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Telemedicine: A brief analysis

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Abstract: This paper reveals the present status of wireless telemedicine system for m-health application. Wireless telemedicine network equipped with mobile, computer and telecommunication technologies which provide medical data, information and services from distant locations. Telemedicine opens a world of healthcare delivery by building clinical bridges between patients and available healthcare by integrating Information and Communication Technology, Biomedical Engineering, Medical Science, etc. using minimum costs, effective development and utilization of ancillary infrastructure and services. We have studied 130 research papers on telemedicine and its aspects, this paper is an extraction which emphasized on wireless technologies like GSM, General Packet Radio Services, EDGE, 3G, 4G, 5G, Cognitive Radio Network, World Wide interoperability of Microwave Access, Wireless Local Area Network, Wireless Body Area Network, Very Small Aperture Terminal, Satellite communication and WPAN (Bluetooth) used for m-health application. It also gives the details of storage, security, protocols, optimum bandwidth and fair scheduling schemes used for transmission of medical signals, images and videos.

Subjects: Medicine, Science, Technology

Keywords: telemedicine, QoS

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PUBLIC INTEREST STATEMENT

This is a brief report regarding telemedicine, which helps to provide medical data, information and services from distant locations. This work emphasized on wireless telemedicine networks which assist and improve the present health care environment. The recent researches in this field help to investigate hardware and software system for efficient and cost effective implementation of wireless telemedicine network. This wireless telemedicine network provides an alternative access for those areas where fixed networks are unreachable. The medical data or signals of patient are measured, recorded, analysed or transmitted for investigation, interaction and continuous monitoring.

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1. Introduction

Telemedicine is an integration of wired and wireless transmission of medical data where biological signals, images and videos are transmitted to remote location for diagnosis. This decreases the pressure on healthcare personnel and compensates the physical distance between patients and caretakers. Telemedicine provides the advanced health care system via electronic communication which improves patient health care. The use of mobile communication to send medical information gives rise to a new term m-health, can be described as "mobile computing, medical sensor, and communications technologies for healthcare". This system reduces infrastructure costs and useful in providing health care services at home, understaffed areas such as rural health centres, ships, trains and air planes. This m-health works on 4 A's i.e. "Any time, Anywhere Access with Always best connected features" which bring together the evolution of emerging wireless communication and network technologies, facilitate delivery of the health care over the heterogeneous infrastructure. This is a powerful means of improving the quality of health monitoring and provided an assistance and alternative to current forms of health care delivery which have adopted in some countries (Branagan & Chase, 2012; Fong, Ansari, & Fong, 2012; Istepanian, Jovanov, & Zhang, 2004; Kumar, Singh, & Mohan, 2010; Kyriacoul, Pattichis, Pattichis, Panayides, & Pitsillides, 2007; Siddiqul & Abdul Awa, 2012; Zdravkovic, 2008; Zhang, Hu, & Jiang, 2012).

Space and time are the two most stringent requirements for telemedicine set-ups (Makena & Hayes, 2011). Space enables specialties and more clinics for adapting telemedicine for patients' needs and the wireless technology with rapid internet services support the time requirement of telemedicine with improved mobility and efficiency. For storing and transmitting medical images, the Content-Based Image Retrieval (CBIR) used for extracting relevant images from the database. The authors have suggested a soft computing approach of genetic optimized neural network for compressed medical images CBIR system. In a country like Italy, the family health records are integrated in a software package for health data management supported by health care providers for Personal Health Record while in Africa a software tool called Health Agent provided active relational database systems using Standard Query Language (SQL) (Divya, Janet, & Suguna, 2014; Pinciroli et al., 2011; Puustjarvi & Puustjarvi, 2011).

The main features of telemedicine network are scalability, transparency, fault tolerance, geographic coverage, security, etc. These features enable the specialist doctor and the patient separated by thousands of kilometres to see visually and talk to each other. The doctor can access the physical and mental state of the patient and suggest treatment. The systematic application of communication technologies to practice healthcare rapidly and expands the outreach of healthcare system developed a new concept of Hospital Digital Networking Technologies, in this, internet, mobile and satellite communication systems can connect primitive rural healthcare centres to well advanced modern urban set-ups to provide better consultation and diagnostic care to the needy people (Faust et al., 2010). This has two modes of operation, the basic mode has a low-data transmission rate as well as low-channel bandwidth, so they are used to transmit medical records while the advanced mode has high-data transmission rate as well as high-channel bandwidth, and it is used to support interactive telemedicine conferencing and transmit Electrocardiogram (ECG) signals. The utility of this system primarily depends on various medical equipments which are used to capture patient information and the available telecommunications infrastructure with desired Quality of Service (QoS). The patients data may be collected either in real-time mode or in store-and-forward mode and they are transmitted using mobile communication technologies like General Packet Radio Services (GPRS), third generation(3G), fourth generation(4G), Cognitive Radio Network (CRN), World Wide interoperability of Microwave Access (WiMAX) technologies, etc.

Through this review paper, the authors have given a brief overview of the essential telemedicine elements and emphasized on the analysis of the available wireless communication network for m-health applications. This paper is structured as follows: Section 2 deals with essential

telemedicine elements; Sections 3 and 4 enlighten medical signal perspective and communication perspective, respectively, of telemedicine network; the issues related to telemedicine are raised in Section 5; review report is tabulated in Section 6 which included various wireless networks with brief remarks; and finally, Section 8 concludes the paper.

2. Essential telemedicine elements

The telemedicine supports the patients and health care professionals or care takers for monitoring indoor and outdoor, fixed and mobile patients. It provides healthcare delivery where physicians examine distant patients using telecommunication technologies.

The main components needed to frame telemedicine infrastructure are:

- Terminal devices to capture biomedical signals.
- Telecommunication equipment and systems.
- Services, components and telematic applications for healthcare management.
- Communication networks.
- Remote diagnosis.
- CBIR with proper display.

Through m-health assistance, both routine and emergency vital signals are periodically monitored and transmitted which include blood pressure, heart rate, temperature, ECG, Electroencephalogram (EEG), endoscopes, ultrasound, Positron Emission Tomography, Computed Tomography (CT), Medical Magnetic Resonance (MMR), X-rays and super high definition images (Suzuki et al., 2000). These medical signals, images or video accessed using cameras or sensor-based system. The telemedicine network has following characteristics for the transmission of these signals:

- Reliability of message delivery.
- Transmission of vital signals, images or videos in reasonable time.
- Power conservation.
- Coverage for both fixed and mobile patients.
- Scalability.
- Manageable cognitive load for health care professionals.
- Confidentiality and privacy.

To accomplish all these aspects, researchers have done their work mainly in two broad perspectives, medical signal perspective and communication perspective.

3. The medical signal perspective

The medical images are stored in the standard Digital Imaging and Communication in Medicine (DICOM) and Picture Archiving Communication System (PACS) formats which display on a mobile or Personal Digital Assistant (PDA) using special software that has been completely implemented using Java Programming Language on client and server devices. The available research work showed that a mobile telecommunication-based decision support system reveal using JAVA2 platform on Micro Edition (J2ME) and SQL (Eren, Subasi, & Coskun, 2008; Maglogiannis, Delakouridis, & Kazatzopoulos, 2006).

The experts envisioned that a client server-based integrated architecture for mobile collaborative medical data visualization in which PDA used at the front end. This system composed of mobile client, gateway and parallel rendering server aims to offer interactivity and mobility in visualizing large medical data-sets. Remote users allowed to collaborate in shared contexts and added the feature of collaboration and coordination to the mobile distributed medical system. The authors

reported that PDA with Computer System Cooperative Work (CSCW) architecture provided optimization and tuning techniques effectively (Engelmann, Schroeter, Muench, Bohn, & Meinzer, 2010; Marthinsen et al., 2008; Park, Kim, & Ihm, 2008).

Medical images or videos require large bandwidth for transmission, so they are compressed using any lossy or lossless compression algorithms within defined QoS, then apply scalable coding systems for strong protection from transmission errors. The authors have reported that medical image compression and transmission are the two main aspects for the remote diagnosis. They developed the remote consultation system RDS2000 in which the data, videos and their particular Region of Interest (ROI) are exchanged using User Datagram Protocol, Transmission Control Protocol/Internetworking Protocol (IP) and multi-threading technology. The compressed medical image quality assessment can be done through evaluating various parameters like Mean Square Error, Sum of Absolute Difference, Structural Similarity Index Measurement, etc.(Dilmaghani, Ahmadian, Ghavami, & Aghvami, 2004; Gupta, Bansod, & Gamad, 2013; Yu-zeng, Shi-chao, & Fan Yu-jun, 2008).

4. The communications perspective

Health care delivery through telemedicine involves both wired and wireless technologies with wearable, embedded medical sensors or devices, etc. The wired communication can be achieved through optical networking having high speed or coaxial copper cable networking with relatively low speed, but they are not accessible everywhere (Kang, Partk, Song, Yoon, & Sha, 2011; Kyriacou et al., 2001). A converged radio optical wireless access architecture over fibre technology proposed by authors to transport real time, uncompressed telepathology images over 25-km fibre. It delivered medical data and images independent of bit rates, formats and protocols (Chang et al., 2011; Chowdhury et al., 2010).

Wireless telemedicine advert as a mobile health works on wireless technologies to provide proper health care by conquering the geographical boundaries to aid the remote diagnosis and observations. The main wireless technologies used in telemedicine systems are Cellular Mobile Communication, 3G—Wideband Code Division Multiple Access, CDMA2000, CDMA-evdo, 4G Long Term Evolution (LTE). Other wireless services like satellite communication, Very Small Aperture Terminal (VSAT) links, Wireless Local Area Network (WLAN), WiMAX, Cognitive Radio (CN)-based Wireless Regional Area Networks, Wireless Body Area Networks (WBANs), Ad-hoc, Sensor Networks, etc. Out of them, some wireless telemedicine technologies briefly describe in subsequent sub-section (Devaraj & Ezra, 2011; Martini, 2008; Ng, Sim, Tan, & Wong, 2006; Pattichis et al., 2002, 2007).

4.1. Cellular mobile communication

Wireless technologies provide alternative access for those areas where fixed networks are unreachable. The second generation cellular mobile communication systems (2G) typically support 14.4 kbps speed, which handled very low bit rate telemedicine traffic, later the General Packet Radio Services (GPRS-2.5G), Enhanced Date Rates for GSM evolution (EDGE-2.75G) were introduced with 144 and 384 kbps respective speed with an added feature of packet switching and they also enhanced the telemedicine traffic handling capability. 3G Universal Mobile Telecommunication System (UMTS) supports 2–20 Mbps speed with multimedia applications, recent 4G technologies having projected data rates of approximately 100 Mbps with desired QoS which further added to telemedicine deployment. Futuristic 5G systems may bring in paradigm shift in remote patient monitoring and tracking (Hong et al., 2009; Huang & Chien, 2010; Hunaiti, Garaj, & Balachandran, 2009; Liu, Meng, Tong, Chen, & Liu, 2006; Moon, Barden, & Wohlers, 2009; Oleshchuk & Fensli, 2010; Sandu, Szekely, Robu, & Balica, 2010; Sehgal & Agarwal, 2010). The Wireless Heterogeneous Network which integrated 4G with WLAN enhance the network performance through minimizing the call blocking probability and obtain the optimal transmission scheduling decision (Deif & EI-Badawy, 2010; Niyato, Hossain, & Camorlinga, 2009).

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In the above mentioned wireless communication scenario, the delay and the packet loss are the major concern for the ineffective resource allocation. So, for less delay and low packet loss, the stochastic programming model must be formulated to obtain real-time service oriented architectures with optimal number of reserved connections using constrained Markov decision process (Basilakis, Lovell, Redmond, & Celler, 2010; Logeswaran & Chen, 2008; McGregor & Eklund, 2010; Park & Nam, 2009; Phunchongharn, Niyato, Hossain, & Camorlinga, 2010).

4.2. Satellite communication

The Satellite links are feasible in global coverage, remote and interior areas like islands, mountains, tropical rain forests and in emergencies on planes and ships. The seamless mobile satellite communication has different data rates according to different technologies used for transmitting vital signals. The MERMAID, ATCS, TelePACS, MEDI maritime telemedicine system launched and used by different countries for real-time data transmission but they were too expensive (Kocian, De Sanctis, Rossi, & Ruggieri, 2011; Li, Takahashi, Toyoda, Mori, & Kohno, 2009; Lin, 2010).

4.3. Wireless local area network

The WLAN/IEEE 802.11 is the standard provide moderate to high-data rate communication in a short range generally within the campus. The IEEE 802.11e,i is used for transmitting medical data with desired QoS and also provided security support to IEEE 802.11. The internet-based health telemonitoring with 3G and satellite broadband communication supported by IEEE 802.11b, g provided data rate of 54 Mbps. They increased interactivity and mobility for both physicians and patients by supporting demands over a large scale of networks (Marti, Martin-Campillo, & Curcurull, 2009; Vouyioukas, Maglogiannis, & Pasias, 2007).

4.4. Wireless body area network

WBAN is a technology that provides short range, low power and highly reliable wireless communication for use in close proximity to or inside person's body. It mainly operates on person and may be deployed widely. The interference level from WBAN to other wireless systems must be reduced as small as possible. Their low power emission level helps to reduce the specific absorption rate to protect human tissues. The relevant medical data collected through sensors embedded in the patient's body and transmitted by a network coordinator through WBAN IEEE 802.15.6 which is restricted for internal communication in hospitals or at home (Dabiri et al., 2009; Hao-Hsiang & Huang, 2010; Wang, Nah, Seak, & Park, 2009). The authors have developed an independent unit in Malaysia for the measurements of body temperature, bodyweight, pulse rate and blood pressure using PIC microcontroller, GSM modem, RF and Bluetooth transceiver plus transducers. These measurements are sent as SMS (Short Message Service) via a GSM module to PDA via 2.4 GHz Bluetooth transceiver (Kornain, Abdullah, & Abu, 2012; Suganthi, Umareddy, & Awasthi, 2012).

4.5. Worldwide interoperability of microwave access

The WiMAX/IEEE 802.16 standard used as a broadband wireless access for telemedicine network, provided high speed of data communication for a long range. Its guaranteed broadband channels help in emergency by saving patient's time and travel costs to hospital through remote monitoring and follow-up activities. In a countries like China and Republic of Macedonia, the authors have reported the data rate of non-line-of-sight communication within 3–5 miles from the base station can be 75 Mbps while the same performance can be kept at 20 Mbps from 30 miles away by line-of-sight communication (Chorbev & Mihajlov, 2008; Kim, Yun, & Hur, 2009; Mignanti et al., 2008; Niyato, Hossain, & Diamond, 2007; Su & Caballero, 2010).

4.6. Cognitive radio network

CRN reduces the cost of accessing the licensed spectrum with sufficient amount of bandwidth and low latency. It has flexibility to use where little restriction on air interfaces, coverage area and network topologies. Its MAC protocol and resource allocations can be designed to satisfy telemedicine services based on the network conditions (Feng, Liang, & Zhao, 2010; Phunchongharn et al., 2010).

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4.7. Ambulance equipped with sensors or gadgets and wireless systems

Ambulance equipped with sensors and wireless system achieved high quality health services in emergency condition (during transportation) of patient. The medical data or signals of patient are measured, recorded, analysed or real-time transmitted for investigation, interaction and continuous monitoring. In Japan, the accomplishment of QoS constraints for different services have investigated and quantitative results were provided to demonstrate the feasibility of using UMTS technology for emergency care services on high-speed moving ambulance vehicles (Armengoli, Carricondo, Mingotance, & Gil-Loyzaga, 2009; Banitsas, Tachakra, Stefanidis, & Boletis, 2008; Gallego et al., 2005; Nakajima, 2009; Navarro, Mas, & Navajas, 2007).

The incoming data from the patient includes the International Mobile Subscriber Identity number, which is unique to the Subscriber Identity Module card present in the mobile telephone. This number is used to identify the patient to the system and to permit the storing of additional records for that patient. Such a technology will allow a trauma specialist to be virtually present at the remote location using Emergency medical systems and they participate in pre-hospital care, which improves the quality of trauma care especially for cardiac patients. They transmit the videos, images and vital signals like ECG simultaneously take into account the end-to-end delay, jitter, delivery ratio, inter frame interval, etc. in congestion control and without congestion control environment (Chu & Ganz, 2004; Corchado, Bajo, Tapia, & Abraham, 2010; Triunfo et al., 2010; Wac et al., 2009).

5. Issues related to telemedicine networks

Several issues such as access, information, security, protocols, computational capability, size of the devices, power efficiency, cost, etc. have been limiting the availability of devices and telemedicine services. The discussion on some of them is as follows:

5.1. Access

The most significant problems associated with the hospitals are the limited scope of access to data in proprietary hospital infrastructure systems. They need to replace or decommission medical applications and data services to support a network health care model, storage, post processing requirements of medical data and a centralized repository or common standard for most healthcare data (Constantinescu, Kim, & Feng, 2012).

5.2. Information

The training should be provided to physicians, paramedical and administrative staff on the use and benefits of wireless information technology in medicine and clarification of their legal and ethical issues. By analysing various case studies on telemedicine system, the authors have suggested immediate promotion and application of wireless health systems in hospital and rural health service centres. They reported that a Hospital Information System (HIS) with proper networks need to develop at the Base Unit site (Hospital) where the doctor (Base Unit user) can retrieve information using the hospital archiving unit about the patients' medical history. When HIS is not available, the Hospital needs the database unit to handle the patient medical record (Kyriacou et al., 2001).

5.3. Security

Security about the patients' data is the prime concern where the network is a public way to transmit the information and everyone can access this information. Linear Feedback Shift Register (LFSR) and chaos-based encryption techniques used in spatial and transform domain which was discussed by the authors for ECG and EEG data. Instant messaging (IM) is used for immediate communication which delivered almost in real time. The public IM services has a low level of security and to overcome this the authors have investigated a MediMob architecture for secure enterprise IM service which supports both clients on desktop and mobile devices. This system proved to be very stable and reliable in terms of operation, privacy and security (Blobel & Roger, 2001; Bønes, Hasvold, Henriksen, & Strandenæs, 2007; Parveen, Parashar, & Izharuddin, 2011; Ren, Pazzi, & Boukerche, 2010).

Authors have envisioned 50 threats and 4 information security aspects i.e. confidentiality, integrity, availability and quality where confidentiality identified as most serious threat. Most of the threats to integrity and quality were analysed to have Medium risk, while threats to availability were regarded Low risk. They have suggested Residential Patient Device, where dedicated computer permitting network access for encrypted transfer of messages from outside through a Virtual Private Network or Secure Shell port (Henriksen, Burkow, Johnsen, & Vognild, 2013). The location privacy also achieved by using Mist routers while in Taiwan security assertion markup language adopted for secure data transmission (Li, Wang, Lu, Lin, & Yen, 2010; Maglogiannis, Kazatzopoulos, & Delakouridis, 2009).

5.4. Reliable patient monitoring and power management

Another challenge in wireless transmission is to support reliable patient monitoring using ad hoc networks and to manage power transmission from patient's devices. The author developed Optimal Power from Both Patient and Cooperating Devices (OP-OCD) protocol for optimum power utilization while Maximum power from Patients Device and Cooperating Devices (MP-MCD) protocol leads to very high reliability (Varshney & Sneha, 2006).

5.5. Protocols for telemedicine

The various protocols proposed for efficient transmission of medical data are as follows: Wireless Application Protocol (WAP)-based telemedicine system has been developed by the authors for general inquiry and patient monitoring services. Authorized users can browse the patients' general data, monitored blood pressure (BP) and ECG on WAP devices in store and forward mode. The applications written in wireless markup language (WML), WMLScript and Perl resided in a content server. It can be feasible in remote patient monitoring and patient data retrieval (Hung & Zhang, 2003). The next protocol developed and investigated was Unequal and Interleaved forward error correction and Partial Packet Discard Medium Access Control for wireless communications which integrates voice, MPEG-4 video, SMS and web packet traffic over a noisy wireless channel of high capacity. It achieved high aggregate channel throughput in all cases of traffic load conditions (Koutsakis & Vafiadis, 2006).

Another protocol tested was Dynamic Transmission Control Protocol based on an Additive Increase Multiplicative Decrease approach used in setting up parallel connections. Its high scalability with proper scheduling provided more protocol connections which can be supported by using more threads for reliable transferring video stream data in a client–server system (Wan & Kwok, 2006; Wu & Cheng, 2005).

The performance of a Multiple Access Control (MAC) protocol for transmitting H.264 videoconference streams, voice, SMS and IP data traffic over a high-speed wireless TDMA channel with errors and capture under varying channel conditions developed by the researchers. They proposed two-cell stack random access algorithm and the Call Admission Control mechanism based on video traffic modelling used for next generation networks (Koutsakis, Vafiadis, & Lazaris, 2010).

The system architecture (Cerqueira, Zeadally, Leszezuk, Curado, & Mauthe, 2010) based on 3G networks and advanced signalling protocols (SIP/SDP) which integrated real-time multimedia services over multiple access channels that support IPv4 and IPv6 inter networking. UMTS allowed the simultaneous transmission of real-time clinical data (including ECG signals, blood pressure and blood oxygen saturation), video conference, high-resolution still image and other facilities such as multi-collaborative whiteboard, chat and web access to remote databases.

6. Review report

The authors have studied 130 research papers for this review report on telemedicine. The number of papers in different fields are as follows: General telemedicine concepts and terminology (11), GSM (4), GPRS (3), 3G (3), 4G (3), 5G (1), WiMAX (15), CRN (2), WBAN and Bluetooth (8), Satellite communication (3), WLAN (5), Stochastic and decision Support models (12), storage and security (9), image

compression and coding (3), telemedicine architecture (10), power consumption (2), emergency (ambulance) services (5), simulation (3), optical fibre(2) and deployment of telemedicine or pilot projects (14) by different countries. Out of 130 papers Table 1 on Wireless Communication Technologies for Telemedicine enlisted 52 papers which specify year, authors and brief features of different wireless technologies adopted for m-health application.

7. Telemedicine network architecture

The wireless networks should overcome all spatial, temporal, organizational and infrastructure barriers to provide medical service with desired QoS. The selection of any wireless architecture depends on the cost, speed, QoS, proprietary issue and wireless internet access. The pre-requisite for telemedicine architecture are real-time transmission, traffic condition of the network and desired QoS. Authors evaluated the behaviour of networks which transmitted medical videos where demand of too much bandwidth from network. They modelled traffic for medical activities where Constant Bit Rate (CBR) and Variable Bit Rate-real time (VBR-rt) measured by both simulated and real environments using Network Simulator. They reported that CBR determines available bandwidth and data size restrictions (around hundred of Kbps and below 1500 bytes) and VBR-rt determines delay thresholds (Hirche & Buss, 2003; Martinez, Salvador, Fernandez, & Garcia, 2003). Multimedia Integration Medium Access Control protocol for wireless communications have proposed by the authors to integrates voice, MPEG-4 or H.263 video, e-mail, and web packet traffic over a noisy wireless channel of high capacity (Koutsakis, Psychis, & Paterakis, 2005).

A remote video consultation architecture where video conference servers operate in isolation is inefficient as many patients in medical centres find that servers are busy and they may not get access. So to avoid this, authors proposed Video Consultation on Demand system where video conference servers belonging to different organizations merge into a single virtual server cluster operating under a single virtual organization where significant gains can be achieved in terms of average response time and number of patients (Khalil & Sufi, 2009).

To effectively transmit large size 2D and 3D medical images of remote patient in varying signal condition the wireless network requires large bandwidth without call drop and packet loss. So adaptive bandwidth reservation and scheduling mechanism proposed by the authors for efficient wireless telemedicine traffic transmission incorporated with third 3G or 4G scenario. Their simulation results show that their evaluation works on hexagonal cellular structure which provides full priority and satisfies the very strict QoS requirements of telemedicine traffic without violating the QoS of regular traffic, even in the case of high traffic loads (Qiao & Koutsakis, 2009, XXXX).

The authors reported that mobility telemonitoring architecture is another growing area, which enabled the subjective monitoring of the health status of elderly people living independently in their own homes. It provided the clinician with continuous quantitative data that can indicate an improvement or deterioration in a patients' condition by wearable and communicating sensors of patient sitting into the home. It also helped in emergency condition such as children with cardiac arrhythmias which is the most difficult problems in cardiology both in terms of diagnosis and management can also be performed through a GPRS/UMTS enabled device (Kyriacou et al., 2009; Scanaill et al., 2006).

The authors suggested the Mobile Ad-Hoc Network and the GRID technology for dedicated telemedicine architecture using infinite number of computing devices into any grid environment which provided better computing capability and problem resolution tasks within this operational grid environment. They reported that computer communication-based telemedicine will be implemented in rural area by very low cost for live or store and forward method of transmission and reception. The hardware layer of IR multiplex has also been used to allow multiple infra-red interfaces to be built into the device, permitting the use of different brands of mobile telephones having the infra-red interface in different locations, and using this authors can take ECG traces (Bailo, Barbieri, Cevasco, & Raggio, 2005; Graschew, Roelofs, Rakowsky, & Schlag, 2006; Istepanian, Woodward, &

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Table 1. Wireless Communication Technologies for Telemedicine

S. No.	Author's name	Year	2G	3G	Robotics	WLAN	WIMAX	Cognitive radio	LTE	Remark
1	Qiao and Koutsakis	2011		✓						Adopted an adaptive bandwidth reservation and fair scheduling scheme based on road map information of the hexagonal cellular network on user mobility for telemedicine traffic transmission over wireless cellular networks
2	Saravanan et al.	2011								A computer communication network that provided the services of multipoint to multipoint communication and has a simple connection with its clients
3	Phunchongharn, Hossain, Niyato, and Camorlinga	2010						✓		The optimal scheduling algorithm used to avoid Electromagnetic Interference (EMI) which affects the medical devices and provided desired QoS for health care environment
4	van der Schaar and Meehan	2012				✓			✓	The adaptive modulation fine granularity scalability algorithm proposed for MPEG-4 standard for distribution of multimedia over the Internet which works effectively in varying channel condition.
5	Lam, Tung, Tsang, and Ko	2009					✓			The emergency Wi-medicine system developed which is used in the ambulances to save life
6	Panayides, Pattichis, and Pattichis	2008		✓			✓			Their experiment showed that IBBPBBP group of pictures encoding scheme gave best performance in term of SNR used for medical video streaming over error prone wireless networks
7	Navarro et al.	2007		✓						Designed to communicate the personnel in an ambulance with medical specialists to a remote hospital through UMTS mobile access with IMS using SIP and SCP
8	Constantinescu	2012		✓					✓	The SparkMed data integration framework for m-health to enabled a wide range of heterogeneous medical software and database systems which dynamically integrated into a cloud like peer-to-peer multimedia data store. It delivered medical multimedia data to mobile devices and attaching to non-networked medical software processes without significantly impacting their performance
9	Guainella et al.	2007					✓			WIMAX technology is used for environmental monitoring, fire prevention, telehospitalization and telemedicine
10	Doukas, Maglogiannis, and Pliakas	2007					✓			A context aware platform for medical video transmission and optimized scalable data compression for H.263
11	Liu et al.	2006		✓	✓	✓				Developed model for telemedicine system for efficient and effective medical data transmission between patients and health professionals
12	Hu, Wang, and Wu	2006		✓	✓					Integrated wireless sensor network with 3G to monitor mobile patients serving four classes of multimedia medical calls for ambulance, serious patients, general patients and medical specialists who send sensor query results to the doctor having different QoS parameters
13	Dubois and Chiu	2005								The ATM LAN technology used for the real-time video transmission with reduce latency, increased QoS and increase transmission capacity

(Continued)

Table 1. (Continued)

S. No.	Author's name	Year	2G	3G	Robotics	WLAN	WIMAX	Cognitive radio	LTE	Remark
14	Chu and Ganz	2004		✓						Proposed system simultaneously transmitted video, still ultrasound images and vital signals like ECG which can assist the health care in pre-hospital trauma care
15	Qiut, Zhut, and Zhangt	2002		✓						A wireless network provided service up to 10 Mbps and higher spectral efficiency for packet data network
16	Istepanian et al.	2001	✓							Transmitted ECG from a patient to remote receiving point using sensors, attached to patients at home or in emergency situations
17	Kang et al.	2011				✓				Remotely monitor ECG using MAC layer point coordination function for deterministic packet delivery and the logic link control layer using Reed Solomon coding for error control to achieve high reliability
18	Panayides, Antoniou, Pattichis, and Pattichis	2012					✓			They can be used to communicate low-delay H.264/AVC ultrasound video using high efficiency video coding where bit rate demand reductet to approximately 37%
19	Alinejad	2012					✓			Comparative analytical study of optimized cross-layer ultrasound video streaming over mobile WiMAX and HSUPA networks where mobile WiMAX provided better performance than HSUPA in terms of frames per second, PSNR, and frame size with an average uplink throughput of 1.2 Mbps, acceptable for remote clinical diagnostics
20	Vohra, Sarkar, and Lee	2012			✓					A priority based MAC protocol proposed for scheduling of emergency data, minimal end-to-end delays, higher throughput and efficient bandwidth utilization when compared to the existing standard of IEEE 802.15.4 protocol
21	Kornain et al.	2012	✓		✓					Body temperature, bodyweight, pulse rate and blood pressure measurement which transmitted using Bluetooth and GSM
22	Zhang et al.	2004								A new distortion minimized bit allocation scheme proposed with hybrid Unequal Error Protection and delay constrained Automatic Repeat Request which dynamically adapted to the estimated time varying network conditions tested on scalable video codecs and provides minimum distortion and power consumption
23	Banitsas et al.	2008		✓						A system capable of transmitting video, audio and images from a moving ambulance to a consultation point using HSDPA and HSUPA links with 400 Kbps uplink and 1.1 Mbps downlink and delays were also kept low ranging between 300 ms and 1500 ms depending on the vehicle speed
24	Kyriacou et al.	2001	✓							The device used GSM mobile telephony links, Satellite links or POTS links and allowed the collection and handling of transmission of vital biosignals, still images of the patient and bidirectional telepointing capability
25	Voskarides et al.	2003	✓							The GSM and GPRS systems used for the transmission and reception of X-ray images and video in emergency orthopaedics cases where GPRS is superior to that of GSM. The data transfer rate achieved with GPRS is 32 Kbps with the download time for typical X-ray images of a file size of 200 kilobytes to the mobile device in 60 s

(*Continued*)

Table 1. (Continued)

S. No.	Author's name	Year	2G	3G	Robotics	WLAN	WIMAX	Cognitive radio	LTE	Remark
26	Gupta and Ganz	2004		✓		✓				Developed versatile, light weight and portable unit which can be carried anywhere by a patient allowing 24/7 monitoring capabilities to transmit vital biosignals as well as heavy image files using 3G and WLAN 802.11b
27	Gallego et al.	2005		✓						A multiplexing scheme for providing a multimedia connection between an ambulance and a hospital. The mean number of video users in the same cell ranges from 15 to 30. Voice and video transmission with maximum delay of 400 ms and a packet loss of 3 and 1%, respectively. ECG transmission considered to have a packet delay lower than 300 ms without packet loss
28	Bailo et al.	2005	✓			✓				Low cost consumer technologies used For low band data and real-time video transmission with great portability and stability for HMI and multimedia codecs
29	Lim et al.	2007		✓						Developed a fast delivery of electronic medical reports for referring to medical practitioners
30	Chu and Ganz	2004			✓	✓				The infrastructure uses Bluetooth and 802.11 g-based wireless networks to simultaneously transmit video, still ultrasound images, vital signals and text from multiple disaster sites to the control centre that resides in the disaster area
31	Krohn, Kopp, and Tavangarian	2007				✓	✓			An automatic antenna positioning system designed for the mobile WiMAX subscriber stations using PDA, Global Positioning System (GPS), micro controller and servo or stepper motors
32	Zhang et al.	2008		✓						Remote Monitoring System for telediagnosis to save patients life in ICU/CCU
33	Chorbev and Mihajlov	2008		✓		✓				Used for transmission of Voice Over IP(VOIP), SMS, MRI, X-ray, CT, video streaming using MPEG coding device
34	Wu et al.	2009	✓	✓	✓	✓				A wearable ring type pulse monitoring sensor to identify the position and condition of patient using GPS integrated with a smart phone and Bluetooth
35	Hunaiti et al.	2009	✓	✓						Developed a navigation system for visually impaired people
36	Corchado et al.	2010		✓						Medical image transmission using 3G
37	Mougiakakou, Kouris, Iliopoulou, Vazeou, and Koutsouris	2009	✓	✓		✓				Data regarding type 1 diabetes mellitus like glucose levels, blood pressure, food/drink intake, physical activity and other everyday habits and events transmitted to remote physician using a mobile phone
38	Hong et al.	2009		✓		✓				A portable emergency telemedicine system on PDA was developed over wireless networks for medical videos, patient biosignals, sending images and documents, exchanging messages and triage send using Wi-Fi, HSDPA, and WiBro (Wireless Broadband). The bandwidths of 300 Kbps over HSDPA and 1000 Kbps over WiBro were measured
39	Robert, Istepanian, and Philip	2009		✓			✓			Used for ultrasound streaming application

(*Continued*)

Table 1. (Continued)

S. No.	Author's name	Year	2G	3G	Robotics	WLAN	WIMAX	Cognitive radio	LTE	Remark
40	Li et al.	2009			✓					WBAN combined with satellite communication for data delivery between a rural local area and a remote central hospital which specified that link capacity has strong effect on the transmission delay
41	Chilamkurti, Zeadally, Soni, and Giambene	2010				✓				A cross-layer mapping algorithm which involved exploiting information from both the Application layer and the MAC layer proposed to improve the video quality of H.264 over IEEE 802.11e wireless networks by passing stream along with their requirements by slices
42	Huang and Chien	2010		✓						Transmitting vital bio-signals, sounds, dynamic and still images and videos of patients using compression of MPEG-4 which provided the electronic medical record at video stream rate of 24 frames per second (fps) for a high end PDA
43	Su and Caballero	2010					✓			WiMAX and VSAT technologies integrated to provide connectivity in rural areas consisting of towns and smaller remote communities
44	Singh et al.	2010					✓			They proposed lower modulation and coding scheme which can be used in Broadband Wireless Access (BWA) where voice and video transmitted in emergency with higher bit error rate
45	Pratomo, Yap, Lim, Yeo and Oh	2010					✓			Modified the Media Access Control layer scheduling part especially scheduler for telemedicine application
46	Feng et al.	2010						✓		Transmitted ECG, EEG, blood pressure and glucose monitoring with short delay and very high throughput and priorities can be easily set for emergency cases
47	Sehgal and Agarwal	2010							✓	Proposed algorithm always best connect the user as per his preferences of QoS parameters like bandwidth, cost of service, security level, low call drop probability, etc.
48	Deif and El-Badawy	2010				✓			✓	Proposed algorithm to minimize call blocking probability so efficiently used for telemedicine network
49	Rashkovska, Tomasic, and Trobec	2011			✓					Wireless body sensor used for measuring ECG signals significantly improves the wearing comfort without disturbing the normal life
50	Alinejad, Philip, and Istepanian	2012					✓			WiMAX 802.16j MMR technology proposed to provide a high-data rate in a relatively large coverage area used in ambulance scenario traffic includes blood pressure, heart rate, ROI, ultrasound video streaming, voice and video conference
51	Chu and Ganz	2007				✓				The system used Blue tooth and 802.11 g based wireless networks to simultaneously transmit video, still-ultrasound images, vital signals and text from multiple disaster sites to the control centre that resides in the disaster area
52	Piro, Ceglie, Striccoli, and Camarda	2013		✓					✓	Performance evaluation carried out of the LTE system delivering 3D video with different formats and resolutions

Richards, 2001; Saravanan, Anbu Rajan, Venkatraman, Sriraam, & Thirusakthi Murugan, 2011). The implementation of telemedicine architecture, case studies or pilot projects run in countries like India, Iran, Bangladesh, Jordan, China, Greece, Cyprus, Sri lanka, Hong Kong, Malaysia, Cyprus, Taiwan, Italy, USA, etc. emphasized that the potential for adoption of telemedicine technology to improve health care services is substantial, with major opportunities to increase disease awareness and implement better management (Branagan & Chase, 2012; Chorbev & Mihajlov, 2008; Faust et al., 2010; Hung & Zhang, 2003; Kornain et al., 2012; Kyriacou et al., 2001; Liu et al., 2006; Makena & Hayes, 2011; Mishra, Ganapathy, & Bedi, 2008; Mulvaney et al., 2012; Nakajima, 2009; Pal, Mbarika, Cobb-Payton, Datta, & McCoy, 2005; Siddiqul & Abdul Awa, 2012; Su & Caballero, 2010; Voskarides, Pattichis, Istepanian, Michaelides, & Schizas, 2003; Wan & Kwok, 2006).

8. Conclusion

The number of publications devoted to this subject concludes that future of telemedicine implementation in health care depends on the cost effectiveness, security, access, QoS, etc. for health systems. The emergency health care medical facility in ambulance will increasingly influenced by this technology. The recent researches in this field is to design system hardware and software to implement a mobile telemedicine system that can transmit medical signals of desired QoS with significant loads of multiplexed information in next generation wireless cellular networks. The speed and diagnostic reliability in telemedicine require reliable systems of communication between health professionals in extreme conditions, severity and distances. An international standard needs which codifies the interaction between various modules of a networking system, they involve a joint group consisting of representatives from various medical personnel, hospital administrators networking and communication specialists.

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