Chapter 10
Communication Issues in Pervasive Healthcare Systems and Applications

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ABSTRACT
This book chapter provides a systematic analysis of the communication technologies used in healthcare and homecare, their applications and the utilization of the mobile technologies in the healthcare sector by using in addition case studies to highlight the successes and concerns of homecare projects. There are several software applications, appliances, and communication technologies emerging in the homecare arena, which can be combined in order to create a pervasive mobile health system. This study highlights the key areas of concern and describes various types of applications in terms of communications’ performance. A comprehensive overview of some of these homecare, healthcare applications and research are presented. The technologies regarding the provision of these systems are described and categorised in two main groups: synchronous and asynchronous communications’ systems and technologies. The recent advances in homecare using wireless body sensors and on/off-body networks technologies are discussed along with the provision of future trends for pervasive healthcare delivery. Finally, this book chapter ends with a brief discussion and concluding remarks in succession to the future trends.

INTRODUCTION
The shifting of telemedicine from desktop platforms to wireless and mobile configurations has a significant impact on future healthcare. Obstacles for healthcare services are time and space between the providers and the patients. Wireless technology came to encompass the e-health monitoring everywhere from any given location. The benefits of wireless technology have been illustrated in a number of different examples and applications. Today, patients at rural areas, at accident scenes or even at home are often physically remote to suitable healthcare providers. Research and development advances in the e-health community include data gathering and transfer of vital information, integration of human machine interface technology into handheld devices, data interoperability and integration with hospital legacy systems and electronic patient records. However, several major challenges still need to be clarified so as to expand the implementation and use of mobile health devices and services and reinforce the market development.
In recent years, there has been increased research on commercial mobile health systems based on WLAN (Wireless Local Area Networks), GPRS (General Packet Radio Service) and 3G UMTS (3rd Generation Universal Mobile Telecommunications System) networking technologies. These technologies have been utilized in the deployment of emerging healthcare and homecare systems. The introduction of high speed data rate, wide bandwidth, digital and encrypted communication technology, makes possible the delivery of audio, video and waveform data to wherever and whenever needed. It is hoped that the current deployment of 3G based systems with global operational morphologies will improve some of the limitations of the existing wireless technologies and will provide a well-organized platform for homecare services.

Mobile and wireless concepts in healthcare are typically related to bio-monitoring and home monitoring. Bio-monitoring using mobile networks includes physiological monitoring of parameters such as heart rate, electrocardiogram (ECG), electroencephalogram, (EEG) monitoring, blood pressure, blood oximetry, and other physiological signals. Alternative uses include physical activity monitoring of parameters such as movement, gastrointestinal telemetry fall detection, and location tracking. Using mobile technology, patient records can be accessed by healthcare professionals from any given location by connection to the institution’s internal network. Physicians now have ubiquitous access to patient history, laboratory results, pharmaceutical data, insurance information, and medical resources. Handheld devices can also be used in home healthcare, for example, to fight diabetes through effective monitoring.

The mission of this book chapter is to provide a detailed analysis of the pervasive healthcare technology, applications and uses of mobile technologies in the health sector by using in addition case studies to highlight the successes and concerns of relevant projects. There are a variety of applications, devices, and communication technologies emerging in the electronic healthcare arena, which can be combined to create a pervasive mobile health system. This book chapter will highlight the key areas of concern and describe the various types of applications. A comprehensive overview of some of these electronic health applications and research will be presented. Meanwhile, the technologies regarding the provision of the pervasive health systems will be described and categorised in two main groups: synchronous and asynchronous communications’ systems and technologies. Correspondingly, the classification of the wireless technologies will also be categorized according to their total throughput into small and high data rates within the relevant applications following the end-users view. The recent advances in mobile health (m-health) systems using wireless body sensors and on/off-body networks technologies will be discussed along with the provision of future trends for pervasive healthcare delivery.

In addition, the pervasive healthcare systems operating in patient’s homes define the field of the so called homecare systems. These systems will be presented in a different section of this chapter issue, since the delimitations of the home environment dictates special technical objectives and introduces important problems and obstacles. However, the use of this wireless sensor technology in medical practice not only allows a supreme level of complexity in patient monitoring with regards to existing parameters (such as vital signs), but also offers the prospect of identifying new ways of diagnosing and preventing disease. The book chapter will end with a description of various applied pervasive health platforms along with their applications and services. A comparison of these platforms will be prepared in conjunction with some results and suggestive extensions. A brief discussion, concluding remarks and additional reading will also be given in succession to the future trends.

BACKGROUND

Patient Biosignals and Acquisition Methods - Biosensors

A broad definition of a signal is a ‘measurable indication or representation of an actual phenomenon’, which in the field of biosignals, refers to observable facts or stimuli of biological systems or life forms. In order to extract and document the meaning or the cause of a signal, a physician may utilize simple examination procedures, such as measuring the temperature of a human body or have to resort to highly specialized and sometimes intrusive equipment, such as an endoscope. Following signal acquisition, physicians go on to a second step, that of interpreting its meaning, usually after some kind
of signal enhancement or ‘pre-processing’, that separates the captured information from noise and prepares it for specialized processing, classification and decision support algorithms. Biosignals require a digitization step in order to be converted into a digital form. This process begins with acquiring the raw signal in its analog form, which is then fed into an analog-to-digital (A/D) converter. Since computers cannot handle or store continuous data, the first step of the conversion procedure is to produce a discrete-time series from the analog form of the raw signal. This step is known as ‘sampling’ and is meant to create a sequence of values sampled from the original analog signals at predefined intervals, which can faithfully reconstruct the initial signal waveform. The second step of the digitization process is quantization, which works on the temporally sampled values of the initial signal and produces a signal, which is both temporally and quantitatively discrete. This means that the initial values are converted and encoded according to properties such as bit allocation and value range. Essentially, quantization maps the sampled signal into a range of values that is both compact and efficient for algorithms to work with. The most popular biosignals utilized in pervasive health applications are shown in Choudhri (2003), Kifor (2006), Malan (2004) and Gouaux (2004). In addition to the aforementioned biosignals, patient physiological data (e.g., body movement information based on accelerometer values), and context-aware data (e.g., location, environment and age group information) have also been used by pervasive health applications (Barger, 2005). The utilization of the latter information is discussed in the following sections.

In the context of pervasive healthcare applications, the acquisition of biomedical signals is performed through special devices (i.e. sensors) attached on the patient’s body (see Figure 1) or special wearable devices (see Figure 2) (Barger, 2005). The transmission of the collected signals to the monitoring unit is performed through appropriate wireless technologies discussed in the following Section on pervasive networking and communication issues. Regarding the rest multimedia information concerning the patient, most applications are based on data collected from video cameras, microphones, movement and vibration sensors.

Sensor configurations enclosed on wearable clothing have been manufactured in order to enhance usability, comfort and convenience for the users. Many companies have applied this technology to produce high-tech clothing aiming at ameliorating the user’s quality of life. Typical examples are the Vivometric’s Lifeshirt (see Figure 2c) as well as the Georgia Tech Wearable Motherboard which allow connection to vital signs sensors positioned on different body locations (Vivometrics, 2009). The LifeShirt System is the first non-invasive, continuous ambulatory monitoring system that can collect data on cardiopulmonary function and other physiological patient parameters, and correlate them over time. It contains embedded inductive plethysmographic sensors, accelerometer, and a single-channel ECG.

The Georgia Tech Wearable Motherboard (Georgia Institute of Technology, 2009), is a high tech vest that uses optical fibers to detect bullet wounds and monitor the body vital signs during combat conditions. The Georgia Tech Wearable Motherboard (Smart Shirt) provides an extremely versatile framework for the incorporation of sensing, monitoring and information processing devices. Applications such as the Georgia’s Motherboard and the Vivometric’s Lifeshirt can incorporate several devices and combine evolutionary technologies for a broader range of health parametric data (breath rate sensor, temperature sensors, ECG electrodes, shock/fall sensors, global positioning system (GPS) receiver) and more precise outcomes. Smart nanocomposite materials are of particular interest for self-sensing in health monitoring, or self-actuating to improve the performance and efficiency of structures and devices. It has been shown that conductive textiles and piezo-resistive fabric can be integrated into shirts to measure patient movements, peripheral pulse, respiration, and biopotentials (De Rossi et al. 2003). Additional efforts for construction of further high-tech accessories have been made (rings, wrist-watches etc). Reinforced polymers, carbon nanotube solid polymer electrolyte actuator, and piezoresistive sensors have been developed for several potential applications in the sense of miniaturizing the monitoring devices. The patient monitoring finger ring sensor measures PPG signals, skin temperature, blood flow, blood constituent concentration and or pulse rate of the patient. The data are encoded for wireless transmission by mapping a numerical value associated with each datum to a pulse emitted after a delay of a specified duration, following a fiducial time. Multiple ring bands and sensor elements may be employed for deriving three-dimensional dynamic characteristics of arteries and tissues. A number of research organizations have studied portable and wearable device of physiological signal monitors. Rantanen et al. (2003),
developed a smart clothing system that adjusts the clothes temperature in order to facilitate persons living in the arctic environment. The specific smart clothing system measures the heart rate, the humidity and the temperature of body surface. These data may be transmitted wirelessly for further analysis. Significant related work on wearable systems may be found in the literature (Montgomery et al., 2004), (Mangas and Oliver, 2005), (Jafari et al., 2005).

**Figure 1.** Accelerometer, gyroscope, and electromyogram (EMG) sensor for stroke patient monitoring.

![Accelerometer, gyroscope, and electromyogram (EMG) sensor for stroke patient monitoring.](image)

(a) (b) (c)

**Figure 2.** Wearable medical sensor devices: (a) A 3-axis accelerometer on a wrist device enabling the acquisition of patient movement data, (b) A ring sensor for monitoring of blood oxygen saturation, (c) The Vivometric’s Lifeshirt System

Pervasive Networking and Communication Issues

In recent years, there has been increased research on commercial mobile health systems based on WiFi (Wireless Fidelity), GPRS (General Packet Radio Service) and 3G UMTS (3rd Generation Universal Mobile Telecommunications System) networking technologies. These technologies have been utilized in the deployment of emerging healthcare systems (Istepanian, 1999; Jones, 2005). The introduction of high speed data rate, wide bandwidth, digital and encrypted communication technology, makes possible the delivery of audio, video and waveform data to wherever and whenever needed. It is hoped that the current deployment of 3G based systems with global operational
morphologies will improve some of the limitations of the existing wireless technologies and will provide a well-organized platform for mobile healthcare services. The shifting of telemedicine from desktop platforms to wireless and mobile configurations has a significant impact on future healthcare. Obstacles for healthcare services are time and space between the providers and the patients. Wireless technology came to encompass the e-health monitoring everywhere from any given location. The benefits of wireless technology have been illustrated in a number of different examples and applications (Pattichis, 2002). Today, patients at rural areas, at accident scenes etc. are often physically remote to suitable healthcare providers.

Broadband connectivity is rapidly evolving around the globe using a diversity of means involving wire-line (e.g. Asynchronous Digital Subscriber Line - ADSL), wireless (e.g. Wi-Fi, WiMax) and satellite interconnections. Multimedia-rich services provided via broadband connections can potentially change the way of communicating ideas, doing business, or acting in the modern digital world. In this framework, European Space Agency (ESA) has initiated the Digital Video Broadcasting with Return Channel via Satellite (DVB-RCS) technology enabling almost all potential locations - even the most geographically dispersed and isolated ones - to gain access to broadband services using low-cost Satellite Interactive Terminals (SITs). Nowadays, the DVB-RCS technology enhanced with the DVB-S2 knowledge is a mature broadband communications technology with comparable implementation and operational costs to the other broadband terrestrial technologies, effectively satisfying the Quality of Service (QoS) requirements of high demanding applications in electronic healthcare.

E-Health via High-Speed Satellite Networks

In the era of mobile computing the trend in medical informatics is towards achieving two goals: the availability of software applications and medical information anywhere and anytime and the invisibility of computing, while the computing modules are hidden in multimedia information appliances. The DVB-RCS technology seems capable of providing such pervasive e-health services. DVB-RCS is an ETSI (European Telecommunications Standards Institute) standard that specifies the provision of the interaction channel for interactive (two-way) satellite networks using Return Channel Satellite Terminals referred to as RCST or simply SITs. The DVB-RCS Hub is vital for the operation of the DVB-RCS satellite communications network and essentially manages the network operation: it enables SIT access to the satellite network, assigns bandwidth to SITs, relays traffic between SITs inside the satellite network and between the SITs and other networks (e.g. Internet) and also monitors the operation of the SITs. Tele-medicine provided via satellite communications is an evolving area of healthcare services and provision of medical information, which utilizes the new developments in satellite networks such as DVB-RCS. In fact, satellite communication systems are considered an attractive networking solution for telemedicine platforms, since they have the advantage of worldwide coverage and offer a variety of data transfer rates, even though satellite links involve high operating costs. However, with the application of the DVB-RCS technology, the operating costs of satellite links tend to be significantly reduced.

The topology of a typical interactive satellite network is star with the central gateway, known simply as DVB-RCS Hub, at its center and the SITs around the DVB-RCS Hub. The DVB-RCS Hub is vital for the operation of the DVB-RCS satellite communications network and essentially manages the network operation: it enables SIT access to the satellite network, assigns bandwidth to SITs, relays traffic between SITs inside the satellite network and between the SITs and other networks (e.g. Internet) and also monitors the operation of the SITs. Note that data communication between two SITs can only take place through the DVB-RCS Hub, thus effectively being a two-hop communication. For the sake of simplicity in this book chapter from this point forward, the transmission from the DVB-RCS Hub towards all SITs will be referred to as Forward Link (FL) and the transmission from each SIT towards the DVB-RCS Hub will be referred to as Return Link (RL). Data rates on the FL can reach 45 Mbps and data rates on the RL can reach 2 Mbps. Bandwidth
allocations on both FL and RL can be guaranteed (constant rate) or dynamic, depending on the available bandwidth at certain time periods.

Tele-medicine applications span the areas of emergency healthcare, homecare, patient tele-monitoring, tele-cardiology, tele-radiology, tele-pathology, tele-dermatology, tele-ophthalmology, tele-psychiatry and tele-surgery (Kyriacou, 2003; Maglogiannis, 2004). These applications enable the provision of prompt and expert medical services in underserved locations, like rural health centers, ambulances, ships, trains, airplanes as well as at homes (homecare) (Pattichis, 2002; Shimizu, 1999; Istepanian, 2004; Maglogiannis, 2006). The combination of the medical profession's advanced procedures and equipment with regional healthcare communication networks, may offer complete, integrated healthcare delivery systems made up of hospitals, outpatient services, pharmacies and large rural home health operation. From the patient's perspective, that means not only having the necessary technology at hand, but also a centralized environment that is comfortable, convenient and dedicated to the care of their specific condition.

The general topology of a tele-medicine system using satellite network is depicted in Figure 3. The architecture of the systems is hierarchical, involving an access network based on the Wi-Fi technology and a core network based on DVB-RCS. The DVB-RCS satellite core network can gain access by any satellite provider using the expensive but necessary satellite bandwidth (satellite transponder) in order to provide SIT and DVB-RCS Hub interconnection. The only limitation of the network is the satellite coverage footprint (coverage map) (Brady, 2002; Breynaert, 2005).

Figure 3. Satellite Tele-medicine Network Architecture
The platform may consist of one or more Remote Sites (RSs) placed in several remote areas. Every RS can be equipped with appropriate communication devices (i.e. videoconference units, videophones, patient tele-monitoring unit, IP phones etc). Optionally, the communication device at the RS may have the capability to connect to medical data acquisition units collecting various biosignals and physical data. Each RS has access (Ethernet IP connection) to a wireless access point that utilizes the Wi-Fi technology (IEEE 802.11g), through which the RS is wirelessly connected to a Regional Access Point (RAP). The range of communication between a RS and a RAP is generally less than 1 km. The RAP concentrates video/voice/data from a number of RSs and communicates through the corresponding (located at the site) DVB-RCS SIT, the utilized communication satellite and the available DVB-RCS Hub of the satellite network, with the Center Node (CN), essentially being a hospital or a medical center. Naturally, the equipment of the CN, among others, includes a SIT for communication with the satellite network. The medical personnel (physicians and nurses) at the CN can communicate and provide help to the patients with health incidents as well as potentially realize regular and irregular medical examinations from distance using the platform. The locations of the RSs, RAPs and CN are assumed to be random. Considering the characteristics of the equipment used in the framework of the proposed tele-medicine platform, teleconference/VoIP communication with the patients, tele-monitoring, glucose level and blood pressure measurements, supervision of injuries, monitoring and/or confrontation of hypoglycemia or hyperglycemia symptoms, confrontation of possible heart attack incidents as well as monitoring of the respiratory system of patients can be efficiently performed using the tele-medicine platform described in this book chapter.

Each Remote Site (RS) is equipped with a communication unit that utilizes a VoIP, a special integrated videoconference and/or a medical data acquisition unit. The medical personnel, through the embedded teleconference capability of the device, is able to communicate with the patients using VoIP, real-time video, as with a simple videophone, even permitting the realization of regular and irregular medical examinations from distance.

The required infrastructure at the Center Node (CN) consists of one data Collector Personal Computer (C-PC), one Database Computer (DB-PC), one Multipoint Conference Unit (MCU), two or more Videoconference Units (VCUs), two or more IP phones, two or more TV monitors, one Ethernet Hub or Switch and one SIT to communicate with the RAPs. The C-PC is used for the communication with the special videoconference/medical data collector units located at the RSs. Special software consolidate and process all the medical data coming from the aforementioned units and it will update the medical records of the patients. The DB-PC is used to facilitate the communication to the C-PC and support the database, where the medical history data of the patients will be contained. The VCU gives the opportunity to the doctor at the CN to communicate with his patient (or patients) using real-time video.

There are several situations that this platform can integrate. The first situation concerns a patient, who recently was discharged from hospital after some form of intervention, for instance, after a cardiac episode, cardiac surgery or a diabetic coma. These types of patients are less secure and require enhanced care even at home. However, the home offers a considerably different environment than a hospital or a health unit. The patient or elder will mainly require except video surveillance, also monitoring of his vital signals (i.e., ECG, blood pressure, heart rate, breath rate, oxygen saturation and perspiration).

The second situation concerns a patient, who suffers from saccharoid diabetes and he exhibits hypoglycemia symptoms (e.g. abstractness and ephidrosis). Supposing the patient is located at the RS X2, equipped with a videoconference/medical data collector unit, connected to a glucose meter, allowing a direct connection with a physician at a Center Node (CN), upon his request. The attached glucose meter measures the level of blood glucose and sends the results to the CN. The doctor gains access to these medical data and he also retrieves the patient’s medical history from an EHR (Electronic Health Record) relational database system. According to the examination results, the symptoms described by the patient following to the doctor’s questions and the patient’s medical history, the doctor decides if further medical attention is needed (i.e. if an ambulance has to be sent to the patent’s home or not) and then provides appropriate advise in order to address his uncomfortable condition.
E-Health via High-Speed Mobile Networks

HSPA (High Speed Packet Access) for uplink and downlink, together with 3G and 4G systems are expected to enforce the m-health applications and overcome the boundaries between time and space. High usability, support for multimedia services with good reliability and low transmission cost, personalization of the services, more capacity and spectrum efficiency are some of the key features of the evolving mobile technologies. Such technologies will make available both mobile patients and end users to interactively get the medical attention and advice they need, when and where is required in spite of any geographical obstructions or mobility constrains.

HSPA is an evolution of WCDMA-UMTS technology, achieving greater bit rates and reduced delays. Responsible for the standardization of HSPA is 3GPP (www.3gpp.org; 3GPP TS 25.308, 2004; 3GPP TR 25.896, 2004). The commercial utilization of this technology is rather new. New HSDPA (downlink) networks are launched by European providers continuously, while the first Enhanced Uplink (HSUPA - uplink) networks were implemented during the last months. Theoretically, on the downlink the maximum achieved bit rate is about 10.7 Mbps using 16-QAM modulation, while on the uplink the maximum bit rate exceeds 5.5 Mbps per Node-B. Currently 3.6 Mbps and around 1.5 Mbps are the common peak bitrates provided by mobile providers for downlink and uplink correspondingly.

HSPA incorporates a significant number of innovative features, such as Adaptive Modulation and Coding, short Transmission Time Interval (2 msec), fast Hybrid Automatic Repeat Request (HARQ), customized schedulers for the proper manipulation and routing of the data, as well as the possibility for a Multiple Input Multiple Output (MIMO) add-on. HS-DSCH (High-Speed Downlink Shared Channel) is also used in HSDPA to send packets on the downlink to the user equipments. The downlink and uplink characteristics of HSPA are depicted in Tables 1 and 2 correspondingly.

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<th>QPSK/16QAM</th>
<th>A number of software bits per channel</th>
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*Table 1. HSDPA parameters*

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<tr>
<td>Category 2</td>
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</table>
Category 3 1.46 Mbps
Category 4 2.93 Mbps
Category 5 2.00 Mbps
Category 6 5.76 Mbps
Category 7 (3GPP Release 7) 11.5 Mbps

Table 2. Enhanced Uplink parameters

Due to the increased capacity that HSPA is able to offer and its packet based nature, the implementation of a variety of applications over cellular networks is now feasible (Holma, 2006). Typical applications may be Voice over IP, browsing, video on demand, mobile TV and video or radio streaming, interactive services, data and music download etc. The ability of HSDPA to serve simultaneously a sufficient number of mobile terminals running multiple demanding applications while keeping the end to end delay low, makes it an ideal candidate for a vast number of new services. Considering the constant geographical expansion and technical development of HSPA networks, they should be soon ready to credibly host e-health services, emphasizing on mobile e-health, emergency and follow-up applications. Figure 4 depicts the HSPA architecture and the interconnection of the fundamentals elements, such as the Radio Network Controller (RNC), the 3G base station (Node-B) and the user equipments (UEs).

![HSPA Radio Access Network Architecture](image)

Figure 4. HSPA Radio Access Network Architecture

The ability of HSPA to serve simultaneously a sufficient number of mobile terminals running multiple demanding applications while keeping the end to end delay low, makes it an ideal candidate for a vast number of new services. Due to the increased capacity that HSPA is able to offer and its packet based nature, the implementation of a variety of applications over cellular networks is now feasible (Holma, 2007; Holma, 2006). Considering the constant geographical expansion and technical development of...
HSPA networks, they should be soon ready to credibly host e-health services, emphasizing on mobile e-health, emergency and patient follow-up applications.

Electronic healthcare applications, including those based on wireless technologies span the areas of emergency healthcare, telemedicine in various forms (telecardiology, teleradiology, telepathology, teledermatology, teleophthalmology and telepsychiatry) and electronic access to health records. The range and complexity of telecommunication technology requirements vary with specific medical or health applications. Except for medical images and running through full-motion video, the majority of biosignal medical devices require relatively low data transmission rates (Ackerman, 2002; Maglogiannis, 2006).

There are several healthcare applications that can serve via the 3.5G communication technology. For instance, for emergency services in case of accidents and the support of transport healthcare units (i.e. ambulances) or primary care units (i.e. rural centers) in case of accidents. Since, for practical and financial reasons primary care or transport healthcare units cannot be staffed by specialized physicians, general doctors can only rely on directions provided to them by experts. An m-health service in this case allows specialized physicians located at a hospital site, to coordinate remote located primary care or ambulance services paramedical staff via telediagnosis and interactive teleconsultation means.

For teleconsultation collaborative sessions between moving physicians, a teleconsultation session implements a collaborative working environment for physicians in dispersed locations, by enabling; a) electronic exchange of medical data, b) voice/video/chat communication and c) common workspace management (i.e. common image processing toolbox, annotations etc). In case one at least of the commuting doctors is moving or in a random location with no availability of fixed networks a 3.5/4G platform may be used as a communication medium.

For the transmission of medical information Management service and the mobile access to Electronic Health Records (EHRs), this service is related to applications, enabling the mobile ubiquitous delivery of medical data and implementations of mobile Electronic Health Records (EHR), accessible by PDA’s or Tablet PC’s. This service is provided to physicians that require immediate access to patient’s medical data from random locations. Therefore only broadband cellular systems (i.e 3/4G) may be used due to the corresponding data sizes.

Regarding the transmission of medical images there are essentially no theoretical bandwidth requirements, but lack of bandwidth needs longer transmission time. Yet, high quality medical images such as a single chest radiograph may require from 40 to 50 Megabytes. In practice, it is desirable to transmit medical images during a single patient visit, so as to at-least avoid a follow-up visit. Medical image compression techniques have primarily focused on lossless methods, where the image has to be reconstructed exactly from its compressed format, due to the diagnostic use. The following section discusses the two basic transmission modes in pervasive healthcare systems; namely real time or synchronous and “Store and Forward” or asynchronous which more or less set the requirements for the underlying network infrastructure.

SYNCHRONOUS AND ASYNCHRONOUS ELECTRONIC HEALTHCARE SYSTEMS

A basic issue concerning communication is the choice between the transmission of real time multimedia, electronic health record and biosignals data and the “Store and Forward” method with implies asynchronous communication. The “Store and Forward” system is simpler, cheaper and does not require synchronous communication of the two stations. Due to the asynchronous transmission of data the delays of the network are less important and thus lower bandwidth network can be used. Furthermore, the clinical examination procedure is quite easy to program due to the fact that both sides (physician and patient) can interact with the system independently. However “Store and Forward” systems may not be applied for the provision of emergency electronic healthcare services in case of accidents. In addition the physicians seems to prefer in general the synchronous electronic healthcare systems since they offer interactive contact with the patient and simulate better the clinical examination. The most typical scenarios for the provision of pervasive healthcare services are summarized in the following subsections.
Emergency Services in case of accidents

This service refers to the support of transport healthcare units (i.e. ambulances) or primary care units (i.e. rural centers) in case of accidents. Recent studies conclude that early and specialized pre-hospital patient management contributes to emergency case survival. Especially in cases of serious injuries of the head, the spinal cord and internal organs the way of transporting and generally the way of providing care is crucial for the future of the patient. Unfortunately, general practitioners in remote health centres or ambulance personnel, who usually are the first to handle such situations, do not have the required advanced theoretical knowledge and experience. Since, for practical and financial reasons primary care or transport healthcare units cannot be staffed by specialized physicians, general doctors can only rely on directions provided to them by experts. A pervasive health service in this case allows specialized physicians located at a hospital site, to coordinate remote located primary care or ambulance services paramedical staff via telediagnosis and interactive teleconsultation means.

Follow-Up Service – Patient Telemonitoring

This service is provided to high risk or post surgical patients for monitoring their biosignal data periodically so that if any unusual condition is detected a corresponding alarm rises. Patients recently discharged from hospital after some form of intervention, for instance, after a cardiac incident, cardiac surgery or a diabetic coma are less secure and require enhanced care. The most common forms of special home monitoring are ECG arrhythmia monitoring, post surgical monitoring, respiratory and blood oxygen levels monitoring and sleep apnoea monitoring (Ward, 2006).

Intrahospital m-health Services

The use of pervasive health services in hospitals may be divided into two broad categories (Lahtela, 2008). The first one relates to applications, enabling the mobile ubiquitous delivery of medical data and implementations of mobile Electronic Health Records (EHR), accessible by PDA’s or Tablet PC’s. The second category refers to systems that are used for the monitoring and diagnosis of patients. More details about such systems are presented in Section 3.1.

Homecare Services

Telehomecare is generally used for rehabilitation of the elder patients to minimize the number of visits for therapists, and thereby, the risk involved in moving the patients (Guang-Zhong, 2004). The elder mainly requires monitoring of his vital signals (i.e., ECG, blood pressure, heart rate, breath rate, oxygen saturation and perspiration). Facilities for medical practice at home are limited by the availability of medical devices suitable for producing biosignals and other medical data (Yang, 2009) (Choudhury, 2008). There is a number of active research and commercial projects developing homecare systems. These systems are surveyed in Section 3.2.

Medical Information Management Service

This type of services is similar to the first category of the aforementioned intrahospital services related to the mobile access to Electronic Health Records (EHR) (Fei, 2008). This service is provided to physicians that require immediate access to patient’s medical data from random locations. Therefore only cellular systems (i.e 2.5/3G) may be used.

SMALL AND HIGH DATA RATES OF WIRELESS ELECTRONIC HEALTHCARE SYSTEMS

Wireless mobile systems may realize various m-health services. Due the variability of the healthcare scenarios and the extended performance of the mobile and satellite networks in terms of throughput, new m-health services can be implemented. The main restrictions of the potential m-health scenarios can be the functional m-health application, the emergency of the patient’s situation, the patient’s
condition, the territorial state of the patient, etc. Following, there are several prospective scenarios along with their required data rates.

Electronic healthcare applications, including those based on wireless technologies span the areas of emergency healthcare, telemedicine in various forms (telecardiology, teleradiology, telepathology, teledermatology, teleophthalmology and telepsychiatry) and electronic access to health records. In addition, health telematics applications enabling the availability of prompt and expert medical care have been exploited for the provision of healthcare services at understaffed areas like rural health centers, ambulance vehicles, ships, trains, airplanes as well as for home monitoring (Pattichis, 2002; Tachakra, 2003). The range and complexity of telecommunications technology requirements vary with specific medical or health applications. However, generically defined digital medical devices impose the telecommunications performance requirements. Table 3 illustrates a sampling of several of the more common digital medical devices that may be used in distributed telemedicine. Except for the last few items contained in the table (starting with ultrasounds and running through full motion video).

As long as the transmission of the medical images is concerned, there are no time or bandwidth requirements. In practice, medical image compression techniques have primarily focused on lossless methods, where the image has to be reconstructed exactly from its compressed format, due to the diagnostic use.

About the digital video compression, the Digital Imaging and Communications in Medicine (DICOM) committee has not yet adopted any standard. The adoption of MPEG-2 is possible, but this is limited by the MPEG-2 requirement for constant delay method for frame synchronization. On the other hand, the transmission of offline video is still possible. It is important to distinguish among the requirements for: real-time video transmission, offline video transmission, medical video and audio for diagnostic applications, and non-diagnostic video and audio. Real-time video transmission for diagnostic applications is clearly the most demanding. Offline video transmission is essentially limited by the requirement to provide patient doctor interaction. Real-time diagnostic audio applications include the transmission of stethoscope audio, or the transmission of the audio stream that accompanies the diagnostic video. A typical application will require a diagnostic audio and video bit stream, in addition to a standard teleconferencing bit stream (ITU-D Study Group 2, 2004; LeRouge, 2002).

<table>
<thead>
<tr>
<th>Digital device</th>
<th>Signal or Image Resolution</th>
<th>Temporal / Spatial (No. of samples per second)</th>
<th>Contrast / Resolution (bits per sample)</th>
<th>Data rate required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Blood Pressure Monitor (sphygmomanometer)</td>
<td>1</td>
<td>x16</td>
<td>&lt; 10 kbps</td>
<td></td>
</tr>
<tr>
<td>Digital thermometer</td>
<td>5</td>
<td>x16</td>
<td>&lt; 10 kbps</td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td>50</td>
<td>x6</td>
<td>&lt; 10 kbps</td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td>25</td>
<td>24</td>
<td>&lt; 10 kbps</td>
<td></td>
</tr>
<tr>
<td>Body Temperature</td>
<td>5</td>
<td>16</td>
<td>80 kbps</td>
<td></td>
</tr>
<tr>
<td>Common workspace management controls</td>
<td>-</td>
<td>-</td>
<td>~ 10 kbps</td>
<td></td>
</tr>
<tr>
<td>Digital audio stethoscope (Heart Sound)</td>
<td>10000</td>
<td>x12</td>
<td>~ 120 kbps</td>
<td></td>
</tr>
<tr>
<td>Galvanic skin response (GSR), or skin conductance response (SCR),</td>
<td>40-100</td>
<td>x16</td>
<td>&lt; 10 kbps</td>
<td></td>
</tr>
<tr>
<td>Patient movement</td>
<td>1000</td>
<td>x11</td>
<td>~ 110 kbps</td>
<td></td>
</tr>
</tbody>
</table>

(accelerometers, gyroscopes and tilt)
Future challenges in m-health systems are already mentioned in Istepanian (2004). In general m-health applications may be categorized in two groups depending on the required transmission mode:

- **Real time applications**: These are referred to multimedia connections between centers and moving vehicles including audio and video exchange, biomedical signals and vital parameters transmission, such as electrocardiogram (ECG) signal, blood pressure, oxygen saturation, etc.

- **Near Real Time applications**: These correspond to applications enabling access to administrative files and Electronic Patient Report (EPR) transfer (from medical data exchange between centers and moving vehicles or specialty sections), clinical routine consults during accesses to databases, queries to medical report warehouse, etc.

**PERSONAL AREA NETWORKS: ON-BODY (WEARABLE) AND OFF-BODY NETWORKS**

Through the tremendous spread of wireless sensors networks (Mukhopadhyay, 2004) and wireless network systems (WLAN, WMAN, UMTS, Bluetooth, etc.), the wireless user interfaces components increased the abilities and consequently the applications of WPANs (e.g., wearable networks) to medical applications. Infrastructure, topology, coverage, connectivity, heterogeneity, size, lifetime and quality of service are some of the specifications that have to be investigated for selecting the proper wireless user interface component and wireless network.

Wireless sensors are being used to monitor vital signs of patients in home and hospital environment (Baldus, 2004). Compared to conventional approaches, solutions based on wireless sensors are intended to improve monitoring accuracy while also being more convenient for patients. Seven vital signals are presented henceforward. Each provides different and complementary information on the well being of the subject and for each specific examinee the anticipated range of signal parameters is different. For example, heart rate may vary between 25 and 300 beats/min for normal people in different circumstances; likewise, breathing rate could be between 5 and 50 breaths/min. EEG, ECG,
and EMG are considerably more complex signals with spectra spanning up to 10 kHz. Voltage levels of the recorded signals vary from less than 1 µV to tens of millivolts. Not all the signals are required for each examinee.

There are two main networking technologies that the networks can be categorized according to their topology: on-body (wearable) and off-body networks. The notion of a wearable network of interactive devices aiding users in their day-to-day activities is extremely appealing, but still a lot of open issues need to be addressed by researchers. Recent technological advances have made possible a new generation of small, powerful, mobile computing devices.

A wearable computer must be small and light enough to fit inside clothing. Occasionally it is attached to a belt or other accessory, or is worn directly like a watch or glasses. At the same time, it must be able to accommodate various electronic devices—sensors, cameras, microphones, wireless transceivers, and so on—along with a microprocessor, a battery, memory, and a convenient and intuitive user interface. It must also be able to convey information even when not in use, such as a new e-mail alert. Unlike intelligent wristwatches, wearable radios, and other similar devices, wearware can be reconfigured as required, which greatly widens the scope of applications (Ramachandran, 2008).

An important factor in wearable computing systems is how the various independent devices interconnect and share data. An off-body network connects wearware to other systems that the user does not wear or carry, while an on-body or personal area network connects the devices themselves—the computers, peripherals, sensors, and other subsystems. The advent of portable computers and wireless communication technologies such as IEEE 802.11 has ensured reasonable anytime, anywhere connectivity.

For the area of e-health applications, various low-cost sensor networks have been developed taking into account different technical issues (Ghasemzadeh, 2009). Energy, size, cost, mobility, infrastructure, network topology, connectivity and coverage are some of the requirements that the developer must take into consideration. The most important is size and power consumption. Varying size and cost constraints directly result in corresponding varying limits on the energy available, as well as on computing, storage and communication resources. Low power requirements are necessary both from safety considerations and because in mobile communications the battery lifetime must be commensurate with the application, often several hours. Hence, the energy and other resources available on a sensor node may also vary greatly from system to system. Power may be either stored or scavenged from the environment (e.g., by solar cells).

Mobility is another major issue for pervasive e-health applications because of the nature of users and applications and the easiness of the connectivity to other available wireless networks. Both off-body and personal area networks must not have line-of-sight (LoS) requirements. Consumers generally prefer wireless devices because wires can tangle, restrict movement, be tripped over, and get caught on other objects. Devices such as WPAN wristwatches would not be accepted commercially if wired to other wearables.

The various communication modalities can be used in different ways to construct an actual communication network. Two common forms are infrastructure-based networks and ad hoc networks. The effective range of the sensors attached to a sensor node defines the coverage area of a sensor node. With sparse coverage, only parts of the area of interest are covered by the sensor nodes. With dense coverage, the area of interest is completely (or almost completely) covered by sensors. The degree of coverage also influences information processing algorithms. High coverage is a key to robust systems and may be exploited to extend the network lifetime by switching redundant nodes to power-saving sleep modes.

There are many ad-hoc multi-hop routing algorithms, where network routes are discovered through a self-organizing process. Similarly, many multi-hop routing components are among the most diverse and numerous implementations. These are divided into three classes: tree-based collection, where nodes route or aggregate data to an endpoint, intra-network routing where data is transferred between in-network end-points, and dissemination, where data is propagated to entire regions. Essentially applications use some form of broadcast or dissemination to convey commands, reconfigure, or control in-network processing.
Off-Body Networks

Off-body communications rely on wireless local area network (LAN) technologies and, increasingly, Manets. There is no single ideal solution, with each varying according to data-rate requirements. Improvements in the area of tiered networks and wireless metropolitan area networks (WMANs) will integrate voice, data, and other multimedia services. Table 4 summarizes the current off-body wireless networking solutions.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Operational spectrum</th>
<th>Maximum data rate</th>
<th>Coverage</th>
<th>Power level issues</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wireless LANs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• IEEE 802.11b</td>
<td>2.4 GHz</td>
<td>22 Mbps</td>
<td>100 m</td>
<td>&lt; 350 mA current drain</td>
<td>Medium (&lt; $100)</td>
</tr>
<tr>
<td>• HomeRF</td>
<td>2.4 GHz</td>
<td>10 Mbps</td>
<td>&gt; 50 m</td>
<td>&lt; 300 mA current drain</td>
<td>Medium (&lt; $100)</td>
</tr>
<tr>
<td>• HiperLAN 2</td>
<td>5 GHz</td>
<td>32-54 Mbps</td>
<td>30-150 m</td>
<td>Uses low-power states such as &quot;sleep&quot;</td>
<td>High (&gt; $100)</td>
</tr>
<tr>
<td>Cellular telephony</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• CDMA200</td>
<td>Any existing frequency; band with 2/1 × 3.75 MHz channels</td>
<td>2 Mbps</td>
<td>Area of a cell</td>
<td>Sophisticated power control with different classes of operation</td>
<td>Very high (&gt; $1,000)</td>
</tr>
<tr>
<td>• UMTS (WCDMA)</td>
<td>1.920-1,980 MHz and 2,110-2,170 MHz; 2 × 5 MHz channels</td>
<td>2.048 Mbps</td>
<td>Area of a cell</td>
<td>Sophisticated power control with different classes of operation</td>
<td>Very high (&gt; $1,000)</td>
</tr>
<tr>
<td>Wireless MANs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• IEEE 802.16</td>
<td>10-66 GHz; line of sight required; 20/25/28 MHz channels</td>
<td>120/134.4 Mbps for 25/28 MHz channel</td>
<td>Typically a large city</td>
<td>Complex power control algorithms for different burst profiles</td>
<td>Not available</td>
</tr>
</tbody>
</table>

Table 4. Off-body networking technologies

High-speed applications such as wireless multimedia delivery and digital imaging require higher and more guaranteed data rates than Bluetooth can offer. On the other hand, WLAN technologies are too costly for many commercial application systems. To fill this gap, IEEE802.15 task group 3 (TG3) has worked since 2000 with the aim of established PHY and MAC level standard for high-rate (20 Mbit/s or greater) wireless personal area networks. Besides the high data rate, the target of the IEEE802.15 TG3 is a low-power and low-cost technology addressing the needs of portable consumer devices (IEEE802.15 TG3), (WiMedia).

To support the work of IEEE802.15 TG3 and promote commercial application systems based on the standard, the WiMedia alliance has been launched in September 2002. The WiMedia alliance is a non-profit open industry association formed to promote personal area range wireless connectivity and interoperability among multimedia devices in a networked environment. The current IEEE802.15.3 standard version supports communication on the same unlicensed frequency band as the Bluetooth (2.4 GHz) with five selectable data rates 11, 22, 33, 44 and 55 Mbit/s. The transmit power is approximately 8 dBm, and the communication range 5 - 55 m. The modulation formats are BPSK, QPSK and QAM. Power management, security, coexistence with Bluetooth and WLAN, and Quality of Service (QoS) capabilities have been incorporated to support high-quality multimedia transport, portable devices and ad hoc networking. The products will be more expensive than Bluetooth products but less expensive than WLAN products. Concerning power consumption, the IEEE802.15.3 based products will be between the Bluetooth and WLAN products (Gandolfo, 2002).

On-Body Networks

Personal Area Networks are generally classified as wire-based, infrared-based, or radio-frequency-based, with wired solutions being the predominant technology for wearware. Many off-body solutions could be used on a smaller scale for on-body communications but would involve a colossal waste of resources. Current on-body networking solutions are summarized in Table 5.
With many small devices such as simple sensors and actuators, continuous communication with high data rate is not usually necessary. Occasional wireless communication through interconnections with the maximum data rate of a few, a few tens or a few hundreds of kilobits per second, and the maximum communication range of a few tens of meters, can facilitate the portability or installation of this kind of devices. Compared to maximizing the data rate, it is usually more important to minimize costs, physical size and power consumption. Many applications belong to the cost critical consumer market. In many places, the electronics should be non-visible. Power supply through the mains, or recharging or replacing the batteries weekly or even monthly is impossible. Instead, the power supply has to be based on energy scavenging (Rabaey, 2000) or a small battery lasting several months or years. This often calls for average power consumption far below one milliwatt per device. Since the year 2000, IEEE802.15 task group 4 (TG4) has worked to standardize a physical and a MAC-layer applicable in very low-power wireless application systems, which should be able to operate at least several months on a battery without replacement (IEEE802.15 TG4). In parallel with IEEE802.15 TG4, the ZigBee alliance has been founded, now incorporating about twenty industrial companies and aimed at establishing open industry specifications for unlicensed, untethered peripheral, control and entertainment devices requiring the lowest cost and lowest power consumption communications between compliant devices anywhere in and around the home. The target for the power consumption is 0.5 to 2 year's operation with two AA-size batteries. According to the alliance, the first commercial products appeared on the market in 2003 (ZigBee).

The IEEE 802.15.4 standard defines two PHYs representing three license-free frequency bands that include sixteen channels at 2.4 GHz, ten channels at 902 to 928 MHz, and one channel at 868 to 870 MHz. The maximum data rates for each band are 250 kbps, 40 kbps and 20 kbps, respectively. The 2.4 GHz band operates worldwide while the sub-1 GHz band operates in North America, Europe, and Australia/New Zealand. The IEEE standard is intended to conform to established regulations in Europe, Japan, Canada and the United States.

Both PHYs use Direct Sequence Spread Spectrum (DSSS). The IC contains a 900 MHz physical layer (PHY) and portion of the media access controller (hardware-MAC). The remaining MAC functions (software-MAC) and the application layer are executed on an external microcontroller. All PHY functions are integrated on the chip with minimal external components required for a complete radio. A low-cost crystal is used as a reference for the PLL and to clock the digital circuitry. To optimize energy consumption in sleep mode while still keeping an accurate time base, a Real Time Clock reference can be used.

Some extra features of the PHY include receiver energy detection, link quality indication and clear channel assessment. Both contention-based and contention-free channel access methods are supported with a maximum packet size of 128 bytes, which includes a variable payload up to 104 bytes. Also

Table 5. On-body networking technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Operational spectrum</th>
<th>Maximum data rate</th>
<th>Coverage</th>
<th>Power level issues</th>
<th>Interference</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>IrDA</td>
<td>Infrared; 850 nm</td>
<td>4 Mbps</td>
<td>&lt; 10 m</td>
<td>Distance-based</td>
<td>Present</td>
<td>Low (&lt;$10)</td>
</tr>
<tr>
<td>BodyLAN</td>
<td>Not available</td>
<td>32 Kbps</td>
<td>&lt; 10 m</td>
<td>5.4 mA</td>
<td>Present</td>
<td>Not available</td>
</tr>
<tr>
<td>IEEE 802.15.1</td>
<td>2.4 GHz ISM band</td>
<td>Up to 1 Mbps</td>
<td>&lt; 10 m</td>
<td>1 mA-60 mA</td>
<td>Present</td>
<td>Low (&lt;$10)</td>
</tr>
<tr>
<td>IEEE 802.15.3</td>
<td>11-55 Mbps</td>
<td>&lt; 10 m</td>
<td>&lt; 80 mA</td>
<td>Present</td>
<td>Medium (&lt;$50)</td>
<td></td>
</tr>
<tr>
<td>IEEE 802.15.4</td>
<td>2.4 GHz and 868/915 MHz</td>
<td>&lt; 20 m</td>
<td>20-50 pA</td>
<td>Present</td>
<td>Very low (&lt;$5)</td>
<td></td>
</tr>
</tbody>
</table>

With many small devices such as simple sensors and actuators, continuous communication with high data rate is not usually necessary. Occasional wireless communication through interconnections with the maximum data rate of a few, a few tens or a few hundreds of kilobits per second, and the maximum communication range of a few tens of meters, can facilitate the portability or installation of this kind of devices. Compared to maximizing the data rate, it is usually more important to minimize costs, physical size and power consumption. Many applications belong to the cost critical consumer market. In many places, the electronics should be non-visible. Power supply through the mains, or recharging or replacing the batteries weekly or even monthly is impossible. Instead, the power supply has to be based on energy scavenging (Rabaey, 2000) or a small battery lasting several months or years. This often calls for average power consumption far below one milliwatt per device. Since the year 2000, IEEE802.15 task group 4 (TG4) has worked to standardize a physical and a MAC-layer applicable in very low-power wireless application systems, which should be able to operate at least several months on a battery without replacement (IEEE802.15 TG4). In parallel with IEEE802.15 TG4, the ZigBee alliance has been founded, now incorporating about twenty industrial companies and aimed at establishing open industry specifications for unlicensed, untethered peripheral, control and entertainment devices requiring the lowest cost and lowest power consumption communications between compliant devices anywhere in and around the home. The target for the power consumption is 0.5 to 2 year's operation with two AA-size batteries. According to the alliance, the first commercial products appeared on the market in 2003 (ZigBee).
employed are 64-bit IEEE and 16-bit short addressing, supporting over 65,000 nodes per network. The MAC provides network association and disassociation, has an optional super frame structure with beacons for time synchronization, and a guaranteed time slot (GTS) mechanism for high priority communications. The channel access method is carrier sense multiple access with collision avoidance (CSMA-CA).

ZigBee defines the network, security, and application framework profile layers for an IEEE 802.15.4-based system. ZigBee’s network layer supports three networking topologies; star, mesh, and cluster tree as shown in Picture 3. Star networks are common and provide for very long battery life operation. Mesh, or peer-to-peer, networks enable high levels of reliability and scalability by providing more than one path through the network. Cluster-tree networks utilize a hybrid star/mesh topology that combines the benefits of both for high levels of reliability and support for battery-powered nodes. To provide for low cost implementation options, the ZigBee Physical Device type distinguishes the type of hardware based on the IEEE 802.15.4 definition of reduced function device (RFD) and full function device (FFD). An IEEE 802.15.4 network requires at least one FFD to act as a network coordinator.

As an alternative to ZigBee, Nokia has proposed a Bluetooth evolution to IEEE 802.15 TG4. Nokia's proposal takes Bluetooth as the basis but suggests relaxation of some parameters such as data rate, transmitted power, receiver sensitivity and frequency hopping to enable very low-power implementation. One of the main ideas of the proposal is to use standard Bluetooth RF parts as far as possible, which would enable better integrability to the mobile phone environment (IEEE 802.15 TG4b). Table 6 provides a comparison between different wireless standards related to various attributes of the specific networks.
CASE STUDIES OF EXISTING PERVERSIVE HEALTH SYSTEMS

Nowadays, the utilization of modern biomedical data acquisition devices and the deployment of fast wireless networks have enabled the introduction of several pervasive health systems. Hereafter, we review some of the most representative pervasive health applications found in the literature.

In Takizawa (2001), a mobile healthcare unit was implemented utilizing a Ku-band satellite system. The mobile unit consists of a van that houses a spiral computed-tomography (CT) machine and various telecommunications equipment. The unit allows medical examination, CT scanning, and online two-way transfer of image data / teleconferencing to a medical center for consultation with various specialists. For trauma cases during the game period of Olympic Games of 1998, images of CT scans were uploaded at an efficient transmission speed of 437.5 kb/s, over a period of 5 min. Video conferencing was achieved at a transmission speed of 384 kb/s. As already mentioned, the major disadvantage of such system is the high cost of the satellite link.

In Salvador (2005), a platform built around three information entities (patient, healthcare agent, and central station) was designed to enable patients with chronic heart disease to complete specifically defined protocols for out-of-hospital follow-up and monitoring. The patients were provided with portable recording equipment and a cellular phone that supported data transmission (electrocardiogram - ECG) and wireless application protocol (WAP). The data rate limitations due to the GSM network operation are once again obvious.

The goal of the MobiHealth project (Bults, 2004) was to develop mobile health services using GPRS and UMTS for connection of patient’s body area network and hospital servers. Body Area Network (BAN) comprises of various healthcare sensors wirelessly connected to a mobile phone or a PDA. A mobile phone or a PDA acts as a gateway towards wide area networks, thus providing access to remote databases or doctors in charge. For the emergency cases, trials have been conducted showing tele-trauma care both for patients and for health professionals (ambulance paramedics). The trauma patient BAN measured vital signs which were transmitted from the scene to the members of the trauma team located at the hospital.

Finally Chu (2004) have presented a cost-effective portable tele-trauma system was introduced that can assist the healthcare in pre-hospital trauma care. With the commercially available 3G wireless link, the system can simultaneously transmit video, still-ultrasound images, and vital signals. The system enables the trauma physician to continuously monitor the patient’s situation during the pre-hospital routine through visual communication (e.g., video) in addition to voice and vital signs information exchange.
In Controlled Environment (Hospitals, Medical Centers)

As mentioned in Section 2.3.3 the use of pervasive systems in controlled environments, such as hospitals and medical centers may be divided into two broad categories. The first one relates to applications, enabling the mobile ubiquitous delivery of medical data and implementations of mobile Electronic Health Records (EHR), accessible by PDA’s or Tablet PC’s in a hospital equipped with Wireless LAN infrastructure (Finch, 1999). Several research groups (Hall, 2003; Maglogiannis, 2004) have experimented on the use of handheld computers of low cost and high portability, integrated through a wireless local computer network within the IEEE 802.11 or Bluetooth standards. Regarding the medical data exchange, DICOM (www.dicom.org) and HL7 (www.hl7.org) standards are used in the data coding and transmission via mobile client/server applications capable of managing health information.

On the other hand, pervasive systems are used for the monitoring and diagnosis of patients. A wide range of medical monitors and sensors may enable the mobile monitoring of a patient, which is able to walk freely without being tied to the bed. Pervasive systems in a hospital environment are mostly based in Bluetooth communication technology. For example, Khoor (2001) have used the Bluetooth system for short-distance (10m-20m) data transmission of digitized Electrocardiograms (ECGs) together with relevant clinical data. Hall (2003) have demonstrated a Bluetooth based platform for delivering critical health record information in emergency situations, while Andreasson (2002) have developed a remote system for patient monitoring using Bluetooth enabled sensors. The above examples show that the merging of mobile communications and the introduction of handhelds along with their associated technology has potential to make a big impact in emergency medicine.

Moreover, many market projections indicate that mobile computer is both an emerging and enabling technology in healthcare (Finch, 1999). Each biosignal provides different and complementary information on a patient status and for each specific person the anticipated range of signal parameters is different. For example, heart rate may vary between 30 and 250 beats/min for normal people in different circumstances; likewise, breathing rate could be between 5 and 50 breaths/min. Electroencephalogram (EEG) and Electrocardiogram ECG are considerably more complex biosignals with spectra up to 10 KHz (Gouaux, 2003).

In Random Locations - Home Care Systems

Facilities for medical practice in non hospital settings are limited by the availability of medical devices suitable for producing biosignals and other medical data. There is a number of active research and commercial projects developing sensors and devices, which do not require local intervention to enable contact with a clinician remote from the care environment. These new systems provide automated connection with remote access and seamless transmission of biological and other data upon request. Pervasive systems in non hospital systems aim at the better managing of chronic care patients, the controlling of health delivery costs, the increasing quality of life and quality of health services and the provision of distinct possibility of predicting and thus avoiding serious complications.

The patient or elder will mainly require monitoring of his vital signals (i.e., ECG, blood pressure, heart rate, breath rate, oxygen saturation and perspiration). Patients recently discharged from hospital after some form of intervention, for instance, after a cardiac incident, cardiac surgery or a diabetic coma are less secure and require enhanced care. The most common forms of special home monitoring are ECG arrhythmia monitoring, post surgical monitoring, respiratory and blood oxygen levels monitoring and sleep apnoea monitoring. In the case of diabetics, the monitoring of blood sugar levels resigns the patient to repeated blood sampling which is undesirable and invasive. One possible solution is the development of implantable wireless sensor devices that would be able to give this information quickly, and in a continuous fashion. Current conditions where home monitoring might be provided include: hypertension, diabetes (monitoring glucose), obesity (monitoring weight), CHF (monitoring weight), asthma and COPD (monitoring spirometry/peak flow), and, in the near future, conditions utilizing oximetry monitoring. Other home monitoring conditions might include pre-
eclampsia, anorexia, low birth-weight infants, growth abnormalities, and arrhythmias. Most chronic health conditions in children and adults could be managed and/or enhanced by home monitoring. In most applications two monitoring modes are foreseen: the Batch and the emergency mode. Batch Mode refers to the every day monitoring process, where vital signs are acquired and transmitted periodically to a health monitoring centre. The received data are monitored by the doctor on-duty and then stored into the patient’s electronic health record maintained by a Healthcare Centre. The Emergency Mode occurs because the patient does not feel well and, thus, decides to initiate an out-of-schedule session, or because the monitoring device detects a problem and automatically initiates the transfer of data to the corresponding centre. Application emergency episode detection and the corresponding alarm processing are important for the protection of the patient. An alarm represents a change in status of a physiological condition or a sensor reading state outside of agreed limits.

Telemonitoring of patients at home: a software agent approach (Rialle, 2003) is an article that describes the general architecture, the various components of the model, and methodology that has been used. It concretely faces the problem of depiction in the object-oriented system of various dimensions of the included systems: the natural world of sensors of domestic biological signals, the numerical world of software experts and everything relative with the internet, and the world of doctors and patients and all-purpose practitioners. In this system, the main part of information passes from the biophysical world of patients in the house, in the social-medical world of experts of care of persons from a chain of appliances including sensors, network of local region, domestic computer, distant central computer, and server computers. Each appliance of software is specialized with different levels of knowledge and complexity. The technologies of Internet and Java provide the structural units of drawn telecontrol of software. The laboratorial experiments have been realized using complete equipped smart home for the telecontrol. This system allows multiple communications of the computers simultaneously and sharing of information among patients, as can be seen in Figure 5 (Rialle, 2003).

Figure 5. Computer architecture of the software agent approach

A Portable Real Time Homecare System Design with Digital Camera Platform (Kao, 2005) presents a low-cost homecare system based on a platform of digital camera. According to the multimedia functions of recording a digital camera, such as JPEG and MPEG-1/MPEG-4 recording, the proposed system can be further elaborated and depress the mark of a phono cardio graph (PCG).
An ideal portable system homecare as shown in Figure 6 (Kao, 2005), should provide the following characteristic traits:

- diagnostics collection and treatment of data,
- television and acoustic contact between the doctor and the patient for the communication in real time,
- portable appliances with batteries so the doctor can check the patients everywhere and
- the wireless contact of communication.

Due to the limitation of wireless bandwidth communication, the audio and TV data and the vital data should first be compressed before transmitted. The main difficulty in constructing this ideal homecare system is the limited capacity of the battery of the mobile devices.

Figure 7 (Kao, 2005) presents a proposed portable embedded system, based in a platform of digital cameras. The platform incorporates the basic elements of multimedia such as CCD, A/D converter, D/A converter and other processors for the compression of the elements. The microphone and the speaker can also be used for communication between the patients and the doctors, if the wireless appliances are incorporated in the system. Based on this platform, the remainder issues develop a good quality algorithm in order to establish the calculating ability and in order to completely use the calculating resources from the software, so as the acoustic/television recordings can be accomplished simultaneously with the treatment diagnoses.
*CodeBlue* (Malan, 2004) is a wireless infrastructure intended for deployment in emergency medical care, integrating low-power, wireless vital sign sensors, PDAs, and PC-class systems. CodeBlue will enhance first responders’ ability to assess patients on scene, ensure seamless transfer of data among caregivers, and facilitate efficient allocation of hospital resources. Intended to scale to very dense networks with thousands of devices and extremely volatile network conditions, this infrastructure will support reliable, ad hoc data delivery, a flexible naming and discovery scheme, and a decentralized security model.

CodeBlue is designed to provide routing, naming, discovery, and security for wireless medical sensors, PDAs, PCs, and other devices that may be used to monitor and treat patients in a range of medical settings. CodeBlue is designed to scale across a wide range of network densities, ranging from sparse clinic and hospital deployments to very dense, ad hoc deployments at a mass casualty site. CodeBlue may also operate on a range of wireless devices, from resource-constrained motes to more powerful PDA and PC-class systems. CodeBlue is depicted in Figure 8 (Malan, 2004) and offers a scalable, robust “information plane” for coordination and communication across wireless medical devices. It provides protocols and services for node naming, discovery, any-to-any ad hoc routing, authentication, and encryption. CodeBlue is based on a publish/subscribe model for data delivery, allowing sensing nodes to publish streams of vital signs, locations, and identities to which PDAs or PCs accessed by physicians and nurses can subscribe. To avoid network congestion and information overload, CodeBlue will support filtration and aggregation of events as they flow through the network. For example, physicians may specify that they should receive a full stream of data from a particular patient, but only critical changes in status for other patient on their watch.

![Figure 8. The CodeBlue communication substrate](image)

*Wealthy* (Paradiso, 2005) it is a fabric surface filled with sensors, electrodes and connections in fabric moulds that give signals for technical and modern telecommunications systems. The sensors, the electrodes and the connections are realized through conductive and durable threads. The ability of the system to acquire simultaneous various biomedical signals (e.g. electrocardiogram, respiratory activity) has been discovered and compared with a standard system. Moreover, two different techniques are presented for the acquisition of respiratory signal with fabric sensors. The proposed system is designed to monitor individual components that are influenced by cardiovascular disease, particularly during the recovery phase. The system can also help workers affected by physical or psychological stress and / or environmental and occupational health risks.
Wealthy will become completely acceptable if it is an appliance easy to use and adaptable to the needs of each customer without he or she feeling depression, specifically in his daily activities. The fabric approaches the application of sensor elements that exists in the clothes allowing firstly at low cost to achieve a long-lasting control ill and an easy adaptation in the configuration of sensor of each customer, according to their needs. This device helps to prevent an acute crisis or heart problems of workers in conditions of extreme stress. Simultaneous replication of critical signals allows the export of the parameters specifying a new link to all the signals that contribute to risk messages, adding data to the personal health records of patients. In the wealthy appliance, the electrocardiogram signals are sampled at 250Hz. Special treatment is applied to parameters such as heart rate and duration of the QRS with a respectable number of samples. In order to reduce the amount of data transferred via GPRS, the ECG signals have been cut to prevail samples of 100Hz. The activities of breathing and movement result from the sensors that have been sampled at 16Hz. The portable system of the patient (PPU) is designed by a simple surface with two LEDs, a button aiming at the warning of the user and a button that gives the option to the user of regulating manually the alarm. The communication of this appliance is based on the GPRS protocols. The central system is comprised by:

- Web server
- Database Application module
- Central Control module
- Doctor’s desktop/laptop module

**FUTURE RESEARCH DIRECTIONS**

The technological advances of the last few years in mobile communications, biomedical data acquisition and mobile computing have facilitated the introduction of pervasive healthcare applications. Healthcare can benefit from pervasive computing benefits in at least four ways:

- Enabling distributed access and processing of medical data;
- Lowering costs by getting appropriate care to the people who need it much faster than previously possible;
- Making expert care accessible to more people, thereby increasing the scale at which first-rate healthcare is applied and
- Making healthcare more personalized, prompting individuals to take more responsibility for maintaining their health.

However there are still issues and challenges that have to be addressed. The most significant according to our view is the fact that the vast majority of the existing implementations do not interoperate sufficiently, resulting in segmented solutions. Moving to a fully pervasive system would be a complex transition requiring several steps and incremental budgetary increases to create the necessary infrastructure. This process should not interfere with the basic functioning of the current systems. In addition the introduction of more intelligent approaches and methods, like context-awareness and agent environments is a desired feature of the forthcoming pervasive health systems that might help in overcoming obstacle such as interoperability and collaboration issues. Privacy and security are also potential problems. Healthcare data should be available anytime anywhere, but only to authorized persons. This important aspect of pervasive health systems has not yet been dealt sufficiently in existing systems. The usability of pervasive healthcare solutions is another challenge, at least in the near future. Those who are less technically savvy are generally willing to use pervasive mobile devices if these devices enrich their lives, give them more independence, and offer intuitive interfaces. Training healthcare professionals as well as patients to use such devices will become less problematic as handhelds and other wireless products become commonplace in society.
CONCLUSIONS

In this chapter book we analyzed the tremendous impact of wireless technology in the homecare and healthcare environments. We described a number of different case studies of the existing pervasive health systems, showing great performance and the biosensors that will mark swift growth in the future and will become integral part of our life. There are appliances easy in their use precious and very important for the patient, contributing to the improvement and in the prevention of his or her health. The use of new technologies for the applications of telemedicine and concretely the homecare system appears today as an obligatory solution: the wireless systems have become a standardized infrastructure for access in the complex applications of telemedicine from substantially any machine and functional system. Such standardized platform of communication guarantees the advantages of possibility of access and possibility of utilization both in the customers and in the suppliers (patients and general practitioners). In other words we can declare that the use of these technologies offer to the patients who typically fill the chambers and the corridors of hospitals, services of high quality and efficiency, outweighing the provisional cost.

Although wired communication technologies, such us ATM (Asynchronous Transfer Mode) and optical communication, are widely used, the key aspect for pervasive healthcare communication is the transfer of high-speed and ubiquitous health data in every place in earth securely and promptly. Wireless technology came to encompass the e-health monitoring everywhere from any given location, providing the so-called m-health services. During the last years, there has been increased research efforts on the production of commercial mobile health systems based on WiFi (Wireless Fidelity), GPRS (General Packet Radio Service) and 3G UMTS (3rd Generation Universal Mobile Telecommunications System) networking technologies. The introduction of high speed data rate, wide bandwidth, digital and encrypted communication technology, makes possible the delivery of audio, video and waveform data to wherever and whenever needed. It is anticipated that the current deployment of wireless-based systems with global operational morphologies will improve some of the limitations of the existing wireless technologies and will provide a well-organized platform for mobile healthcare services.

Such wireless technologies will make available both mobile patients and end users to interactively get the medical attention and advice they need, when and where is required in spite of any geographical obstructions or mobility constrains. Consequently, it can serve as a new generation technology for mobile health systems providing immediate and ubiquitous health care in a range of different circumstances, as it may handle a variety of telemedicine needs, especially in the fields of emergency health care provision in ambulances, rural hospital centers or any other remote and dispersed located health center and intensive care patients monitoring.

The management of integrated electronic health records and other telemedicine applications and services the system supports, is now internationally well known and has been repeatedly showed interest in the transfer of technology and the know-how to other regions of Europe. Nevertheless, various questions exist that should be discussed in-depth, regarding to the applications relative with the benefit of attention in the distance, called today telecare applications. In the telecare applications the role of patient becomes vital, through the actively inclusion in the stage of management of treatments and care, and through the responsibility for the collection of certain measurements and relative information.

The technologies of today are tools for a high-quality coordination procedure. Their capabilities are improving rapidly from time to time and their cost decreases exponentially with their use. What is needed is coordination of relevant concepts, attitudes and best practices, so that we can seize the great opportunities that they provide.

REFERENCES


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## ADDITIONAL READING


The association of telehealth service providers; [http://www.atsp.org](http://www.atsp.org)


KEY TERMS & DEFINITIONS
Satellite, mobile, wireless, m-health, telemedicine, biosensors, healthcare, pervasive