30. Wireless Networks in Mobile Healthcare

Pantea Keikhosrokiani[1], Nasriah Zakaria[1,2], Norlia Mustaffa[1], Tat-Chee Wan[1,3], Muhammad Imran Sarwar[3], and Keyvan Azimi[4]

[1] School of Computer Sciences, Universiti Sains Malaysia, 11800 USM, Penang, Malaysia
[2] Medical Education Department, College of Medicine, King Saud University, Riyadh
[3] National Advance IPv6 Centre (NAv6), Universiti Sains Malaysia, Penang, Malaysia
[4] School of Electrical Engineering, Universiti Sains Malaysia, Penang, Malaysia
pantea.kia@ieee.org, {tcwan,norlia,nasriah}@cs.usm.my, imran@nav6.usm.my, keyvan.azimi.64@gmail.com

Keywords: Mobile healthcare, Wireless technologies, Cellular network, Satellite, Diagnosis, Emergency, Remote monitoring, Location-based services.

1 Introduction

With the advancement of telemedicine systems, health information can now be transferred as interactive video over wireless networks. The key features of a mobile wireless network based system are portability, long battery life, ease of use, full duplex support, and optional encrypted communication (Pattichis, 2002). Rapid advances in wireless and mobile communication technologies have led to new categories of services to support healthcare. Telemedicine can be used to deliver healthcare and medical information remotely using wired or wireless telecommunication technologies. POTS (plain old telephone system) and ISDN (integrated services digital network) are two types of wired communication technologies; GSM (global system for mobile communication), GPRS (general packet radio service), UMTS (universal mobile telecommunication systems) and satellite communication are examples of modern wireless telecommunication technologies (Pattichis, 2002).

Mobile wireless communication systems have improved reliable delivery of medical multimedia information services that can be applied to emergency ambulance service, mobile hospital (m-hospital), general health care, early warning systems for health care, and more. Patient information, including videos, images, electrocardiogram (ECG) can be transmitted from the hospital emergency room to other places via 4G cellular network, mobile WiMAX wireless networks and mobile satellite communication systems (MSC). These new options are beneficial for doctors, medical care staff in ambulances, and medical students who are learning and observing medical treatment long distance (Lin et al., 2010). Rapid advancements in network technologies and mobile wireless network infrastructure, along with

S. Adibi (ed.), *Mobile Health*,
Springer Series in Bio-/Neuroinformatics 5, DOI: 10.1007/978-3-319-12817-7_30

improvements in multimedia-based applications, and opening new horizons for those services in the health care management sector and medical informatics.

Mobile telemedicine is one of these new 21st century state of the art technologies. It provides an architecture for transferring biomedical patient information over a wireless communication system anytime, from anywhere with great speed and reliability. Telemedicine encompasses regular healthcare, mobile hospitals, emergencies, maritime, remote monitoring and more. By merging biomedical signals and information technology through a robust wireless communication system which can enable remote medical treatment or health monitoring medical service at any location (Lin and Lee, 2009). Using mobile healthcare systems enables healthcare personnel to improve the efficiency and quality of service (QoS) of medical care. Such healthcare systems can also decrease the number of patient visits to the hospital as well as length of patient stay, since adequate follow-up care can be delivered after the patient has been discharged (Lin et al., 2010).

The objective of this paper is to present a review of the different communication technology components used by healthcare systems as well as various types of healthcare systems that use wireless communication networks as a means of efficient and effective communication between remote patients and healthcare providers. Following this, we highlight the most used commonly used wireless technologies in healthcare systems today.

The structure of this chapter is as follows. Section 2 discusses wireless and cellular communication technologies in use in the healthcare followed by section 3 that highlights medical data transmission in healthcare systems. Section 4 offers a classification of healthcare systems based on publications. Section 5 contains discussion of findings, followed by concluding remarks in Section 6.

2 Communication Technologies in Healthcare

In this section, we review different communication technologies used in healthcare systems and highlight their pros and cons. Some communication technologies are suitable for healthcare systems while others are not. Selecting the right communication technology depends on the specific healthcare situation as well as on the user population.

Healthcare systems are increasingly delivering biomedical signals and other healthcare information over long distances using communication technologies. These same services can be delivered anytime from anywhere using mobile communication systems with high speed and high reliability. Such mobile communication technologies can be applied to a mobile hospital (M- hospital), emergency ambulance services, early warning systems for diseases, illness rehabilitation, general healthcare and so on. As part of pre-hospital medical care, patient information including videos, images, electrocardiogram (ECG) data and pulse biomedical signals can be transmitted via Global System for Mobile communication (GSM), General Packet Radio Service (GPRS), third generation and forth generation (3G and 4G) mobile cellular systems, WiMAX, and mobile satellite communication (MSC) systems (Pattichis et al., 2002, Rashvand et al., 2008). In this section we summarize the main wireless technologies that are used in healthcare systems today, such as GSM, GPRS, 3G, 4G, LTE, Wi-Fi, WiMAX, satellite, WAP, wireless IP, wireless LAN, Wireless Personal Area Networks (WPAN), Wireless Sensor Networks, and Wireless Body Area Network (WBAN). These technologies, along with their frequency band and data transmission rates are illustrated in Table 1.

Table 1 Mobile telephony and satellite communication networking technologies and standards (Kyriacou et al., 2007, Zain et al., 2012)

Type	Sub-Type	Frequency Band	Data Transfer Rate
3G	FDD,WCDMA	1920-1980 MHz UL, 2110-2170 MHz DL	144 hbps- 2Mbps. Typically between 220-384 kbps
	TDD, DTD, CDMA	1900-1920 MHz UL, 2010-2025 MHz DL	As above
	HSDPA	As above	Up to 14.4 Mbps. Typically between 400 kbps- 2 Mbps
Satellite	Satellite	1980-2010 MHz UL, 2170-2200 MHz DL	
	ICO	C, S band	2.4 kbps
	Globalstar	L, S , C band	Up to 56 kbps
	Iridium	L, Ka band	2.4-10 kbps
	Inmarsat	L, C band	4-492 kbps
	Thuraya	L, C band	9.6-144 kbps
	IntelSat	C, Ku band	64 kbps-45 Mbps
	MSAT	L band	1.2-4.7 kbps
Wireless LAN	IEEE 802.11	2.4 GHz	2 Mbps
	IIEEE 802.11la	5 GHz	20 Mbps
	IEEE 802.1 lb	2.4 GHz	11 Mbps
	IEEE 802.1 lg	2.4 GHz	22 - 54 Mbps
	Hiperlanl	5 GHz	20 Mbps
	Hiperlan2	5 GHz	54 Mbps
	HiS WANa	5 GHz	54 Mbps
WiMAX	TDD	3.5 GHz	45 Mbps/Channel
	FDD	3.5 GHz	45 Mbps/Channel
	TDD	5.8 GHz	45 Mbps/Channel
BAN, PAN	Bluetooth	2.4 GHz	2 Mbps
	Zigbee	10 channels at 902- 928 MHz, and 1 channel at 868	20-250 kbps
LTE			50 Mbps to 86.4 Mbps on the uplink, 100 Mbps to 326.4 Mbps on the downlink
4G		700 MHz, 1700/2100 MHz	Min 50-100 Mbps , average 200 Mbps

2.1 GSM

Global System for Mobile communications (GSM) is a second generation mobile communication network. Although GSM was designed for voice telephony, it can carry data as well (Kyriacou et al., 2007, 2012a). Standard GSM supports voice and data-transfer speeds of up to 9.6 kbps together with transmission of SMS (Short Message Service). Enhanced GSM, which is known as High-Speed Circuit-Switched Data (HSCSD), supports data transmission of up to 43.3kbps (Kyriacou et al., 2007, Pattichis et al., 2002, Kumar et al., Kumar et al., 2010). Many frequencies are available for GSM according to the various GSM sub-types, but the most common are 900, 1800, and 1900 MHz (Hillebrand, 2002, Pattichis et al., 2002).

2.2 GPRS

General Packet Radio Service (GPRS) is a packet-based mobile data service. It is designed to work on 2G and 3G cellular communication systems that are used for voice communications, such as GSM and PDC (Personal Digital Cellular). Maximum downlink data rate for GPRS is around 171 kbps (Kumar et al., Kyriacou et al., 2007). GPRS enables users to access advanced online services on the move, including e-mail, multimedia messages, social networking, ftp, HTTP-based web services, and location-based services from almost anywhere (Kumar et al., 2010).

Most telemedicine applications use GSM/GPRS networks to support prehospital treatments. These applications are divided into two main groups: 1) those transmitting bio-signals such as ECG, oxygen saturation, blood pressure, etc.; and 2) those transmitting medical images (Kyriacou et al., 2007, Kumar et al., 2010). Some applications combine both types of information (Pavlopoulos et al., 1998, Istepanian et al., 2001). Some applications transfer bio-signals in order to allow healthcare providers to monitor chronic heart disease patients (Salvador et al., 2005) while other applications are limited to transferring only images (Schächinger et al., 1999, Voskarides et al., 2003). GSM/GPRS can also be used to access electronic patient records (Istepanian et al., 2006b).

2.3 Third-Generation (3G) Wireless Networks

Mobile telemedicine becomes faster and more effective as it moves from second generation (2G) to 2.5 G and 3G (W-CDMA, CDMA2000, TD-CDMA) systems as these systems provide a faster data transfer rate (Kyriacou et al., 2007). With 3G enabled systems, telemedicine systems can employ a data-transfer speed of 14.4 Mbps (typically, around 1 Mbps) which was formerly only feasible on wired communication networks (Kyriacou et al., 2007, 2012a). Because of this high data-transfer rate of 3G, many healthcare systems prefer it. The first application of 3G to medical service was by (Chu and Ganz, 2004) who presented a cost-effective portable teletrauma system to offer prehospital trauma care. The proposed system would transmit a patient's medical images, video, and electrocardiogram signals over 3G wireless cellular data service to the responsible healthcare center. (Navarro et al., 2006) proposed a multi-collaborative mobile healthcare system using 3G mobile networks.

The next application (Lim et al., 2007) was a system for delivering medical reports from a medical imaging department to the referring doctor via 3G GSM mobile phones. Another relatively recent application (Garawi et al., 2006) investigated transmission of real-time ultrasound video by presenting end-to-end mobile tele-echography using an ultra-light robot (OTELO) over the 3G mobile communications network. Y. Chu and A. Ganz (2004) proposed a mobile tele-trauma system that would provide pre-hospital care for patients residing at remote locations using 3G cellular networks. The system could be installed on mobile tablet PCs in ambulances and patient information such as video, image, and electrocardiogram signals could be transmitted through cellular networks (Chu and Ganz, 2004). Due to the low data rate of 3G networks, compression technology was used to make the transmission more efficient. A similar system employing Universal Mobile Telecommunication System (UMTS) was used for communication between ambulance and hospital (Gallego et al., 2005). Trauma care through the transmission of patient video, medical images, and ECG along with OTELO was extensively investigated and implemented as applications over 3G cellular networks by (Chu and Ganz, 2004, Garawi et al., 2006). The HYGEIAnet project encompassed the design, development and deployment of advanced e-health and m-health services at various levels of the healthcare system, including primary care, pre-hospital emergency management, and so on. The system accommodates 600,000 people across 7 hospitals and 16 primary health centers using. 3G cellular network for communication between different hospitals and centers (Tsiknakis et al., 2002). The deployment of HYGEIAnet project services has shown significant economic, clinical and access care benefits with 65% of pre-hospital care managed by paramedics, and won a 2005 eEurope award.

2.4 Fourth-Generation (4G)

Fourth Generation (4G) mobile phone communication is a more advanced version of 3G which provides mobile ultra-broadband internet access. In the next few years, 4G wireless networks will become more widespread and users will be able to access multiple networks without changing from network to network manually (Varshney, 2007). 4G systems have higher transmission speeds than 3G (min 50-100 Mbps, average 200 Mbps) and they are supported by internet protocols (IPv6). They can provide services from anywhere at any time because 4G networks are IP-based heterogeneous networks. In addition, users can access and run a broad range of applications from multiple networks. All of these factors demonstrate the high usability of 4G. Moreover, multimedia services provided by 4G systems have lower per-bit transmission costs with high data transfer rate and good reliability. The services can be more personalized in order to meet diverse users' demands and users are able to take advantage of multiple services from different service providers at the same time. Consequently, future healthcare networks will offer "personalized predictive healthcares" and "Virtual Mobile Hospitals and Specialised M-Health Centers." 4G technologies will allow the healthcare sector to develop effective medical care delivery that will benefit both patients and physicians (Istepanian et al., 2006c).

Istepanaian and Zhang (2012) introduced the new and novel concept of 4G health which they argue represents the long-term evolution of m-health, and discussed the long-term evolution, challenges, and future implementation issues of 4G m-health (Istepanaian and Zhang, 2012).

2.5 Long Term Evolution (LTE)

The recent growth of mobile applications motivated the 3rd Generation Partnership Project (3GPP) to work on a new project which they dubbed Long-Term Evolution (LTE). LTE is a standard for wireless data communications technology and an evolution of the GSM/UMTS standards. The main goal of LTE is to provide a unique and efficient mobile system for public use. In the beginning, the focus was on broadband service using GSM framework. LTE has been used in most parts of the world with advanced mobile communication technology.

Several features of 3G needed to be modified in order to improve mobile communication networks and their service sectors. Therefore, the next project of LTE was the achievement of 4G which is advanced personal mobile communication technology with "all packet-based system" and focused on IPv6 (Adibi et al., 2010). Technology remains a concern for wireless networks in mobile healthcare applications. Managing healthcare systems, especially in emergency situations, is crucial; network support is thus an important issue in healthcare, especially in location tracking and routing protocols. The healthcare system must be reliable in order to provide continuous monitoring of patients in various environments. To meet healthcare systems' various needs and requirements, Fourth generation (4G) networks are proposed as a way to tackle these limitations and enable high speed broadband communication within the service providers' networks. LTE could be the best candidate for supporting robust healthcare applications and making them available anytime and anywhere to a wide range of potential users (Zain et al., 2012).

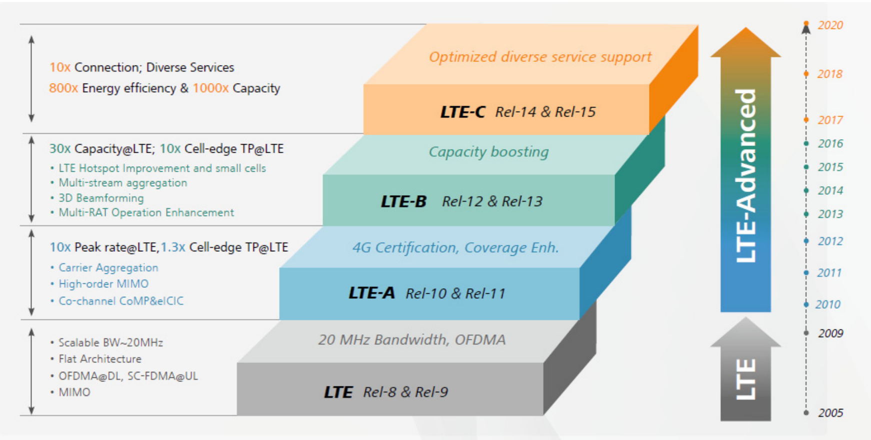

Fig. 1 The Evolution of LTE for 2005 to 2020

The cellular industry has, in the past several years, undergone a profound paradigm shift. The shift to mobile broadband has resulted in not just an increased appetite for mobile data services but also a philosophical shift in end-user habits, from relying on personal computers to relying on mobile smartphones. As a consequence of this socio-technological trend, the amount of data carried on cellular networks is growing explosively. Anticipating this, 3GPP initiated an investigation into E-UTRA (Evolved Universal Terrestrial Radio Access) in 2004; E-UTRA specified the first release of LTE (Rel-8) in March 2009, with later releases of LTE-Advanced to meet ITU-R IMTAdvanced (also called as 4G) requirements; while LTE-Advanced continues to evolve, introducing new features and supporting higher performance and broader services, including multiple market phases; LTE-A, and LTE-B, may be followed by LTE-C and so on in the future, as shown in the LTE roadmap in Figure 1.

2.5.1 LTE-A

Release 10 of the 3GPP specifications, released in 2011, is the initial phase of LTE-Advanced. LTE-A is one a framework for further advancements in LTE in order to meet 4G requirements and has been approved by the International Telecommunications Union- Radiocommunication sector (ITU-R). Attaining the data rates set by the International Mobile Telecommunications Advanced (IMT-Advanced) standard was one of the goals of LTE, and the LTE-A accomplishes this. LTE-A extends LTE to "the coverage of high data rates, group mobility, temporary network deployment, the cell-edge throughput or to provide coverage in new areas" (Lee and Vasilakos). LTE-A is expected to support instantaneous peak data rates of 1Gbps and 500Mbps for the downlink and uplink respectively. Moreover, the standard is also expected to provide wider bandwidth, lower latency, and higher peak and average efficiency (Saleh et al., 2009, Stencel et al., 2010). Other performance enhancements considered in LTE-A include coordinated multipoint transmission and reception (CoMP), relaying, support for heterogeneous networks, LTE self-optimizing network (SON) enhancements, home enhanced-node-B (HeNB) mobility enhancements, and fixed wireless customer premises equipment (CPE) RF requirements.

2.5.2 LTE-B

LTE-B is the second phase of LTE-Advanced and was developed for capacity boosting. LTE-B will reduce the cost and energy consumption per bit of transmission as well as offering excellent support for social networking, video sharing and so on. LTE-B provides stable access with more throughput at cell edge in comparisone with the LTE Rel-8 system. LTE-B is designed to improve the standard in several categories including: further multi-antenna enhancements with 3D-beamforming, LTE hotspot improvements along with small cell spectrum efficiency enhancements, small cell efficient operation with traffic adaption and interference coordination, heterogeneous networks (HetNet) mobility enhancement and multiple stream aggregation, HetNet frequency-division duplexing(FDD)/ time-division duplexing (TDD) joint operation, LTE interworking enhancement, WiFi interworking, minimization of drive test (MDT). It will also offering new services such as machine type communications (MTC), proximity based services (ProSe), and group communication service for LTE (GCSE_LTE).

LTE-B combines multiple technologies such as HetNet deployment with Macro-assistant coordinated small cells, 3D MIMO technology, LTE-centric multi-RAT operations, and more. This combination of technologies allows LTE-B to be a highly efficient, cost effective and flexible system more capable of fulfilling end user expectations. In particular the enabling technologies offer improved the capacity, more efficient network operation, flexible multi-radio access technology (RAT), all of which will enable it to support diverse applications and new services that are expected in the future. It will form the backbone of a new world of high definition mobile social video with ubiquitous broadband access and edge-free user experience.

2.5.3 LTE-C

LTE-C (Rel14/Rel15) the third phase of LTE-Advanced is currently being developed. Its goals are to further improve energy efficiency, capacity, connection and diverse services.

2.6 IEEE 802.16/WiMAX Systems

Worldwide interoperability for Microwave Access (WiMAX) is a wireless communication standard defined by IEEE 802.16. WiMAX provides broadband wireless access up to 50 km for fixed stations and 5-15 km for mobile stations. WiMAX thus has advantages over WLAN and is intended for wireless “metropolitan-area networks” (WMANs). WiMAX works between 2 GHz and 66 GHz with a maximum throughput of 70Mbps (Niyato et al., 2007, 2012b). WiMAX is considered a more suitable technology for healthcare applications than WLAN for several reasons. WiMAX can provide broadband access to both fixed mobile networks. It can use high bandwidth to transfer high-quality medical images and provide good video-conferencing between patient and healthcare center. It incorporates MAC layer security features (Niyato et al., 2007). Li, et al. (2012) designed a WiMAX-based emergency system in order to provide immediate online emergency treatment instructions via video and audio transmission between healthcare center, hospitals and emergency ambulances (Li et al., 2011). Lam, et al. (2009) proposed a WiMAX-based telemedicine system for emergency medical assistance in the ambulance; the system will shorten the emergency period and organize medical treatment properly to the arrival at the hospital (Lam et al., 2009).

2.7 Ad-Hoc and Sensor Networks in Healthcare

Most wireless systems require a built infrastructure and wired backbone network; ad-hoc and sensor networks, however, do not need any wired infrastructure. In Mobile Ad-hoc Networks (MANETs), mobile nodes are geographically distributed and interact with one another while on the move over a wireless medium. Thus, there is no communication with base stations. In terms of emergency systems where there are time limitations and deficiencies of wired infrastructure these kinds of networks are really helpful (Karl and Willig, 2005). A sensor network consists of many sensor nodes inside, or close to, the object or area of interest. Each sensor has an on-board processor and is able to collect and rout data. In the case of healthcare systems, these sensor nodes can be positioned to monitor patients (Akyildiz et al., 2002). Varshney (2008) designed a framework for patient monitoring that would support emergency messages by using a wireless ad hoc network. The system consists of patient monitoring devices, routing protocols and information presentation for vital signs and parameters. The performance results demonstrate the reliability of message delivery and low monitoring delays that can be accomplished through multicast or broadcast-based routing schemes (Varshney, 2008).

2.8 Satellite in Healthcare

Satellite has some advantages over other technologies. It has various data transferring rates (from 2.4 kbps to more than 2 x 64 kbps) and satellite links can function all around the world. However, satellite needs higher power as well as line-of-sight for transmission (Reinaldo, 1999, Pattichis et al., 2002). Thus, satellite has been used in many healthcare systems with different functions such as remote monitoring, emergency services, and telecardiology, especially in aircraft and ship settings (Pattichis et al., 2002). Adequate emergency healthcare services are essential for those traveling by aircraft or ship, as well those living in remote locations (e.g., mountains, islands forests). Mobile satellite communication (MSC) methods are a good solution for these kinds of situations, since they can provide interactive medical video conferencing. Numerous researchers (Murakami et al., 1994, Anogianakis et al., 1998, McDermott et al., 1999, Seon-Cheol and Myoung-Ho, 2000, Pierucci and Del Re, 2000) have explored the idea of video conferencing using a satellite communication system due to its advantages of wide-area coverage and ability to provide broadcast and multicast connections.

(Murakami et al., 1994) proposed a telemedicine technique using satellite communication for aircraft and ship. The study measured various characteristics such as channel capacity, real-time operation, size of the system, electromagnetic interference, and reliability of vital sign transmission along with overall effectiveness of the system. The proposed system would send color images, audio, ECG (3channels) data and blood pressure reading from the mobile device to the ground station, and transmit audio and error control signals from the ground station to the mobile device. Experiments with medical data transmission were conducted while participating ships and aircraft were moving. Therefore, the feasibility of this technique has been verified.

Satellite technology is particularly useful for remote healthcare delivery in a maritime environment. A number of projects have been proposed, including the EU's MERMAID project as well as others by Anogianikis, McDermott, Seon-Cheol & Myoung-Ho, and more. Refer to section 4.3.1 for a more detailed discussion of this research area (Anogianakis et al., 1998). McDermott et al. (1999) also proposed a maritime telemedicine system for high-speed medical data transmission using satellite networks (McDermott et al., 1999).

Seon-Cheol and Myoung-Ho, (2000) developed the telePACS maritime telemedicine system that can access a hospital`s picture archiving and communication system (PACS) servers using the Internet. They used Java to implement their system for browsing medical data and images via browsers such as Netscape. Finally, they proposed a fast and cost-effective PACS using web technology not only for inter-hospital but also for public use (Seon-Cheol and Myoung-Ho, 2000). (Pierucci and Del Re, 2000)developed a telemedicine application called Medical Environment for Diagnostic Images (MEDI) to provide remote medical care services. This system uses the broadcast and multicast ability of satellite as well as wide-band capacity. The system uses a Java client-server architecture based on TCP/IP. They evaluated the performance of the proposed application based on satellite connection. Li and Takahashi et al. (2009) proposed a Wireless Body Area Network (WBAN) system using satellite communication to sustain remote medical treatment and healthcare especially in emergency cases in rural or isolated areas. The system sends equivalent biosignals to the hospital so that doctors can assist patients remotely. The delay of system data delivery is measured that demonstrate that satellite link capacity has strong effect on transmission delay (Li et al., 2009).

2.9 WAP-Based Healthcare System

A combination of Internet and mobile communication along with improved handheld devices, wireless infrastructures, application programming languages, and protocols has made it possible to offer mobile Internet access. Wireless Application Protocol (WAP), which is a technical standard for accessing information over a mobile wireless network, has become a hot trend in telecommunication. WAP provides a communication protocol and application environment for the purpose of advanced telephony services and Internet access from mobile devices. E-banking, e-shopping, email, and games are typical examples of WAP application. WAP overcomes the limitation of interactive data services offered by service providers. Thus, WAP can be valuable in the healthcare field (Kumar et al., Hung and Zhang, 2003). Hung and Zhang (2003) developed a WAP-based telemedicine system for patient monitoring which utilized WAP devices as mobile access terminals for general inquiry in store-and-forward mode (Hung and Zhang, 2003). On the other hand, Paro (2001) pointed out that WAP has some limitations such as lower bandwidth, connection stability, and predictable availability; push operation is not specified; and a lack of cookies for session management. These disadvantages negatively affect the efficiency of WAP (Paro, 2001).

2.10 Wireless IP for Healthcare

Internet Protocol (IP) telephony is defined by the International Telecommunication Union (ITU) as “the conveyance of voice, fax and related services partially or wholly over packet-switched IP-based networks". It consists of Internet telephony and Voice-over-Internet-Protocol (VoIP); Internet telephony utilizes the public Internet, while VoIP employs privately managed IP-based networks, in addition to the public Internet (Zhao et al., 2002). Nowadays, VoIP is attracting more attention due to its ability to deliver real-time, two-way, synchronous voice and data traffic over packet-switched IP-based networks (Davidson and Peters, 2000). IP developed into a unifying platform for all methods of communication after deployment of 3G systems, and may be useful in the future development of public switched telephone network (PSTN), mobile network, fixed wireless and the Internet in the communication industry. IP telephony can be used for the transmission of voice as well as a combination of voice with other information because it uses network capacity more efficiently, reduces cost, manages enhanced services better, and offers more flexibility (Zhao et al., 2001).

Currently the use of wireless and IP based applications in healthcare systems is still in the development phase. These kinds of applications will improve healthcare systems by offering capabilities that are impossible through the usual telephony. Zhao, et al (2001) proposed a prototype wireless IP telephony system for telemedicine that would transmit voice and data in a wireless mobile environment (Zhao et al., 2001). Pandian et al. (2007) proposed a prototype wireless IP based store-and-forward telemedicine system that applied Very Small Aperture Terminal (VSAT), satellite communication and WLAN. Physiological data and medical images with videoconferencing were supported by this system (Pandian et al., 2007). (Husni et al., 2006) designed a mobile telemedicine system that would transfer medical healthcare data in emergency situations using a combination of Mobile Internet Protocol version 6 (MIPv6), and MANET, and IEEE 802.11 WLAN technology.

2.11 Wireless LAN in Healthcare

A Wireless Local Area Network (WLAN) is a wireless communication method that provides a connection to the wider internet via access points (cells). A WLAN data communication system is an extension of wired LAN but with higher flexibility. WLANs become popular in the healthcare environment after the introduction of the 802.11 standards; around 50% of hospitals have 802.11 local-area networks (LANs) installed (Baker and Hoglund, 2008). WLAN also became popular in retail, manufacturing, warehousing, and academia. It offered a data transmission rate of tens Mbps and limited user mobility. WLAN coverage is limited to about 100 meters per cell, making it sufficient for covering the area of a hospital (Kyriacou et al., 2007, Pattichis et al., 2002). Lin et al. (2010) proposed a WLAN transmission scheme based on the IEEE 802.11n standard to develop an effective wireless telemedicine application. This system is able to transmit clinical information with a high quality of service (Lin et al., 2010). In the case of a disaster situation where many people might be injured in a small areas, a WLAN-based monitoring application was proposed in order to monitor the condition of the injured (Palmer et al., 2005, Lenert et al., 2005). These applications could transmit CT (computed tomography) and MRI (magnetic resonance imaging) images collected by the bio-signal and sensor networks (Kim et al., 2005).

2.11.1 Wi-Fi (IEEE 802.11)

Wi-Fi can be defined as any WLAN that is based on the IEEE 802.11 standard. The original IEEE 802.11 was finalized in 1997. It specified a Medium Accesses Control (MAC) sub-layer combined with three physical layers: Frequency Hopping Spread Spectrum (FHSS), Direct-Sequence Spread Spectrum (DSSS) and Infra-Red (IR). These three physical layers ran at 1 and 2 Mbps. Two of these three layers FHSS and DSSS, were radio based with 2.4 GHz carrier. Two years later in 1999, IEEE 802.11a was ratified. It introduced a physical layer with orthogonal frequency division multiplexing (OFDM) operating in the UNII band (5GHz) and 54 Mbps. In mid 1999, IEEE 802.11b was proposed; it had a similar physical layer to the original IEEE but specified a higher net bit rate of 11 Mbps using complementary-code keying (CCK) (Paul and Ogunfunmi, 2008). In early 2003 IEEE 802.11g was released, which was a merging of IEEE 802.11a and IEEE 802.11b. 802.11g specifies four physical layers with a data rate of 2.4GHz and bit rate of 54Mbps. The four physical layers were Extended Rate Physicals (ERP)-DSSS/CCK, ERP-DSSS/PBCC, ERP-OFDM and DSSS-OFDM. The first two layers were the same physical layers used by IEEE 802.11b while the last two were new layers introduced with IEEE 802.11g. This new standard offers short preamble support, interoperability and CTS-to-self mechanism(Vassis et al., 2005).

(A) IEEE 802.11n: Although simulation testing proved the good performance of IEEE 802.11g, especially in the case of improving channel capacity, some issues remain. For example, a demand for simultaneous high-quality video-streaming by more than one user brought a motivation for providing higher throughput. IEEE 802.11n was the first attempt to fulfill this goal. It was published after 11 drafts in 2009. It is designed to provide a variety of services like higher data rates, better Quality of Service (QoS), more reliability, and network security. IEEE 802.11n improved both the physical layer and MAC layer to support throughputs beyond 100 Mbps, surpassing previous 802.11 standards. It maintains backwards compatibility by being compatible with previous IEEE 802.11 standards (Perahia and Stacey, 2008). The physical layer consist of: (1) Enhanced OFDM, which produces a high data rate of 65Mbps and achieves higher transmission speed; (2) Multiple-Input Multiple-Output/ spatial division multiplexing (MIMO/SDM) technology, which uses multiple antennas in both transmitter and receiver to send more than one data stream simultaneously. This is the most significant technology in the physical layer. Its pivotal feature is to increase data rate with SDM to 135Mbps in the real world. Link robustneed is improved by using MIMO along with optional techniques such as space-time block coding (STBC), spatial expansion, receive diversity, transmitter beamforming and low-density parity check (LDPC). (3) Channel bonding, which provides a 40MHz channel in both the 2.4GHz and 5GHz band by bonding two adjacent 20MHz channels. The combination of channel bonding with OFDM maximizes performance. Coupling MIMO with wider bandwidth can increase the data transfer rate up to 600Mbps (Perahia and Stacey, 2008).

The MAC layer consists of two components: (1) Frame aggregation, used in IEEE 802.11n to improve transmission efficiency. It aggregates multiple data frames coming from the upper layer into a single frame in order to reduce overhead. There are two types of aggregation: Aggregate MAC Service Data Unit (A-MSDU) and Aggregate MAC Protocol Data Unit (A-MPDU). (2) Block ACK (BA) mechanism used in IEEE 802.11n with a frame aggregation mechanism because a larger data frame causes an increased frame error rate. If an error is found in a frame, a BA will be generated to the sender stating that an error has occurred. The sender has to retransmit only those parts of the frame which are incorrect. BA can be applied on A-MPDU but not on A-MSDU (Perahia, 2008).

(B) IEEE 802.11ac: The rapid growth of mobile data traffic worldwide requires a high data rate to support video, live gaming and voice. Consequently, a standard is needed to be able to deal with next-generation mobile networks. IEEE 802.11ac builds upon IEEE 802.11n to provide throughputs of 500 Mbps for a single user and at least 1 Gigabit per second (Gbps) for multiple user on the 5 GHz band (Eng Hwee et al., 2011). IEEE 802.11ac takes advantage of existing IEEE802.11n features as well as adding some new features to afford Very High Throughput (VHT). New features specified in the physical layer including the following : (1) Multi-user MIMO technology, an evolution of MIMO, to transmit data to multiple clients simultaneously from a single access point; (2) Channelization for 20, 40, 80 and 160 MHz, to support wider channel bandwidth -- this is a low cost alternative to achieve higher data rates (Eng Hwee et al., 2011). New features in the MAC layer include explicit channel feedback to regularly provide information about channel state to the access point in order to achieve reliable communication in multi-antenna systems (Redieteab et al., 2012).

(C) IEEE 802.11ad: Throughput intensive applications like wireless I/O and uncompressed high-definition multimedia transmissions, which demand high data retests, motivated the industry to use 60MHz band . IEEE802.11ad is able to support multi-gigabit data transmission up to 7 Gbps (Perahia and Gong, 2011, Xiaoyi et al., 2011). Features proposed in the physical layer include: (1) Two operating modes in 2.16GHz channel bandwidth: OFTM for high performance application and Single Carrier (SC) for low power transceivers with low complexity; (2) a common preamble used by CS and OFDM for a simpler implementation and better coexistence (Cordeiro et al., 2010). Features proposed in the MAC layer include: (1) A combination of contention-based CSMA/CA along with a contention free TDMA, to support all kind of applications like web browsing with lower average latency or video transmission that demands a high QoS; three types of ACK mechanism offered are No- ACK, Block ACK and immediate ACK (Xiaoyi et al., 2011). (2) Personal Basic Service Set (PBSS), a new architecture, which enables two devices to have a direct communication with each other without any special devices like AP; this architecture makes possible new applications such as fast audio-video transmission to a projector or fast device synchronization; (3) Fast Session Transfer (FST), a pivotal major innovation mechanisms, which provides fast transition between different channel/ bands and enables devices to switch from a high frequency channel like 60 MHz to a lower frequency channel (Cordeiro et al., 2010).

Wi-Fi is widely used by hospitals today as it offers reliable, security-protected transmission of data and messaging. Wi-Fi can assist hospitals in track assets and patients inside its walls. As a consequence of the needs in hospitals -- from PC networking to the proliferation of Wi-Fi devices such as Smartphones, tablets, and patient monitoring devices -- Wi-Fi systems in hospitals are growing significantly. Wi-Fi networks offer hospitals a proven, interoperable and security-protected system for handling a broad range of devices and data transfers. However, in order to maximize the benefits of Wi-Fi for hospitals several points specific to the hospital environment must be considered. Among these are security requirements for patient records, the mobility needs of devices, "always on" network uptime requirements to accommodate patient monitors and applications, real-time access to records and data transfers, and continuously increasing bandwidth demands.

2.12 IEEE 802.15

2.12.1 Wireless Personal Area Networks (WPAN)

A wireless personal area network (WPAN) is a short-range wireless network defined by IEEE standard 802.15. It can cover only few meters and it can be used only for personal devices such as cell phones or personal digital assistants (PDAs), printers, and computers without any wired connection. The most relevant WPAN technologies in the healthcare field are Bluetooth (Blueooth, 2012) and ZigBee (Kumar et al., 2010). Bluetooth is a wireless technology that works at the 2.4 GHz frequency to allow communication electrical devices. The data transmission rate of Bluetooth is 723 kbps (Barnes, 2002, Rasid and Woodward, 2005). Since Bluetooth is a low-cost, low-size and low-power wireless technology, it is appropriate for short-range personal area network (PAN) applications. Data transmission range is 10-100 meters and obstacles such as walls do not have any effect (Kumar et al.). Rasid and Woodward (2005) discussed a processor that would transmit biomedical signals to a mobile phone using Bluetooth (Rasid and Woodward, 2005). ZigBee (IEEE 802.15.4 standard) has a low data rate of 20-250 kbps. and uses 16 channels at 2.4 GHz, ten channels at 902- 928 MHz, and one channel at 868-870 MHz. It has very long battery life and very low complexity. ZigBee can also be used in short-range wireless telemedicine applications (Kumar et al., Lin, 2010, Kumar et al., 2010).

2.12.2 Wireless Body Area Network (WBAN)

Body Area Networks (BANs) play an important role in healthcare systems today. A BAN consists of different nodes capable of sensing, sampling, processing, and communicating physiological signals (e.g., body temperature, heart rate, blood pressure, blood oxygen saturation, blood glucose level), physical activity (e.g., body posture, type and level of activity), and environmental parameters (e.g., location, temperature, humidity, light, atmospheric pressure). These nodes can be located directly on the human body or attached to clothing. If they communicate wirelessly, the system is referred to as a Wireless Body Area Network (WBAN) (Jovanov and Milenkovic, 2011). WBAN developed as a means of increasing the use of wireless networks in healthcare and minimizing the electrical devices. In a WBAN, these wearable sensors have ability of establishing wireless communication network. The wearable sensors are used to monitor patients continuously and send real time feedback to medical personnel (Arrobo and Gitlin, 2011, Crosby et al., 2012, Beno et al., 2011, Latre´ et al., 2010).

(W)BANs consist of three types of components, which may or not be wireless sensors, actuators, and (Wireless) personal device (PD). Sensors measure certain parameters of the human body internally or externally as shown in Figure 2, including heartbeat, body temperature or even recording a prolonged electrocardiogram (ECG). It comprises several components: sensor hardware, a power unit, a processor, memory and a transmitter or transceiver. Actuators perform specific actions consistent with the data they receive from the sensors or through interaction with the user -- for instance, an actuator equipped with a built-in reservoir and pump that administers the correct dose of insulin to a diabetics patients based on glucose level measurements. An actuator consists hardware (e.g. a reservoir to hold insulin), a power unit, a processor, memory and a receiver or transceiver. The personal device (PD) is responsible for collecting all the information obtained by the sensors and actuators and gives the user (patient, doctor, nurse, etc) the necessary information by displaying it on the device. PD components are a power unit, a (large) processor, memory and a transceiver (Latre´ et al., 2010).

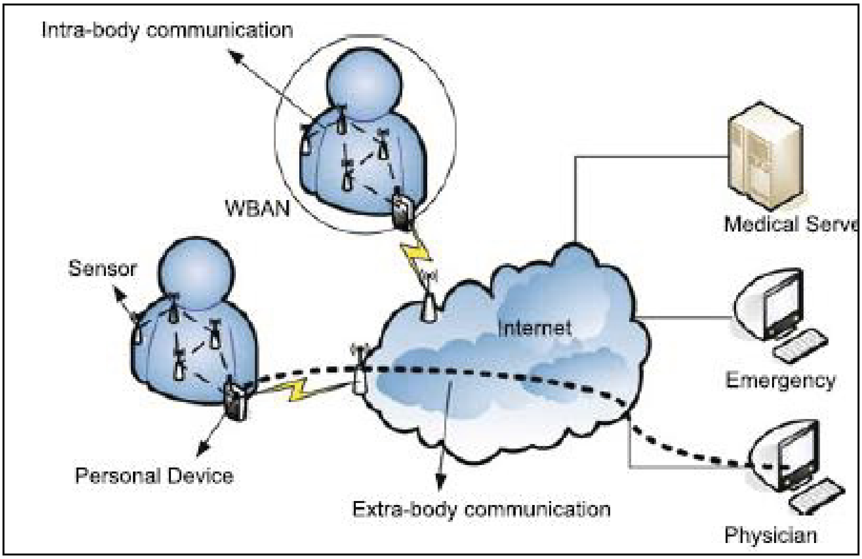

Fig. 2 Intra-body and Extra-body Communication in a WBAN

Data rates will be different depending on the application (simple data at a few kbs to video at several Mbps). Table 2 illustrates the data rates for a range of different applications. In addition, it shows the desired accuracy of the measurements as well as required bandwidth. As depicted in the table, the essential data rates for a WBAN are not high. However, the data rate can reach a few Mbps by adding devices such as motion sensors, ECG, EMG, glucose monitoring, etc. (Penzel et al., 2001, Arnon et al., 2003, Beno et al.). WBAN applications can be categorized according to usage of that application. WBAN is usually used for medical treatment and diagnosis in healthcare networks. There are WBAN applications for the diagnosis and treatment of many diseases, such as Cardiovascular Disease (CVD), Paraplegia, Cancer, Alzheimer`s, depression, Hypertension, Diabetes, Asthma, Defective Tooth positions, epileptic Seizures, Visual impairments, High Blood pressure, Parkinson's disease, renal failure, and Post-operative monitoring (Barakah and Ammad-uddin).

Table 2 Examples of Medical WBAN Applications (Beno et al., 2011, Theogarajan et al., 2006, Penzel et al., 2001, Arnon et al., 2003, Gyselinckx et al., 2007, Latre´ et al., 2010)

Application	Data Rate	Bandwidth (Hz)	Accuracy (bits)
ECG(12 leads)	288 kbps	100–1000	12
ECG (6 leads)	71 kbps	100–500	12
EMG	320 kbps	0–10,000	16
EEG (12 leads)	43.2 kbps	0–150	12
Blood saturation	16 bps	0–1	8
Glucose monitoring	1600 bps	0–50	16
Temperature	120 bps	0–1	8
Motion sensor	35 kbps	0–500	12
Cochlear implant	100 kbps	–	–
Artificial retina	50-700 kbps	–	–
Audio	1 Mbps	–	–
Voice	50-100 kbps	–	–

3 Medical Data Transmission in Healthcare

Transmitting various kinds of data and using different types of communication technologies makes for a wide diversity among remote healthcare systems. Data that is transmitted by healthcare systems can be bio-signals such as electrocardiogram (ECG), electroencephalogram (EEG), surface electromyogram (SEMG); bioacoustic signals (lung, heart, and bowel sounds) (Hadjileontiadis, 2006); vital statistics such as blood pressure, oxygen saturation, body temperature, pulse, saturation of haemoglobin (SpO2), blood glucose, etc. Remote healthcare systems may also want or need to transmit image or video data (Kyriacou et al., 2007, Pattichis et al., 2007, Lin, 2010, Hadjileontiadis, 2006). Remote access to electronic patient record (EPR) data will be mandatory for the healthcare system in order to improve the quality of care delivered in emergency situations (Hall et al., 2003). The underlying communication technology that sends the required patient data to the hospital, clinic, medical laboratory, or other facility can be GSM, GPRS, 3G, CDMA, satellite, wireless LAN, 4G, WiMAX etc. As discussed earlier, each of these communication technologies has its own frequency band, data transfer rate and coverage rate. The figure shows the abstract architecture for all the telemedicine systems that are discussed and covered in our paper. Telemedicine includes healthcare, mobile hospital, emergency situation, maritime telemedicine, remote monitoring system, etc.

4 Classification of Mobile Healthcare Systems

This section provides an overview of different healthcare services. We have categorized them into four main groups: (1) diagnostic healthcare systems (e.g., tele-cardiology and tele-radiology), (2) emergency healthcare systems (e.g., consultation), (3) remote monitoring systems (e.g., maritime healthcare; healthcare systems for diabetics), and (4) location-based healthcare systems. These are summarized in Figure 3 for further elaboration. Furthermore, we discussed about the wireless technologies used in these systems, type of data transmitted by these systems, and their system framework and features.

Fig. 3 Classification of Healthcare Systems

4.1 Diagnostic Healthcare Systems

Diagnostic healthcare systems refer to those systems that determine or identify the possible disease or disorder. Mobile health (mHealth) systems would allow physicians to diagnose, monitor, and treat patients remotely without compromising standards of care. The following sections discuss tele-cardiology and along with tele-radiology. Table 3 provides some examples of diagnostic healthcare systems along with the transferred biomedical data, the technology that they use, and their system features.

4.1.1 Tele-Cardiology

(Ernest et al., 2011) proposed a ZigBee-based Tele-cardiology system for remote healthcare service delivery that minimizes the communication gap between doctor and patient by giving doctors the ability to monitor and diagnose their patients remotely via the Internet. They proposed ZigBee communication technology be used to transmit data from sensors on the patient`s body to the hospital. (Chin-Teng et al., 2010) presented a novel and intelligent telecardiology system that was cost-effective and provided features like wireless communication, ambulatory service, real-time and auto-alarm intelligent telecardiology system. In their system, a small, light-weight, power-saving wireless device collects ECG signals and transmits them to a nearby mobile or ubiquitous device via Bluetooth, where they are then processed and sent to the remote database server that can be accessed via an Internet browser. Their system also has the capability to notify EMS if the sensors detect an emergency. In order to transmit ECG signals and images , (Sufi et al., 2009) proposed an ECG compressed algorithm, real-time and auto-alarm intelligent system that would use lightweight power saving wireless ECG mobile and ubiquitous devices with automatic expert wireless system that has the ability to activate EMS. Furthermore, (Iftikhar et al., 2010) proposed a novel approach for providing cost-effective cardiac services in remote rural areas; it would evaluate patients using a hybrid approach combining frequent tele-consultation with in-frequent in-person meetings, as well as offering an educational component.

4.1.2 Tele-Radiology

Teleradiology is a rapidly evolving specialty in telemedicine. Mobile based teleradiology was proposed and discussed by (Ninos et al., 2010). In their system, a PDA acts as a terminal with a secure connection for thyroid nodule diagnostics, enabling the hospital's picture archiving and communication through DICOM protocol using Wi-Fi communication technology. They evaluate their proposed system in terms of features such as mobility, usability, stability, and performance with their prime focus on ease of use for the medical practitioners who would use their system. (Ruotsalainen, 2011) proposed a privacy and security model for teleradiology in order to gain the trust of both patients and medical practitioners. Their proposal explains how teleradiology can be integrated into an eHealth telemedicine system using sms and email. Their security features include dynamic and context-aware security and privacy policies. (Abdullah et al., 1999) explained the brief history of teleradiology and its role in healthcare telemedicine with options using ISDN, ATM and satellite communication.

Table 3 Examples of Diagnostic Healthcare Systems

Author	Framework	Biomedical data	Technology	System features
		Tele-cardiology		
(Ernest et al., 2011)	Remote healthcare service delivery	ECG serial stream data,	ZigBee, Internet	• Diagnosis and continuous monitoring remotely
(Chin-Teng et al., 2010)	System using wearable and wireless ECG to detect atrial fibrillation	ECG wireless signals	Bluetooth, Internet	• Wireless, ambulatory, real-time and autoalarm intelligent system • Lightweight and power saving wireless ECG device • Automatic expert wireless system • Ability to activate EMS
(Sufi et al., 2009)	ECG compressed algorithm	Wireless signals	SMS, MMS, HTTP, custom socket	• ECG compressed algorithm for bandwidth constrained wireless link • Algorithms for cardiovascular abnormality detection • Mobile phone based cardiovascular monitoring systems 6.75 times faster than existing
(Iftikhar et al., 2010)	Telecardiology for e-Diagnosis and e-Learning in rural area	Lab data, clinical findings, ECG, X-rays	Emai,l 3G, Wi-Fi, UMS	• A novel approach for Cardiac Services in rural medicine • Effective cardiac care for variable distance • Specialize services for the cardiovascular patients I remote location • Evaluate patients by hybrid approach (frequent teleconsultation and in-frequent real meeting) • Less healthcare cost and education system
		Tele-radiology		
(Ninos et al., 2010)	PDA-based teleradiology	Image	Wi-Fi	• PDA serving as teleradiology terminal with secure connection for thyroid nodule diagnostics • Enabling picture archiving and communication through DICOM protocol • Mobility, usability, stability, performance • Easy to use
(Ruotsalainen, 2011)	Privacy and security in teleradiology	Image, X-rays, CT	SMS, Email, Internet	• Encourages teleradiology trust • Integrates teleradiology services with eHealth • Dynamic & context aware security and privacy features
(Abdullah et al., 1999)	Impact of teleradiology in clinical practice	Image, data	ISDN, ATM, Satellite	• Brief history of teleradiology • Role of teleradiology in health care • Telecommunication technology options for teleradiology

4.2 Emergency Healthcare Systems

Li et al. (2012) designed a WiMAX-based emergency system capable of transmitting physiological data and providing immediate online instructions on emergency treatment via video and audio. This system linked healthcare centers, hospitals and emergency ambulances (Li et al., 2011). An Android-based emergency alarm and healthcare management system has been proposed by Yuanyuan et al (2011). Using GPS and GSM technologies, the system can track the location of a patient in an emergency and send a message about the patient's location and situation to the doctor and the patient's family. Moreover, the system handles the health records of users so that it can send information regarding a patient`s physical condition to the appropriate doctor (Yuanyuan et al., 2011). Bergrath et al (2011) evaluated a multifunctional telemedicine system for emergency medical service (EMS) from the user's perspective. The system would transmit a patient`s vital signs and ECG data as well as pictures from an ambulance to the appropriate healthcare center. In addition, the system would allow voice communication and video transmission from the ambulance to the teleconsultation center. WLAN, LAN, and GSM have been used as communication technologies (Bergrath et al., 2011). Ren-Guey et al. (2007) proposed and implemented an intelligent mobile care system with alarm mechanism for chronic care environment (Ren-Guey et al., 2007). Patients, nurses, physicians and health providers are equipped with a mobile device that communicates with the servers in the health care center. Moreover, they designed physiological signal recognition algorithms that can be built into a chronic patient's Bluetooth-capable mobile device. Doctor can observe physiological parameters such as blood pressure, pulse, and saturation of haemoglobin (SpO2), and collect electrocardiogram (ECG) data. In addition to observation, important and/or abnormal physiological information can be uploaded to the healthcare center. An alert management mechanism in the healthcare center could handle emergency cases by sounding the alert if it receives an emergency message from a patient`s mobile device (Ren-Guey et al., 2007).

Takeda et al. (2010) proposed a mobile health monitoring system for emergency and regular situations based on 3G and Internet. The system could transmit a patient's vital medical data to a specialist while the patient is located in an ambulance, home or rural health care center, or in remote areas or any other outdoor environment. Doctors can access the patient's collected data in a real time mode or store-and-forward mode, and can initiate real-time video conferencing with the patient or other doctors if required (Takeda et al., 2010). El-Masri and Saddik (2012) designed an emergency system to automate ambulance calls in accident cases. The proposed system would first locate the nearest ambulance and the nearest hospital; once the patient is on board the ambulance it would access the patient's online health record. The mobile device would need access to the Internet and would be equipped with a GPS receiver. All of the ambulances would have high-speed wireless Internet access through General Packet Radio Service (GPRS) or Worldwide Interoperability for Microwave Access (WiMAX) (El-Masri and Saddik, 2012). Table 4 summarizes a few proposed projects in the emergency healthcare system category, showing their framework, biomedical data transmitted, technology, and system features.

4.2.1 Consultation in Healthcare Systems

Traditional consultation, whereby the patient must make an appointment with their doctor to visit a medical care center or hospital, is no longer the only option. Today it is possible to have remote monitoring and video consultation by means of mobile devices or computers using the latest advanced communication technologies like 4G and LTE. The patient can subscribe to a medical healthcare centre that will diagnose any disease and suggest medical consultation based on the patient`s current health conditions. Through the continuous efforts of researchers and medical advisors, it is becoming more convenient for remote patients to have video consultation sessions with medical doctors regardless of geographic distance. This is especially beneficial for geriatric patients, patients with a physical disability, or patients living in a remote location. Remote consultation not only benefits patients but also doctors, for example by enabling a doctor to solicit and receive valuable advice during a difficult surgery, or provide consultation to his hospital while traveling. Moreover, live or recorded video of medical activities and consultation can be broadcast to universities for distance learning/distance education purposes for medical students. An advance

Table 4 Examples of Emergency Healthcare Systems

Author	Framework	Biomedical Data	Technology	System features
(Yuanyuan et al., 2011)	Emergency Management System	Message, Audio	GSM, GPS	• Call • SMS • Online mode
(Li et al., 2011)	Emergency Care System (in hospitals and ambulances)	ECG, blood pressure,pulse, heart beat, body temperature, Video, Audio	WiMAX	• Physiological data transmission • Online instructions on emergency treatment via video and audio transmission
(Bergrath et al., 2011)	Multifunctional Telemedicine System in an Emergency Medical Service	vital signs data, ECG, Image, Audio, Video	WLAN, LAN, GSM	• Vital signs data • 12-lead-ECG data transmission • Sending pictures • Voice communication and video transmission from an ambulance
(Lam et al., 2009)	A telemedicine System for emergency medical assistance in the ambulance	Multimedia	WiMAX	• Simple diagnosis and resource arrangement within "the platinum ten minutes after receiving an emergency call • Shortening of the emergency period • Videoconferencing between doctor and emergency officer • Receipt of instructions from doctor, arrange medical treatment for patient • Can find the shortest path for ambulance with least congestion
. (Ren-Guey et al., 2007)	A Mobile Care System With Alert Mechanism	Blood pressure, Pulse, Saturation of haemoglobin (SpO2), Electrocardiogram (ECG) data	Bluetooth, GSM/GPRS	• Physiological signal recognition algorithms • Transmission of s physiological parameters • Monitoring of important or abnormal physiological information • Alert management mechanism
(Takeda et al., 2010)	Mobile Health Monitoring System	Vital medical data, Multimedia	3G, Internet	• Transmission of vital medical data • Access to patient's data in a real-time or store-and-forward mode • Real time video conferencing
(El-Masri and Saddik, 2012)	Emergency System for Ambulance	Medical data	GPS, GPRS, WiMAX	• Locate nearest ambulance and hospital • Access the patient's online health record • Book a bed or cubicle for the incoming patient

tele-echography robotic system has been developed that allows a medical ultrasound expert to perform procedures on a distant patient. The ultrasound images are monitored and controlled at the expert station, while the patient station is equipped with a robotic preholder system, an ultrasound device and video conferencing link. The two sites are connected via ISDN, satellite and 3G communications link were (Vieyres et al., 2006).

4.3 Remote Monitoring Systems

Takeda et al. (2010) proposed a mobile health monitoring system for emergency and regular situations based on 3G and Internet. The system transmits a patient's vital medical data to the specialist while the patient is located in an ambulance, home or rural health care center, or in a remote area or other outdoor environment. The doctors can access the patient's collected data in a real-time mode or store-and-forward mode. The doctor can initiate real-time video conferencing with the patient or with other doctors if required (Takeda et al., 2010). We have subdivided remote monitoring mHealth systems into maritime healthcare system and healthcare systems for diabetics. The different remote monitoring systems are summarized in Table 5.

4.3.1 Maritime Healthcare System

Emergency healthcare services are essential for those who are traveling by aircraft or ship as well as those living in remote areas (mountains, islands, forests). Mobile satellite communication (MSC) methods are a good solution for these situations, as they provide for interactive medical video conferencing. Numerous research articles (Murakami et al., 1994, Anogianakis et al., 1998, McDermott et al., 1999, Hwang and Lee, 2000, Pierucci and Del Re, 2000) have discussed video conferencing using a satellite communication system, as satellites have the advantages of wide-area coverage and the ability to provide both broadcast and multicast connections.

(Murakami et al., 1994) proposed a telemedicine technique using satellite communication to support clinical diagnosis and emergency care services on a moving vehicle, aircraft or ship. Their study measured several characteristics such as channel capacity, real-time operation, size of the system, electromagnetic interference, and reliability of vital sign transmission along with overall effectiveness of the system. The proposed system can send color images, audio signals, ECG (3 channels) and blood pressure from a mobile device to the ground station, and transmit audio and error control signals from the ground station to the mobile device. Experiments were conducted while ship and aircraft were moving, verifying the feasibility of this technique.

MERMAID is a European Union (EU) project initiated in 1998 to provide maritime telemedicine services via Integrated Services Digital Network (ISDN) video conferencing. This system not only supports medical services for the crew but also for travelers aboard ship. MERMAID supports telemedicine conferencing as well as multimedia communication and file and image transfer using low, medium, and high-bandwidth requirements. MERMAID utilizes coaxial cable, optical fiber, satellites, WLAN, cellular radio, Bluetooth, and ultra-wideband (UWB) as communication media and employs the Internet, ISDN, and asynchronous transfer mode (ATM) as network technologies (Anogianakis et al., 1998). McDermott et al. (1999) proposed a maritime telemedicine system for high speed medical data transmission using satellite networks (McDermott et al., 1999). Seon-Cheol and Myoung-Ho (2000) developed the telePACS maritime telemedicine system that can access a hospital`s picture archiving and communication system (PACS) server using the Internet. They used Java to implement their system for accessing medical data and images via browsers such as Netscape. Finally, they proposed a fast and cost-effective PACS using web technology not only for inter-hospital but also for public use (Hwang and Lee, 2000). (Pierucci and Del Re, 2000) discussed a telemedicine application called Medical Environment for Diagnostic Images (MEDI) designed to provide remote medical care services by exploiting the broadcast and multicast ability of satellite as well as its wide-band capacity. Java was used for the client-server architecture based on TCP/IP and performance of the proposed application based on satellite connection was evaluated.

Table 5 Examples of Remote Monitoring Systems

Author	Framework	Biomedical Data	Technology	System features
Remote Monitoring				
(Takeda et al., 2010)	Mobile Health Monitoring System	Vital medical data, Multimedia	3G, Internet	• Transmission of vital medical data • Access the collected patient's data in a real-time mode or store-and-forward mode • Real time video conferencing
(Ernest et al., 2011)	Remote Healthcare Service Delivery	ECG Serial stream data,	ZigBee, Internet	• Diagnosis and continuous monitoring remotely
Maritime				
(Murakami et al., 1994)	Telemedicine using satellite communication by moving vehicle	Image, Audio signal,	3G, Satellite	• Supports clinical diagnosis and emergency care services on moving vehicle (aircraft ship) • Channel capacity, real-time operation, and size of the system, electromagnetic interference • Reliability of vital sign transmission • Data send from mobile to base station
(Anogianakis et al., 1998)	MERMAID	File, Image, Video	ISDN, Satellite, Wi-Fi, Bluetooth, UwB, ATM, Internet	• Telemedicine services via Integrated Services Digital Network (ISDN) • Supports video conferencing • Interactive and effective
(McDermott et al., 1999)	Satellite based maritime telemedicine system	Medical Images, Data	ATM, Ethernet, Satellite	• High speed medical data transmission using satellite networks • Detailed reports
(Hwang and Lee, 2000)	telePACS maritime telemedicine system	Medical Data, Image	Internet	• Picture archiving and communication system (PACS) server • Java-based • Access to medical data and images via browsers such as Netscape • Fast and cost-effective using web technology
(Pierucci and Del Re, 2000)	Medical Environment for Diagnostic Images (MEDI)	Medical Data, Image, Video	Satellite	• Remote medical care services • Broadcast and multicast ability of satellite as well as wide-band capacity • Client-server architecture based on TCP/IP • Effective performance
Diabetes				
(Mougiakakou et al., 2010)	SMARTDIAB platform	Medical Data, Image	Wi-Fi, 3G, GPRS, Web Services	• Support monitoring, management, treatment • Databases approach • Consist of patient unit, patient management unit • System can be used with PC/mobile
(JansÃ et al., 2006)	Structured Therapeutic Education Program	Medical Data, Image and Video	Bluetooth	• Assessment of telecare system • Evaluation of existing technology • Cost analysis • GlucoBeep Patient device
S. Franc, et al (Franc et al., 2009)	Flexible intensive insulin therapy (FIT)	Medical Data	GPRS	• Real-life application and validation • Algorithm to adjust prandial insulin • PDA-based electronic diary • Individualized parameters that permit fast and accurate adjustment

4.3.2 Healthcare Systems for Diabetics

Diabetes is one of the most common diseases in any part of the world, in both developed or developing nations. Millions of people around the globe die from diabetes every year due to lack of proper treatment and monitoring of their health conditions. SMARTDIAB was proposed by (Mougiakakou et al., 2010) to support the monitoring, management and treatment of the diabetic patient. Their system is very big and easily scalable, making it suitable for big hospitals. It consists of a patient unit and a patient management unit, accessible via PC and mobile device, and uses Wi-Fi to get medical data from the patient, 3G/GPRS to transmit the data from the patient to the hospital. The Structured Therapeutic Education Program (JansÃ et al., 2006) was proposed as a tool for the assessment of telecare systems and to evaluate the existing telemedicine systems and the communication technologies they are using. The researchers conducted a cost analysis of entire system and tried to make it affordable. In their system, patients use a GlucoBeep device that checks the patient's diabetic information and sends it to the server using Bluetooth technology. Flexible Intensive Insulin Therapy (Franc et al., 2009) was designed to use real-life application and validation and employs an algorithm to adjust the prandial insulin of the patient. It also uses a PDA-based electronic diary to reduce the amount of manual work conducted and make it more efficient. The system focuses on individualized parameters to permit fast and accurate adjustments.

4.4 Location-Based Healthcare Systems

A very recent trend in the field of telemedicine relates to applications in which the location of the patient is continuously monitored; these are referred to as Location-based Telemedicine systems. An Android-based emergency alarm and healthcare management system has been proposed by Yuanyuan, et al (2011). Using GPS and GSM technologies, the system can track the location of a patient in an emergency and send a message containing the patient's location and situation to the doctor and patient's family. Moreover, the system handles the health records of users and so can send information regarding the patient`s physical condition to the appropriate doctor (Yuanyuan et al., 2011). El-Masri and Saddik (2012) designed an emergency system for dispatching of ambulances in accident cases. The proposed system would first locate the nearest ambulance and the nearest hospital; once the patient is on board the ambulance it would access the patient's online health record. The mobile device would need access to the Internet and would be equipped with a GPS receiver. All of the ambulances would have high-speed wireless Internet access through General Packet Radio Service (GPRS) or Worldwide Interoperability for Microwave Access (WiMAX) (El-Masri and Saddik, 2012). (Yuanyuan et al., 2011) proposed a location-based telemedicine system that continuously monitors the location of the patient through GPS technology and sends location details as well as audio using GSM/GPRS. (El-Masri and Saddik, 2012) proposed a location-based emergency system for hospital ambulances. Their system would identify the quickest route in order to help the ambulance locate the emergency patient as well as the location of the nearest hospital using GPS, GPRS and WiMAX communication technologies. Their system would allow the medical care unit to access the patient`s health record history and even book a private room or bed in the surgical unit for the incoming patient before the ambulance reaches the hospital. EmerLoc proposed by (Maglogiannis and Hadjiefthymiades, 2007) was based on sensor technology attached on the body of the patients that send the signals to the hospital by the help of GSM, GPRS, GPS and indoor positioning system. Their proposed system was technically feasible and the transmission was based on DICOM protocol. Their proposed system was technically feasible. In order to improve their system and gain information about training the medical staff, they administered questionnaires to doctors and medical staff. ZUPS (ZigBee and ultrasound positioning system) (Marco et al., 2008) was designed to pinpoint the indoor location of the patient; its focus was especially on elderly and disabled people. Apart from continuous monitoring and navigation, it also had an alarm in case of any emergency.

Some location-based healthcare systems along with their framework, transferred biomedical data, their technology communication technology and system features are summarized in Table 6.

Table 6 Examples of Location-Based Healthcare Systems

Author	Framework	Biomedical Data	Technology	System Feature
(Yuanyuan et al., 2011)	Location-Based	Message, Audio	GSM, GPS	• Call • SMS • Online mode
(El-Masri and Saddik, 2012)	Emergency System for Ambulance	Medical data	GPS, GPRS, WiMAX	• Locates nearest ambulance and hospital • Access to patient's online health record • Book a bed or cubicle for incoming patient
(Maglogiannis and Hadjiefthymiades, 2007)	EmerLoc	Medical Data, Image	GSM, GPRS, GPS, indoor UCLA	• System based sensor technology • Technically feasible • Uses DICOM protocol • Questionnaire to physicians experiments
(Marco et al., 2008)	ZUPS (ZigBee and ultrasound positioning system)	Medical Data, Text	ZigBee	• Pinpoints indoor location • Sends location to innovative services for elderly and disabled people • Alarm and monitoring
(Chew et al., 2006)	Hybrid mobile-based patient location tracking (PLT)	Medical Data, Image, Text	GPS, GPRS, 3G	• Hybrid mobile-based location technique • GPS and cellular mobile network • Good accuracy for positioning tracking

5 Discussion

It evident that 3G performance is not sufficient to meet the needs of future high-performance applications, such full-motion video, wireless videoconferencing etc. Research shows that the current UMTS standard has fundamental capacity limitations for high user loads. Also, when the number of active users increases beyond a certain point, the aggregate system capacity starts to decline. On top of that, present systems can't support seamless handover and mobility among heterogeneous IP networks including cellular networks and wireless local area networks (WLANs), which are the driving factors for 4G telecommunications networks and systems. One of the terms used to describe 4G is MAGIC—Mobile multimedia, Anytime anywhere, Global mobility support, Integrated wireless solution, and Customized personal service. The ITU definition of a 4G system, known as IMT-Advanced, requires a target peak data rate of 100Mbps for high mobility and 1Gbps for low mobility applications.

Healthcare solutions comprises as variety of patient diagnostic methods used by hospital consulting teams to research the particular cause of the disease from which a patient is suffering. Once the patient`s disease has been diagnosed, remote monitoring can be conducted continuously in order to check and analyze the patient`s health conditions based on the diagnosis done earlier. In case of emergency, EMS will be activated and proper measures will be taken to treat the patient and, following discharge, provide the best health care services to maintain the good health of patients. Constant consultation is required along with continuous guidance and monitoring.

Location based services in healthcare not only allow remote monitoring of the patient but also link in with the emergency management system. In remote monitoring of the patient, the consultation team can analyze patient data that is collected and transmitted to them via a Bluetooth mobile device. The mobile device should always be near the patient since Bluetooth has limited data transmission coverage. Thus, in the personal area network (PAN), the strictest requirement should be data coverage range. Once the signal received from the Bluetooth device, the location of the patient will be requested using GPS and A-GPS technology. GPS is used if the patient is outside, while indoor location coordinates are calculated in a different way. Hence, the requirement for location retrieval will be a mobile device with GPS and A-GPS technology. Text-based health information does not have a hard QoS requirement and can be transmitted with even low signal coverage, while monitoring, consultation and emergency systems may require pictures or multimedia video in order to properly evaluate the patient`s condition. Multimedia audio or video rhas strict QoS requirements such as minimizing packet loss, jitter, and out-of-order-delivery and (most importantly) having adequate bandwidth. Weak wireless signals will directly impact QoS parameters resulting in disconnections, missing video or incomplete video transmission.

The QoS parameters are as follows:

Low Throughput: A wireless network is an open network wherein resources are shared among its users. When the threshold of the resource utilization is maximized, due to limited bandwidth users will compete to fulfill their application requirements. Similarly, if the patient is located in an area where the wireless throughput is low or limited then the data transmission will be affected. The most adversely affected system will be remote consultation or continuous remote monitoring that requires the transmission of video and audio. It is a responsibility of both patient and medical provides to have reliable wireless service from their Internet Service Provider (ISP) so the throughput issue will not arise.

Packet Loss: Due to limited resources in the wireless network, congestion can occur which might result in data corruption or packet drop on the router due to buffer overflow. Packet loss is the most crucial problem that can affect all the categories of healthcare systems discussed above. For instance, important patient information might be lost during remote monitoring and tele-consultation services. Similar to the solution of low throughput, both patient and healthcare provides should have a good wireless service carrier that will provide adequate data resources.

Error: Packets might become corrupt due to interference of line of sight (for example, being indoors or behind walls). The information can be transmitted in case of packet loss, but sometimes errors may not be detected. Imagine the danger if a patient's data gets corrupted and sent to the healthcare unit. With the wrong data transmitted, the healthcare unit will not have accurate information about the patient's situation, a potentially dangerous situation. It is important that there should not be any interference between the patient's Bluetooth device and the mobile device, in order to reduce the chances of data becoming corrupted.

Latency: Sometimes congestion in the network can cause a packet to reach its destination late. Latency is very important when audio or video transmission is taking place. In mild cases the patient information (audio/video) will simply be delivered a bit late to the other end, but if the lag is severe it may render the audio or video unintelligible that obviously is dangerous in emergency cases.

Jitter: Like latency, jitter causes packets to travel from source to destination with different delays. This unpredictable behavior varies with the packet`s position in the queue of the router or shortest path etc. This variation in delay might seriously affect the quality of video and audio as much of the information gets lost. Imagine a scenario where video arrives before the audio or vice versa. This is potentially dangerous for healthcare services that require audio and video transmission.

6 Case Studies

Case Study 1: Mobi-Dev: Mobile Devices for Healthcare Applications (Istepanian et al., 2006a)

Mobile Devices for Healthcare Applications (Mobi-Dev) is a project involving healthcare institutions, universities and IT companies from Italy, Spain, Greece, Belgium and the United Kingdom. This project started in January 2001 and finished after 30 months. In order to quality of healthcare services, this project aimed to offer a next generation mobile communication tool for healthcare professionals. Mobi-Dev concentrates on three main objectives: (1) Mobility: ability to access to the clinical information systems from inside and outside of the workplace anytime. (2) Ease of Use: enable to input data onto the Hospital Information System (HIS) by voice, (3) Security and confidentiality: protection of data transmission, management and authentication via smart card. This project was provided for hospital medical and nursing staffs who must be connected all the time with HIS in the hospitals. Figure 4 illustrates connectivity in Mobi-Dev using wireless technologies. Mobi-Dev user interface was designed in such a way the users could perform several daily tasks such as: (1) edit medical/nursing history, (2) handle pharmaceutical prescriptions by voice, (3) benefit from a "red flag" control system, (4) checking against the input of wrong or out-of-range values - e.g. for vital signs or lab results, (5) receive and give orders related to medical/nursing care, receive “early warnings”. Beside those functionalities, Mobi-Dev enable to store and retrieve medical information files and pharmaceutical formularies, install useful medical programs, exchange e-mails and browsing the Internet.

The user requirement analysis was conducted at the beginning of the project using an internal panel of qualified end users (hospital institutions and university polyclinics). The analysis aimed to evaluate to different technical solutions, respectively called (1) **Web Mobi-Dev** and (2) **Synch Mobi-Dev**. Web Mobi-Dev was arranged to meet some requirements such as: Natural Language Understanding (NLU), Wireless web access to the Hospital Information System (HIS), Digital signature based on smart cards MOBI-DEV, Portability. Synch Mobi-Dev aimed to provide Remote wireless synchronisation with the HIS, Digital signature based on smart cards.

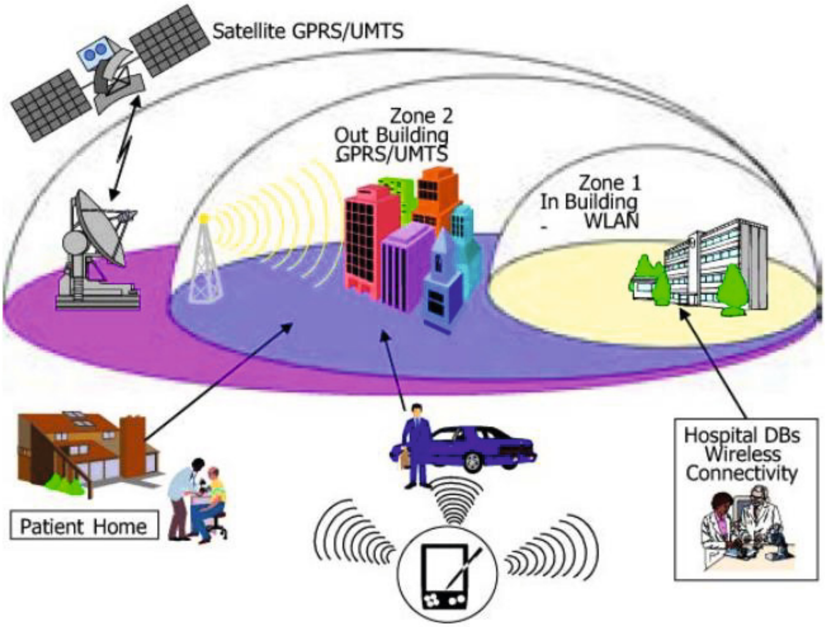

Fig. 4 Mobi-Dev's connectivity capabilities: healthcare practitioners can use the Mobi-Dev palm device to connect to the hospital DB, by exploiting WLAN connectivity if in the hospital or GPRS/UMTS mobile network in all other situations

Web Mobi-Dev: is based on client server architecture as shown in Figure 5. It provides wireless connectivity for handheld devices in order to access securely to data stored into a generic relational database (DB). For this purpose, a middleware software and an ad-hoc web interface is used. Specific application must be installed on the palm device in order to authenticate users by comparing user credentials with encrypted data stored on a smart card, perform data input by voice, initiate a wireless SSL session for data transmission and safely record data onto a remote DB.

Synch Mobi-Dev: Synch Mobi-Dev is different from Web Mobi-Dev as because of two reasons. First, there are no speech recognition functionalities in Synch Mobi-Dev because of the lack of solution available on the market yet for capturing and managing voice data in Greek. Nothing impedes to implement this functionality on the system at a further step, if required. Second, it uses remote synchronisation providing WWAN independency. Based on this method, data are selectively moving from/to the target database, to/from the distributed personal and/or PDA database systems. Figure 6 depicts high-level architecture of the Synch Mobi-Dev system.

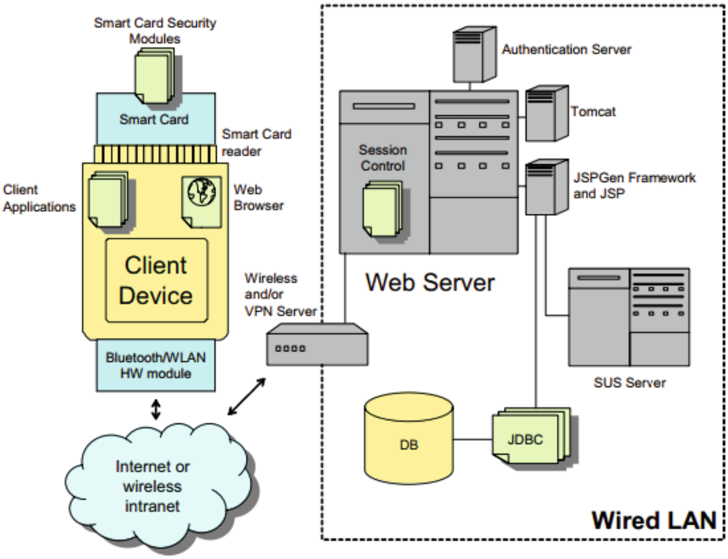

Fig. 5 Web Mobi-Dev general architecture

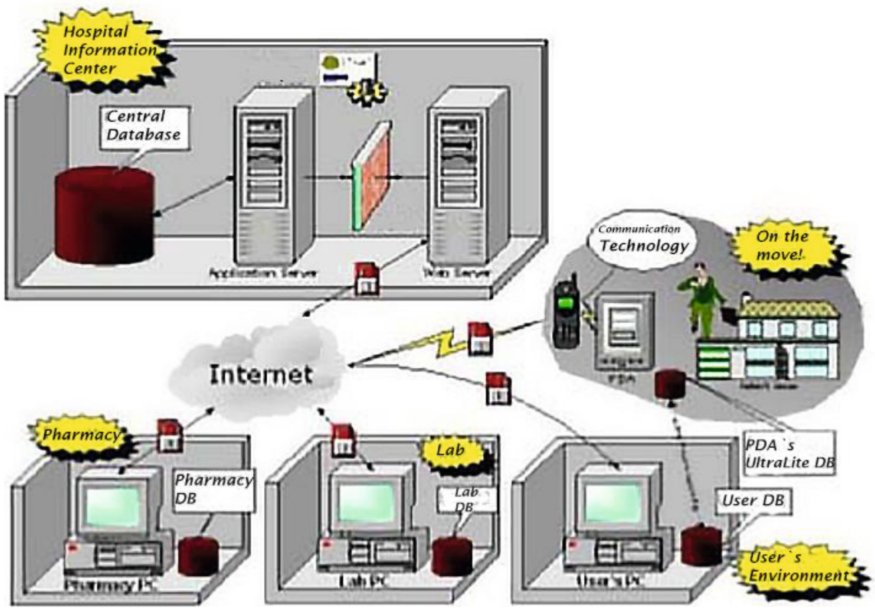

Fig. 6 High level architecture of the Synch Mobi-Dev system

Validation Methodology for Mobi-Dev: the most important assessment criteria for validation of this project consist of relevance, effectiveness, process evaluation, efficiency evaluation, impact evaluation. The validation plan covers all aspects of the Mobi-Dev system such as hardware, software and network components. Another important issue in evaluation was security. All of these issues and queries have been addressed in the validation and the first results. In order to yield information on either non-quantifiable characteristics of the system or intangible aspects of the Mobi-Dev service, such as those related to performance or costs, a standard approach has been followed, based on questionnaires. All users involved in the validation in the four pilot sites have been requested to respond to a series of pre-established questionnaires. An additional group of health professionals, who do not participate directly in the pilot phase, will also be contacted in order to get their opinion on the Mobi-Dev service.

Open Problems and Remaining Barriers: The main obstacles to the penetration of mobile solutions based on handheld devices and wireless technology includes limitation of current technology resources, the reluctance of healthcare professionals, the need to fulfill very restrictive regulations, ensure decision traceability in each step of care delivery and guarantee the patients against privacy violations.

Conclusion: finally, they conclude that Mobi-Dev is able to shorten the time needed to achieve the goal. They believed healthcare systems will continue technological path. Older physicians will be retired soon, and the young doctors who knows how to use modern healthcare systems will be taking over.

Case Study 2: A Tele-Operated Robotic System For Mobile Tele-Echography: The OTELO Project (Istepanian et al., 2006d)

OTELO project aimed to develop an advanced tele-echography robotic system. The system was able to perform echography along with a reliable echographic diagnosis on a distant patient located at the isolated site by medical ultrasound expert, located at the closest university hospital. The system consists of three main parts as illustrated in Figure 7: (1) the expert station where the experts receives ultrasound images of the patient's organ on the control monitor. (2) Patient station that is equipped with the robotic probe holder system an ultrasound device and a videoconference link. (3) Communication line between two stations that can be terrestrial when ISDN infrastructure is available in particular for homecare market or satellite (mobile or fixed), when there is coverage, in order to reach isolated populations such as islands or Amazonian regions.

Test was conducted in a clinical environment at the UMPS Unit (University of Tours, France) for the overall chain evaluation. The expert was located at the control desk in expert station while patient was placed in a room far from the expert station within the same hospital. Two internal ISDN lines, giving a total bandwidth of 128 kbps, connected the two stations. The experts from the ambient images monitored via videoconferencing supervised the positioning of the robot.

Echographic examinations were performed on 20 patients to obtain longitudinal and transverse views of four groups of organs. Using ISDN, satellite, and 3G communication links, the examination was successful. In addition, using satellite and three ISDN connections the system was exploited between the Nicosia General Hospital and the Kyperounta Medical Centre in Cyprus, with the University of Tours and the Barcelona Hospital Clinic.

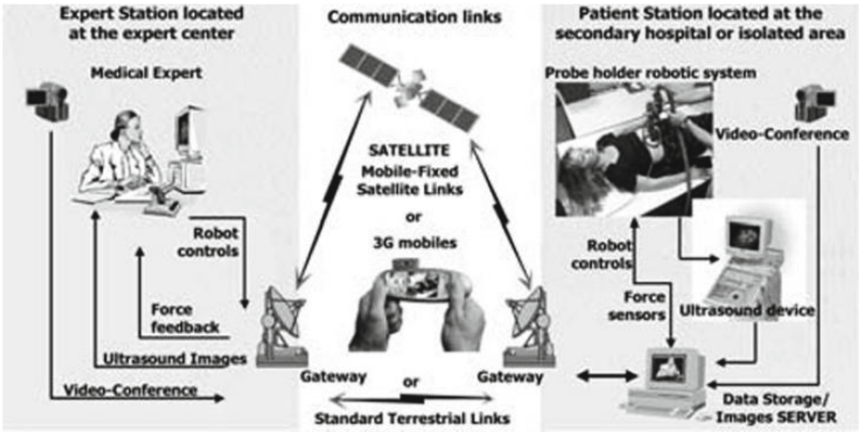

Fig. 7 The overall OTELO tele-echography chain

The OTELO project was conducted by nine partners, includes several disciplines such as mechanical design of the probe holder, robot control laws, graphic user interface, image coding and communication links. OTELO will provide better access to healthcare in remote areas, allow the maintenance of local infrastructures, such as small maternity units supported by large expert centers. It can offer an alternative for medical centers while there is lack of experts in order to assist isolated patients. Moreover, it can reduce the cost, as there is no need for patient transportation. OTELO can be used to train the future clinical ultrasound specialists.

7 Future Direction

Evolution of wireless technological advancement and rapid improvement of application solutions for mobile healthcare facilitates the remote patient. The coverage of wireless and cellular communication becomes vastly available even in the remote location that compliments the healthcare solutions for the patients anywhere anytime. Although in some cases, the stringent quality of service requirements for healthcare system can be concern in case of limited bandwidth availability and weak wireless architecture. Researchers and Industry experts are working on the improvement of wireless infrastructure, algorithm, and architecture suitable for healthcare solutions in even unstable wireless networks. Due to the efforts of researchers that it is possible that the current wireless communication technologies and infrastructure makes it possible to have reliable and efficient healthcare solutions like emergency systems, Tele-cardiology, tele-radiology, remote monitoring, consultation and location-based healthcare system with quality audio and visual medium to facilitate patients as well as hospital consulting team.

Evolution of these technologies will evolve further with advancement of application solutions that will require more requirements to facilitate the end user. With advancement of technologies, some technologies such as GSM, GPRS WiMAX, and 3G are already obsolete in healthcare. Recently progressed communication standard of LTE-A, B, C have more bandwidth and data coverage that will complements the healthcare sector. LTE-based cellular communication technology will not only offer excellent data transmission parameters but also lower the energy consumption per bit transmission as well as performance improvement for audio and video transmission that is highly required by the Telemedicine and healthcare applications for remote patients. Current issues such as network congestion, packet loss, jitter and error transmission can be minimized using the upcoming advance wireless and cellular communication transmission technologies. One of the key factor of LTE-based technology is its integration with existing wireless communication medium especially IEEE 802.11 WiFi networks that is commonly deployed in vast majority of urban and rural areas. This enabling technologies, will be highly efficient and cost effective with increase of flexibility and integration that promises to enhance the level, features and experience of future mobile healthcare systems. Fast and accurate location-based healthcare systems can be a new horizon in the future of healthcare systems in order to track the patient indoor and outdoor with high accuracy.

8 Concluding Remarks

The evolution of wireless technology and the rapid improvement of application solutions for mobile healthcare have the potential to vastly improve service to the remote patient. The coverage of wireless and cellular communication widely available even in remote locations, which complements the healthcare solutions for patients anywhere, at anytime, although the stringent QoS requirements for healthcare systems can be a concern in cases of limited bandwidth availability and weak wireless architecture. Researchers and industry experts are continually working on the improvement of wireless infrastructure, algorithms, and architecture suitable for healthcare solutions even in unstable wireless networks. Due to the efforts of researchers, it is possible that current wireless communication technologies and infrastructure make it possible to have reliable and efficient healthcare solutions including emergency systems, tele-cardiology, tele-radiology, remote monitoring and consultation and location-based healthcare systems with quality audio and visual. This will benefit patients as well as doctors and hospital consulting teams.

These technologies will evolve further in tandem with new application solutions that will require yet more robust standards to support them. Some technologies such as GSM, GPRS WiMAX, and 3G are already obsolete in healthcare. The progressively more powerful communication standards of LTE-A, B, C have more bandwidth and data coverage, which will help meet the needs of the healthcare sector. LTE-based cellular communication technology not only offers excellent data transmission parameters but also lower the energy consumption per bit transmission as well as improving performance for audio and video transmission, a necessity for telemedicine and healthcare applications for remote patients. Current issues such as network congestion, packet loss, jitter and error transmission can be minimized by using the upcoming advanced wireless and cellular communication transmission technologies. One of the key factors of LTE-based technology is its integration with existing wireless communication media especially IEEE 802.11 WiFi networks that are commonly deployed in the vast majority of urban and rural areas. This enables new technologies to be highly efficient and cost effective with an increased flexibility and integration that promises to enhance the level, features, and experience of future mobile healthcare systems. Fast and accurate location-based healthcare systems that accurately track the patient, whether indoors or out represent a new horizon in the future of healthcare.

References

GSM [Online]. GSAMA Company, `http://www.gsmworld.com` (accessed)

WiMax.com (2012b), `http://www.wimax.com/` (accessed)

Abdullah, B.J., Ng, K.H., Pathmanathan, R.: The impact of teleradiology in clinical practice–a Malaysian perspective. The Medical Journal of Malaysia 54, 169–174 (1999)

Adibi, S., Mobasher, A., Tofighbakhsh, M.: Fourth-Generation Wireless Networks: Applications and Innovations. IGI Global (2010)

Akyildiz, I.F., Weilian, S., Sankarasubramaniam, Y., Cayirci, E.: A survey on sensor networks. IEEE Communications Magazine 40, 102–114 (2002)

Anogianakis, G., Maglavera, S., Pomportsis, A.: Relief for maritime medical emergencies through telematics. IEEE Transactions on Information Technology in Biomedicine 2, 254–260 (1998)

Arnon, S., Bhastekar, D., Kedar, D., Tauber, A.: A comparative study of wireless communication network configurations for medical applications. IEEE Wireless Communications 10, 56–61 (2003)

Arrobo, G.E., Gitlin, R.D.: Improving the reliability of wireless body area networks. In: 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBC, August 30-September 3, pp. 2192–2195 (2011)

Baker, S.D., Hoglund, D.H.: Medical-Grade, Mission-Critical Wireless Networks [Designing an Enterprise Mobility Solution in the Healthcare Environment]. IEEE Engineering in Medicine and Biology Magazine 27, 86–95 (2008)

Barakah, D.M., Ammad-Uddin, M.: A Survey of Challenges and Applications of Wireless Body Area Network (WBAN) and Role of a Virtual Doctor Server in Existing Architecture. In: 2012 Third International Conference on Intelligent Systems, Modelling and Simulation (ISMS), February 8-10, pp. 214–219 (2012)

Barnes, S.J.: Under the skin: short-range embedded wireless technology. International Journal of Information Management 22, 165–179 (2002)

Beno, Latr, T., Braem, B., Moerman, I., Blondia, C., Demeester, P.: A survey on wireless body area networks. Wirel. Netw., 17, 1–18

Latré, B., Braem, B., Moerman, I., Blondia, C., Demeester, P.: A survey on wireless body area networks. Wirel. Netw. 17, 1–18 (2011)

Bergrath, S., Rörtgen, D., Rossaint, R., Beckers, S.K., Fischermann, H., Brokmann, J.R.C., Czaplik, M., Felzen, M., Schneiders, M.-T.R.S., Skorning, M.: Technical and organisational feasibility of a multifunctional telemedicine system in an emergency medical service - an observational study. Journal of Telemedicine and Telecare 17, 371–377 (2011)

Blueooth. Bluetooth SIG (2012) `http://www.bluetooth.com` (accessed)

Chew, S.H., Chong, P.A., Gunawan, E., Goh, K.W., Kim, Y., Soh, C.B.: A Hybrid Mobile-based Patient Location Tracking System for Personal Healthcare Applications. In: 28th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS 2006, August 30-September 3, pp. 5188–5191 (2006)

Chin-Teng, L., Kuan-Cheng, C., Chun-Ling, L., Chia-Cheng, C., Shao-Wei, L., Shih-Sheng, C., Bor-Shyh, L., Hsin-Yueh, L., Ray-Jade, C., Yuan-Teh, L., Li-Wei, K.: An Intelligent Telecardiology System Using a Wearable and Wireless ECG to Detect Atrial Fibrillation. IEEE Transactions on Information Technology in Biomedicine 14, 726–733 (2010)

Chu, Y., Ganz, A.: A mobile teletrauma system using 3G networks. IEEE Transactions on Information Technology in Biomedicine 8, 456–462 (2004)

Cordeiro, C., Akhmetov, D., Park, M.: Ieee 802.11 ad: introduction and performance evaluation of the first multi-gbps wifi technology. In: Proceedings of the 2010 ACM International Workshop on mmWave Communications: from Circuits to Networks, pp. 3–8. ACM (2010)

Crosby, G.V., Ghosh, T., Murimi, R., Chin, C.A.: Wireless Body Area Networks for Healthcare: A Survey. International Journal of Ad Hoc, Sensor & Ubiquitous Computing, IJASUC 3 (2012)

Davidson, J., Peters, J.: Voice over IP fundamentals. Cisco Press (2000)

El-Masri, S., Saddik, B.: An Emergency System to Improve Ambulance Dispatching, Ambulance Diversion and Clinical Handover Communicationâ-A Proposed Model. Journal of Medical Systems 36, 3917–3923 (2012)

Eng Hwee, O., Kneckt, J., Alanen, O., Zheng, C., Huovinen, T., Nihtila, T.: IEEE 802.11ac: Enhancements for very high throughput WLANs. In: 2011 IEEE 22nd International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), September 11-14, pp. 849–853 (2011)

Ernest, K., Lamei, C., Mohamed, S., Shakshuk, M., Badreldin, I., Elbabli, I.: A ZigBee-based telecardiology system for remote healthcare service delivery. In: 2011 1st Middle East Conference on Biomedical Engineering (MECBME), February 21-24, pp. 442–445 (2011)

Franc, S., Dardari, D., Boucherie, B., Riveline, J.P., Biedzinski, M., Petit, C., Requeda, E., Leurent, P., Varroud-Vial, M., Hochberg, G., Charpentier, G.: Real-life application and validation of flexible intensive insulin-therapy algorithms in type 1 diabetes patients. Diabetes & Metabolism 35, 463–468 (2009)

Gallego, J.R., Hernandez-Solana, A., Canales, M., Lafuente, J., Valdovinos, A., Fernandez-Navajas, J.: Performance analysis of multiplexed medical data transmission for mobile emergency care over the UMTS channel. IEEE Transactions on Information Technology in Biomedicine 9, 13–22 (2005)

Garawi, S., Istepanian, R.S.H., Abu-Rgheff, M.A.: 3G wireless communications for mobile robotic tele-ultrasonography systems. IEEE Communications Magazine 44, 91–96 (2006)

Gyselinckx, B., Penders, J., Vullers, R.: Potential and challenges of body area networks for cardiac monitoring. Journal of Electrocardiology 40, S165–S168 (2007)

Hadjileontiadis, L.J.: Biosignals and Compression Standards. In: Istepanian, R.S.H., Laxminarayan, S., Pattichis, C. (eds.) M-Health – Emerging Mobile Health Systems. Springer (2006)

Hall, E.S., Vawdrey, D.K., Knutson, C.D., Archibald, J.K.: Enabling remote access to personal electronic medical records. IEEE Engineering in Medicine and Biology Magazine 22, 133–139 (2003)

Hillebrand, F.: The Status and Development of The GSM Specifications. In: Zvonar, Z., Jung, P., Kammerlander, K. (eds.) GSM: Evolution Towards 3rd Generation Systems. Kluwer Academic Publisher (2002)

Hung, K., Zhang, Y.-T.: Implementation of a WAP-Based Telemedicine System for Patient Monitoring. IEEE Transactions on Information Technology In Biomedicine 7 (2003)

Husni, E.M., Heryadi, Y., Woon, W.T.H., Arifianto, M.S., Viswacheda, D.V., Barukang, L.: Mobile ad hoc network and mobile IP for future mobile telemedicine system. In: 2006 IFIP International Conference on Wireless and Optical Communications Networks, p. 5 (2006)

Hwang, S.-C., Lee, M.-H.: A Web-based TelePACS using an asymmetric satellite system. Trans. Info. Tech. Biomed. 4, 212–215 (2000)

Iftikhar, M., Singh, H.M.P., Arifianto, M.S.: Telecardiology for e-Diagnosis and e-Learning in Rural Area of Sabah, Malaysia: A Novel Approach for Cardiac Services in Rural Medicine. In: 2010 Third International Conference on Advances in Human-Oriented and Personalized Mechanisms, Technologies and Services (CENTRIC), August 22-27, pp. 83–88 (2010)

Istepanaian, R.S.H., Zhang, Y.T.: Guest Editorial Introduction to the Special Section: 4G Health, The Long-Term Evolution of m-Health. IEEE Transactions on Information Technology in Biomedicine 16, 1–5 (2012)

Istepanian, R.S.H., Laxminarayan, S., Pattichis, C., Altieri, R., Incardona, F., Kirkilis, H., Ricci, R.: Mobi-Dev: Mobile Devices for Healthcare Applications. In: M-Health. Springer US (2006a)

Istepanian, R.S.H., Laxminarayan, S., Pattichis, C., Kontaxakis, G., Sakas, G., Walter, S.: Mobile Tele-Echography Systems – Teleinvivo: A Case Study. In: M-Health. Springer US (2006b)

Istepanian, R.S.H., Laxminarayan, S., Pattichis, C.: Ubiquitous M-Health Systems and the Convergence Towards 4G Mobile Technologies. In: M-Health. Springer US (2006c)

Istepanian, R.S.H., Laxminarayan, S., Pattichis, C., Vieyres, P., Poisson, G.R., Courrèges, F., Smith-Guerin, N., Novales, C., Arbeille, P.: A Tele-Operated Robotic System for Mobile Tele-Echography: The Otelo Project. In: M-Health. Springer US (2006d)

Istepanian, R.S.H., Hadjileontiadis, L.J., Panas, S.M.: ECG data compression using wavelets and higher order statistics methods. Trans. Info. Tech. Biomed. 5, 108–115 (2001)

Jansã, M., Vidal, M., Viaplana, J., Levy, I., Conget, I., Gomis, R., Esmatjes, E.: Telecare in a structured therapeutic education programme addressed to patients with type 1 diabetes and poor metabolic control. Diabetes Research and Clinical Practice 74, 26–32 (2006)

Jovanov, E., Milenkovic, A.: Body Area Networks for Ubiquitous Healthcare Applications: Opportunities and Challenges. Journal of Medical Systems 35, 1245–1254 (2011)

Karl, H., Willig, A.: Protocols and Architectures for Wireless Sensor Networks. John Wiley & Sons, New York (2005)

Kim, D.-K., Yoo, S.K., Kim, S.H.: Instant wireless transmission of radiological images using a personal digital assistant phone for emergency teleconsultation. Journal of Telemedicine and Telecare 11, 58–61 (2005)

Kumar, B., Singh, S.P., Mohan, A.: Emerging mobile communication technologies for health. In: 2010 International Conference on Computer and Communication Technology (ICCCT), September 17-19, pp. 828–832 (2010)

Kumar, B., Singh, S.P., Mohan, A.: Emerging mobile communication technologies for health. In: 2010 International Conference on Computer and Communication Technology (ICCCT), September 17-19, pp. 828–832 (2010)

Kyriacou, E., Pattichis, M.S., Pattichis, C.S., Panayides, A., Pitsillides, A.: m-Health e-Emergency Systems: Current Status and Future Directions [Wireless corner]. IEEE Antennas and Propagation Magazine 49, 216–231 (2007)

Lam, K.L., Tung, H.Y., Tsang, K.F., Ko, K.T.: WiMAX telemedicine system for emergence medical service. In: 7th International Conference on Information, Communications and Signal Processing, ICICS 2009, December 8-10, pp. 1–5 (2009)

Latré, B.T., Braem, B., Moerman, I., Blondia, C., Demeester, P.: A survey on wireless body area networks. Wirel. Netw. (2010)

Lee, K.-D., Vasilakos, A.: Access stratum resource management for reliable u-healthcare service in LTE networks. Wireless Networks 17, 1667–1678

Lenert, L.A., Palmer, D.A., Chan, T.C., Rao, R.: An Intelligent 802.11 Triage Tag For Medical Response to Disasters. In: American Medical Informatics Association (AMIA), Annual Symposium Proceedings (2005)

Li, H.-B., Takahashi, T., Toyoda, M., Mori, Y., Kohno, R.: Wireless Body Area Network Combined with Satellite Communication for Remote Medical and Healthcare Applications. Wireless Personal Communications 51, 697–709 (2009)

Li, S.-H., Cheng, K.-A., Lu, W.-H., Lin, T.-C.: Developing an Active Emergency Medical Service System Based on WiMAX Technology. Journal of Medical Systems 36, 3177–3193 (2011)

Lim, E.Y., Chiang, L., Weidong, C., Dagan, F., Fulham, M.: Development of an Electronic Medical Report Delivery System to 3G GSM Mobile (Cellular) Phones for a Medical Imaging Department. In: 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS 2007, August 22-26, pp. 6726–6729 (2007)

Lin, C.-F.: Mobile Telemedicine: A Survey Study. Journal of Medical Systems, 1–10 (2010)

Lin, C.-F., Lee, H.-W.: Wireless multimedia communication toward mobile telemedicine. In: Proceedings of the 9th WSEAS International Conference on Applied Informatics and Communications. World Scientific and Engineering Academy and Society (WSEAS), Moscow (2009)

Lin, C.F., Hung, S.I., Chiang, I.H.: An 802.11 n wireless local area network transmission scheme for wireless telemedicine applications. In, Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine (2010)

Maglogiannis, I., Hadjiefthymiades, S.: EmerLoc: Location-based services for emergency medical incidents. International Journal of Medical Informatics 76, 747–759 (2007)

Marco, A., Casas, R., Falco, J., Gracia, H., Artigas, J.I., Roy, A.: Location-based services for elderly and disabled people. Computer Communications 31, 1055–1066 (2008)

Mcdermott, W.R., Tri, J.L., Mitchell, M.P., Levens, S.P., Wondrow, M.A., Huie, L.M., Khandheria, B.K., Gilbert, B.K.: Optimization of wide-area ATM and local-Area Ethernet/FDDI network configurations for high-speed telemedicine communications employing NASA's ACTS. IEEE Network 13, 30–38 (1999)

Mougiakakou, S.G., Bartsocas, C.S., Bozas, E., Chaniotakis, N., Iliopoulou, D., Kouris, I., Pavlopoulos, S., Prountzou, A., Skevofilakas, M., Tsoukalis, A., Varotsis, K., Vazeou, A., Zarkogianni, K., Nikita, K.S.: SMARTDIAB: A Communication and Information Technology Approach for the Intelligent Monitoring, Management and Follow-up of Type 1 Diabetes Patients. IEEE Transactions on Information Technology in Biomedicine 14, 622–633 (2010)

Murakami, H., Shimizu, K., Yamamoto, K., Mikami, T., Hoshimiya, N., Kondo, K.: Telemedicine using mobile satellite communication. IEEE Transactions on Biomedical Engineering 41, 488–497 (1994)

Navarro, E.A.V., Mas, J.R., Navajas, J.F., Alcega, C.P.: Performance of a 3g-based mobile telemedicine system. In: 3rd IEEE Consumer Communications and Networking Conference, CCNC 2006, January 8-10, pp. 1023–1027 (2006)

Ninos, K., Spiros, K., Glotsos, D., Georgiadis, P., Sidiropoulos, K., Dimitropoulos, N., Kalatzis, I., Cavouras, D.: Development and evaluation of a PDA-based teleradiology terminal in thyroid nodule diagnosis. Journal of Telemedicine and Telecare 16, 232–236 (2010)

Niyato, D., Hossain, E., Diamond, J.: IEEE 802.16/WiMAX-based broadband wireless access and its application for telemedicine/e-health services. IEEE Wireless Communications 14, 72–83 (2007)

Palmer, D.A., Rao, R., Lenert, L.A.: An 802.11 Wireless Blood Pulse-Oximetry System for Medical Response to Disasters. In: American Medical Informatics Association (AMIA), Annual Symposium Proceedings (2005)

Pandian, P.S., Safeer, K.P., Shakunthala, D.T., Gopal, P., Padaki, V.C.: Internet Protocol Based Store and Forward Wireless Telemedicine System for VSAT and Wireless Local Area Network. In: International Conference on Signal Processing, Communications and Networking, ICSCN 2007, February 22-24, pp. 54–58 (2007)

Paro, D.D.: Wireless Application Protocol (WAP) "What is it all about....How does it work". SANS Institute (2001)

Pattichis, C.S., Kyriacou, E., Voskarides, S., Pattichis, M.S., Istepanian, R., Schizas, C.N.: Wireless telemedicine systems: an overview. IEEE Antennas and Propagation Magazine 44, 143–153 (2002)

Pattichis, C.S., Kyriacou, E.C., Pattichis, M.S., Panayides, A., Mougiakakou, S., Pitsillides, A., Schizas, C.N.: A brief overview of m-Health e-Emergency Systems. In: 6th International Special Topic Conference on Information Technology Applications in Biomedicine, ITAB 2007, November 8-11, pp. 53–57 (2007)

Pattichis, C.S., Kyriacou, E., Voskarides, S., Pattichis, M.S., Istepanian, R., Schizas, C.N.: Wireless telemedicine systems: an overview. IEEE Antennas and Propagation Magazine 44, 143–153 (2002)

Paul, T., Ogunfunmi, T.: Wireless LAN Comes of Age: Understanding the IEEE 802.11n Amendment. IEEE Circuits and Systems Magazine 8, 28–54 (2008)

Pavlopoulos, S., Kyriacou, E., Berler, A., Dembeyiotis, S., Koutsouris, D.: A novel emergency telemedicine system based on wireless communication technology-AMBULANCE. IEEE Transactions on Information Technology in Biomedicine 2, 261–267 (1998)

Penzel, T., Kemp, B., Klosch, G., Schlogl, A., Hasan, J., Varri, A., Korhonen, I.: Acquisition of biomedical signals databases. IEEE Engineering in Medicine and Biology Magazine 20, 25–32 (2001)
Perahia, E.: IEEE 802.11n Development: History, Process, and Technology. IEEE Communications Magazine 46, 48–55 (2008)
Perahia, E., Gong, M.X.: Gigabit wireless LANs: an overview of IEEE 802.11 ac and 802.11 ad. ACM SIGMOBILE Mobile Computing and Communications Review 15, 23–33 (2011)
Perahia, E., Stacey, R.: Next Generation Wireless LANs: Throughput, Robustness, and Reliability in 802.11n. Cambridge University Press (2008)
Pierucci, L., Del Re, E.: An interactive multimedia satellite telemedicine service. IEEE Multimedia 7, 76–83 (2000)
Rashvand, H.F., Salcedo, V.T., Sanchez, E.M., Iliescu, D.: Ubiquitous wireless telemedicine. IET Communications 2, 237–254 (2008)
Rasid, M.F.A., Woodward, B.: Bluetooth telemedicine Processor for multichannel biomedical signal transmission via mobile cellular networks. IEEE Transactions on Information Technology in Biomedicine 9, 35–43 (2005)
Redieteab, G., Cariou, L., Christin, P., Helard, J.F.: PHY+MAC channel sounding interval analysis for IEEE 802.11ac MU-MIMO. In: 2012 International Symposium on Wireless Communication Systems (ISWCS), August 28-31, pp. 1054–1058 (2012)
Reinaldo, P.: Chapter 8 Space environment and interference. Wireless Communications Design Handbook. Academic Press (1999)
Ren-Guey, L., Kuei-Chien, C., Chun-Chieh, H., Chwan-Lu, T.: A Mobile Care System With Alert Mechanism. IEEE Transactions on Information Technology in Biomedicine 11, 507–517 (2007)
Ruotsalainen, P.: Privacy and security in teleradiology. European Journal of Radiology 73, 31–35 (2011)
Saleh, A.B., Redana, S., Raaf, B., Hamalainen, J.: Comparison of Relay and Pico eNB Deployments in LTE-Advanced. In: 2009 IEEE 70th Vehicular Technology Conference Fall (VTC 2009-Fall), September 20-23, pp. 1–5 (2009)
Salvador, C.H., Carrasco, M.P., De Mingo, M.A.G., Carrero, A.M., Montes, J.M., Martin, L.S., Cavero, M.A., Lozano, I.F., Monteagudo, J.L.: Airmed-cardio: a GSM and Internet services-based system for out-of-hospital follow-up of cardiac patients. IEEE Transactions on Information Technology in Biomedicine 9, 73–85 (2005)
Schächinger, U., Kretschmer, R., Neumann, C., Nerlich, M.: NOAH A Mobile Emergency Care System. Studies in Health Technology and Informatics 64, 85–92 (1999)
Seon-Cheol, H., Myoung-Ho, L.: A Web-based TelePACS using an asymmetric satellite system. IEEE Transactions on Information Technology in Biomedicine 4, 212–215 (2000)
Stencel, V., Muller, A., Frank, P.: LTE Advanced - A further evolutionary step for Next Generation Mobile Networks. In: 2010 20th International Conference on Radioelektronika (RADIOELEKTRONIKA), April 19-21, pp. 1–5 (2010)
Sufi, F., Qiang, F., Khalil, I., Mahmoud, S.S.: Novel methods of faster cardiovascular diagnosis in wireless telecardiology. IEEE Journal on Selected Areas in Communications 27, 537–552 (2009)
Sorwar, G., Ali, A.: Advanced Telemedicine System Using 3G Cellular Networks and Agent Technology. In: Takeda, H. (ed.) E-Health 2010. IFIP AICT, vol. 335, pp. 187–197. Springer, Heidelberg (2010)

Theogarajan, L., Wyatt, J., Rizzo, J., Drohan, B., Markova, M., Kelly, S., Swider, G., Raj, M., Shire, D., Gingerich, M., Lowenstein, J., Yomtov, B.: Minimally Invasive Retinal Prosthesis. In: IEEE International Solid-State Circuits Conference, ISSCC 2006. Digest of Technical Papers, February 6-9, pp. 99–108 (2006)

Tsiknakis, M., Katehakis, D.G., Orphanoudakis, S.C.: An Open, Component-Based Information Infrastructure for Integrated Health Information Networks. International Journal of Medical Informatics (2002)

Varshney, U.: Pervasive healthcare and wireless health monitoring. Mob. Netw. Appl. 12, 113–127 (2007)

Varshney, U.: A framework for supporting emergency messages in wireless patient monitoring. Decision Support Systems 45, 981–996 (2008)

Vassis, D., Kormentzas, G., Rouskas, A., Maglogiannis, I.: The IEEE 802.11g standard for high data rate WLANs. IEEE Network 19, 21–26 (2005)

Vieyres, P., Poisson, G., Courrèges, F., Smith-Guerin, N., Novales, C., Arbeille, P.: A Tele-Operated Robotic System for Mobile Tele-Echography: The Otelo Project. In: Istepanian, R.H., Laxminarayan, S., Pattichis, C. (eds.) M-Health. Springer US (2006)

Voskarides, S.C., Pattichis, C.S., Istepanian, R., Michaelides, C., Schizas, C.N.: Practical evaluation of GPRS use in a telemedicine system in Cyprus. In: 4th International IEEE EMBS Special Topic Conference on Information Technology Applications in Biomedicine, April 24-26, pp. 39–42 (2003)

Xiaoyi, Z., Doufexi, A., Kocak, T.: Throughput and Coverage Performance for IEEE 802.11ad Millimeter-Wave WPANs. In: 2011 IEEE 73rd Vehicular Technology Conference (VTC Spring), May 15-18, pp. 1–5 (2011)

Yuanyuan, D., Yu, C., Dan, W., Jinzhao, L., Yongqiang, L.: An android-based emergency alarm and healthcare management system. In: 2011 International Symposium on IT in Medicine and Education (ITME), December 9-11, pp. 375–379 (2011)

Zain, A.S.M., Yahya, A., Malek, M.F.A., Omar, N.: 3GPP Long Term Evolution and its application for healthcare services. In: 2012 International Conference on Computer and Communication Engineering (ICCCE), July 3-5, pp. 239–243 (2012)

Zhao, Y., Yagi, Y., Juzoji, H., Nakajima, I.: A Study of Wireless IP for Telemedicine. In: Fourth International Symposium on Multimedia Communications (WPMC 2001), Aalborg, Denmark, pp. 1597–1600 (2001)

Zhao, Y., Yagi, Y., Nakajima, I., Juzoji, H.: IP telephony - New horizon for telemedicine and e-health. Journal of Medical Systems 26, 277–283 (2002)

Questions

Q1. What Are Long Term Evolution Technology and How Many Standards it Currently Has?

Q2. How Technology Plays in Improving Mobile Healthcare? Give Examples.

Q3. What Are the Important Classification of Mobile Healthcare Systems?

Q4. What Is Quality of Service (QoS) and Its Parameters? How QoS Can Impact on Mobile Healthcare?

Q5. How Author Make Discuss about the Current Mobile Healthcare System and Evolution of Communication Technology?

Q6. What Are the Future Prospects of Mobile Healthcare?