a moving ambulance vehicle to a central hospital
	Clarke *et al.* [21]	04	√					Wireless connection to sensors and transmission of data from an ambulance
	Kyriacou *et al.* [22]	05	√	√				Ambulance emergency support through wireless transmission of biosignals and images
	Salvador *et al.* [23]	05	√				√	Transmission of ECG and other parameters to support patients with chronic heart diseases
	Clemmensen *et al.* [24]	05	√					Transmission of ECG signals to a cardiologist's PDA to improve time to reperfusion
	Campbell *et al.* [25]	05	√					Wireless transmission of ECG from Emergency medical care personnel to the department and through wireless LAN to the on-call cardiologist who is carrying a PDA
	Giovas et.[26],	06	√					Wireless transmission of 12-lead ECG from a moving ambulance vehicle to a central hospital
	Sillesen *et al.* [26]	06	√					Transmission of ECG signals to a cardiologist's PDA in order to improve time for PCI treatment
	Schδchinger *et al.* [28]	99		√				Early hospital admission
	Reponen *et al.* [29]	00		√				Transmission of CT scans using GSM and PDAs. Images transmitted to a neuroradiologist for preliminary consultation
	Oguchi *et al.* [30]	01		√			√	Use of personal handyphone system to transmit CT images using a web based application
	Voskarides *et al.* [31]	02		√				Transmission of X-ray images in emergency orthopedics cases
	Hall *et al.* [32]	03			√			Wireless access to Electronic Patient Record
	Kontaxakis *et al.* [33]	06				√		Tele-echography system and 3D-ultrasound
3G	Chu *et al.* [34]	04	√	√		√		Trauma care through transmission of patient's video, medical images and ECG
	Garawi *et al.* [35]	06				√		Tele-operated robotic system for mobile Tele-Echography (OTELO-Project)
	Martini *et al.* [50]				√			A cross layer approach for wireless medical video streaming applied for robotic teleultrasonography

move' with one another over a wireless medium instead of communicating wirelessly to a base station [9]. These kinds of networks are particularly useful in the absence of a wired infrastructure or under strict time constraints when no time is available to set a network up. This characteristic may prove particularly useful for emergency systems.

III. M-HEALTH E-EMERGENCY SYSTEMS

A. An Overview

The MEDLINE and IEEE Explore databases were searched with the following keywords: wireless telemedicine emergency, wireless telemedicine ambulance, wireless telemedicine disaster, wireless ambulance, wireless disaster, and wireless emergency. The number of journal papers found to be published under these categories is around 210. Out of these a total of 33 applications were selected and are briefly summarized in Table 1. These systems cover the whole spectrum of wireless emergency telemedicine applications presented during the recent years. The papers are grouped using the wireless technologies types which are: GSM/GPRS, 3G, satellite and wireless LAN. The data transmitted are coded under the columns: "ECG and other biosignals", "IMG" for medical images or patients images, "EPR/Data" for Electronic Patient Records or just DATA, "Video" for video conferencing or medical video transmission. The column "Web" identifies which of the applications were developed supporting web technologies.

The majority of the applications (21) used the GSM/GPRS network while a lot of applications use Wireless LAN (11) Applications presented in the other two categories 3G and Satellite are rather limited.

In the first group of applications which use the Mobile Telephony networks GSM/GPRS, we have the highest number of applications. These applications could be divided

Table 1b. Selected applications of m-health e-emergency systems that use Satellite and Wireless LAN [3]

Commun. Technol.	Author	Year	Data Transmitted: ECG and/or other signals	Data Transmitted: IMG	Data Transmitted: EPR/ DATA	Data Transmitted: Video	Web application	Comments
Satellite	Kyriacou *et al.* [20]	03	✓	✓				Wireless transmission of biosignals and images from a Rural Health Center and a moving ambulance vehicle to a central hospital
	Strode *et al.* [36]	03		✓				Examination of trauma using focused abdominal sonography (military)
	Vieyres *et al.* [37], & Canero *et al.* [38]	05				✓		Tele-operated robotic system for mobile Tele-Echography (OTELO-Project)
	Virgin Atlantic Airways [39]	06	✓	✓				The Tempus 2000 device will be used for monitoring a passenger's blood pressure, pulse rate, temperature, ECG, blood oxygen and carbon dioxide levels in emergency cases.
Wireless LAN	Garrett *et al.* [40]	03				✓		Echocardiogram transmission in cardiac emergency from an ambulance in transit to a tertiary care facility
	Lorincz *et al.* [41]	04	✓					Sensor networks for emergency response, system tested using two vital signs monitors
	Clarke *et al.* [21]	04	✓					Wireless connection to sensors and transmission of data from an ambulance Telecare project
	Maki *et al.* [42]	04	✓					Wireless monitoring of sensors on persons that need continuous monitoring, when an emergency occurs the specialized personnel listens a sound alarm or a notification through mobile phone
	Campbell *et al.* [25]	05	✓					Wireless transmission of ECG from Emergency medical care personnel to the department and through wireless LAN to the on-call cardiologist who is carrying a PDA
	Palmer *et al.* [43]	05	✓				✓	Wireless blood pulse oximeter system for mass casualty events designed to operate in WIFI hotspots. The system is capable of tracking hundreds of patients. Suitable for disaster. Control
	Lenert *et al.* [44]	05	✓		✓			Medical care during mass casualty events, transmission of signals, alerts monitor.
	Nakamura *et al.* [45]	03				✓		Wireless emergency telemedicine LAN with over 30 Km distance used in the Japan Alps used for mountain climbers emergency telemedicine
	Pagani *et al.* [46]	03		✓			✓	Web based transmission of cranial CT images. Comparison of the results
	Kim *et al.* [47]	05		✓				Transmission of CT and MRI images through a PDA and wireless high-bandwidth net to neurosurgeons
	Hall *et al.* [32]	03			✓			Wireless access to Electronic Patient Record
	Doukas *et al.* [49]	07			✓			A framework for advanced medical video delivery services, through network and patient-state awareness

into two main categories, those transmitting biosignals such as ECG, Oxygen Saturation, Blood pressure etc., and those transmitting medical images or just pictures of a patient. Some of the presented applications are a combination of both categories. Most of the applications concern the transmission of biosignals and images in order to support prehospital treatment such as [15], [17], or the transmission of biosignals in order to monitor patients with chronic heart diseases [23]. Some of the applications concern the transmission of images only [28]-[31]. Imaging modalities are rapidly changing, thus affecting the medical procedures and the need for new telemedicine applications in order to support these procedures. Finally, one application is used for the access of electronic patient records [33].

The second group covers those applications that use 3G mobile networks. The first one [34] concerns the transmission of biosignals and images of the patient, something that has been extensively presented by many applications in earlier stages. The second one [35] investigates the transmission of real time ultrasound video captured via a remotely controllable robotic arm.

For satellite links; we have only found four new significant studies. We do note however that a significant number of studies using satellite links were published prior to these studies (not reported here). The applications found here, mostly concern the transmission of ultrasound video [36]-[38]. Two of the papers [37], [38] also include the use of a robotic mechanism in order to remotely control the ultrasound acquisition as described above, in the section of 3G networks, while the other two papers [20], [39] concern the transmission of biosignals and images for emergency cases. The Virgin Atlantic press release [39] announces the first wireless telemedicine system that will be adopted by a major airline carrier that will be available in all its flights.

The last category of applications covers the use of Wireless LANs. Basically these applications are for disaster control cases where a lot of injured people might be concentrated in a small area and a Wireless LAN is used in order to monitor the condition of these people. Most of the applications presented here concerns the transmission of biosignals, and the use of sensor networks [41]-[44]. Three of the applications are transmitting images [45]-[47], with CT

images transmitted in [46] and CT and MRI images in [47]. Also, one application is used for the access of electronic patient records [32].

B. Case Study INTERMED- INTERREG III ARCHIMED

A case study of an e-emergency system is the system being developed through the EU Interreg III Archimed, INTERMED project (see http://www.dat.demokritos.gr:8080/intermed). This project supports: a) Tele-collaboration and tele-consultation services between health care personnel. These services will support the provision of expert's advices from central hospitals to rural medicine centers and smaller health facilities, in order to support the diagnosis procedure with a second opinion. b) Home care telemedical services for "at risk" citizens, e.g. elderly, patients with chronic diseases, and post-surgery patients. Those services include the utilization of wireless communications for the provision of on site expert's advices after evaluation of the transmitted vital signals and c) Tele-medicine services in emergency situations, e.g. passengers onboard a ship. Those services will be provided through interconnecting a ferry serving a Mediterranean Sea area via satellite with the hospitals of the network. The services are being supported on a Mediterranean sea network being setup between partners in Cyprus, Greece, and Italy. The communication is being performed using several wireless communication means, depending on each case.

IV. Concluding Remarks

This paper reviews wireless technologies. It also provides an overview of recently published wireless emergency healthcare systems, in which some of the reviewed technology is presented. These systems clearly demonstrate the benefits and the need for their wider deployment.

In a recent study carried out by the World Health Organization (WHO) on e-health tools and services including m-health, it was concluded that countries need: support in the adoption of policy and strategy for the development for e-health; advice on needs assessment and evaluation of eHealth services; information on best practice and trends; and advice on e-health norms and standards. That is countries require consultancy services to assist in all aspects of e-health, and a need for education and training in this area [48].

Concluding, it is expected that m-health e-emergency systems will significantly affect the delivery of healthcare; however, their exploitation in daily practice as well as the monitoring and evaluation of these systems still remains a novel goal, yet to be achieved.

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