Chapter XXXII

Trends and Prospects of Telemedicine

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**ABSTRACT**

Recent development in telecommunication and information technologies came up with several technology options for telemedicine applications in hospitals and for medics for quality healthcare to patients. The research trends therefore need to be addressed for the proper deployment of technologies in a clinical setting or in a telemedicine environment with the adaptive compromise of technology and suitability. In this chapter, along with a description of the research trends and system design issues concerned with telemedicine, a mobile telemedicine system architecture and design have been proposed. Other current telemedicine technology options and prospects and challenges of future research in this emerging area are also described to indicate the possible future research challenges. Research in telemedicine is a future to provide improved and quality access to the healthcare professionals and patients. Therefore, developing telemedicine systems with state-of-the-art technologies is of paramount importance and hence, this chapter would link up an important step in system analysis and design perspective to this evolving research arena.

**INTRODUCTION**

Telemedicine has been defined as the use of telecommunication to provide diagnostic and therapeutic medical information and to provide healthcare services between patient and doctor without either of them having to travel across geographic, time, social, and cultural barriers. In other words, telemedicine is the delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis,
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treatment, and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities. The ongoing advancement of the sensors, low-power integrated circuits, and wired or wireless high data-rate broadband communication services under the umbrella of the telecommunication technology recently flickered renewed research trends and prospects for the efficient and cost-effective deployment of state-of-the-art technologies in telemedicine. It is therefore worthwhile to evaluate the technologies involved in telemedicine applications and establish a relationship between telemedicine system analysis and design to efficiently deliver services in a wider geographic area depending on the bandwidth and user requirements. This chapter therefore describes the trends and prospects of research in telemedicine in this emerging world of broadband convergence with a view to review and establish system design issues in this area. First we will review the definitions of telemedicine with some background information on the development of telemedicine. Subsequent sections of this chapter explore the different applications and design issues of telemedicine in different settings of technologies. As a part of telemedicine system development using current wireless technologies, the system architecture of a mobile telemedicine application is detailed thereafter. Later on, we narrate the other research issues in telemedicine and finally summarize the possibilities and future directions in a technical perspective.

BACKGROUND

The term “telemedicine” derives from the Greek “tele” meaning “at a distance” and the present word “medicine,” which itself derives from the Latin “mederi” meaning “healing” (Feliciani, 2003, p. 114). A 1999 definition adopted for a Congressional briefing on telemedicine in the USA produces a statement as follows:

Telemedicine utilizes information and telecommunication technology to transfer medical information for diagnosis, therapy and education.

The World Health Organization (WHO) describes the definition of telemedicine as follows:

The practice of medical care using interactive audiovisual and data communications including medical care delivery, diagnosis, consultation and treatment, as well as education and the transfer of medical data.

In addition to patient records, medical professionals can obtain vital signs and other reference data through telemedicine applications. Depending on the need and availability of communications infrastructure, telemedicine uses a variety of transmission modes including integrated services digital network (ISDN), local area network (LAN), asynchronous transfer mode (ATM), digital subscriber line, satellite, microwave, digital wireless, and the Internet. With all these ranges of technology deployment, telemedicine works have paved the right impetus for a cost-effective telemedicine network.

Telemedicine can be divided into two modes of operations: real-time mode (synchronous), in which patient data are available at the remote terminal immediately after acquisition, and store-and-forward mode (asynchronous), which involves accessing the data at a later time (Craig, 1999, p. 5).

In the store-and-forward mode, a digital image is taken, stored, and then forwarded to another location to a medical specialist for consultation and avoids the simultaneous communication between both parties in real time. Teleradiology, where radiographic images are needed to be transferred or in dermatology, where visually skin lesions are examined, are very good examples of this kind of mode. Store-and-forward also includes the asynchronous transmission of clinical data, such as blood glucose levels and electrocardiogram (ECG) measurements, from one site (e.g., patient’s home) to another site (e.g., home, health agency, hospital, or clinic).
In the real-time mode, both locations need to have the necessary equipments like cameras or monitors to complete the interaction. Real-time mode can use something as simple as telephone calls or as sophisticated as virtual reality robotic surgery or telesurgery. The patients and providers in this mode can communicate in between themselves using audiovisual and wireless or microwave signals. It is particularly useful for monitoring of long-term care patients or patients at their home. Applications of this type of mode can be in cardiology, neurology, and gynecology.

Therefore, telemedicine unit basically consists of the following modules:

- Biosignal acquisition module through sensors and peripheral devices.
- Digital camera for image or video capturing.
- Processing unit: computers.
- Communication module: Global system for mobile communication (GSM), general packet radio services (GPRS), third generation (3G), satellite, plain old telephone system (POTS), modem, Internet, WAN, metropolitan area networks (MAN), personal area networks (PAN), and so forth.

To date back to history, telemedicine was not developed as a segregated well-defined discipline with specialized protocols. With the advent of technologies, clinicians began to adopt the new technology for other purposes depending on availability. In the 1920s, radio-linked public health physicians watched at the sea stations to ships at sea with medical emergencies because sea-voyages were the principle means of international travel at that time. The most celebrated example is the Italian International Radio Medicine Centre, which began in 1935 and had assisted over 42,000 patients, mainly seafarers, by 1996 (Stanberry, 1998).

Widespread availability of black and white television in the 1950s greatly enabled the option to visualize the patients’ condition for diagnosis. At the same year, Robert Ledley pioneered the use of digital computers in the U.S. for medical purposes for dental projects at the National Bureau of Standards. For education and consultations between consultants and general practitioners (GP), the Nebraska Psychiatric Institute developed a two-way link with Norfolk State Hospital, 112 miles away, in 1964 using the closed-circuit television service (Benschoter, 1971). The link was used by doctors who consulted with each other on patient cases and also gave psychiatric consultations to patients on the other end of the link. In the late 1950s, the US Public Health Service and the National Aeronautics and Space Administration (NASA), sought to provide medical care to rural communities of Papago Indians in Arizona via the transmission of electrocardiographs and X-rays to centers staffed by specialists by the project Space Technology Applied to Rural Papago Indians Advanced Health Care (STARPAHC) (Bashshur, 1980). Another significant early implementation of telemedicine was a microwave video link set up in April of 1968 between the Massachusetts General Hospital (MGH) and Boston’s Logan airport. The link was established to provide immediate health services to airport employees and passengers. It eliminated the need to have physicians permanently assigned to the clinical facilities at the airport, while avoiding the delays associated with patient transportation. Examinations at Logan included radiology, dermatology, and cardiology (Bashshur, 1975).

Later in the 1970s, the large-scale demonstrations involving the ATS-6 satellite projects took place. The paramedics in remote Alaskan and Canadian villages were linked with hospitals in distant towns or cities. In Japan, telemedicine dates back to the 1970s. In 1971, the first teledmedical experiment took place in the Wakayama prefecture. The experiment involved closed-circuit television (CCTV) and the telephone circuit. CCTV was temporarily installed to provide medical care to rural mountain areas that had limited technology. Direct images and sounds were transmitted; documents were also transmitted by facsimile (called
copying transmission then). Also, the North-West telemedicine project in Queensland, Australia was the only major telemedicine project outside North America until 1990 which used the satellite links to serve rural communities, including aborigine populations (Watson, 1989, p. 68). In December 1988, NASA established SpaceBridge to Armenia due to the terrible earthquake. Video, voice, and facsimile applications were used in this project for the consultations between specialist centers in USA and a medical center in Yerevan, Armenia to provide the first truly international telemedicine program.

Another groundbreaking use of telemedicine (in a completely different setting) occurred in 1998, when a team of researchers from Yale and MIT collaborated with several of their research sponsors on the Everest Extreme Expedition (E3) to monitor climbers’ physiological and performance parameters using “bio-packs” as they scaled the highest mountain on Earth (Lau, 1998). The system used on Mount Everest provided audio and video communications to a medical unit at the base camp via satellite and to experts at MIT, Yale Medical, and Walter Reed Army Hospital.

In USA, Allen and Grigsby reported that nearly 40,000 teleconsultations were performed in 1998 in more than 35 different specialties (Allen & Grigsby, 1998), which showed clear invasion of telemedicine. The transition from analog to digital communications and the advent of mobile communication technologies with the Internet have dramatically increased the research impetus in this telemedicine area since the late 1980s. Due to the initial lead in telemedicine research, 50% of the primary research is now conducted in USA compared with the 40% in the whole of Europe and around 10% in Australasia (Wootton & Craig, 1999).

Wireless/mobile telecommunication solutions play a key role in providing telemedicine services, due to their flexibility in installation, portability, and mobility, among other advantages. Existing systems are mostly based on wireless local area network (WLAN), WiFi, and wireless personal area network (WPAN) (e.g., Bluetooth) technologies, in indoor applications, and on 2.5-generation cellular mobile services (mostly GPRS) in wide area applications. But in terms of coverage and/or data area, 3G wireless technology offers better services and is attractive for certain high bandwidth applications in recent days. Mobile telemedicine therefore is a new research area that exploits recent advances in next generation cellular communications networks, which provide the potential for highly flexible medical services that are not possible with standard telephony. In 1996, Garner et al. assembled a mobile demonstration terminal with a PC and a GSM modem. Image files of simulated wounds were transmitted over the system as e-mail attachments. Reponen et al. (1998) performed computerized tomography (CT) examinations at a remote portable computer that wirelessly connected to a computer network also via GSM cellular phone in 1998. The group later did similar tests with wireless personal digital assistants (PDA) (Reponen et al., 2000). The design of a prototype integrated mobile telemedicine system that is compatible with existing public mobile telecommunication network, code division multiple access (CDMA) 1xEVDO, was demonstrated in 2005 (Jung, 2005). The mobile telemedicine system consists of two parts. One is the physiological signal measuring part, and the other is a PC system for the signal processing and telecommunication. The system uses NetMeeting to transmit video, audio, and patient biosignals from a moving ambulance to a hospital and delivers the information to the personal computer of the doctor.

The development of a mobile telemedicine system with multicomunication links was proposed (Ibrahim et al., 2006). The system design goal is to provide patient monitoring during the prehospital transport and to offer health services for people who live in underserved areas. Therefore, medical information transmission becomes very crucial, since there is no transmission link stability guarantee. To deal with this issue, multicomunication links, including very high frequency (VHF) radio, Internet, GSM/CDMA mobile phones, and GPRS, are applied for the system. Selection of the commu-
nication links depends on the availability of the local communication infrastructure in their work. With the deployment of a combination of technologies in telemedicine area, the security and management of data have been considered as prime importance. Health Level 7 (HL7) is such an organization whose mission is to provide standards for the exchange, management, and integration of data that support clinical patient care and the management, delivery, and evaluation of healthcare services.

Most recently, telemedicine is currently in practice at sites such as the University of Kansas, where telemedicine has been used to care for patients in rural jails and hospice care, and at Johns Hopkins, where surgery was performed remotely on a man in Bangkok, Thailand.

The diversified technologies involved in telemedicine research are therefore key accelerators in the growth of this area. The next section encompasses the technological developments, design issues, and research trends of this demanding sector. Along with other current research trends in this area, a mobile telemedicine system analysis and design are also described in the following section as a possible solution for a telemedicine applied networked environment to provide best healthcare with wireless connectivity.

**RESEARCH TRENDS IN TELEMEDICINE WITH DESIGN ISSUES AND A SYSTEM ANALYSIS**

In a telemedicine system, generally four types of data are required to be transferred which are text and data, audio, still images, and video. Table 1 shows the file size requirements of these different types of data. Hence, depending on the file size, choice and performance of the telemedicine equipments are decided according to the clinical needs.

There are lots of factors that affect the performance of the types of data that are intended to be transferred in a telemedicine environment from one place to other locations without face-to-face consultation between the patients and physicians. The availability of different telecommunications technologies in telemedicine applications has also opened the enormous options of choosing a particular one according to requirements in a specific clinical setting. The alternative telecommunication options with the performance criteria for telemedicine applications are henceforth discussed briefly. And later in the following subsection, the research trends in this area will also be discussed with a description of a proposed system architecture of a mobile telemedicine system as mentioned earlier in this chapter. Thus, the main focus of this section will encompass the current research inclinations and system design issues among the ranges of technology options available in telemedicine research and to provide a system analysis and design of a mobile telemedicine system to wirelessly provide telemedicine services.

![Public Switched Telephone Network (PSTN)](image)

Also known as POTS, the early version of analog PSTN telephony was inadequate for telemedicine applications due to the low quality and low band-

<table>
<thead>
<tr>
<th>Source of data</th>
<th>Type</th>
<th>Typical File Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Notes</td>
<td>Text</td>
<td>&lt; 10 KB</td>
</tr>
<tr>
<td>Electronic Stethoscope</td>
<td>Audio</td>
<td>100 KB</td>
</tr>
<tr>
<td>Chest X-ray</td>
<td>Still Image</td>
<td>1 MB</td>
</tr>
<tr>
<td>Foetal Ultrasound</td>
<td>Video</td>
<td>10 MB</td>
</tr>
</tbody>
</table>

*Table 1. Examples of telemedicine data types (Wootton & Craig, 1999)*
width problems and was limited to only transmit audio sounds (e.g., speech) for remote diagnosis. With the advent of digital PSTN applications, limited audio, video, and data sharing are possible through the low bandwidth of 56 Kbps. But using high speed processors, encoding techniques, compression algorithms, and video display software can sustain this technology option because PSTN technology is generally available throughout the world.

**Integrated Services Digital Network (ISDN)**

In this purely digital service, there are two categories, which are basic rate interface (BRI) and primary rate interface (PRI). BRI comprises two 64 Kbps (B) channels and a 16 Kbps data signal (D) channel. In another word, this is an ISDN interface that provides 128k of bandwidth for videoconferencing or simultaneous voice and data services. Multiple BRI lines can be linked together using a multiplexer to achieve higher bandwidth levels. For instance, a popular choice among telehealth networks is to combine three BRI lines to provide 384k of bandwidth for video-conferencing. It should be noted that BRI ISDN services are not available in some rural locations. The advantages of BRI ISDN are immediate availability in most areas, inexpensive telecommunications equipment and line rates, and greater protocol support among existing computing hardware and software (Akselsen et al., 1993, pp. 46-51). But, BRI ISDN does not provide the bandwidth necessary for a large number of telemedicine applications which require simultaneous multimedia bit-streams, especially diagnostic-quality, full-motion video. The PRI has up to 30 B channels with a single 64 Kbps D channel. Channels can be coupled together so that a two-channel BRI system can work at 128 Kbps and a six-channel PRI set-up can function at 384 Kbps, which is fast enough to provide smooth video under most circumstances (Brebner et al., 2000). The community healthcare centers, located in major Indian cities, are connected via ISDN, with a redundant backup very small aperture terminal (VSAT) channel open.

The accepted international standard for videoconferencing is H.320 which includes support for video (H.261) and audio (G.722, G.728) compression/decompression, multiplexing, and synchronization, as well as document sharing (T.120). H.320 is designed to work over the range of ISDN connections (from 64 Kbps to 1.92 Mbps). In locations where ISDN is not available, POTS could be used to support H.324 videoconferencing, a derivative of H.320 which includes support for communications at up to 64 Kbps. Without compression, a large image transfer of 250 Mb over ISDN would require more than 2,000 seconds at 128 Kbps or 130 seconds at 1.92 Mbps where with 20:1 compression, this transfer would require 100 seconds at 128 Kbps or 6.5 seconds at 1.92 Mbps.

**Asynchronous Transfer Mode (ATM)**

ATM is a network technology based on transferring data in cells or packets of a fixed size. The cell used with ATM is relatively small compared to units used with older technologies. The small, constant cell size allows ATM equipment to transmit video, audio, and computer data over the same network, and assure that no single type of data hogs the line. ATM creates a fixed channel, or route, between two points whenever data transfer begins. This differs from TCP/IP, in which messages are divided into packets and each packet can take a different route from source to destination.

The advantages of ATM are higher bandwidths and statistical multiplexing of small packets (cells) without compression and minimal latency and jitter (Handel et al., 1993). Unlike ISDN, the range of bandwidths supported by ATM is sufficient for the entire range of telemedicine applications, including moving pictures expert group (MPEG)-2 video streams. A large image transfer of 250 Mb would require 1.6 seconds at 155 Mbps without compression, ignoring network overhead. With 20:1 compression and ignoring the time necessary to compress and decompress the images, this transfer would require only 0.08 seconds at 155 Mbps. In
addition, because ATM connections sharing physical links are logically separate, excess traffic from one connection would not impact other connections, including connections between the same source and destination.

ATM also offers “bandwidth on demand,” which allows a connection to deliver a higher bandwidth only when it is needed. The disadvantages of using ATM for telemedicine are the high costs and nonavailability of ATM equipment and telecommunications lines, especially to rural areas. However, ATM equipment and line availability have been increasing steadily and are expected to improve considerably in the future, and costs are expected to decrease as the size of the ATM market and user acceptance increases. It should be noted that ATM is one of the technologies being evaluated by telecommunications and interactive television companies for providing video dial tone services to the home. Besides contributing to the ATM infrastructure, ATM to the home would have major implications for telemedicine, including emergency services, remote monitoring of vital signs, and home patient education, thus providing a communications infrastructure to realize an ultimate goal in telemedicine, the “electronic house call,” limited to the first three only. Also, when coupled with the resilient synchronous optical Network (SONET) configurations, ATM systems offer high-quality and low-delay conditions.

**Microwave Links**

The term microwave generally refers to alternating current signals with frequencies between 300 MHz (3 x 10^8 Hz) and 300 GHz (3 x 10^11 Hz). For wide area network telemedicine applications, microwave connections can be a good option. Wireless LAN protocols, such as Bluetooth and the IEEE 802.11g and b specifications, also use microwaves in the 2.4 GHz industry, science and medicine (ISM) band, although 802.11a uses an ISM band in the 5 GHz range. Licensed long-range (up to about 25 km) wireless Internet access services can be found in many countries (but not the USA) in the 3.5–4.0 GHz range. MAN protocols, such as worldwide interoperability for microwave access (WiMAX), are based in the IEEE 802.16 specification. The IEEE 802.16 specification was designed to operate between 2 to 11 GHz. The commercial implementations are in the 2.5 GHz, 3.5 GHz, and 5.8 GHz ranges. Cable TV and Internet access on coax cable as well as broadcast television use some of the lower microwave frequencies. Some mobile phone networks, like GSM, also use the lower microwave frequencies.

It is of a higher frequency than a radio and is totally dependent on line of sight from transmitter to receiver. It is usually used on a point-to-point basis over distances up to 50 kilometers. Quite high bandwidths can be achieved if used in telemedicine applications. Hence, one disadvantage of the microwave link setup is that it requires line-of-sight between antennas in order to operate without interference, a requirement that is not always easy to satisfy in highly mountainous regions.

**Satellite Technology**

Satellites are able to receive radio signals from Earth and then retransmit them back. The device which does this is a satellite transponder. The geographic area covered by the satellite signal is known as the satellite’s footprint. Most communications satellites are in geostationary orbit over 40,000 kilometers above the equator and have footprints covering very large regions. The equipment required to transmit a signal to a satellite in geostationary orbit is expensive. The equipment required to receive the signal from the satellite is much less expensive. For this reason, satellite technology is often used to broadcast signals, for example, television or as a means of “trunking” an aggregated signal between telecommunications hubs. Satellite charges have been falling as their numbers and overall capacity have increased.

The advantages that satellite communications can bring to telemedicine include instant access to
broadband services, particularly in remote areas where telecommunications are poor or nonexistent, and swift response in disaster situations where speed is vital. Satellites also provide a powerful and relatively inexpensive tool, particularly for video links between multiple users. Plus, costs are constantly decreasing and satellites are a tried, tested, and extremely reliable means of telecommunication. Many existing mobile medical systems for disaster situations use satellites to establish communication between the disaster area and remote base hospitals (Garshnek & Burkle, 1999).

**Wireless Technologies**

In a telemedicine environment, the physicians and healthcare workers need to be mobile most of the time due to their respective duties in a clinic or hospital. Therefore, there is an obvious necessity to provide ubiquitous connectivity to the physicians or health workers so that they can access to the central database of clinical records of patients in a computer from a remote mobile terminal whenever needed. Also, light and smaller size with longer battery life, lower costs, and better user interfaces of mobile devices have strengthen the applicability of wireless technologies in telemedicine applications. So, the term mobile telemedicine is the fastest changing term in telemedicine applications since the wireless technology is moving towards third generation to fourth generation and therefore the transmission rates of different wireless techniques vary from one to another.

GSM offers 9.6 Kbps bandwidth and therefore restricts potential mobile telemedical services and the type, speed, and quantity of medical information to be transmitted. But the advent of GPRS promises data rates from 56 up to 114 Kbps and continuous connection to the Internet for mobile phone and computer users. Also, enhanced data rates for global evolution (EDGE) is a radio-based high-speed mobile data standard. It allows data transmission speeds of 384 Kbps to be achieved when all eight timeslots are used. EDGE was initially developed for mobile network operators who fail to win the universal mobile telephone system (UMTS) spectrum. EDGE gives incumbent GSM operators the opportunity to offer data services at speeds that are near to those available on UMTS networks. With EDGE, the operators and service providers can offer more wireless data application, including wireless multimedia, e-mail (Web-based), Web infotainment, and above all, the technology of video conferencing which has certainly alleviate the limitations faced by GSM in telemedicine applications.

Emergence of 3G mobile phone networks created and increased a number of systems which use mobile phones to transfer vital signs such as ECG and heart rate rather than early mobile medical system using satellites to establish communications between remote sites and base hospitals. 3G mobile phone is a digital mobile phone based on the International Telecommunication Union (ITU) IMT-2000 standard. In 3G communication networks, basically a CDMA system is used and provides a lot of services using the high bandwidth and multimedia transmission capabilities. Since the 3G mobile phone adopts the CDMA system, noise and cut-off in communication is reduced, and high-speed data transmission can be done at the rate of 384 Kbps at the most which was not acquired in 2G mobile phones. For example, Chu and Ganz (2004) report use of 3G networks for simultaneous transmission of video, medical images, and ECG signals. They describe a portable teletrauma system that assists healthcare centers by providing simultaneous transmission of a patient’s video, medical images, and ECG signals. They characterize a portable teletrauma system that assists healthcare centers by providing simultaneous transmission of a patient’s video, medical images, and ECG signals. They describe a portable teletrauma system that assists healthcare centers by providing simultaneous transmission of a patient’s video, medical images, and ECG signals.
throughput of such cellular links is fluctuant. Also, different types of streams such as real time video, images, vital signs, or other readings from medical sensors have different transmission requirements. Therefore, it is also needed to coordinate, prioritize, and compress the diverse media streams to eliminate distortion of multimedia content in cellular networks which are also essential criteria in design issues of telemedicine system involving cellular networks.

A collection of intelligent, physiological, and wearable sensor nodes capable of sensing, processing, and communicating one or more vital signs can be seamlessly integrated into wireless personal or body networks (WPANs) for health monitoring. The most important features of a wearable health monitor are long battery life, lightweight, and small size. If integrated into a telemedical system, these systems can even alert medical personnel when life-threatening changes occur. In addition, patients can benefit from continuous long-term monitoring as a part of a diagnostic procedure, can achieve optimal maintenance of a chronic condition, or can be supervised during recovery from an acute event or surgical procedure. Long-term health monitoring can capture the diurnal and circadian variations in physiological signals. These variations, for example, are a very good recovery indicator in cardiac patients after myocardial infarction (Binkley, 2003). In addition, long-term monitoring can confirm adherence to treatment guidelines (e.g., regular cardiovascular exercise) or help monitor effects of drug therapy. Other patients can also benefit from these systems; for example, the monitors can be used during physical rehabilitation after hip or knee surgeries, stroke rehabilitation, or brain trauma rehabilitation. During the last few years there has been a significant increase in the number of various wearable health monitoring devices, ranging from simple pulse monitors, activity monitors, and portable Holter monitors (Holter Systems, 2007), to sophisticated and expensive implantable sensors. However, wider acceptance of the existing systems is still limited by the following important restrictions.

Traditionally, personal medical monitoring systems, such as Holter monitors, have been used only to collect data. Data processing and analysis are performed off-line, making such devices impractical for continual monitoring and early detection of medical disorders. Systems with multiple sensors for physical rehabilitation often feature unwieldy wires between the sensors and the monitoring system. These wires may limit the patient’s activity and level of comfort and thus negatively influence the measured results (Martin et al., 2000). In addition, individual sensors often operate as stand-alone systems and usually do not offer flexibility and integration with third-party devices. Finally, the existing systems are rarely made affordable. Recent technology advances in integration and miniaturization of physical sensors, embedded microcontrollers, and radio interfaces on a single chip, wireless networking, and microfabrication have enabled a new generation of wireless sensor networks suitable for many applications. A number of physiological sensors that monitor vital signs, environmental sensors (e.g., temperature, humidity, and light), and a location sensor can all be integrated into a wearable wireless body/personal area network (WWBAN) (Jovanov et al., 2005). When integrated into a broader telemedical system with patients’ medical records, the WWBAN promises a revolution in medical research through data mining of all gathered information. The large amount of collected physiological data will allow quantitative analysis of various conditions and patterns.

A LAN is used to connect digital devices such as personal computers and mainframe computers over a localized area such as a building or campus of a hospital, university, or factory. In a hospital they are often used to access a patient master index, medical record tracking, appointment booking systems, and pathology test results. Distances are small, 1-2 kilometers at the most, and this allows high data transmission rates. A wide area network (WAN) is a network which covers a greater geographic area than a LAN. In health applications, a typical WAN would connect the LANs from all the hospitals in
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a city or region. A wireless LAN or WLAN is a wireless local area network, which is the linking of two or more computers without using wires. Thus, now-a-days, WLAN systems capable of transmitting at high speeds are being developed and installed around the world. They possess a number of advantages ranging from installation flexibility and mobility to increased scalability. Hospitals are in need of such technology as it will ensure faster and more accurate addressing of patient needs, allowing for delivery of services to the point of care, even though the treating staff could be in a different place at the time.

Originally WLAN hardware was so expensive that it was only used as an alternative to cabled LAN in places where cabling was difficult or impossible. Early development included industry-specific solutions and proprietary protocols, but at the end of the 1990s these were replaced by standards, primarily the various versions of IEEE 802.11 (Wi-Fi) and HomeRF (2 Mbit/s, intended for home use, unknown in the UK). An alternative ATM-like 5 GHz standardized technology, high performance local area network (HIPERLAN), has so far not succeeded in the market, as with the release of the faster 54 Mbit/s 802.11a (5 GHz) and 802.11g (2.4 GHz) standards. Table 2 represents the lists of the available WLAN protocols for the application in telemedicine.

Among the available protocols, Bluetooth is a low cost, low power, short-range radio technique introduced by Ericsson and others. Bluetooth was originally and essentially a replacement for physical cables. The goal of eliminating cables has lead to the creation of the notion of PAN, a close range network surrounding a person carrying several heterogeneous devices equipped with wireless communication techniques. It has the capability to allow mobile devices to communicate with computers within a 10 m distance which can be helpful in patient monitoring and emergency alarms to remote locations.

The merging of Internet and mobile computing is promoting the developments of handheld devices, wireless infrastructures, application programming languages, and protocols, all aiming to provide mobile Internet access. Among these is the wireless application protocol (WAP), a communication protocol and application environment for the deployment of the information resources, advanced telephony services, and Internet access from mobile devices. So WAP can be a possible option for telemedicine applications. Hung et al. (2003) utilize WAP devices as mobile access terminals for general enquiry and patient-monitoring services. In this experiment, an authorized user, may it be doctor or the patient’s relatives, can browse the patient’s general data, monitored blood pressure, and electrocardiogram in store-and-forward mode.

From the aforementioned technology options, it is now vivid that more and more investigations relating the mobile telemedicine area need to be explored because of tremendous data transmission capabilities of the future ubiquitous next generation wireless networks. Therefore, a system architecture based on the WLAN system to utilize in a mobile telemedicine environment is described in the following sub-section.

System Design Architecture of a Mobile Telemedicine System

Mobile telemedicine involves more than just communicating via a mobile phone or PDA that sends and receives some medical data. It involves some swiftly moving vehicles that are equipped with high quality, broadband wireless systems to assist patients in undeserved regions or in disaster areas. Ambulances with wireless systems provide links between the hospital physician and the paramedic in the ambulance while a patient is being transported to the hospital. Real time patient signals like ECG and spot oxygen saturation (SpO₂) can be monitored even before the patient reaches the hospital. On the other hand, conventional home care basically involves a fixed and limited number of visits by a trained nurse to a patient’s home. All activities during these visits are controlled by the nurse; they may
include vital signals recording, general assessment of the patient’s therapy progress, medication, and patient’s instruction on particular needs observed during the visit (Guillén et al., 2002). By using mobile phones, a telehomecare system is possible where the phones can interact with electromedic devices (EMDs)—like patient monitors, for example—and transmit vital signals through Internet protocols, such as transmission control protocol (TCP/IP) and user datagram protocol (UDP).

In this subsection, a design and system architecture of a mobile telemedicine system using 3G mobile communications technology with the application of orthogonal frequency division multiplexing (OFDM) scheme in a wireless LAN environment to provide an enhanced, seamless and ubiquitous healthcare information exchange is presented. The telemedicine system will include videoconferencing as well as communication of patient signals including data, images, and videos. The proposed wireless LANs for this system are IEEE 802.11a and IEEE 802.11b depending on the application area and the requirement of speed and bandwidth needed. A telehomecare system will be also included to exploit maximum benefits of the proposed model.

The most widely used wireless protocol today is the IEEE 802.11b. In the market since 2000, it usually uses complementary code keying (CCK) and direct signal spread spectrum (DSSS) techniques to spread its signal over a frequency range and avoid interference while achieving a top speed of 11 Mbps an advertised range of about 300 m which is 20-30 m in practice (Flickenger, 2003). As sophisticated as this technique is, it behaves relatively poorly in multipath environments when compared with newer modulation schemes like OFDM.

As mentioned before, IEEE 802.11b operates in the 2.4 GHz frequency band (a band also known as ISM). It is one of the least favorite frequency bands, as at 2.44 GHz water molecules resonate and microwave ovens operate. To cope with this problem, WLANs usually use some kind of spread spectrum technique, either frequency hopping spread spectrum (FHSS) or DSSS to spread their signal over a frequency range so they can avoid interference at a specific frequency. DSSS is the most widely used method and is considered slightly better than FHSS.

Regardless of the spreading technique used, the wireless transmission signal will still suffer from attenuation, especially when the mobile terminal

### Table 2. WLAN protocols

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Release Date</th>
<th>Frequency</th>
<th>Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE 802.11</td>
<td>1997</td>
<td>2.4 GHz</td>
<td>1, 2 Mbps</td>
</tr>
<tr>
<td>IEEE 802.11a</td>
<td>1999</td>
<td>5 GHz</td>
<td>6, 9, 12, 18, 24, 36, 48, 54 Mbps</td>
</tr>
<tr>
<td>IEEE 802.11b</td>
<td>1999</td>
<td>2.4 GHz</td>
<td>5.5, 11 Mbps</td>
</tr>
<tr>
<td>IEEE 802.11g</td>
<td>2003</td>
<td>2.4 GHz</td>
<td>6, 9, 12, 18, 24, 36, 48, 54 Mbps</td>
</tr>
<tr>
<td>IEEE 802.11n</td>
<td>expected mid-2007</td>
<td>2.4 GHz</td>
<td>540 Mbps</td>
</tr>
<tr>
<td>IEEE 802.15 (Bluetooth)</td>
<td>1999</td>
<td>2.4 GHz</td>
<td>1 Mbps</td>
</tr>
<tr>
<td>IEEE 802.16 (Wi-MAX)</td>
<td>December 2005</td>
<td>6-66 GHz</td>
<td>up to 75 Mbps</td>
</tr>
<tr>
<td>HomeRF</td>
<td>IEEE 802.16 December 2005</td>
<td>&lt;5 GHz</td>
<td>10 Mbps</td>
</tr>
</tbody>
</table>
Trends and Prospects of Telemedicine

(MT) is moving away from the access point (AP). For this reason, 802.11b is designed to fall back on its speed in order to maintain signal integrity. This means that as the received signal is deteriorating, the connection speed will automatically fall from 11 Mbps to 5.5, 2, and finally to 1 Mbps. Keeping in mind that real-time applications (like telemedicine) are bandwidth demanding, the reduced bandwidth is rarely capable of accommodating the needs of real-time applications.

An attempt to increase the available bandwidth is the IEEE protocol, 802.11a, capable of operating at speeds of as high as 54 Mbps. Although suggested and standardized first, 802.11a was released after 802.11b and up until recently was only operating in the USA. This is because 802.11a operates in the 5 GHz band that is reserved in most European countries. This band is called universal networking information infrastructure (UNII) and consists of three separate bands: UNII-1 for indoor use, UNII-2 for either indoor or outdoor use, and UNII-3 for outdoor bridging only. Reflections are much more apparent in the 5 GHz spectrum, so any kind of reflective surface can have devastating effects on signal quality. The most visible consequence is when trying to cover a space with AP, a lot more are needed if 802.11a is used compared to 802.11b.

A new protocol, high performance local area network (HIPERLAN/2), also operating in the 5 GHz band, has been developed by the European Technical Standards Institute (ETSI) and promises true quality of service (QoS) and speeds of 54 Mbps. Unfortunately, despite its development for over 4 years, hardware supporting this protocol is not yet commercially available. Both HIPERLAN/2 and 802.11a share almost the same characteristics with the exception of the intermediate fallback speeds: 6, 9, 12, 18, 24, 36, 48, and 54 Mbps for IEEE 802.11a and 6, 9, 12, 18, 27, 36, and 54 for HIPERLAN/2. Since the modulation is practically the same, one can conclude that the issues discussed here concerning 802.11a apply to HIPERLAN/2 (Doufexi & Armour, 2002).

In most wireless communications, the signal does not travel from transmitter to receiver through a straight line. Mountains, buildings, floors, ceilings, furniture, and even people reflect the signal depending on the operating frequency. The lower the frequency, the more it can penetrate through objects and not get reflected. The higher the frequency, the more reflections take place and a multipath effect is more dominant.

During the multipath effect the receiver not only receives the signal directly from the transmitter, but also receives all the reflections of that signal. What makes this an undesirable effect is that since the straight-line transmission arrives the earliest, all other packet transmissions arrive with a time delay and collide with next-frame data. Depending on the distance between receiver and transmitter and the number of reflected paths, the signal can be rendered useless, even though its power would be sufficient in the absence of this effect.

The above discussion indicates that IEEE 802.11a would suffer from a much higher multipath loss than 802.11b since it is using a higher frequency band. However, a different kind of modulation from that used in 802.11b can be used in both 802.11a and HIPERLAN/2 to address this problem; OFDM rather than using CCK.

Thus the proposed OFDM system in the mobile telemedicine system can offer improvement which would mean that more data can safely go through the communication channel and, for the specific telemedical application, a better video quality can be transmitted and consequently the doctors can make a more accurate diagnosis. For the telehomecare system, the system takes advantage of the serial port available in new mobile phones using OFDM to implement a generic interface for patient monitors. The vital signals are acquired from the EMD using the RS232 interface and transmitted through the Internet.

In the proposed mobile telemedicine system, one central server and a mobile server is required. The mobile server will have a high-end laptop computer with a WLAN personal computer memory card international association (PCMCIA) card using the IEEE 802.11a/b protocol depending on the dis-
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Tolerance requirement and it will permit total mobility within the emergency department of the hospital and beyond. An AP within the emergency department acts as a wireless bridge for the network data to be transmitted to and received from the rest of the network. A high-quality digital camcorder is connected to the laptop and high-quality video and audio and still pictures can be transmitted. Medical instruments like otoscopes and dermascopes can also be connected to the system. The central server will have a fixed computer within the existing hospital network or a mobile computer. Expert consultants and doctors will be sitting there. It can be in the same hospital or a remote hospital. The central server will have the facility to provide teleconferencing and it should be able to transmit video to a PDA. Existing 3G and also future 4G mobile devices will also be used as the terminals in the central server.

The telehomecare will be provided by the interface RS232 of the mobile phones of the patients staying home. The patient’s vital signals, such as ECG, heart rate, blood pressure, SpO2, respiration rate, and temperature will be taken by the patient monitor, that is, EMD, and sent by the mobile phone through RS232 interface. The signals are converted in packets and transmitted to the server using TCP/IP and/or UDP protocols. The central server settled in hospital stores data in a relational database. Then, healthcare providers or consultants monitor their patients using the server application. Videoconferencing arrangement in the patient’s home can further improve the diagnosis.

Incoming emergency patients can be dealt with by the mobile server which can communicate to the central server depending on needs. The patients on the way to hospital in the ambulance can be communicated by the mobile device—with the 3G/4G technique having video options—and treated according to the advice provided by doctors. In the disaster areas or remote areas, the similar advantage of 3G/4G mobile technology with high data rate applications, that is, video or teleconferencing, can be applied. Figure 1 shows the block diagram representation of the whole system architecture.

In the model, from the 802.11b, it will be good to use the extended range it has, its increased compatibility with radio regulatory committees all over the world, and its relatively cheap hardware. From the 802.11a, use its higher tolerance to multipath noise, a factor that affects extensively the signal quality and speed of the WLAN. Using OFDM modulation instead of CCK in the system will provide two advantages at the same time.

Fortunately, most wireless hardware (APs and client cards) in the market today give the user the ability to upgrade the firmware (software inside ROM) of the system in order to support different technologies. Also, today’s hardware has embedded microprocessors that can perform a wide variety of tasks, including inverse fast Fourier transform (IFFT) and fast Fourier transform (FFT), necessary for OFDM modulation.

It is obvious that in these kinds of systems, QoS plays a critical role. It would be useless if the system could not guarantee the level of service necessary for accurate diagnosis. Despite the fact that none of the IEEE 802.11 protocols have guaranteed QoS, there are several parameters that a developer can optimize in order to keep a high operational level of the wireless network. Some of these include connection establishment delay, throughput, transit delay, residual error rate, protection, priority, and resilience. While protection refers to the security that the system applies to the transmitted data (Owens et al., 2001), throughput and resilience are definitely some of the most important QoS parameters in a WLAN. In order to maximize the throughput one has to minimize the number of errors that appear in the communication channel. One of these erroneous factors is the multipath phenomenon and that is why the OFDM modulation scheme in the IEEE 802.11 will provide better performance. Newer technology like IPv6 can also be used to provide broadband wireless network services.
OTHER CURRENT RESEARCH IN TELEMEDICINE

Telemedicine can be divided into three areas: aids to decision making, remote sensing, and collaborative arrangements for the real-time management of patients at a distance. As an aid to decision making, telemedicine includes areas such as remote expert systems that contribute to patient diagnosis or the use of online databases in the actual practice of medicine. This aspect of telemedicine is the oldest in concept. Remote sensing consists of the transmittal of patient information, such as electrocardiographic signals, x-rays, or patient records, from a remote site to a collaborator in a distant site. It can also include transmittal of grand rounds for medical education purposes or teleconferences for continuing education. Collaborative arrangements consist of using technology to actually allow one practitioner to observe and discuss symptoms with another practitioner whose patients are far away. This raises important issues of referral and payment arrangements, staff credentialing, liability, and licensure potentially crossing state lines. Two-way work stations which provide smooth digital motion pictures have been integral to the long distance, real-time treatment of patients. As new technology is found, collaborative arrangements are the future of telemedicine.

Perhaps the greatest impact of telemedicine may be in fulfilling its promise to improve the quality, increase the efficiency, and expand the access of the healthcare delivery system to the rural population and developing countries. As wireless technology becomes more ubiquitous and affordable, applications such as video-telephony over POTS will gradually migrate towards 3G and 4G wireless systems. This will certainly improve the quality of telemedicine applications.

The holomer (HOLO-graphic M-edical E-lectronic R-epresentation) (see Figure 2) is a three dimensional holographic digital image of a specific person, derived from a CT scan, MRI, ultrasound, or other modality. Physicians will be able to interact with the holomer as if it were the patients themselves. Soon, every patient will have their own...
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unique holomer, containing not only anatomically precise information, but also physiologic, biologic, genetic, demographic, and other information contained within the image. Physicians will interact with these holomer as if they were the patients themselves. They are a human surrogate in cyberspace, an informational equivalent of the person in bits and bytes. For diagnosis, all the relevant data about the patient can be retrieved in the form of a visual medical record. In therapeutic, if a complex surgical procedure is required, the holomer can be used for preoperative planning (as is already used for complex orthopedic, neuro- and craniofacial surgery), selecting the best surgical approach for that patient. Using surgical simulation, the surgeon can practice the procedure on the holomer, until a “perfect” operation is obtained.

Now-a-days, robots roll from room to room in hospital, displaying the face of a doctor or nurse (see Figure 3) who can videoconference with patients via a wireless net connection. Science-fiction moved a step closer to reality when robots nicknamed “Sister Mary” and “Doctor Robbie” started work at a London hospital on May 18, 2005. The pair allows doctors to visually examine and communicate with patients, whether they are in another part of the hospital or even another part of the world.

Minimally invasive surgery (MIS) is a revolutionary approach in surgery. In MIS, the operation is performed with instruments and viewing equipment inserted into the body through small incisions created by the surgeon, in contrast to open surgery with large incisions. This minimizes surgical trauma and damage to healthy tissue, resulting in shorter patient recovery time. Unfortunately, there are disadvantages due to the reduced dexterity, workspace, and sensory input to the surgeon which is only available through a single video image. The “robotics lab” of University of California at Berkeley has developed (see Figure 4) a prototype glove-like device that senses the positions of the surgeon’s fingers and wrist with its index, thumb, and wrist flex sensors and wrist rotation sensor. The glove provides a more natural means of control than current minimally invasive tools. It could be used as a master to drive the miniature slave robotic hand, if force feedback is not needed.

While research into telesurgery helps to jump-start robotics in the operating room, distant operations have remained an elusive application. However, it may eventually prove to be one of the most significant uses of robotic surgery.

For the discipline of surgery, the surgical console is the interface between the real and information world; virtual reality meets real reality. From the console, the surgeon can perform open surgery, minimally invasive surgery, remote telesurgery, surgical preplanning, surgical procedure rehearsal, intraoperative image guided surgery, and surgical simulation. All these actions are possible from the single point of the surgical console. The first telesurgical procedure upon a patient was performed by Prof Jacques Marescaux in September 1991. He made a set up at his surgical console in New York City and performed a laparoscopic cholecystectomy on his patient who was in Strasbourg, France, over 4,000 km away.

Battle-field casualty care now-a-days can be totally monitored using state-of-the-art technologies in remote sensing and medical informatics. The keys are: remote monitoring of every soldier’s location and vital signs with personal status monitor

Figure 2. Holomer in virtual soldier project in US (source: Virtual Soldier Project, http://www.virtu alsoldier.us/showcase.htm)
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(PSM) assistance at the casualty side to the medic from a remote physician with telementoring; providing immediate surgical care on the battlefield with telepresence surgery; monitoring en route therapeutics and transportation of casualties in a trauma pod; simulation of battle wounds for surgical practice; and medical forces planning and training with virtual reality.

Now-a-days, military medics carry an electronic device with an antenna to read data recorded on the tag of an injured soldier. Using the device, medics can upload the information on the soldier’s medical history and add new information on medical condition, triage code, and eye and motor response into a miniature, handheld computer. In addition, once the wounded soldier is placed upon the life support for trauma and transport (LSTAT) (see Figure 6), which is a portable intensive care unit (ICU), the surgeon back in the mobile advanced support hospital (MASH) can receive by telemedicine the vital signs, change the respirator settings, and control the flow of the intra-venous fluids and medications. The LSTAT has been used since 2000 in the conflict in Bosnia and Kosovo. From the time of wounding when the soldier is placed on the LSTAT, to the helicopter evacuation, to the ambulance transfer to the MASH, to the emergency triage, to the operating room, and finally in the post-operative ICU, the casualty is continuously monitored and the medical record is automatically recorded. In the Afghanistan and Iraq Wars, the LSTAT was recalled for servicing; however, the medics would not send them back because they were so valuable.

However, defense services place particular emphasis on encryption and other security measures for telemedicine. Computer-based telemedicine systems for military or commercial customers can offer strong safeguards to keep unauthorized eyes and ears from sensitive information.

Surgical simulators have become a leading edge technology. One of the most sophisticated systems is the endoscopic sinus surgery simulator (ES3) (see Figure 7).

Starting from the beginning level to expert level, this simulator has multiple levels of training. In the expert level, the procedures must be accomplished realistically. The student’s performance is recorded, errors are counted, and the student is given an objective score of their performance. Lockheed Martin delivered the first ES3 simula-

Figure 3. Medical robot at St Mary’s NHS Trust and Imperial College London (“Take two aspirin and call the robot in the morning?” 2005)

Figure 4. Prototype dextrous master (source: Robotics lab, University of California, Berkeley)
Figure 5. Surgical console using the da Vinci Surgical System (What is robotic surgery, http://www.drslawin.com/robotic_prostatectomy.html)

Advances in robotics also enabled changes in the operating room environment. Dr. Michael Treat (Columbia University, New York City) has developed Penelope, a robot to replace a scrub nurse. Using robotics, automatic target recognition, voice activation, intelligent decision support, and other common methods from other industries, Dr. Treat is able to use the robot to hand and pick-up and hand off surgical instruments during a surgical procedure. The United States military has a new program called “Trauma Pod” (see Figure 8) in which it is envisioned that they will build an “operating room without people.”

The Trauma Pod will not require human medical personnel on-site to conduct the surgery, and will be small enough to be carried by a medical ground or air vehicle. A human surgeon will conduct all the required surgical procedures from a remote location using a system of surgical manipulators. The system’s actions are then communicated wirelessly to the surgery site. All phases of the operation will be conducted by the surgeon with the necessary support from the automated robotic systems.

The Israeli based company “Given Technologies” has miniaturized a camera and transmitter and placed it into a capsule that can be swallowed; an image is taken two times a minute and sends to a...
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belt-worn video cassette recorder. After the camera passes, the video tape is given to the gastroenterologist to review instead of doing an endoscopic procedure.

There are number of types of disasters such as earthquakes, nuclear/hazardous chemical accidents, civil disorder/riots, bomb threats/terrorist attacks, bio-wars, and so forth. In such situations, the existing terrestrial infrastructure could be damaged. The space systems then suitably complement partly destroyed terrestrial infrastructure to answer the requirements of emergency healthcare services such as fast deployment of the management of logistic and medical means or remote medical expertise. Appropriate new telemedicine applications can improve future disaster medicine outcomes, based on lessons learned from a decade of civilian and military disaster (wide-area) telemedicine deployments. Emergency care providers must begin to plan effectively to utilize disaster-specific telemedicine applications to improve future outcomes.

Ever since September 11, 2001, with terrorist attacks in the USA and the spate of anthrax outbreaks there and elsewhere, the specter of global terrorism has become more real. In recent times, the increasing threats to use biological weapons of mass destruction have triggered off an urgent need to review current methods of disease surveillance. Some of the existing (or in the process of being developed) disease surveillance systems are as follows:

a. Electronic Disease Reporting & Management System (EDRMS).
b. Real-time Outbreak and Disease Surveillance (RODS).
c. Lightweight Epidemiological Advanced Detection & Emergency Response system (LEADERS).

A number of micro sensors and other MEMS technologies are being embedded into insects to act as living sensors. Bumble bees with microsensors for anthrax and a small transmitter have been used to identify simulated biologic agents during military exercises and transmit the information back to the soldiers so they can avoid the biologic agent.

The medical informatics and technology applications consortium (MITAC) is a unique NASA research partnership center (RPC), established to develop, evaluate, and promote information and medical technologies for space flight and ground applications. It is comprised of partners from government, academic institutions, and industry that have a commercial interest in products and technology related to telemedicine, medical informatics, and medical technology.

For the discussions above, it can be well inferred that research directions in telemedicine area involve lots of technologies and their successful implementations. The current research scenario in telemedicine therefore confronts some research challenges as well for the proper implementation of a myriad of technologies available. The following section details some of the research challenges to meet.

**FUTURE TRENDS**

Telemedicine is going to be an attractive solution for the future of healthcare. The future research trends and challenges in this area are described below.
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Standardization

Generally, standards are developed to provide security and integrity of information that is sent effectively through the telecommunications. Currently, inadequate standardization of procedures, terminology, equipment requirements, health service identifiers, service identifiers, and data transfer are substantial barriers to the successful implementation of telemedicine. The department of Health and Human Services (DHHS) estimates that 400 formats are used in the United States today for healthcare-related transactions. Due to the lack of standardization, vendors find it difficult to develop software and thus cost also increases for the healthcare providers. Efficient and effective use of telemedicine requires the development of proper standards in respective applications of telemedicine for remote healthcare and the healthcare industry can thus exploit the capabilities of the systems developed. Medical files, such as X-ray images, must be presented in formats that physicians are used to seeing, but there are not many standards yet for digitizing the hardcopy images and sending them over the Internet; like a radiological image interpretation apparatus and method where a radiology healthcare network provides high quality, timely medical interpretations of radiological images on a national (e.g., across the U.S.) and regional basis.

Interoperability

The collaboration of software and hardware requires a platform to render incompatible telemedicine standards compatible, called middleware. Therefore, it requires a set of rules or policies to drive the technology so that the development in hardware and software can proceed in this area. H.320 and HL7 are some examples in this regard which have set some rules in their respective fields mentioned previously to provide interoperability. Newer technologies need similar types of interoperability to enhance the utilization of the systems.
Medical Sensors

Sensor networks are emerging as one of the emerging fields of telemedicine. Sensor networks consist of small sensing areas and typically reside in homes or in a patient. When they reside so, they are called the patient’s body area network (PAN). PAN helps to monitor many facets of a patient’s physical health through means of “conventional sensors” based on piezo-electrical material for pressure measurements to infrared sensors for body temperature estimation and optoelectronic sensors monitoring SpO2, heart rate, HRV, and blood pressure (Istepanian et al., 2004, p. 407). In this research, Robert et al. confirm that using existing technology such as mobile medical sensors for communication in healthcare along with prospective ideas for 4G wireless communications is the future of healthcare. Therefore, smart medical sensor design requires special attention.

Medical Robots

Intelligent medical robots, though not a new concept, will expand their functionalities in the future telemedicine research. It is expected that each person’s personal health record with intelligent avatar will exist in Internet and a medical robot would be able to interact with Internet for enquiry of the medical history of a person. In this process, medical robots will play an important role in improved healthcare, timely clinical decision making, and so forth.

Human-Machine Interface

Natural language is the most natural human-machine interface now-a-days and hence development in this area requires designing sophisticated natural language depending on the needs on both sides of patient and doctor. Adding intelligence with natural language processing hence requires special attention.

Micro-Electro-Mechanical Systems (MEMS)

MEMS can offer future research opportunities in telemedicine. Application of MEMS in 3G mobile technologies can allow users to use sensors for data processing and communication components. And thus it can be possible to use this technology to consistently monitor patients. MEMS can take different forms, including MEMS robots in noninvasive arthroscopic surgery, MEMS-encapsulated cameras that can be swallowed to provide detailed images of the digestive tract, and so on. Therefore, extensive research is required in this promising area both from the academic and industry point of view.

Cellular Technology

According to ITU specification, 3G systems will offer 384 Kbps when a device is at a pedestrian speed, 128 Kbps in a car and 2 Mb in fixed applications. But the disappointing fact is, though data rates will increase, there is not enough bandwidth to transfer large e-mail attachments quickly, let alone the audio or video stream at the broadcast quality the cell phone vendors first claimed. With the natural progression of epoch-making development of technologies in cellular communication, the need for multirate services and broadband convergence have been obvious to piggyback voice, data, videos, and automated applications in a single mobile device (Razibul et al., 2005). 4G promises integrated modes of wireless communications from indoor networks, such as Bluetooth and WLAN, to cellular systems, to radio and TV broadcasting, to satellite communication. It has an expectation of supporting at least 100 Mbps in full mobility wide area coverage and 1 Gbps in low-mobility local area coverage. Therefore, using 4G technologies will also reduce transmission errors and high resolution imaging and processing will also be possible. Therefore, research in adoption of 4G technologies in telemedicine area should also continue.
Security of Data

Telemedicine heavily depends on the transmission of data, video, and audio in telecommunication networks and so secure network access and data transmission are necessary for the confidentiality and privacy of patients’ personal data. Research in network-level firewall and application-level firewall is important to prevent unauthorized access to computer data across the Internet. Secret key encryption and public key encryption mechanisms are also necessary to develop secure data transmission. Therefore it is important for telemedicine applications to employ end-to-end encryption mechanisms securing the data channel from unauthorized access of modification. Adaptability of newer technologies with the secure network access and data transmission capability therefore requires research.

CONCLUSION

Telemedicine is the indispensable future road of providing healthcare. Developed and developing countries both have prospects using telemedicine. Cost-adaptive, in terms of money and time deployment of telemedicine, will become acceptable in the developing and rural communities as well as developed countries. Research trends and challenges discussed above unveil the application areas of telemedicine with the existing research outcomes and represent the areas of research to be explored to exploit the maximum benefits respectively. As mentioned, the OFDM-based mobile telemedicine model discussed will provide high data rate patient monitoring systems both in emergency and home-care situations along with remote and disaster-prone areas. As telemedicine technologies and processes gradually mature, the extent and breadth of medical specialties where telemedicine technologies could prove clinically useful should expand. Indeed, reports of telemedicine implementations are appearing in orthopedics, dermatology, psychiatry, oncology, neurology, pediatrics, internal medicine, ophthalmology, and surgery. Apart from the development of standards and adoption of technologies, ethical and legal aspects of telemedicine need to be considered for successful implementation of telemedicine technologies which was not covered in this chapter. Finally, for the greater needs of mankind, telemedicine research should maximize eradicating the impossibilities of healing the patients into possible from any part of the world with the wand of state-of-the-art technology deployment in all respect.

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**KEY TERMS**

**Broadband:** Communications (e.g., broadcast television, microwave, and satellite) capable of carrying a wide range of frequencies; refers to the transmission of signals in a frequency-modulated fashion, over a segment of the total bandwidth available, thereby permitting simultaneous transmission of several messages.

**Cholecystectomy:** A cholecystectomy is the surgical removal of the gallbladder. In a laparoscopic cholecystectomy, four small incisions are made in the abdomen. The abdomen is filled with carbon dioxide, and the surgeon views internal structures with a video monitor. The gallbladder is located and cut with laparoscopic scissors. It is then removed through an incision.

**Encryption:** The rearrangement of the “bit” stream of a previously digitally encoded signal is a systematic fashion to make it unrecognizable until restored by the necessary authorization key. This technique is used for securing information transmitted over a communication channel with the intent of excluding all others than the authorized receivers from interpreting the message.

**Endoscopy:** Endoscopy allows the doctor to look at the interior lining of the esophagus, stomach, and first part of the small intestine through a thin, flexible viewing instrument called an endoscope. The tip of the endoscope is inserted through the mouth and then gently advanced down the throat into the esophagus, stomach, and upper small intestine (duodenum). Endoscopy can reveal problems that do not show up on X-ray tests, and it can sometimes eliminate the need for exploratory surgery.

**Firewall:** A system designed to prevent unauthorized access to or from a private network. Firewalls can be implemented in both hardware and software, or a combination of both. Firewalls are frequently used to prevent unauthorized Internet users from accessing private networks connected to the Internet, especially *Intranets.* All messages entering or leaving the Intranet pass through the firewall, which examines each message and blocks those that do not meet the specified security criteria.

**H.320:** This is the technical standard for videoconferencing compression standards that allows different equipment to interoperate via T1 or ISDN connections.

**H.324:** This is the technical standard for videoconferencing compression standards that allows different equipment to interoperate via plain old telephone service (POTS).

**Moving Pictures Expert Group (MPEG):** The term refers to the family of digital video compression standards and file formats developed by the group. MPEG achieves high compression rate by storing only the changes from one frame to another, instead of each entire frame. MPEG uses a type of *lossy compression* since some data are removed. But the diminishment of data is generally imperceptible to
the human eye. There are three major MPEG standards: MPEG-1, MPEG-2, and MPEG-4. MPEG-2 offers resolutions of 720x480 and 1280x720 at 60 frames per second, with full CD-quality audio. This is sufficient for all the major TV standards, including NTSC, and even HDTV. MPEG-2 is used by DVD-ROMs. MPEG-2 can compress a 2 hour video into a few gigabytes.

**Personal Digital Assistant (PDA):** It is a hand-held device that combines computing, telephone/fax, Internet, and networking features. A typical PDA can function as a cellular phone, fax sender, Web browser, and personal organizer. Some PDAs can also react to voice input by using voice recognition technologies. PDAs of today are available in either a stylus or keyboard version.

**RS-232:** It is a well established interface device. Short for recommended standard-232C, it is a standard interface approved by the Electronic Industries Alliance (EIA) for connecting serial devices.

**Synchronous Optical Networks (SONET):** It is a standard for connecting fiber-optic transmission systems. With the implementation of SONET, communication carriers throughout the world can interconnect their existing digital carrier and fiber optic systems.

**Telecare:** Telecare is the use of information and communication technologies to transfer medical information for the diagnosis and therapy of patients in their place of domicile.

**Telehealth:** Telehealth is the latest hybrid approach of information and communication technologies to transfer healthcare information for the delivery of clinical, administrative, and educational services.

**Telemonitoring:** The use of information and communications technologies to enable the monitoring of patient health status between geographically separated individuals.

**Transmission control protocol/Internet protocol (TCP/IP):** It is a suite of standard protocols for connecting computers across networks over the world.

**Very Small Aperture Terminal (VSAT):** An earthbound station used in satellite communications of data, voice, and video signals, excluding broadcast television. A VSAT consists of two parts: a transceiver that is placed outdoors in direct line of sight to the satellite and a device that is placed indoors to interface the transceiver with the end user’s communications device, such as a PC. The transceiver receives or sends a signal to a satellite transponder in the sky. The satellite sends and receives signals from a ground station computer that acts as a hub for the system. Each end user is interconnected with the hub station via the satellite, forming a star topology.