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Smart home technology for aging

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ABSTRACT

SMART HOME TECHNOLOGY
FOR AGING

by
Fareedh Meeran

The majority of the growing population, in the US and the rest of the world requires some degree of formal and or informal care either due to the loss of function or failing health as a result of aging and most of them suffer from chronic disorders. The cost and burden of caring for elders is steadily increasing. This thesis focuses on providing the analysis of the technologies with which a Smart Home is built to improve the quality of life of the elderly. A great deal of emphasis is given to the sensor technologies that are the back bone of these Smart Homes. In addition to the Analysis of these technologies a survey of commercial sensor products and products in research that are concerned with monitoring the health of the occupants of the Smart Home is presented. A brief analysis on the communication technologies which form the communication infrastructure for the Smart Home is also illustrated. Finally, System Architecture for the Smart Home is proposed describing the functionality and users of the system. The feasibility of the system is also discussed. A scenario measuring the blood glucose level of the occupant in a Smart Home is presented as to support the system architecture presented.

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FOR AGING

by
Fareedh Meeran

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To my beloved grandparents

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CHAPTER 1

INTRODUCTION

1.1 Objective

The objective of this thesis is to present the various types of sensors used in Smart Homes for capturing vital information of occupants that need medical assistance. This report provides in detail explanation on the applications of each of the sensors used in Smart Homes and presents an integrated architecture of a Smart Home with all the necessary modules in it.

1.2 Introduction

The majority of the growing elder population, in the US and the rest of the world requires some degree of formal and or informal care either due to the loss of function or failing health as a result of aging. Nearly three quarters of elders over the age of 65 suffer of one or more chronic diseases. The cost and burden of caring for elders is steadily increasing. If given the choice, many elders would prefer to lead an independent way of life in a residential setting with minimum intervention from the caregiver. On the other hand, the role of informal caregivers in providing care to elder population has greatly increased over the past two decades and has resulted in shifting the responsibility for care during recuperation, rehabilitation, and a long term disability from institutions to individuals and families in the community. In order to be universally beneficial to lessen the burdens on the caregivers and to increase the quality of care and life issues for the elders, the concept of Smart Home evolved.

The definition of a Smart Home according to [1] is "A dwelling incorporating a communications network that connects the key electrical appliances and services, and allows them to be remotely controlled, monitored or accessed ". The Smart Home we are concerned here is more or like a Smart Nursing Home. The main difference between a Smart Home and other houses is that a communications infrastructure is installed that allows the various systems and devices in the home to communicate with each other.

1.3 What is Smart Home Technology

Smart Home technology is a collective term for information and communication technology (ICT) as used in houses, where the various components are communicating via a local network [2]. Smart Home technology gives a totally different flexibility and functionality, than does conventional installations and environmental control systems because of the wide range of technologies used for specific purposes. This report deals with some of the vital technologies that are used in the Smart House to help aid the elderly lead a quality of life monitoring their health remotely and take preventive action whenever needed. There are two key features that are provided by a Smart House with respect to the occupants themselves which is Safety and Independence. Safety could be still broken down into personal safety and health safety. Personal safety deals with providing the occupants of the house with a safe environment to dwell. Health safety is concerned with monitoring the health of the occupants and providing necessary information to the caregivers or the occupants themselves which is again specific to the disability of each occupant. As evident from the study conducted by the WHO, 85 percentile of the elderly people do not want to move out of their homes to nursing homes due to several reasons. In a Nursing Home the independence of the elderly people is taken away and they get a long time to get adjusted to the environment and some times never do. One of the other reasons could be cost of living in Nursing Homes is way to high and is not affordable by all. These factors led to development of Smart Homes and the recent advances in technology sound potential to meet most of the requirements.

1.4 Components of a Smart Home

The components of a Smart Home can be classified into five components. Although these are five discrete units of a Smart House, they will be considered as a single unit and more focusing will be emphasized on their application point of view.

Sensors: Sensors are the most vital integral unit of a smart home. These are the units which monitor and submit messages in case of changes. There are a variety of sensors which are being used to monitor specific data which are discussed in detail in the following chapters.

1. **Actuators:** Actuators perform physical actions; examples of actuators could be automatic light switches and relays. Mostly the components of environmental control systems are actuators.
2. **Controllers:** Controllers make choices based on programmed rules and occurrences. Controllers are microprocessors often built- in with sensors and actuators. They receive and process values from the sensor or other controllers.
3. **Central Unit:** A central unit which acts as a data repository of all the vital information from the various types of sensors. This central unit can also be used

to program logic based on the data collected and control other actuators and sensors.

4. **Communication Modules:** These are the modules which facilitate the flow of information in and out of a Smart Home. The communication module totally depends upon the type of communication technology being used for the specific purpose. A snapshot of a smart home is illustrated in the Figure 1.1.

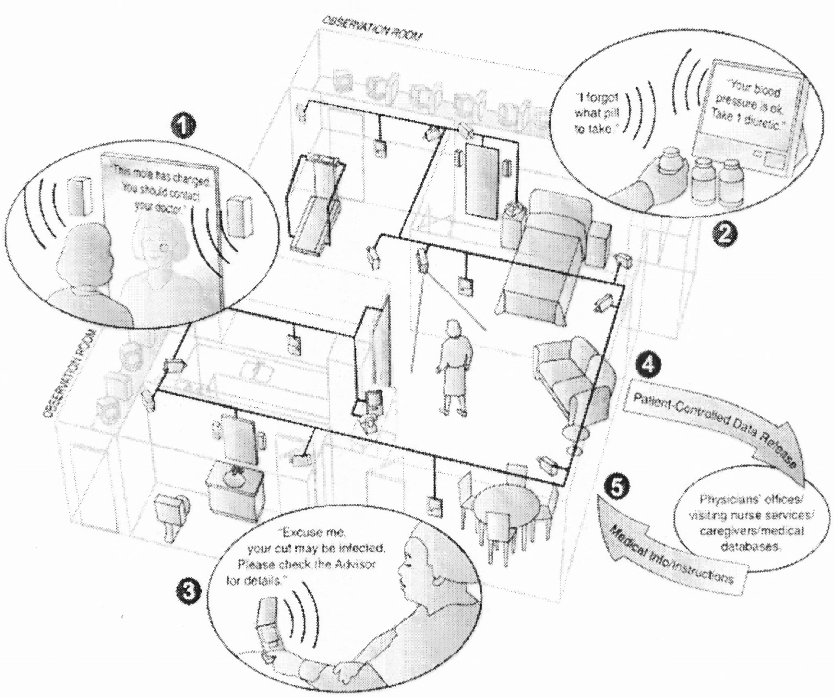

Figure 1.1 Smart Home overview.

1.5 Overview of the Chronic Diseases in Elderly

This section provides you a brief overview of the chronic diseases which are common among the elderly people. The medical definition of a chronic disease is "A disease that persists for a long time "according to [3]. The most common chronic diseases in developed countries include Arthritis, Alzheimer's Dementia, Cardiovascular diseases such as heart attacks and stroke, Cancer, Diabetes, Epilepsy, Neurovascular diseases and Osteoporosis.

The following paragraph gives a description of these diseases in short. Arthritis as defined by [3] is a joint disorder featuring inflammation, literally meaning inflammation of one or more joints where a joint is an area of the body where two different bones meet. Alzheimer's Diseased (AD) as defined by [3] is a progressive disease of the brain that is characterized by the impairment of memory and a disturbance in at least one other thinking function. This results in the loss of mental and physical functions due to the damage to the nerve cells. Cardiovascular diseases as defined by [3] are a disease that affects the heart or the blood vessels. Diabetes mellitus as defined by [3] is a group of metabolic diseases characterized by high blood sugar glucose levels which results in insulin secretion, or action, or both. Epilepsy as defined by [3] is a physical condition caused by sudden, brief changes in how the brain works, it occurs when the nerve cells in the brain fire electrical impulses at a rate of up to four times higher than normal which causes a sort of electrical storm in the brain, known as seizure. A pattern of repeated seizure is referred to as epilepsy. Neurovascular diseases refer to diseases associated with blood vessels and arteries that supply blood to the brain. These diseases require frequent monitoring of health conditions, taking of necessary required pills at right time and a close surveillance. Thus patients having theses diseases become potential candidates of our Smart Houses.

1.6 Use of Sensors in Smart Homes

What are sensors? Sensors as defined by [4] are "Electronic devices to measure a physical quantity such as temperature, pressure or loudness and convert it into an electronic signal of some kind". Smart Sensors which are the topic of interest on the other hand are sensors that provide extra functions beyond those necessary for generating a correct representation of the sensed quantity. Sensors are used in a variety of applications in Smart Homes and they form their backbone structure. The basic purpose of a sensor is to collect data or measure a variable. The application of sensors used in Smart Homes in this thesis are classified mainly into three types

- Sensors in relation to the subjects (The occupants of the house are referred to as subjects).
- Sensors in relation to the environment.
- Hybrid sensors that are inter-related to both the environment and the subjects.

These three types have been further classified into different types which have been discussed later in the following chapters.

CHAPTER 2

ANALYSIS OF THE SENSOR TECHNOLOGIES

2.1 Introduction

This chapter emphasizes on the technologies that are being used in the sensors in Smart Homes. It gives an overview of the technology, why this technology was chosen as a candidate for sensor application in Smart homes, the advantages of using the technology and finally the disadvantages. Although there are a wide range of sensor technologies, only the technologies specific to the area of interest and those of being in research have been discussed.

"Sensor is a physical device or biological organ that detects, or senses, a signal or physical condition and chemical compounds" [5]. The topic of our interest here is a smart sensor; a smart sensor is a sensor that provides extra functions beyond those necessary for generating a correct representation of the sensed quantity. Sensors used can be classified as one among the following four applications used in a Smart House. The major four applications used in smart home

- **Object Trackers:** Here the sensors are used to locate the subject in the Smart Nursing Homes. There are various technologies used for object tracking and overviews of these technologies are provided in this chapter.

- **Data Aggregators:** Here the sensors are used to collect the necessary medical data appropriate to their application. These sensors monitor vital information like cardiac health, blood glucose level, minor movements and distress etc.

- **Environmental Controllers:** These sensors control the environment of the Smart Home. This may control the lighting circuits in the home, the temperature etc.

- **Emergency Response Controllers:** These are special types of units which respond in case of emergency situations with in the Smart Nursing Home and initiate any alert mechanism according to the call of the emergency handling scenario.

The sensors which are categorized as Object trackers and Data Aggregators are sensors pertaining to with respect to the subject. The subject here is the occupant of the smart home. These sensors which sense information with respect to the subject are of two types namely invasive and non- invasive sensors. There are many advantages of non invasive monitoring over invasive or surgical methods of remote monitoring. The advantages include the cost of surgery, the distress involved in the surgery and any biological implications caused by these sensors inside the body. The non invasive sensors on the other hand are easy for the patients to use, do not cause any distress. There are also another kind of sensors which are minimally invasive. The invasive type of sensors is not explored in this report, and is regarded as out of the scope of this report.

The sensor technologies that are discussed include the RFID Technology, Bluetooth, Fiber optics and Bio Technologies. Each of the technology is taken as a potential candidate in the developing sensor networks in Smart Houses. The new trends in these technologies with respect to their application in Smart Homes are explained in detail.

2.2 RFID Technology

2.2.1 Introduction

The basic concept of Radio Frequency Identification (RFID) is that a query is sent out over radio waves ("What or who are you?") and then a subsequent reply is received ("This is what or who I am") [6]. The underlying technology architecture of RFID is based on these components

- Tag and its associated data structure.
- Reader and its associated software.
- Communications protocol Suite.
- Communications network.
- Database for providing data synchronization.

A RFID reader can be either stationary in a fixed state or handheld. The tag is a miniature chip with an affixed radio antenna. A radio wave signal is transmitted between a reader and tag to communicate an Electronic Product Code (EPC). This EPC is used to uniquely identify the tag. These readers can obtain more information by using a special EPC look up into the Object Name Service (ONS), and then the ONS will redirect a query on a specific EPC by resolving the EPC code into an Internet Address, where a considerable detail may be stored.

There are currently two types of tags namely passive and active. Passive tags have no directly associated power source while active tags have an active power source. There are two types of classes associated with each of the tags namely Class 0 which is a read only tag and Class 1 which are capable of both read and write. The approved frequency range for RFID applications is 900MHz for Class 0 and either 13.56 MHz ISM Band or

860-930 MHz for Class1, depending on the strength of the signal required. In case of the passive tag the reader initiates the communication via a radio signal strong enough to enable the tag to return a radio signal containing the information regarding to the item to which it is attached. In the case of an active tag either the reader or the tag can initiate communication. A reader has a field within which it can query via radio waves for whatever tags may be present. The reader follows a protocol that is intended to enable it to avoid duplicate reads but capture all tags present within its range. There is a large variation in reader capabilities, ranging from how many tags a reader can capture within a specific time period to more complicated tasks like filtering and communicating with a database. Readers have to be matched to tag type: active or passive class: 0 (read only) or 1 (read/write), gen1 or gen2 tags. Some readers can capture multiple tags, but as far as our requirements are concerned there is no need for these kinds of readers. These EPC codes will be stored in the database with link to their corresponding information. The two dominant standards bodies for definition of air interface and tag data structure standards for RFID are EPCglobal and the International Organization for Standardization (ISO). EPCglobal has laid out the following tag interface specifications which are described in Table 2.1.

Table 2.1 Tag Interface Specifications by EPCglobal

Frequency	Class
900 MHz	Class 0 RF Identification
13.56 MHz ISM	Class 1 RF Identification
860 MHz – 930 MHz	Class 1 RF Identification

2.2.2 Selecting RFID Systems

Basically there are four categories of systems in the RFID showroom,

- Low Frequency (<135 kHz)
- High Frequency (13.56 MHz)
- Ultra High Frequency (433 MHz, 860 MHz, 928 MHz)
- Microwave (2.45 GHz and 5.8 GHz)

Since its all about carrying and moving data in a wireless fashion, these are the categories on which an RFID system needs to be chose

Data capacity: This specifies how much data the tag can carry. It is often expressed in bits. For example, a 64 bit carrier is effectively capable of carrying eight digits and eight characters or a combination of characters and digits

Read-write capabilities: This specifies what is possible in terms of read-only and read-write capability.

Read-only devices: These are generally less costly and may be factory programmable read only or (OTP) One Time Programmable. One-time programmability provides the opportunity to write once then read many times.

Read/write data carriers: They offer the facility for changing the content of the carrier as when appropriate with a given application. Some devices will have both a read-only and read-write component that can support both identification and other data carrier needs.

Data transfer: This specifies how fast the data can be transferred from tag to host management system. It is generally quoted in bits per second.

Data security and error control support features: This deals with what is required to support the realization of security-centric applications where stored or encrypted data is used as part of security application.

Time to read: This is the time it takes to read a tag, which is of course is related to data transfer rate. Various factors can influence read time including competing readers and tags.

Interference: Systems need to be immune from interference by signals or fields from other sources and commissioned to ensure that they comply with regulatory requirements and do not cause interference with other systems.

Form and Robustness: This relates to the various forms that the data carriers may take in respect to the physical form, size and weight and robustness of the tags and facilities attachment to items.

Standards: Knowing what technical and application standards are applicable to the applications envisaged.

Regulatory requirements: Knowing what regulations govern the usage of RFID systems, including spectrum usage, safety regulations and guidelines'

Costs: The costs relate to the costs associated with basic parts of the system. This should also include the support costs that can have an important bearing upon determining and justifying an application for RFID.

Application features: This can have a significant bearing upon the type of RFID system to be used and provide insight into where best the technology can be applied.

2.2.3 Role of RFID Technology in Smart Home

The RFID tags in Smart homes are used to locate the occupants of the Smart Home. With the help of tracking the patient with the tag we can obtain his/her identification. With the help of the identity of the occupant we would be able to access the medical records from the medical database. Here choosing a passive RFID tags would be cheaper when compared to an active RFID tags. Although RFID technology is used not only for object tracking it has other applications in a Smart Home. Both the Commercial and Research products are discussed in the following chapters. The Figure 2.1 illustrates the use of RFID as a solution to asset tracking in a Smart Home.

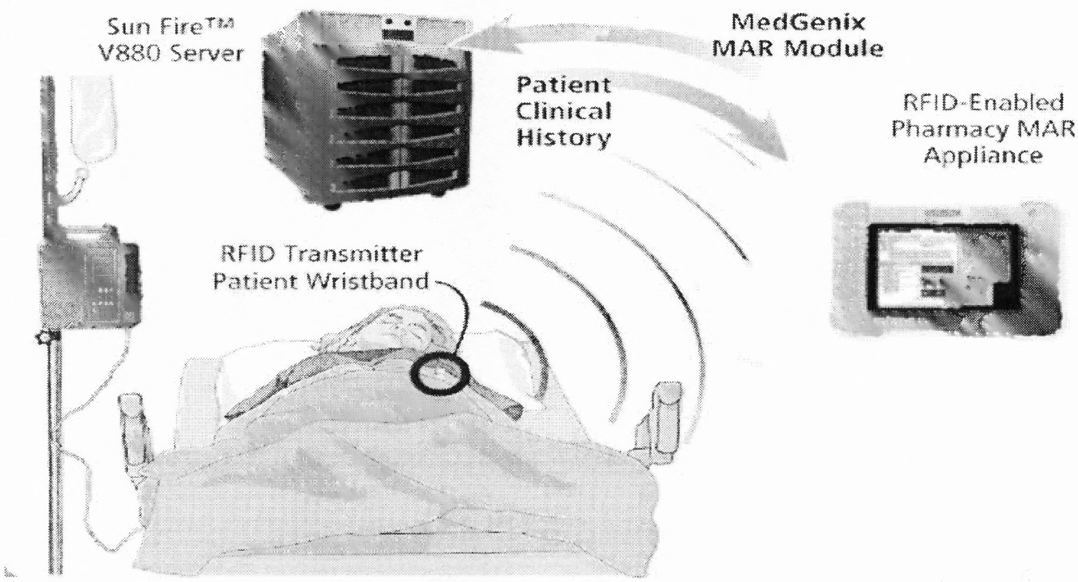

Figure 2.1 Use of RFID in smart home.

2.2.4 Advantages of RFID

This section describes the advantages of choosing RFID technology as candidate for location sensing in a Smart Home. The significant advantage of all types of RFID systems is the no contact, no-line-of-sight nature of this technology. Tags can be read through a variety of substances such as hard walls and other visually and environmentally challenging conditions, where barcode or other optically read technologies would be useless. RFID tags can be read in challenging circumstances at remarkable speeds, in most cases responding in less than 100 milliseconds. The read/write capability of an active RFID system is also a significant advantage where in there is need to add information to the RFID tag in an adhoc fashion. This is generally useful if the priority at which an occupant in a Smart Home is changed due to recent developments in his health conditions and needs more attention. The other advantages are the capability of the reader to track multiple tags at the same time and support to portable databases. The main advantages of the market trend moving towards to RFID technology is its cost effectiveness in along run.

2.3 Fiber Optics Technology

2.3.1 Introduction

Today's low glass fiber optic cable offers almost unlimited bandwidth and unique advantages over all previously developed transmission media. The basic point-to-point fiber optic transmission system consists of three basic elements

- Optical Transmitter
- Fiber optic cable

- Optical Receiver

All the three basic elements are described in the Figure 2.2. The optical transmitter converts an electrical analog or digital signal into a corresponding optical signal. The operation for optical transmitters are 850, 1300, or 1550 nanometers. The fiber optic cable consists of one or more glass fibers, which act as waveguides for optical signal. Fiber optic cable is similar to electrical cable in its construction, but provides special protection for the optical fiber within. For systems requiring transmission over distances of many kilometers, or where two or more fiber optic cables must be joined together, an optical splice is commonly used. The optical receiver converts the optical signal back into a replica of the original electrical signal. The detector of the optical signal is either a PIN-type photodiode or avalanche-type photodiode.

The basic optical transmitter converts electrical input signals into modulated light for transmission over an optical fiber. Depending on the nature of this signal, the resulting modulated light may be turned on and off or may be linearly varied intensity between two predetermined levels. The most common devices used as light source in optical transmitters are the light emitting diode (LED) and the laser diode (LD).LED's have a relatively large emitting areas and as a result are not good light sources as LDs. Once the transmitter has converted the electrical input signal into whatever form of modulated light is desired, the light must be "launched" into the optical fiber. There are two methods of placing the fiber's tip in very close proximity to an LED or LD. The fiber optic cable comes in all sizes and shapes. Like coaxial cable, its actual construction is a function of its intended application. The basic optical fiber is provided with a buffer coating which is mainly used for protection. This fiber is then enclosed in a central PVC loose tube which allows the fiber to flex and bend, particularly when going around corners or when being pulled through conduits.

Optical Connectors are the means by which fiber optic cable is usually connected to peripheral equipment and to other fibers. There are many different types of optical connectors in use today. The most popular type of optical connector in use today is the ST connector. ST connectors are available for both multimode and single mode fibers, where tolerance being the difference factor.

2.3.2 Types of Optical Fibers

Understanding the characteristics of different fiber type's aides in understanding the applications for which they are used. There are two basic types of fiber namely multi mode fiber and single mode fiber. Multimode fiber is best designed for short transmission distances and is suited for use in LAN (Local Area Network) systems and video surveillance. Single mode fiber is best designed for longer transmission distances, making it suitable for long distance telephony and multi channel broadcast systems.

Multimode fiber simply refers to that fact that numerous modes or light rays are carried simultaneously through the waveguide. Multimode fiber may be further categorized as step-index or graded index fiber. Because the core's index of refractions higher than the cladding's index of refraction, the light that enters at less than the critical angle is guided along the fiber. A graded index refers to the fact that the refractive index of the core gradually decreases from the center of the core. The increased refraction in the center of the core slows the speed of some light rays, allowing the light rays to reach the receiving end at approximately the same time, reducing dispersion. The difference in these two types of fibers is due to the difference in the index of refraction between the cladding and the core. Single mode fibers allows for a higher capacity to transmit information because it can retain the fidelity of each light pulse over long distances, and it exhibits no dispersion caused by multiple modes. The smaller core diameter makes coupling light into the core more difficult. The tolerances for single mode connectors and splices are also much demanding.

2.3.3 Choices for Choosing the Right Fiber Optic Cable

The deciding criteria for choosing a right Fiber optic cable is based on

- The Cable Type
- Mode of Transfer: Single/ Duplex/ Multi mode
- Rate of Transfer (in microns)

2.3.4 Use of Fiber Optic Sensors in Smart Homes

The fiber-optic based sensor technology addresses the growing need for non-invasive, reliable and low-cost monitoring systems for such sleep disorders. Obstructive sleep apnea is a serious disorder caused by obstruction of the upper airway during sleep which affects around 18 million Americans. Fiber-optic coupler sensors provide the basis for non-invasive system that can be used to detect the heart beat, breathing rate and blood pressure of patients whether awake or sleeping. By resting on a single pulse point, one of these physiological sensors can be used to detect heartbeat and respiration simultaneously. With an addition of a second sensor, blood pressure can also be monitored with squeezing or constricting a patient's arm or finger. Software associated with the sensor can identify changes in breathing and can factor out body movements. To measure these kinds of physiological parameters a single mode fiber can be used and can be incorporated into a smart mattress.

2.4 Ultrasonic Technology

2.4.1 Introduction

Ultrasonic sensors measure the distance or presence of target objects by sending a pulsed ultrasound wave at the object and then measuring the time for the sound echo to return. Knowing the speed of sound, the sensor can determine the distance of the object. The concept of this technology is described in this Figure 2.2

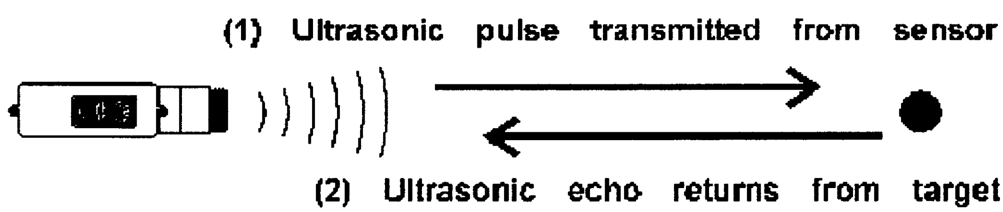

Figure 2.2 Ultrasonic technology overview.

Ultrasonic sensors work in the 40 KHz to 130 KHz range and use the (TOA) time of arrival to acquire distance information.

2.4.2 Main Components of an Ultrasonic System

There are there main components of an ultrasonic system namely

- Pilots: Pilots are nothing but receivers that are normally attached to whose distance is to be measured.
- Beacons: Beacons are nothing but transmitters which are usually fixed in ceilings whose position reference to the pilots is measured.
- Converters: These converters are used to connect to a communication interface for example RS485/ RS232.

2.4.3 Criteria to Design an Ultrasonic System

- Accuracy and Precision: This refers to the range acquired by the system.
- Scale: This refers to the number of number of beacons installed per square feet.
- Cost: This refers to the cost of the system
- Limitations

2.4.4 Use of Ultrasonic Sensors in Smart Homes

The Application of ultrasonic sensors in Smart Homes is to locate the occupants of the Smart Home. The indoor ultrasonic location systems provide fine-grained position data , and with the help of broadband transducers the disturbances caused by noise and signal collisions are minimized. According to [22] the advantage of using an Ultrasonic Positioning system the location of an object can be estimated with a high degree of resolution. Some of the location systems that are under current research have been discussed in the following chapter.

2.5 Bluetooth Technology

2.5.1 Introduction

Bluetooth is a wireless technology that enables any electrical device to wirelessly communicate in the 2.5 GHz ISM license free frequency band. It allows devices such as mobile phones, headsets, PDA's and portable computers to communicate and send data to each other without the need for wires or cables to link to devices together. It has been specifically designed as a low cost, low power, radio technology, which is particularly suited to the short range PAN (Personal Area Network) applications. This design of this technology differentiates it from the IEEE 802.11b wireless LAN technology. The main features of Bluetooth has been summarized in the following Table 2.2

Table 2.2 Bluetooth Features

Feature	Explanation
Operating Frequency	Bluetooth operates in 2.4GHz frequency band
Range	Real-time data transfer is usually possible between 10-100m
Line of Sight	Close proximity is not required as with infrared data communication devices, does not suffer from any obstacles
Type of wireless communication	Supports both point-to-point and point-to-multipoint to enable ad hoc wireless networks

Below are some of the terminologies used in Bluetooth

- **Piconet:** A piconet is a collection of devices connected via Bluetooth technology in an ad-hoc fashion. A piconet starts with two connected devices, such as a portable PC and cellular phone, and may grow to eight connected devices. All Bluetooth devices are peer units and have identical implementations. However, when establishing a piconet, one unit will act as a master and the other(s) as slave(s) for the duration of a piconet.

- **Scatternet:** Multiple independent and non-synchronized piconets form a scatternet.
- **Master unit:** The device in a piconet whose clock and hopping sequence are used to synchronize all other devices in the piconet.
- **Slave units:** All devices in the piconet that are not the master.
- **Mac address:** A 3-bit address to distinguish between units participating in the piconet.
- **Parked units:** The devices in a piconet which are synchronized but do not have a MAC addresses.
- **Sniff and Hold mode:** Devices synchronized to a piconet can enter power saving modes in which device activity is lowered.

2.5.2 Overview of a Bluetooth Wireless Sensor Network

Bluetooth modules, due to their performance and price, will be the standard parts of most electronic systems from mobile phones, personal digital assistants and industry control units. The number of hardware manufacturers adapting the Bluetooth technology and providing Bluetooth modules is rapidly increasing. This has made the modules reasonably cheap and is driving the market to provide smaller highly integrated products. In a Bluetooth sensor network number of sensors is controlled by a strategically placed access point. A simple network is shown in the Figure 2.2.

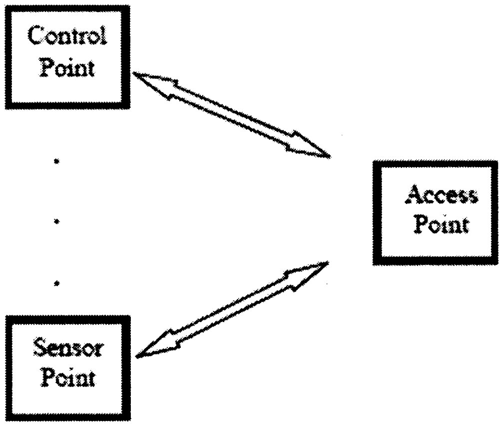

Figure 2.2 Simple sensor networks.

The structure of WSN (Wireless sensor Network) as described in [23] was built up in such a way that an access point, represented by a Ericsson Bluetooth module attached to a PC, served as a controller "allowing" sensors to send data on request. The sensors were implemented as true embedded objects, waiting for access point to wake them up and start sending data. This is illustrated in Figure 2.3

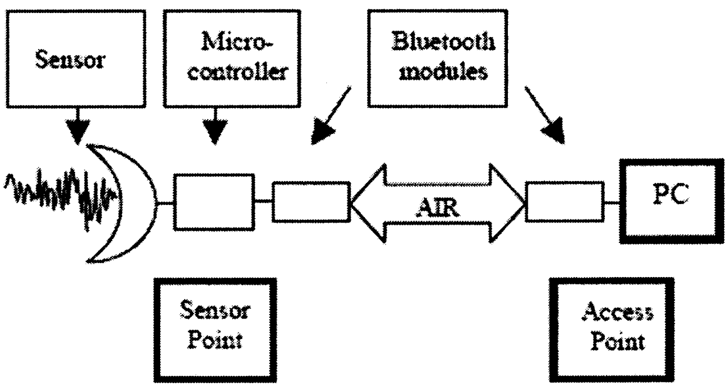

Figure 2.3 Basic configuration.

An implementation of a Wireless sensor network using Bluetooth by [24] is described below. They implemented a sensor network consists of several smart sensor nodes and a gateway. Each smart node can have several sensors and is equipped with a microcontroller and a Bluetooth radio module. The gateway has two wireless interfaces: A Bluetooth for communications with sensors and a GPRS for communication with users. Gateway and smart nodes are members of one piconet and hence maximum 7 smart nodes can exist simultaneously in the network. According to [24] their smart sensor node comprised of three functional blocks a sensing block, a data processing block and a communication block which is a generic sensor implementation. Their gateway was implemented on a Pentium laptop with Linux operating system. The complete software functionality was developed in Java and Java Bluetooth stack was used. This implementation shows the realization of a Bluetooth sensor network.

2.5.3 Bluetooth Modules for Wireless Sensor Networks

There are many advantages of choosing a Bluetooth module for wireless sensor networks. Bluetooth modules avoid the interference with other wireless modules. Blue tooth modules can be developed in small sizes which are suitable for embedding them into wearable devices that are used for monitoring vital information. Autonomous establishment of wireless networks by Bluetooth modules is another major advantage of Bluetooth technology itself. With all these in mind configuration of Bluetooth modules for application is feasible. Three different application modules have been described in [25] namely a wearable module that is attached to the wrist and has a temperature sensor, a PC connection module which is connected to the PC through a serial communication interface and an electrical appliance module connected to electrical appliances which are controlled by the PC connection module. These evaluations and demonstrations prove that the realized module has sufficient performance for the wireless sensor network and effectiveness in the daily life.

2.5.4 Use of Bluetooth in Smart Home

Bluetooth technology can be used in smart home with respect to two functional areas namely as a communication technology and as a sensor technology. Bluetooth as a potential candidate for a communication technology is described in the following chapter. Bluetooth wireless sensor networks can be sued in various ways to improve or enhance health care services. Monitoring of patients, health diagnostics, and drug administration in hospitals, telemonitoring of human physiological data and tracking and monitor doctors inside a hospital are some possible scenarios mentioned in [26, 27, 28, and 29]. Various sensors can be attached to patient's body to collect physiological data that can be either stored locally or forwarded directly to the hospital. Wearable modules can also be used to locate occupants of a Smart Home. These applications are directly related to most of the applications in a Smart Home.

CHAPTER 3

ANALYSIS OF THE COMMUNICATION TECHNOLOGIES

3.1 Introduction

There are a numerous factors to be considered for choosing a communication technology for a remote monitoring system. These factors are specific to the method of monitoring depending on the selected medical context.

The report *Networking Health: Protecting Electronic Health Information* [7] has listed a series of factors that are important to consider in specifying demands of communication technology. The report identified the following five primary factors to be considered namely bandwidth, latency, availability, security and ubiquity. These factors are described as follows. Each of the technology will be analyzed based on these five primary factors in the following sections.

1. **Bandwidth** is the rate at which information is transmitted through a network, measured in bits (or kilobits or megabits) per second. The amount of bandwidth a particular application demands is determined by the amount of data to be transmitted and the time in which that transmission must be completed. This can be categorized in accordance with the how critical is information being transferred.
2. **Latency** is the time required to transmit data across the network (i.e., the delay between the sender transmitting a message and a recipient receiving it). The

latency can be categorized in accordance with type of transmission either synchronous or asynchronous.

3. **Availability** refers to the continuous availability of the network, the individual links of which it is composed, and the services it offers. Availability can be measured in terms of the percentage of the time the network is operational or by the average time between the failures.
4. **Security** comprises of three elements namely System Availability, Confidentiality and Integrity. Confidentiality refers to the ability to prevent communications from being disclosed to unauthorized parties in violation of disclosure rules. Integrity refers to the ability to prevent malicious or accidental alteration of data. Security plays an important role in our subject since we are dealing with PMR ' s (Patients Medical Records).
5. **Ubiquity** refers to the relative accessibility of a network. The ubiquity deals with two things namely the geographical location and participation on whether who all is available to access the network.

The communication technologies to be described are GSM, GPRS, UMTS, SMS, MMS, Bluetooth, ZigBee, WLAN IEEE 802.11b and Analog modem and ISDN.

3.2 GSM

GSM- Global system for Mobile Communications – is a digital cellular communications system developed in order to create a common mobile telephone standard. GSM is now the most popular mobile phone system in the world, accounting for more than 72% of the world's digital mobile phones. The Architecture of the GSM is illustrated in the Figure 3.1

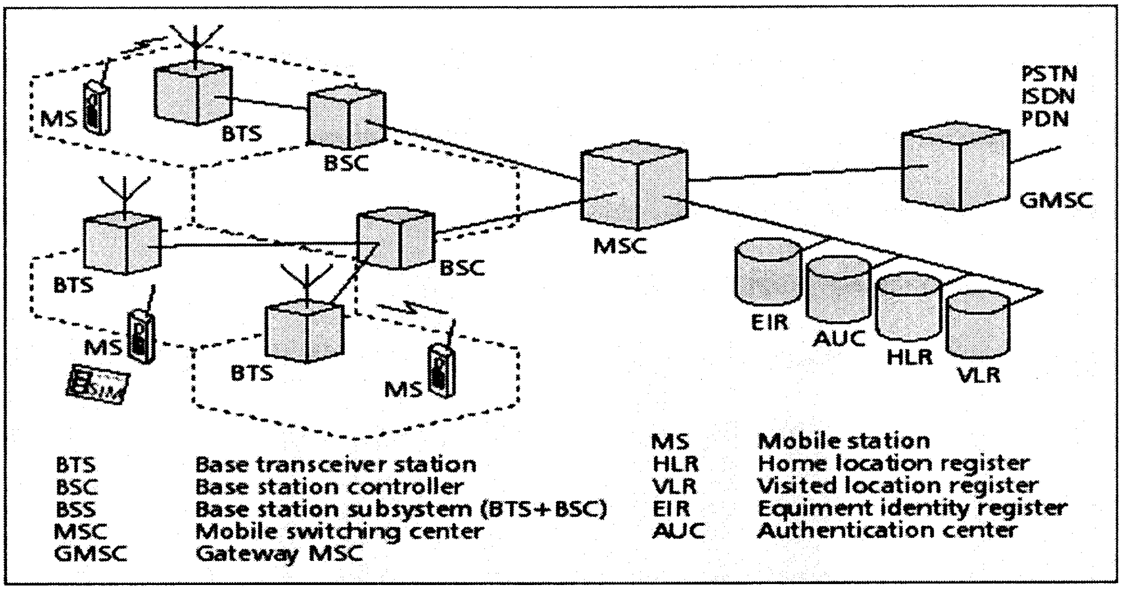

Figure 3.1 GSM Architecture.

- Bandwidth

GSM users can send and receive information up to 9600 bps in normal operation. In the case of High Circuit Switched Data (HSCSD) [8] data rates of 28.8 kbps and 43.2 kbps are achieved.

- Latency

Data transfer across an established line is done in real-time. The establishment of the line may take anywhere from a second to minutes depending on the distance of the call and how quickly the call is answered in the receiving end.

- Availability

Normally the GSM Network is highly available and reliable. There is a possibility of a loss of radio link due to coverage problems or interference.

- Security

GSM remains the most secure public wireless standard in the world with its constantly evolving enhanced transmission protocols and algorithms.

- Ubiquity

GSM network is open to general public and omnipresent throughout the world

3.3 GPRS

GPRS- General Packet Radio Service is a new non voice value added service that allows information to be sent and received across a mobile telephone network according to [9]. It supplements today's Short Message Service and Circuit Switched Data. Rather than sending a continuous stream of data over a permanent connection, packet switching only utilizes the network when there is a data to be sent.

It brings the Internet Protocol (IP) capability to the GSM network for the first time and enables connection to a wide range of public and private data networks using industry standard data protocols such as TCP/IP and X.25. The architecture of the GPRS is illustrated in the Figure 3.2

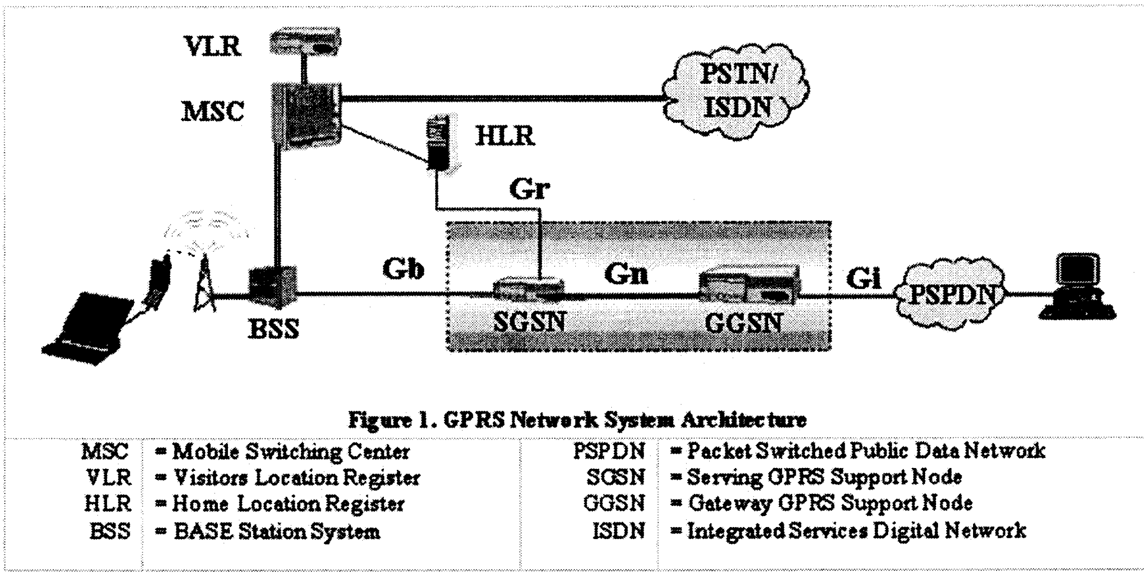

Figure 3.2 GPRS architecture.

- Bandwidth

Theoretical maximum speeds of up to 170 kilobits per second (kbps) are achievable with GPRS using all eight timeslots at the same time. This is about three times as fast as the data transmission speeds possible over today's fixed telecommunications networks and ten times fast as current CSDS on GSM networks. Achieving theoretical maximum GPRS data transmission speed of 170 kbps would require a single user taking over all eight timeslots without any error protection. Clearly, it's unlikely that a network operator will allow all timeslots to be used by a single GPRS user. The bandwidth available to GPRS will therefore be very limited –supporting one, two or three timeslots. GPRS dynamically manages the channel allocation and allow a reduction in peak time signaling channel loading and sending short messages over GPRS channels instead. [9].

- Latency

GPRS packets are sent in all different directions to reach the same destination. This opens up the potential for one or some of those packets to be lost or corrupted during the data transmission over the radio link. The GPRS standards recognize this inherent feature of wireless packet technologies and incorporate data integrity and retransmission strategies. However the result is that potential transit delays can occur.

GPRS facilitates instant connections whereby information can be sent or received immediately as the need arises, subject to radio coverage. No dial-up modem connection is necessary. This is why GPRS users are sometimes referred to as "always connected". [9]

- Availability

In general the GSM network is highly available and reliable. Although, as with any wireless technology, there are possibilities of loss of radio link due to coverage and interference problems.

- Security

The air interface ciphering in GPRS is at the same level as in ordinary GSM network without GPRS. The encryption algorithm in GPRS is GEA. The strength of GEA is roughly equivalent of A5 as used in ordinary GSM. The authentication process of GPRS is very similar to that of the GSM.

- Ubiquity

GPRS network is open to the public, but it is not widely available as the GSM Network.

3.4 UMTS

UMTS- Universal Mobile Telecommunication System, UMTS represents a evolution in terms services and data speeds from today's "second generation" mobile networks. As s key member of the "global family" of third generation (3G) mobile technologies identified by the ITU, UMTS is the natural evolutionary choice for operators of GSM networks. [10]. The architecture of the UMTS is illustrated in the Figure 3.3

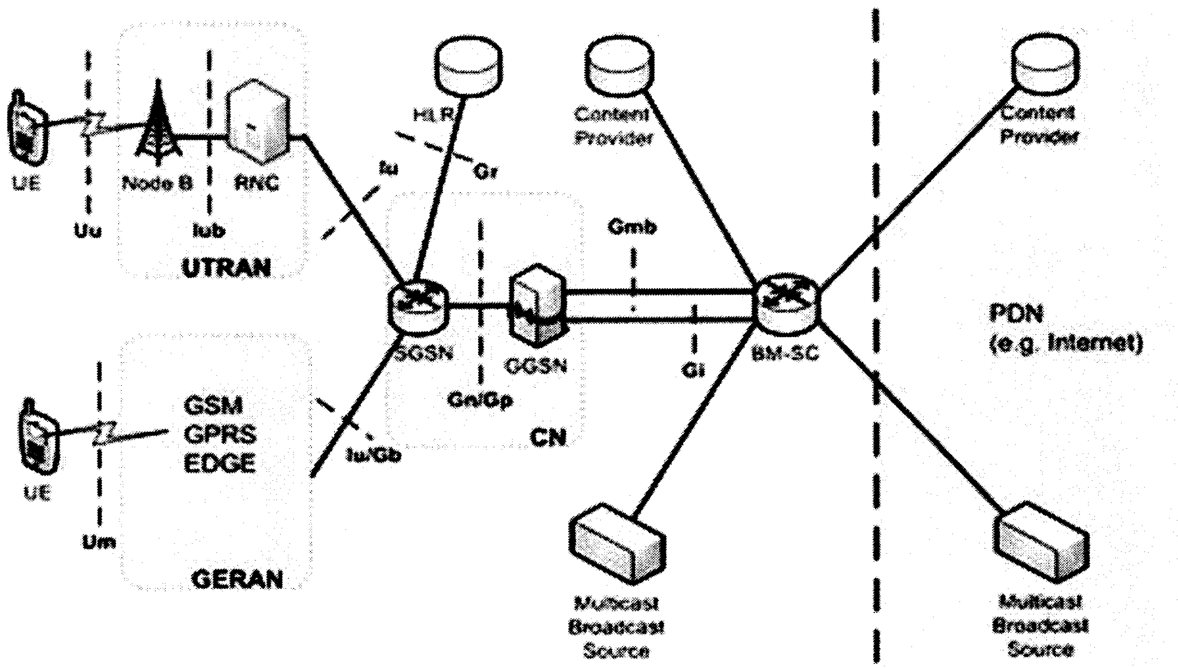

Figure 3.3 Architecture of UMTS.

- Bandwidth

UMTS offers flexible bandwidth with high data rate and high mobility. These features make it useful for all kind of multimedia services. Data rates up to 2 Mbps can be achieved on the basis of CDMA technology. [11]. The Bandwidth of UMTS directly depends upon the number of subscribers connected to the same network cell as of yours. The cells have been divided into three types namely Macro cell, Micro cell and Pico cell.

- Latency

With the help of real time classes that are defined in UMTS it serves time-critical applications, which require a small delay and delay variations. Re transmissions should be designed in case of any loss of packets transferred.

- Availability

Since UMTS is not in the development stage yet the Availability of the UMTS has not been yet exploited. But as far as the theories related to UMTS is concerned it offers the same Availability as that of the GSM networks.

- Security

The security functions of UMTS are based on what was implemented in the GSM. Some of the security functions have been added and some existing features have been improved. The main security elements that are from GSM [11] are Authentication of Subscribers, Subscriber identity confidentiality, Subscriber Identity Module (SIM) to be removable from the terminal hardware and Radio interface encryption. The additional security features provided by UMTS are Security against using false base stations with mutual authentication, Encryption extended from air interface only to include Node-B to RNC connection ciphering keys and Authentication data in the system.

- Ubiquity

UMTS is conceived as a global system comprising both terrestrial and satellite components. With these terminals a subscriber will be able to roam from a private network into a Pico cellular/micro-cellular public one, then into a wide area macro cellular network and then to a satellite mobile one, with minimal break in communication. [12]

3.5 SMS

SMS –Short Message Service is the ability to send and receive text messages to and from mobile telephones. [13]. It's a service within the GSM family of technologies, and is carried by the GSM network and thus the same availability, security and ubiquity. The overview of the SMS server conceptual model is presented in the Figure 3.4

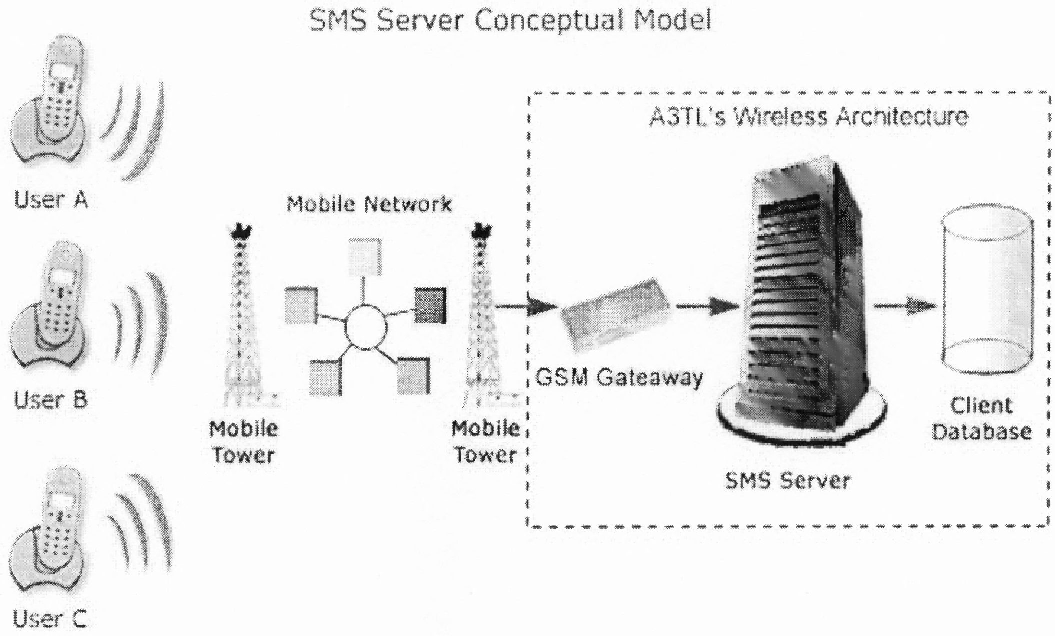

Figure 3.4 SMS sever conceptual model.

- Bandwidth

The bandwidth of an SMS message is quite limited. An SMS message can contain 140 bytes of data equivalent to 160 7-bit characters. This information is transmitted in roughly one or two seconds.

- Latency

The messages are transferred in a store and forward fashion. This means that the network stores the messages until they can be delivered to the destination. The time between sending and delivery can vary from a few seconds and up to a week. There is also a possibility that a message may not be delivered at all. In all usual cases the messages are delivered within a few seconds of sending.

- Availability

Since the GSM Network is used, SMS benefits from the same high availability. In some circumstances where radio coverage is poor, SMS is able to get though when a call cannot. This is due to the lower data rate and shorter time span of an SMS message than a voice call.

- Security

SMS benefits from the same level of security as provided by the GSM network.

- Ubiquity

The ubiquity of the SMS service is also the same as the GSM network. It is open to the general public.

3.6 MMS

MMS- Multimedia Messaging Service is a also a store and forward messaging service same as that of SMS, but the difference is that it allows mobile subscribers to exchange multimedia messages with other mobile subscribers. MMS offers subscribers to send text, picture, audio, video and combinations of the above. It's a service within the GSM family of technologies and is carried by GSM, GPRS or UMTS, and thus has the same availability, security and ubiquity as these technologies. The conceptual model of the MMS service is illustrated in the Figure 3.5

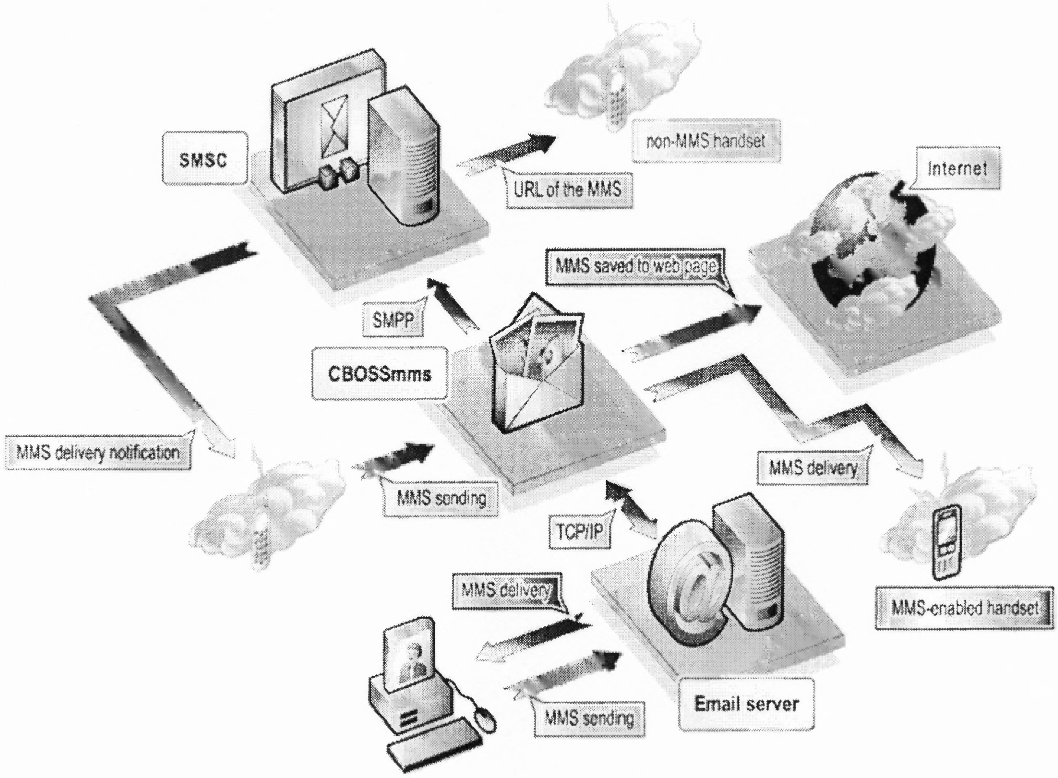

Figure 3.5 Conceptual model of MMS service.

- Bandwidth

The bandwidth of an MMS message is given by the bearer service, GSM, GPRS or UMTS. There is no specified maximum size of an MMS message, but in practice the handset limits the messages by its available memory.

- Latency

The messages are delivered in a store- and –forward fashion. This means that the network stores the messages until they can be delivered to the destination. The time between the sending and arrival is same as that of an SMS.

- Availability

MMS benefits from the same high availability as its bearer services.

- Security

MMS benefits from the same high level of security as its bearer services.

- Ubiquity

The ubiquity of the MMS service is also the same as its bearer technologies. The service is open to the general public, and has roaming capabilities in most of the world.

3.7 Bluetooth

Previously Bluetooth was described as a potential sensor technology, here the strength of Bluetooth technology as a communication technology. Bluetooth is a low power radio technology developed with the objective of replacing the wires currently used to connect electronic devices such as personal computers, printers, faxes and a wide variety of handled devices such as a palm top computers and mobile phones.

- Bandwidth

Although Bluetooth is known to have 1Mbps transmission rate, this is the symbol rate not the realistic file transfer rate. Also the Master Slave configuration makes Bluetooth not a good real-time, high data rate wireless connectivity compared to other high data rate system. This is not a fault with Bluetooth itself, since it is intended to do relative low-speed wireless connections, with low cost [14].

Bluetooth operates in the 2.4GHz ISM (Industrial Scientific Medical) band and devices equipped with Bluetooth should be capable of exchanging data at speeds up to 720 kbps at ranges up to 10 meters. This is achieved using a transmission power of 1mW and the incorporation of frequency hoping to avoid interference. If the receiving device detects that the transmitting device is closer than 10 meters it will automatically modify its transmitting power to suit the range. The device also shifts to a low power mode as soon as the volume of traffic decreases or ceases altogether.

- Latency

Data transfer over a connected link is done in real-time, but there can be some latency in the connecting phase. Turning off the receiver for longer periods saves power. Any device can wake up the link again, with an average latency of 4 seconds. The latency is handled by the Link Controller and defined by the Link Manager. These are the components of the Bluetooth Stack as discussed previously.

- Availability

Since Bluetooth operates in a noisy frequency environment, it uses its fast acknowledgement and frequency hopping scheme to make its link robust. Bluetooth compared to other systems operating in the same frequency band. The Bluetooth radio hops faster and uses short packets. This makes Bluetooth radio more robust. Short packages and fast hopping also limit the impact of random noise on long-distance links. The use of Forward Error Correction (FEC) limits the impact of noise on long distance links. The encoding is optimized for an uncoordinated environment. [15]

- Security

Bluetooth is extremely secure in that it employs several layers of data encryption and user authentication measures. Bluetooth devices use a combination of Personal Identification Number (PIN) and a Bluetooth address to identify other Bluetooth devices. Data encryption can be used to further enhance the degree of Bluetooth Security. The fast Frequency Hopping Spread Spectrum (FHSS) provides another level of security, allowing only synchronized receivers to access the transmitted data. [16]

- Ubiquity

Bluetooth is designed for very low power use, and the transmission range will only be 10 meters. High powered Bluetooth devices will enable ranges up to 100 meters.

3.8 ZigBee

The ZigBee technology is a low data rate, low power consumption, low cost, wireless networking protocol targeted towards the automation and remote control applications. ZigBee was created to address the market need for an industry standard to support these applications, as opposed to proprietary solutions. Philips, Invensys and Honeywell joined forces to draft a Market Requirements Definition for ZigBee. There are presently more than 20 companies, including major semiconductor manufacturers, IP providers and OEMs active in the ZigBee alliance and helping to define this standard.

ZigBee fills the need for a simple, easy to deploy low cost wireless network that can provide a battery life of about 6 months to 2 years using just 2 AA batteries. No other wireless technology was designed from the start to meet this need. [17]. ZigBee is basically a standard developed for mesh networking and is built in the IEEE 802.15.4 Standard. The reliability of this technology is achieved thru the meshed connectivity. As it has very long battery life, it has been designed for low power applications. The data rate achieved by this technology is around 20-250 Kb/sec depending on the band. The networks in ZigBee are self configuring and it allows the formation of ad hoc networks. The installation and configuration of Zigbee networks is very easy. The features of ZigBee are well explained in the Table 3.1 below.

Table 3.1 ZigBee Features

Band	868, 902-928 MHz, and 2.4 GHz
Topology	Ad-hoc, Point-to-Point, Mesh
Data rate	20/40 Kb/s and 250 Kb/s
Power Consumption	Very Low
Range	10-100+ meters
Security	Very High, AES-128 level encryption
Size	Up to 64K nodes in a single logical network

The ZigBee network is formed in a way that it uses a specific 16 bit PAN ID for each PAN (Personal Area Network). A ZigBee Coordinator forms the network and is named as Node "0", it chooses the radio channel and specifies the PAN ID for the network. The network coordinator chooses the security model in effect for the network and the networks formation process is started by specifying the network parameters. The network includes routing and non routing devices. There nodes are classified into two different types of devices namely fully functional device and reduced functional device. The fully functional device performs the routing functions in addition to the normal functions. The reduced function devices are normally the sensors, controllers or actuators. The Figure 3.6 explains both the Star Topology Network and the Cluster Network.

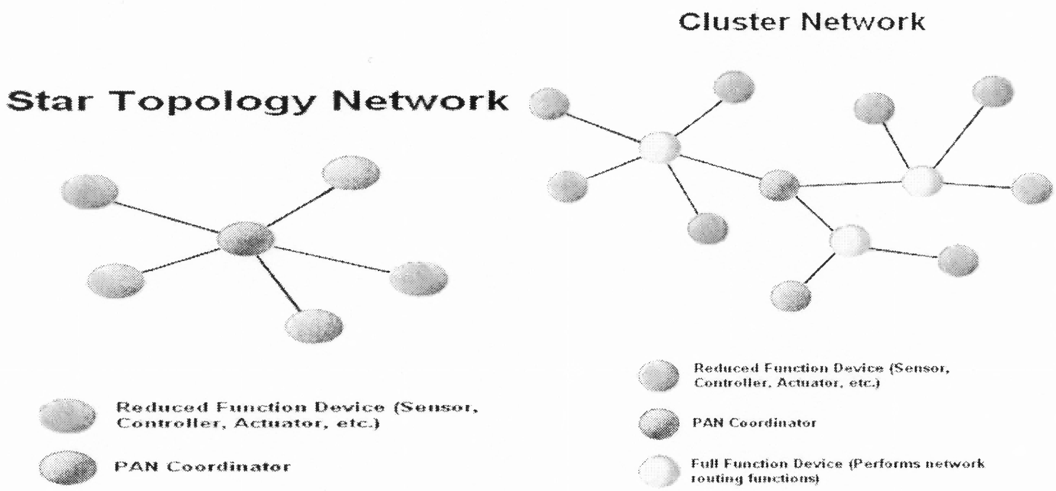

Figure 3.6 Star topology network and cluster network of ZigBee.

- Bandwidth

The technology can operate in any of three bands, the ISM band at 2.4 GHz worldwide, the European 868 MHz band, and the US 915MHz ISM band. The data rate at 2.4 GHz is 250 kbps, for the lower bands it is 20 kbps and 40 kbps respectively. [17]

- Latency

The MAC layer software offers options for guaranteed time slots for low latency applications, dynamic device addressing and a handshake protocols for transfer reliability. [18]

- Availability

There are issues for every protocol operating in the 2.4GHz band. The IEEE 802.10 and 802.15.2 committees are dealing with the coexistence issues. Other technologies send packets- 1000s per day. With ZigBee protocol further ensures reliable delivery of messages because every message is acknowledged. [17]

- Security

Data integrity and authentication are supported by the ZigBee protocol. Encryption methods are currently defined by the IEEE, and these will be incorporated into ZigBee devices that require it. The ZigBee Alliance is in the process of specifying security options that may be used as required per application. [17]

- Ubiquity

The ubiquity of a wireless LAN is limited by the signal coverage range.

3.9 WLAN IEEE 802.11b

The IEEE 802.11 standard specifies the requirements for implementing wireless Local Area Network. There are two approved IEEE 802.11 specifications, and two more are being developed. IEEE 802.11 was ratified in 1997 and supports a data rate of 2 Mbits/second. It is not widely implemented because of its low speed and the availability of a faster alternative.

- Bandwidth

IEEE 802.11b “High Rate” standard wireless local area network (WLAN) operates in the 2.4GHz (2.4 to 2.483 GHz) unlicensed Radio Frequency (RF) band and can transmit up to 11Mbps. [19]

- Latency

The latency of a Wireless LAN is measured in nanoseconds, so this is neglect able for all practical applications.

- Availability

This depends on the setup and the equipment used, but the availability should be very high within the coverage area of the transmitter.

- Security

Two security services are specified in IEEE 802.11, the authentication service and the privacy service. The privacy service is provided by Wired Equivalent Privacy (WEP) algorithm. The authentication service provides two basic levels of security. The first, Open System Authentication (OSA) is mandatory, but provides essentially no security. The second is shared-key authentication that provides the highest level of security available and uses WEP algorithm.

- Ubiquity

The ubiquity of a wireless LAN is limited by the signal coverage range.

3.10 Analog Modem and ISDN

Analog modems use a telephone network. They simply allow digital data to flow over the telephone company's already existing analog network by performing a digital to analog conversion for transmission onto the network and vice versa on the receiving end. The only necessity for analog modems is that each end of the call must have a compatible modem. This makes analog modem connections the most ubiquitous form of data communications available today.

ISDN has been around for many years, but its popularity is only now beginning to increase due to the limitations of analog modems and the rise of Internet usage. ISDN requires the phone company to install services within their phone switches to support this digitally switched connection service. [20]

- Bandwidth

Analog modems are limited by the telephone company's voice bandwidth service. Current analog modems are struggling to achieve rates of only 56 kbps. ISDN provides digital service typically in increments of 64 kbps channels.

- Latency

The latency of analog modems and ISDN is the same as the latency of the supporting telephone network, which is neglect able for short distance communication, and may be up to a few seconds when calling across the globe.

In the traditional Public Switched Telephone Network, the round-trip latency for domestic calls is virtually always under 150 milliseconds. At these levels, the latency is not noticeable to most people. Many international calls (especially calls carried via satellite) will have round-trip latency figures that can exceed 1 second, which can be very annoying for users.

- Availability

The availability of the telephone network is normally close to 100%.

- Security

There is no protection against wiretapping in the analog network, so the security in this aspect is quite low. Tapping of phones and internet communication is a well known phenomenon, and any needed security should be provided by the application.

- Ubiquity

In any developed country most homes are connected to either the analog telephone network or ISDN.

CHAPTER 4

ANALYSIS OF COMMERCIAL PRODUCTS

4.1 Introduction

This chapter gives an overview of some of the commercial products that are available for locating the position of the occupant of a smart home and monitoring of patient data in home. The patient data include various measurements of Heart rate, blood glucose level, Asthma level. The following products are described in detail below.

4.2 Commercial Products for Position Location

4.2.1 Hexamite (Ultrasonic sensors)

These sensors are used to locate the occupants of the Smart Home. In order to build a location positioning system, following are the necessary sensor components namely Receivers, Transmitters and Converters. All the three components are supplied by the Manufacturer Hexamite, Australia. Receiver (HE900M), Transmitter (HE900T) and Converter (HE485) are the manufacturer's components for a location system. The output of the system is generated through a RS 232 / RS 485 port. These sensors provide a range of about 16 meters and a resolution of about 0.3mm. The operating frequency range is about 40 KHz to 130 KHz. A minimum of four sensors are needed to achieve the above mentioned accuracy and precision. The distance is calculated by the TOA (Time of Arrival) technique and the algorithm used is based on the lateration method. The Figure 4.1 shows a Hexamite sensor. The voltage supply needed is between 7 to 14 volts and the maximum current consumption is 12mA.

Figure 4.1 Hexamite sensor.

4.2.2 RFID Tags

Here are some commercial available RFID tags which can be used to identify the location of an occupant in a Smart Home. The RFID tag called Meander insert developed by Intermec Technologies is shown in Figure 4.2, with its characteristics illustrated in Table 4.1.

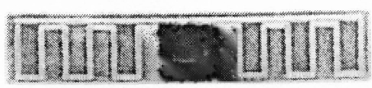

Figure 4.2 Meander insert RFID tag.

Table 4.1 Characteristics of Meander insert RFID Tag

Manufacturer	Intermec Technologies Corp.
Product	Meander Insert
Key Feature	Passive RFID tag
Dimensions	235" x 1.18" x .020"
Operating Temperature	-40C – 85+C/-40F – 185F
Frequency Range	2450 MHz
Read Range	24 Inches
Presentation Format	Single
Tag Type	Passive, Read/Write
Cost	$0.16 – (1000 pieces)

Here is another RFID tag that is developed by Intermec Technologies Corp and the product name is 915 MHz ID card. The tag is show in Figure 4.3 and its characteristics are described in Table 4.2.

Figure 4.3 Intermec 915 MHz ID card.

Table 4.2 Characteristics of 915 MHz ID Card

Manufacturer	Intermec Technologies Corp.
Product	915 MHz ID Card
Key Feature	Passive RFID tag, ID Card Type
Dimensions	2.125"x3.375"x.03"
Operating Temperature	-40C – 85+C/-40F – 185F
Frequency Range	915 MHz
Read Range	10 Feet
Presentation Format	Single
Tag Type	Passive, Read/Write
Cost	$2.00

Another example of RFID tag location system developed by PanGo Networks is explained in detail. The PanGo Active RFID Tag is a small lightweight, power efficient 802.11 based wireless device that attaches to assets –equipment or people for real time tracking. PanGo's Active RFID Tag is a key component of the PanGo Locator system for Enterprise Asset Visibility. PanGo Locator is powered by PanGo's PanOS Platform an open, Web services-based framework that easily integrates location data from multiple providers over a standard operating platform. PanGo Locator consists of two key components: PanGo Active RFID tags that allow users to track assets that are not wireless-enabled and the Locator software that manages asset monitoring, event notification and asset reporting and system configuration. The main advantage of PanGo Active RFID Tag is that it operates over any 802.11 wireless networks. The main characteristics of the PanGo Active RFID tag are summarized in the Table 4.3. The picture of a PanGo RFID is illustrated in Figure 4.4

Figure 4.4 Pango RFID

Table 4.3 Characteristics of PanGo Active RFID Tag

Components	PanGo RFID Tag and Locator Software
Dimensions	2.6" x 1.7" x 0.9"
Security Features	Unique Identification Number, Authorized Access
Battery	Standard Size, Life-3 yrs
Proprietary Platform	Pan OS Platform
Presentation Format	Need a Location Software Configured
Tag Type	Active, Read/Write, Erase
Average Cost	$133.00 for 1 tag and software

Another RFID tag developed by STMicroelctronics which has the following characteristics is been illustrated in the Table 4.4.

Table 4.4 Characteristics of XRAG2

Manufacturer	STMicroelectronics
Product	XRAG2
Key Feature	UHF Technology, Passive, Long Range RFID, Anti Collision Mechanisms.
Frequency Range	860-960 MHz
Readers	In the presence of 10 readers the chip operates in Dense Reading Mode.
Security Features	Password Protection by KILL command.
Memory	EEPROM- 432-Bit Memory
Data	The data can undergo 10,000 Read/Write/Erase cycles. 40 years of Data Retention
Tag Type	Passive, Read/Write/Erase
Cost	$0.07 for 100,000 Pieces

4.3 Commercial Products Monitoring Health

4.3.1 Health Buddy

The Health Hero [11] Health buddy automates data collection to allow health care providers to actively manage, educate, and track a patient's chronic conditions. Early intervention and education allows patient's to become an active member in their own health care while allowing health care providers to increase quality of care and decrease health care costs. The main component of a Health Buddy is the Health Hero Platform. The Health Hero Platform is a one-to-many, two-way communications link between healthcare providers and chronically ill patients. It consists of the Health Hero iCare Desktop a web based application used by the nurse/ care manager to deliver and review patient responses and the Health Hero Health Buddy appliance, used by the patient to receive and respond to the nurse/care manager. The system overview is illustrated in the Figure 4.5

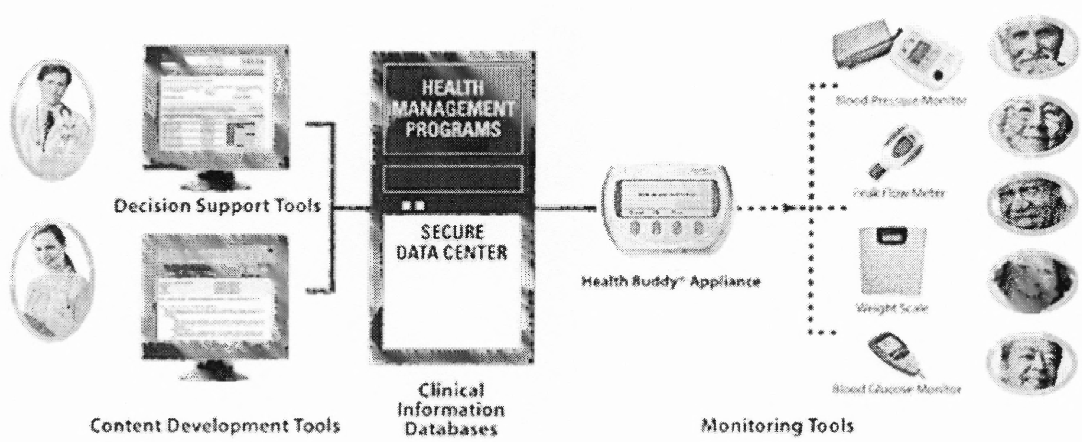

Figure 4.5 Health hero buddy system overview.

To use the Health buddy, the health providers simply need a computer with a standard internet connection and the patients only need a working telephone jack. Medical providers use the Health Hero iCare Desktop to develop queries, reminders, and tips for group of patients. These provider patient “dialogues” can be customized for different disease populations and personalized for individual patients, so each patient receive messages tailored to their needs. Health care professionals also use the web to view current or historical patient information or print out reports. Health Hero includes notification features so care providers can be altered if a patient’s response falls outside the parameter specified by the provider. Each patient enrolled in the Health Hero service receives a Health Buddy appliance , a simple, in home messaging device that plugs into the patient’s existing phone line .When it fits their schedule, patients view new information from their healthcare provider on the Health buddy screen and respond to the queries using the appliance’s four buttons. The simplicity of the Health Buddy appliance ensures it is accessible to all patients, regardless of their familiarity with or ability to use technology. The Figure 4.6 shows the snapshot of the Health Hero Web and Figure 4.7 shows the Health Hero Appliance.

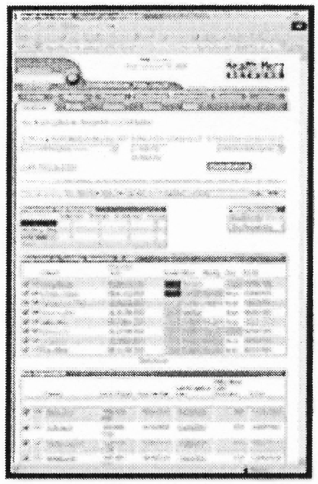

Figure 4.6 Snapshot of Health Hero Buddy web.

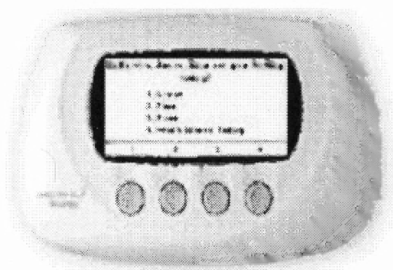

Figure 4.7 Health hero buddy appliance.

4.3.2 Vitaphone Hertz Handy

The Vitaphone Hertz Handy [21] is a complete system for patients to measure ECG (Electro Cardiogram) signal, and then transmit this acquired data to a central location called the Vitaphone Service Center where the data can be stored and processed.

The device itself is a combination of an ECG sensor put together with a fully functional GSM Mobile phone and a built in GPS positioning device. This ensures the global availability of the service wherever the GSM Network has coverage. The backside of the backside of the Vitaphone has four electrode points which, as you press them against your chest, can record an ECG signal. This is then with a few key presses transmitted to the Service Center. In case of emergencies a button on top of the device can be easily reached and will send an alarm signal to the Service Center along with the patient's current GPS position.The parameter that is being recorded by the Vitaphone is the ECG Signal. This product is best suited for patients with cardiovascular diseases. The communication technology being used is GSM for transmitting of the acquired data. An emergency response system is available to execute an alert procedure to alert the Physician and the Patient themselves. The technology used for tracking the patient is GPS (General Positioning System). There is no mentioned any use of open data format standards, so the communication must be considered proprietary. The Vitaphone is illustrated in the Figure 4.8.

Figure 4.8 Vitaphone.

4.3.3 AlereNet

AlereNet [22] web-based technology functions as a data portal that provides clinicians secure, password protected, encrypted access to collected patient information via the internet. With the help of this amazing user interface clinicians can obtain clinical medical data in a timely fashion to accurately access the patient's history and identify a need for clinical intervention as soon as trends indicate a change in patient's health status.

The main advantage of monitoring patients thru AlereNet is to cut down the time-consuming need for office visits, home visits or phone calls.

4.3.4 WelchAllyn Micropaq

The Micropaq [34] combines features such as waveform display, multi parameter monitoring and patient alarm capabilities into a small, rugged, lightweight, patient-wearable device.The Micropaq displays ECG waveforms, heart rate, and SpO_2, as well as alarm messages from the Acuity Central Station. Micropaq also protects and extends patient care by providing patient alarms when it is out-of-range or not connected to the wireless network. Other features include:

- One or two ECG channels for five-lead ECG monitoring.
- Pulse oximetry (SpO_2) monitoring with Masimo SET technology [35] for accuracy under motion and low perfusion conditions.
- Nurses call capability.

Welch Allyn's comprehensive FlexNet patient monitoring network uses technology supplied by Symbol Technologies to integrate the Micropaq into wireless Ethernet Local Area Networks. This two-way communication allows you to monitor, assist and reassure ambulatory patients at the point of care, while also monitoring from the Acuity Central Station. FlexNet links multiple devices such as ambulatory wireless monitors and hardwired and wireless bedside monitors to Acuity Central Monitoring Stations. FlexNet uses Symbol Technology's Spectrum24® radio module that operates in the 2.4 GHz band using spread-spectrum modulation. This technology conforms to IEEE 802.11 wireless Ethernet LAN standards [36]. There is not mentioned any use of open data format standards.

4.3.5 e-San Asthma Monitoring Solution

The e-San solution for asthma monitoring [37] uses a combination of an electronic peak flow meter and a PDA mobile handset which transmits the readings to a central server over a GPRS connection. [38] Careful monitoring of lung function using peak flow meters improves the control of asthma and reduces the risk of an acute asthma attack. A problem is that most sufferers do not always record the peak flow values accurately in their patient diary, which is reviewed retrospectively at the Asthma Clinic every three months, and often go for several days at a time without recording any readings at all. With the e-San solutions, asthma sufferers use the peak flow meter at home in the morning and evening and the system transmits the readings in real time to the server. An electronic patient diary on the PDA also allows the patients to enter information describing their symptoms and this information are transmitted at the same time as the peak flow readings. The Figure 4.9 shows the e-San Asthma monitor.

Figure 4.9 e-Sans asthma monitor.

Whenever no readings have been received for more than a day, a text message is automatically sent to the patient. At any time, GPs or Practice Nurses can access their patients' data stored on the server, enabling them to monitor the patients' condition with up-to-date, accurate and reliable data. This means the e-San solution allows the treatment of asthma to be more proactive, and provides benefits both to the patient, such as greater reassurance and ultimately improved quality of life, and to GPs and the National Health Service as fewer avoidable emergency hospitalizations and call-outs will result in time and cost efficiencies.

4.3.6 e-San Diabetes Monitoring Solution

e-San has developed an integrated monitoring device for diabetics [37], which combines an electronic blood glucose meter and a GPRS mobile phone. The patient switches the blood glucose meter on, connects the cable from the meter to the phone and places a drop of blood onto the reagent strip. Within a few seconds, the blood glucose reading is available at the central e-San server. A few seconds later, the entries from the patient diary regarding insulin dose, meals and physical activity are also available at the server. The long-term complications of damage to the eyes, kidney or nerves are related to hyperglycemia (high blood sugar levels) and occur from the second decade onwards after diagnosis. These complications are, however, potentially preventable. Unfortunately many patients in their late teens and early twenties have poor glycaemic control and are at substantially increased risk of long-term complications.

To optimize glycaemic control patients need to alter their insulin dose to take account of their energy intake and anticipated physical activity. Blood glucose tests provide feedback but the recognition and interpretation of patterns of test results is complex because they occur in the context of changes in diet and physical activity. The incoming readings are monitored on the server and intelligent software will automatically alert a Diabetes Specialist Nurse when required. This will allow the nurse to offer support to individuals at a time when blood glucose levels have moved outside a personally targeted zone.

4.3.7 Telzuit's Bio patch

The Bio patch Wireless Holter Monitor is a full 12- lead, wireless holter monitor, which measures, records and transmits physiological signals associated with patient's cardiovascular system. The Bio patch utilizes the EASI lead placement to capture electrical impulses of the patient's heart and transmits this information via Bluetooth to the patients Bio patch PDA. The PDA receives, records and stores the electrical activity of the patient's heart. Every two to four hours, the recorded information is sent through the cellular telephone towers, frame relay systems and switching stations. Ultimately, the recorded heart activity information is received by our monitoring station and then evaluated by a medical professional. Figure 4.10 describes both the system and Bio patch.

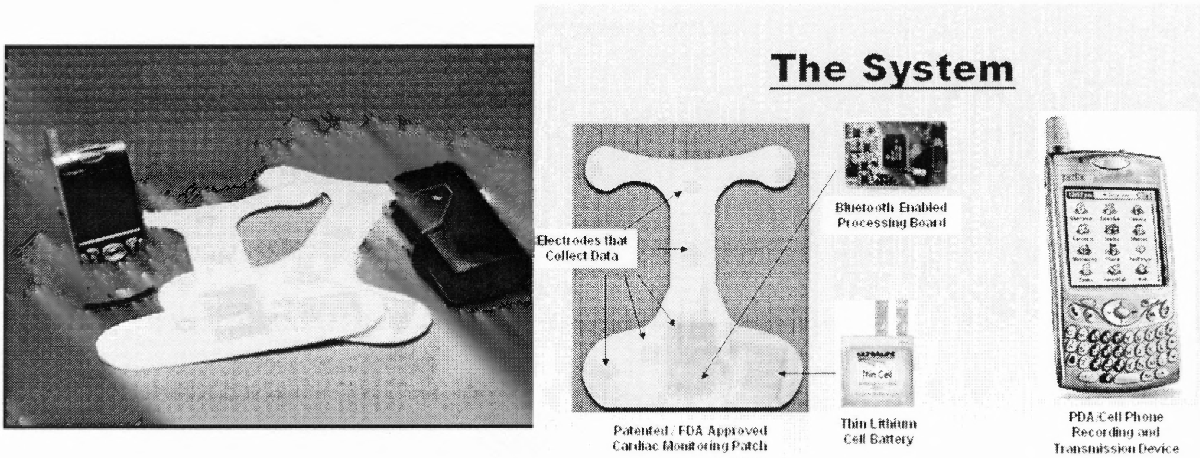

Figure 4.10 Telzuit's bio patch.

4.3.8 IBM's Health Monitoring Tool Kit

The IBM's health monitoring tool kit has a variety of sensors which monitor the vital signs of the patient. It includes a glucose meter which measures the blood glucose level and then transmits to a Hub which is the black box described in the Figure 4.11. The Hub is connected to an IBM server where the information is permanently stored and retrieved for evaluations by the Physicians. It contains a wearable device which monitors the blood pressure of the patient, the blood pressure data is also transmitted using Bluetooth technology to the Hub and then to the server. It contains a tablet dispensing unit, as soon as a pill is removed from the box a message is transmitted to the Hub stating that a particular pill has been removed and consumed by the patient. The ECG monitors the cardiac health of the patient and the appropriate cardiograms are transferred to the server using Bluetooth via the hub. The tool kit also has sensors to monitor patient's weight, patient's activity using a sensor in the foot wear and to monitor the peak flow using the peak flow meter. It consists of an inhalation registration and injection registration unit to register these vital activities and send corresponding messages to the server using Bluetooth via the Hub. Figure 4.6 explains the whole system clearly.

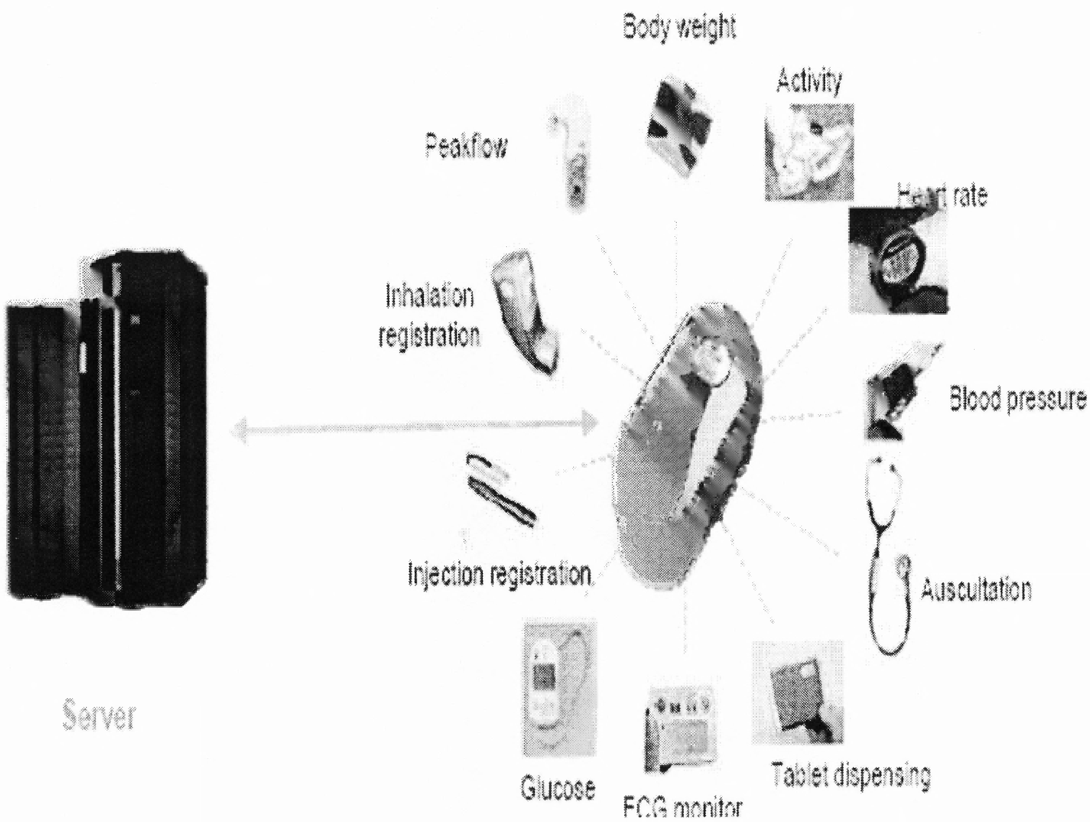

Figure 4.11 IBM's health monitoring tool kit.

4.3.9 Life Shirt

The LifeShirt is a multi-functional ambulatory device capable of simultaneously monitoring several physiological signals and patient reports of symptoms and well being. The LifeShirt system is an extensible data acquisition and processing platform consisting of three parts namely a garment, a data recorder and PC-based analysis software. The Figure 4.12 illustrates how a Life Shirt looks like.

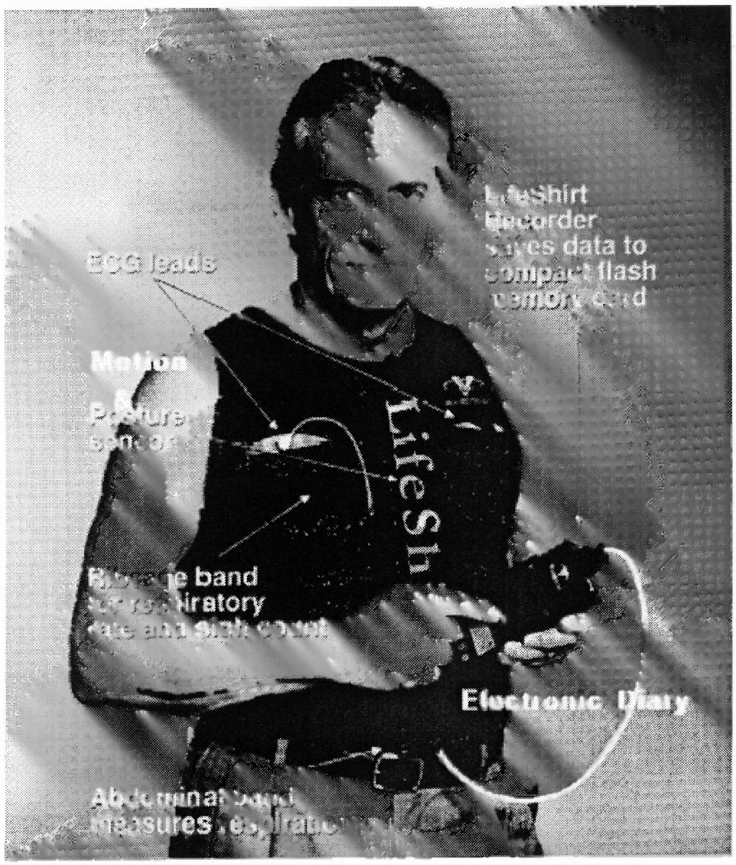

Figure 4.12 Life Shirt.

Sensors in or attached to the LifeShirt garment continuously monitor respiration, the electrocardiogram, activity and posture. The Respiratory parameters derived from the LifeShirt include volumetric, timing and flow measures. This variable together with the accelerometer activity and posture signal yields valuable information regarding activity pattern that aid in interpretation of other signals. The ECG signal is employed to detect arrhythmic activity and to quantify heart rate variability. Other functions can additionally be easily plugged into the LifeShirt system via an available port and concurrently registered including pulse oximetry, the ECG and EOG, blood pressure, temperature, capnometry and acoustic monitoring. Subjective patient data are also easily entered into the LifeShirt recorder PDA by means of a programmable dairy/questionnaire inventory that is easily adapted to any disorder or health-related issue. All data are encrypted and written to a flash memory card. Vivologic analysis software provides full-disclosure analysis and display of high resolution and over 30 derived parameters.

4.3.10 Sensium Chip

The Sensium Chip is a sensor which monitors the vital parameters of the patients and sends it using Bluetooth Technology to a PDA from where it could be sent to an appropriate server. The Sensium chip offers a lot of features namely, it uses ultra low power mechanism to sense these vital signs. If a number of chips are plastered to a patient, it forms a BAN (Body Area Network). It is of low cost when compared to other commercial products of its kind. The measurement of these vitals signs is carried out non intrusively which is also a major advantage. These chips for a wireless sensor interface. Together with an appropriate external sensor the SensiumTM can provide ultra low power monitoring of ECG, temperature, blood glucose and oxygen levels. It can also interface to 3 axis accelerometers and pressure sensors and includes a temperature sensor on chip. One or more SensiumTM enables digital plasters continuously monitor key physiological parameters on the body and report to a base station SensiumTM plugged into a PDA or a Smart phone. The data can be further filtered and processed there by application software. The Sensium chip plaster and the System overview is illustrated in the Figure 4.13

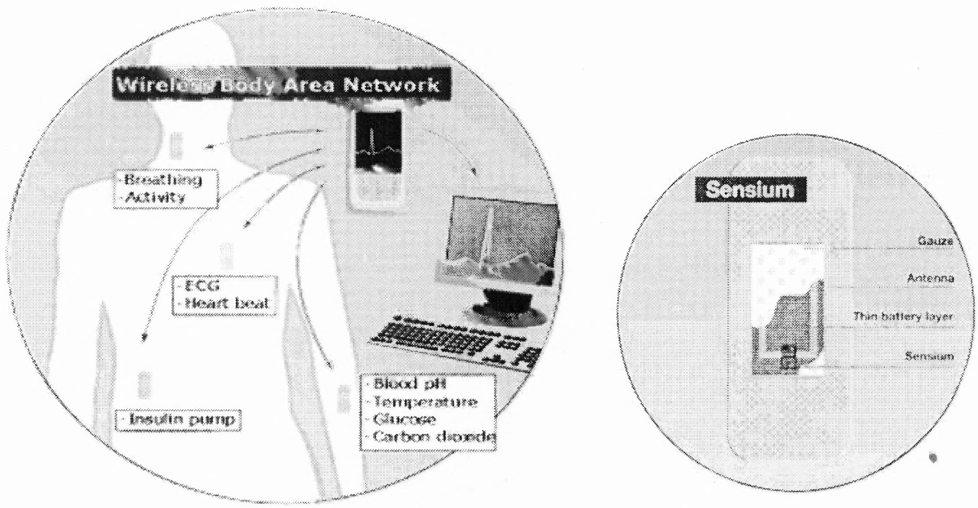

Figure 4.13 Sensium system overview and sensium chip plaster.

4.3.11 Cygnus Glucowatch G2 Biographer

The features of this product are described in the Table below, and Figure 4.14 illustrates the product.

Table 4.5 Cygnus GlucoWatch G2 Biographer

Product	Cygnus GlucoWatch G2 Biographer
Key Point	Alerts for skipped readings, Low and High sugar levels
Time Interval	Measures every 10 minutes
Accuracy	<5% from other meters
Technique	Reverse Iontopharesis
Type	Semi Invasive / Continuous
Manufacturer of the Auto Sensor	Dupont
Cost	$4.36 Auto sensor each

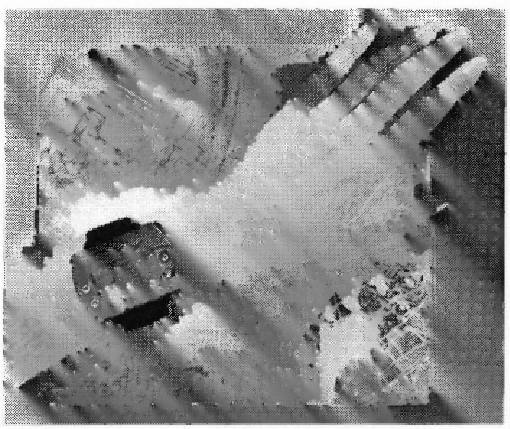

Figure 4.14 Cygnus gluco watch G2 biographer.

CHAPTER 5

SURVEY OF RESEARCH PROJECTS

This chapter describes some of the research projects in the field of sensors that are used in Smart Homes. They are categorized into three categories mentioned earlier namely, sensors that deal with locating the occupants of a Smart Home, sensors that deal with monitoring vital health parameters of the occupants and sensors that control the environment of a Smart Home. Each of this research project described shows the potential use of it in a Smart Home for a number of applications. However a description of these research projects is presented, the realization of each of the project is a question and is not mentioned in this thesis.

5.1 Location Positioning Projects

5.1.1 Introduction

The location positioning systems to be used in smart homes form the vital part of a smart home, since we need a mechanism to locate the occupants of a Smart Home. In addition to that patients suffering from diseases like dementia and mental disorders need close surveillance. Further these location systems can be integrated to databases to provide vocal warnings incase of emergencies. In general a location positioning system can provide two types of location a physical location or a symbolic location. The physical location to refer to the actual location in physical coordinates, for example a GPS system provides physical location. Whereas a symbolic location encompasses abstract ideas of where something is like in the living room, next to the cupboard etc. There has been a lot of research in these areas and most of the important location systems under research have been discussed in this section. These projects include Active Badge, Active Bat, Cricket, RADAR, MotionStar Magnetic Tracker, Easy Living, Smart Floor, CampusAware, Spoton, Motetrack, Wirelss Andrew and ActiveCampus.

5.1.2 Active Badge

Active Badge is one of the first indoor badge systems that was developed. It was developed at AT&T Cambridge [26]. It consists of a cellular proximity system that uses diffuse infrared technology. Each person to be located wears a small badge. These identifiers are captured by fixed infrared beacons that are fixed around the building. A central server collects these data from fixed infrared sensors, aggregates it, and provides an application programming interface for using the data. An Active Badge is shown in Figure 5.1. The Cambridge group also designed one of the first large software architectures for handling this type of location data. [27]

Figure 5.1 Olivetti active badge (right) and a base station (left) used in the system's infrastructure.

To summarize these are the properties of an Active Badge system

- Technology: It uses infrared cellular proximity technology to locate positions based on the position of the badge.
- System Properties: It provides location in terms of physical location. The location positioning system is an absolute location system meaning that uses a shared reference grid for all located objects.
- Accuracy and Precision: The accuracy of an Active Badge system is the Room Size.
- Scale: This system requires 1 base per room, any number of badges in that room.
- Cost: The cost would be mainly associated with administration costs, the tags and bases are relatively cheap.
- Limitation: As with any diffuse infrared system, Active Badges have difficulty in locations with fluorescent lighting or direct sunlight because of the spurious infrared emissions these light sources generate. Diffuse infrared has an effective range of several meters, which limits cell sizes to small or medium sized rooms, in case of larger rooms, the system can use multiple infrared beacons.

5.1.3 Active Bat

AT&T researchers developed the Active Bat location system. This system uses an ultrasound time of flight lateration technique to provide a more accurate physical positioning than that of the Active Badges. [28]. Here the users or the objects are equipped with theses Active Bat tags. The receivers are mounted in the ceiling, in response to a request sent by a controller via a short-range radio, a Bat emits an ultrasonic pulse to a grid of ceiling mounted receivers. At the same time the controller send the radio frequency packet, it also sends a synchronized reset signal to the ceiling sensors using a wired serial network. The ceiling sensors then measure time interval from the reset to ultrasonic pulse arrival and computes its distance from the Bat. The local controller then forwards the distance measurements to a central controller, which performs the lateration computation. The erroneous sensor measurements received by the ceiling sensors which are not received along the direct path from the Bat to the sensor is eliminated by a statistical pruning method. The Figure 5.2 shows an Active Bat.

Figure 5.2 An active bat (Photo courtesy AT&T).

The key point of this system is that it provides a 3D location. The main components of this system are its transmitters and its receivers. The output is transmitted through a high speed serial network including a DSP board. The arrangement of the receivers in a daisy fashion provides maximum efficiency in providing an accurate position. Figure 5.3 shows how the arrangements of the sensors in the ceiling locate an object with the Bat.

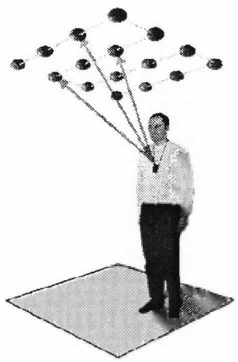

Figure 5.3 Arrangement of sensors for an active bat system.

To summarize these are the features of an Active Bat system

- Technology: The technology used by an Active Bat system is ultrasonic technology. The computational logic for position calculation is done using the lateration algorithm.
- Accuracy and Precision: The accuracy of the system is about 95 %. It can locate Bats to within 9 cm of their true position.
- Scale: The system requires 1 base per 10m2 and 25 computations are performed per second. The system is capable of detecting 75 objects per second.
- Cost: The cost of the system is less than a commercial GPS system. It's less than about $100 including installation. The tags and the bases are of low cost compared to the installation.
- Limitations: The limitation of the system is that the sensors should be arranged in daisy fashion in the ceiling.

5.1.4 Cricket

The cricket positioning location system also uses Ultrasonic technologies. It uses ultrasound emitters to create the infrastructure and embeds receivers in the object being located [29]. This approach forces the mobile objects to perform their own triangulation computations. This system uses the radio frequency not only for the synchronization of the time measurement, but also to delineate the time region during the receiver should consider the sound it receives. This scheme allows multiple uncoordinated beacons to coexist in the same space. Each beacon also transmits a string of data that describes the semantics of the areas it delineates using the short-range radio.

The Cricket system similar to the Active Bat uses ultrasonic time-of-flight data and a radio frequency control signal, but this system does not require a grid of ceiling sensors with fixed locations because its mobile receivers perform the timing and computation functions. This system implements both the lateration and proximity techniques. Receiving signals from multiple beacons lets the receiver triangulate their position. The Figure 5.4 shows the motes developed in the MIT Cricket Project which has been commercialized by Crossbow Technology Inc.

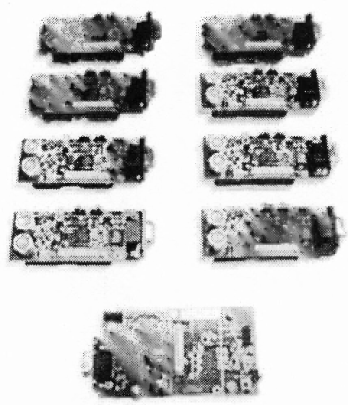

Figure 5.4 Commercialized cricket system motes.

To summarize these are the key features of the Cricket System

- Technology: Cricket system uses a combination of RF and ultrasound technologies to provide location information to attached hosts devices. The position is calculated by taking the advantage of the difference in propagation speeds between RF and ultrasound. Its advantages include decentralized scalability and privacy. The cricket system provides a symbolic location.
- Accuracy and Precision: The accuracy of a Cricket system is approximately 4 square feet with 100 % of precision.
- Scale: The system requires about 1 beacon per 16 square feet for the determination of location.
- Cost: The cost of beacons and receivers are approximately about $10.
- Limitations: The limitation of the Cricket system is that it lacks central management. The load of computational logic is not balanced as only the receiver module computes the location based on the algorithm.

5.1.5 RADAR

RADAR has been developed by a Microsoft Research group. This project was aimed in building a building-wide tracking system based on IEEE 802.11 Wave LAN wireless networking technology [30]. This system measures the signal strength and the signal-to-noise ratios of signals that wireless devices send at its base station. It then uses this data to compute the 2D position within the building. There are two implementations of this system, one system using the scene analysis and the other using lateration algorithm. The main advantages of the RADAR system is that, it requires only a few base stations and it uses the same infrastructure of that of the building's general purpose wireless networking. The implementation using the scene-analysis version provides greater accuracy but significant changes in the environment may necessitate reconstructing the pre defined signal-strength database or creating entirely a new database. There are several commercial products that are based on RADAR which are being sold by companies like WhereNet [31] and Pinpoint [32].

To summarize these are the key features of the RADAR system.

- Technology: The system is implemented using the 802.11 Wireless LAN technologies. The position calculation is done using either RF scene analysis or either Triangulation algorithms. It provides both physical and absolute positions.
- Accuracy and Precision: The accuracy of the system is to provide location within 3-4.3 m and its precision is about 50 %.
- Scale: It needs about 3 bases per floor to determine the position.
- Cost: The cost of the system is the cost involved in the installation of the wireless 802.11 network. Other costs are determined by the cost of (NIC) Network Interface Cards.
- Limitations: In this system all the receivers are assumed to have the capability of connecting wirelessly through the WLAN network.

5.1.6 SMART FLOOR

This system was developed by Georgia Institute of Technology [33], it identifies people based on their footstep force profiles and has been tested against a large pool of footstep data. This system uses the data for position tracking and pedestrian recognition. This unobtrusive direct physical contact system does not require people to carry a device or wear a tag. The Experimental setup for this project is described in Figure 5.5

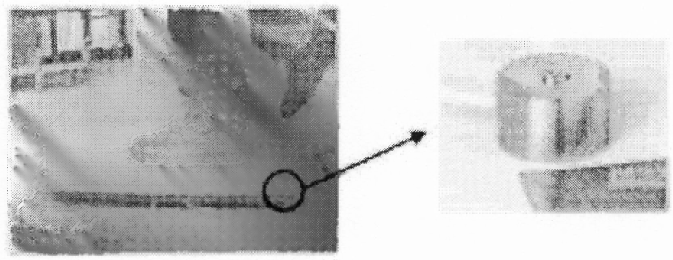

Figure 5.5 SMART FLOOR plate (Right) and load cell (Left).

The main advantage of this system is that with thoughtful design and placement of out floor tiles in a workspace or living space, we can naturally and transparently capture a user's footfalls without requiring the user's to alter his or her behavior.

To summarize these are the key points of the system

- Technology: This system uses the principle of GRF (Ground Reaction Force) and with the help of biometric identification techniques which use HMM (Hidden Macrov Models) identifies the user.
- Accuracy and Precision: The accuracy of this system totally depends upon the placing of the pressure sensors and with efficient placing achieves a 100 % precision. This system has been tested with around 25 foot step profiles to provide this accuracy and precision.
- Scale: The floor should be completely set up with these smart tiles and pressure sensors.

- Cost: The cost involved for this system is the cost for the installation of the sensor grid and the creation of footfall training dataset.
- Limitations: The limitations of this system are that of its poor scalability to large populations and high incremental costs because the floor of each building in which smart floor is deployed must be physically altered to install the pressure sensor grids.

5.2 Monitoring Projects

5.2.1 A Body Monitoring System with EEG and EOG Sensors

A BMS (Body Monitoring System) has been developed by four students from the Slovak University of Technology in Bratislava. This project was developed as a prototype for a mobile sleep laboratory – a body monitoring system with EEG and EOG sensors. The students explored the concept of intelligent data collection from human body sensors. The Body Monitoring system is designed as a mobile device that is able to collect measured data and respond accordingly to instructions set by the supervisor and performs necessary actions. It comprises of a body-monitoring-network. In order to recognize the monitored person's state, the monitor connects to sensors and I/O devices using wireless communication technologies. Data from all the sensors is collected, stored and analyzed in real time and according to the analysis, actions may be performed. The interface to the body monitoring network is a computer which runs a software that allows the supervisor to configure the monitor unit for the monitored person, to connect sensors and I/O devices, define and upload instructions for monitoring and download collected data.

The validation of the system was done by monitoring patients who are admitted in sleep laboratories of hospitals. Since the patients are influenced by the hospital environment and usually show different sleep patterns at home, as a solution to this problem this was implemented as a prototype for a mobile sleep laboratory. The prototype employs an (EEG, which monitors brain waves), an (EOG, which monitors eye movement) and a thermometer. Analysis of EEG and EOG data allows identification of all sleep stages.

The sensor implementation is from a common sensor platform designed in the course of this project. The common sensor platform as shown in the Figure 5.7 contains a detecting element, amplifiers and filters, an AD converter, a microprocessor and a Bluetooth module. The developed prototype can be used for continuous EEG examination, which is very necessary for patients suffering from epilepsy. The system is illustrated in the Figure 5.6 and Figure 5.7

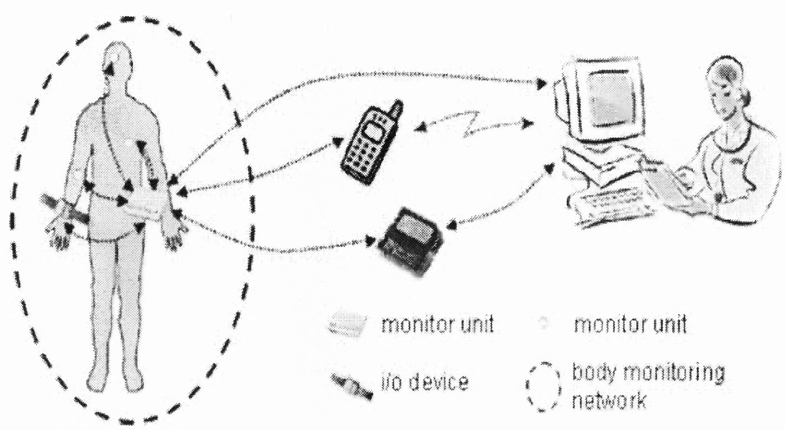

Figure 5.6 System overview of BMS.

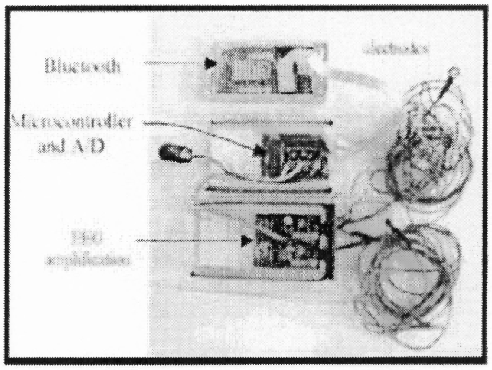

Figure 5.7 System setup for the BMS.

5.2.2 AMON

AMON (Advanced care and alert telemedical MONitor) project is funded by the EC under the IST Programme with reference number “IST-2000-25239”. The project was started in early January 2001 and was completed by the end of December 2002. AMON aims to research, develop and validate an advanced, wearable personal health system that will monitor and evaluate human vital signs using advanced bio sensors. The system monitors by gathering and analyzing the vital information and then transmitting the data to a remote telemedicine center, for further analysis and emergency care, using GMS/UMTS cellular infrastructure. These communication technologies have been described earlier. The WMD (Wrist mounted Monitoring Device) which is also called as a wearable sensor module will include sensors to measure heart rate, heart rhythm, 2-lead ECG, blood pressure , O2 blood saturation, skin perspiration and body temperature. The wearable module is illustrated in Figure 5.8

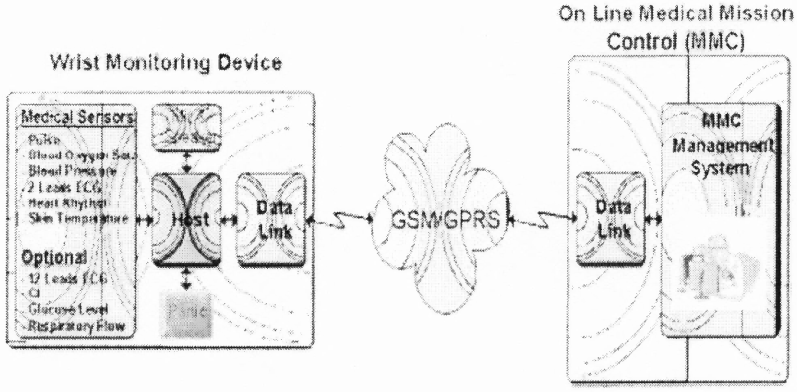

Figure 5.8 AMON Architecture

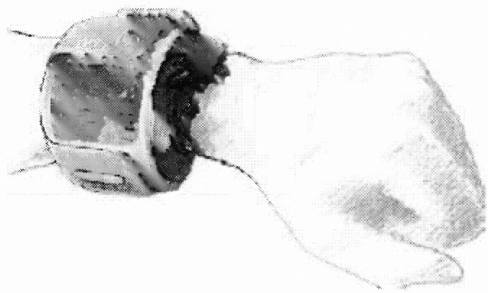

Figure 5.9 Handy device of AMON project.

AMON will enable patients who are not confined to a hospital to monitor continuously analyze their vital signs. AMON will provide care at the point and time of need, giving patients freedom of movement and enhancing their quality of life. The Figure 5.9 shows the picture of the handy device used in the AMON project.

5.2.3 EPI-MEDICS

EPI-MEDICS (Enhanced Personal, Intelligent and Mobile System for Early Detection and Interpretation of Cardio logical syndromes). The EPI-MEDICS project is funded by the EC under the IST Programme with reference number "IST-2000-26164". The project was started in January 2001 and was completed by the end of December 2003. Because of the continuously growing number of cardiac patients, the only practical way to decrease the overall cardiac mortality and morbidity is to supply the occupant with a portable care device that will allow him to monitor his health status and detect early cardiac events such as ischemia and arrhythmia.

EPI-MEDICS has designed a solution based on the interpretation of ECG derived cardio logical syndromes and developed a friendly and easy-to-use, cost effective and intelligent personal device that may be used anywhere, anytime. The device will be able to record and store ECG signals with a professional quality level, incorporate intelligent self-adaptive data processing and decision-making techniques, generate different levels of alarms and forward the alarm messages with recorded signals to the relevant health care professionals by means of new generation wireless communication devices. The main objective of this system developed can monitor the cardiac health of a patient outside the hospitals where most of the cardiac deaths occur. Figure 5.10 shows the EPI-MEDICS potable ECG Monitor.

Figure 5.10 EPI-MEDICS portable ECG monitor.

The embedded device developed will be able to record, store and synthesize standard 12-lead ECGs, incorporate intelligent self adaptive data processing and decision making techniques that will generate different levels of alarms and forward these alarms to the relevant health care providers by means of new generation wireless communication technologies. The system overview of EPI-MEDICS is illustrated in the Figure 5.11

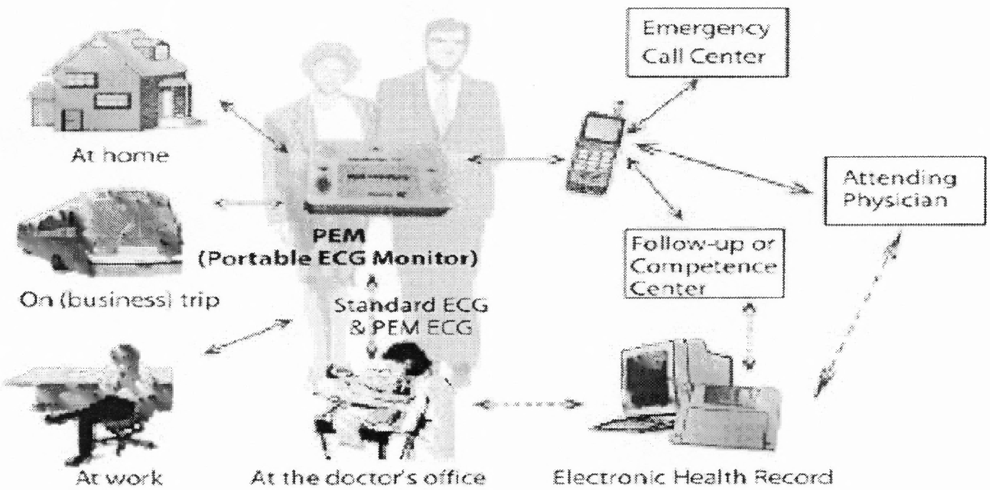

Figure 5.11 EPI-MEDICS system overview.

5.2.4 e-ReMedy

The E-REMEDY project is funded by the EC under the IST Programme with reference number "IST-2000-25146". It was started in January 2002 and was completed by the end of December 2003. e-ReMedy is a project planned to enable patients who need rehabilitation to manage the necessary therapies at home with the goal to improve quality and decrease costs. The project aims top plan, realize and experiment a range of home use equipments that are remotely connected with an external supervisor system. The use of Internet Technology makes also possible the exchange of data necessary to run the rehabilitation protocols.

The overall objective of the e-ReMedy project is to dramatically increase the quality of the rehabilitation services provided by the hospitals and rehabilitation centers to patients, while at the same time reducing the costs incurred. The project designed, developed, tested and validated in pilot installations and commercially exploited an innovative infrastructure to support rehabilitation process with most of the part performed at home, without reducing, and possibly increasing the medical monitoring level.The system architecture of e-ReMedy is been illustrated in the Figure 5.12.

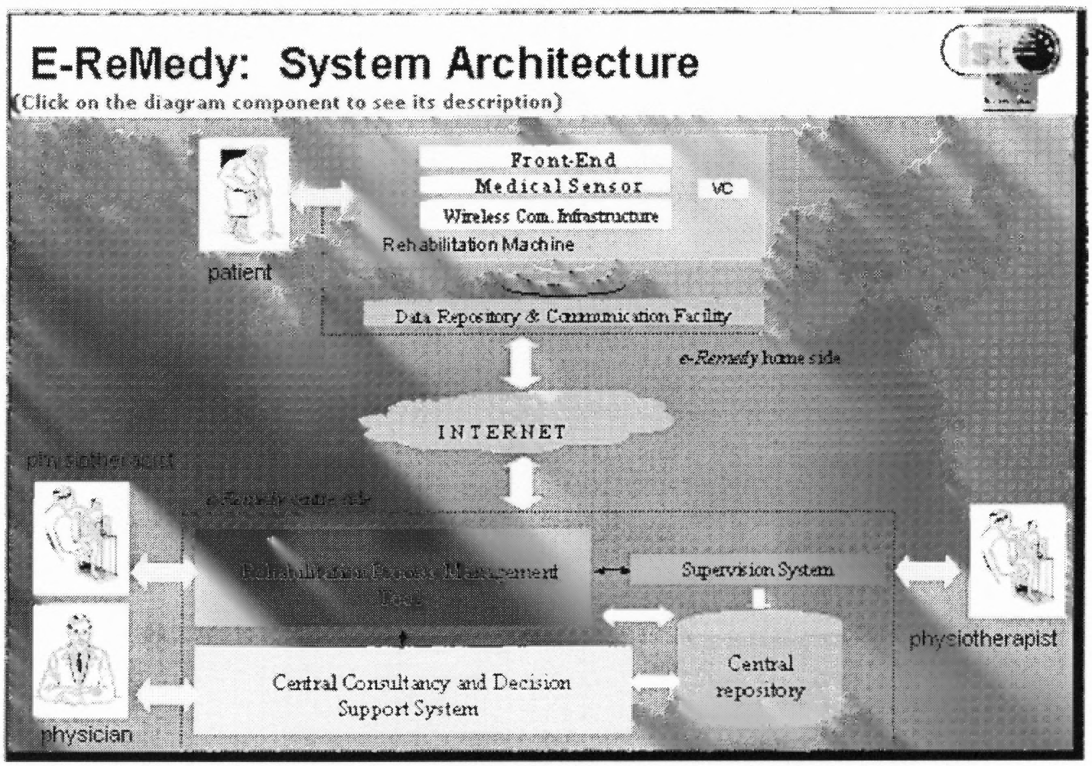

Figure 5.12 E-Remedy system architecture.

The system consists of the following components

- Rehabilitation Machines: These machines will be highly sensorised, open to external connections and programmable machines.
- Innovative Sensors: The innovative sensors will be able to perform the measurement of critical physiological variables like air-flow, oxygen consumption and blood pressure.
- Software system: The internet based, distributed software system, made up of a real time internet connection between the central system and the client system allowing the run-time supervision of patients connected to the Centre through the transmission of data relevant to exercises being performed and the establishment of a video-conference link, a client system will be able to collect and store the acquired data performing filtering and necessary computations.
- Central system: The central system will be able to visualize the patient data, send alerting messages to the specialists at the center, store patient data and provide work flow management aids and act as Decision Support system.

5.2.5 HealthMate

HelathMate project is funded by the EC under the IST Programme with reference number "IST-2000-26154". It was started in January 2001 and was completed by the end of June 2003. A significant proportion of the health demands will be soon satisfied through mobile networks (m-health). This project contributes to the definition of GPRS/UMTS portable personal systems.

This project developed four tele-care innovative platforms to cope up with a large number of potential client groups and health needs: Navigational/ positioning personal terminals; programmable terminals to hold well defined protocols for tele assistance or the management of emergency situations, data capture mobile personal devices; and multi modal high dialogue capacity terminals.

The objective of the system is to develop personal systems for health Tele-care and Tele-consultation based on new generation wireless communication networks; integrating advanced innovative wireless technologies to configure a secure information exchange media between the personal systems and health service providers. Assured service continuity at any time and place.

The results delivered by HealthMate are

- Services to access at any time and any place the right heath information.
- Services to manage predictable emergency situations, based on the capture of pertinent information from the user and the environment.
- Services to asses the geographical position of persons requiring orientation help.
- Services to tele-monitoring to asses patient status.

5.2.6 TOP CARE

The TOPCARE project is funded by the EC under the IST Programme with reference number "IST-2000-25068". It was started in January 2001 and was completed by the end of December 2003. The overall objective of TOPCARE was to develop technical devices and telecommunication structures and to lay the organizational groundwork for bringing cooperative health care services into the home of patients.

A telematic homecare platform was established and evaluated in European cooperative health care environments for the following scenarios: Home monitoring and treatment of patients needing:

- Infusion Therapies
- Controlled ventilatory support
- Monitored medication adjustments and adherence control when treated with anti-coagulants

The TOPCARE system architecture is illustrated in the Figure 5.13. Here are the components of the system described in detail

- **Telematic Home stations:** The telematic home stations are the stations which are installed in home. Occupants of the home are connected to vital sign devices that monitor the health condition of the occupant and transmit data to these stations. The ventilation devices that are installed in the environment get the necessary environment attributes and transmit data to these home stations. The database in the home station stores the patient health reports.
- **Communication Server:** The communication server transfers the data between the telematic home stations and Health professional stations. The document exchange is done via a mailbox. The communication server possesses an interim database to store collected information from different telematic home stations.
- **Health Professional stations:** The patient health reports and the data can be accessed by both the clinic and from the physician's office.

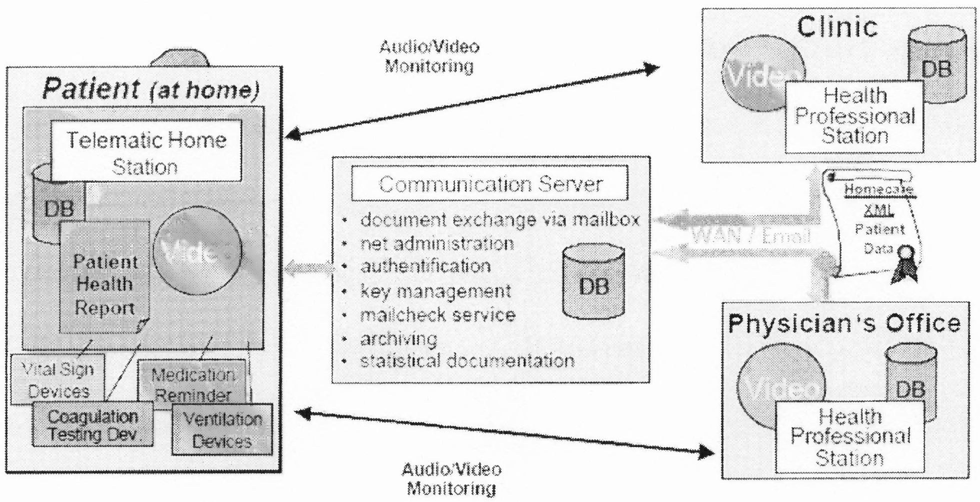

Figure 5.13 TOPCARE system architecture.

5.2.7 @HOME (Remote Home monitoring of Patients)

The @HOME project is funded by the EC under the IST Programme with reference number "IST-2000-26083". It was started in January 2001 and was completed by end of March 2003. The @HOME project aimed to enhance the patient welfare and quality across the Europe Union. The project introduces next generation, user friendly, cost effective and interoperable general interest health services by ensuring hospitals make best use of state of the art of technology in communications (UMTS, Bluetooth, data privacy and secure connections) and ubiquitous medical sensors. The project comes into play when a patient has received hospital treatment and is recovery. During the recovery phase, the patient is often hospitalized in order to monitor critical, but often simple to measure, parameters such as temperature, blood pressure, and pulse rate etc.

The objective of this project is to equip clinics with state of art infrastructure, which will allow for continuity in patient treatment from home and, often, a faster dispatch of patients, this will enable hospitals to perform remote regular and reliable health monitoring of patients residing and recovering at their homes and will promptly advice the clinical staff in case of an emergency. The @HOME project developed a robust platform for real-time monitoring of patients at their home by their doctors at the hospital. The system architecture of the @HOME project is illustrated in Figure 5.14

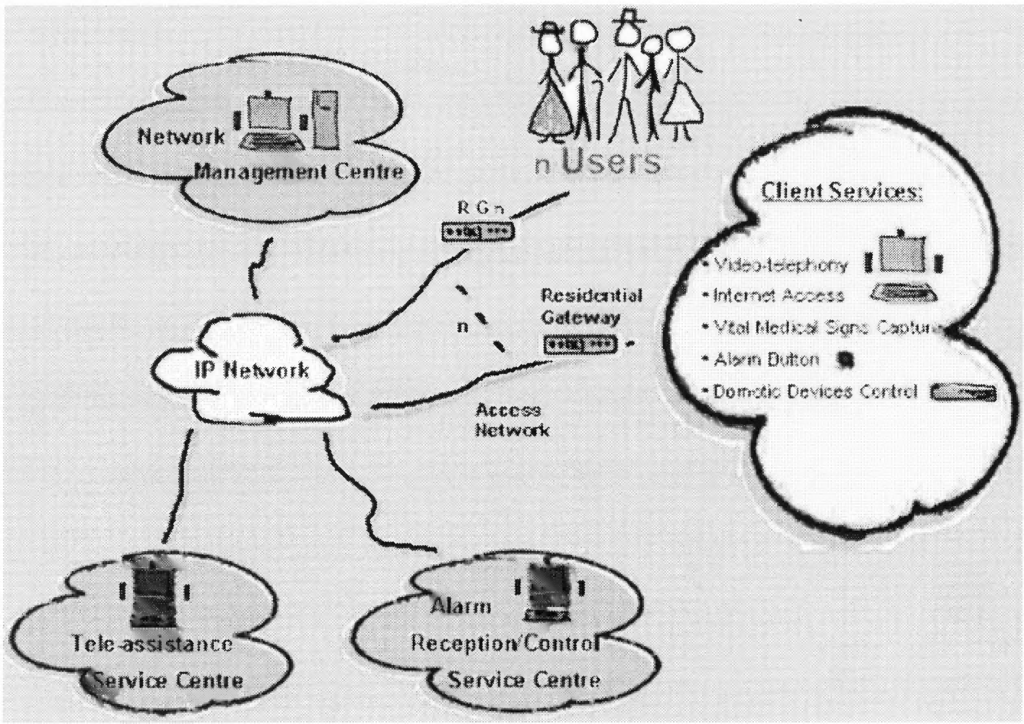

Figure 5.14 @HOME system architecture.

The results delivered by @HOME system are

- Lower relapse rate for chronically ill patients. Monitoring of treatment compliance will enable the doctors to intervene when chronically ill patients do not conform.
- Shorter Hospitalization period for patients. Physically ill patients treated in a hospital will be able to return home sooner. The doctors will be able to monitor their progress remotely in real time by the using the @HOME infrastructure.

- Lower cost of patient treatment. The cost reduction will be the order of 10%-20%.
- Quality of the life of the patient is improved.
- Health information for the patient. @HOME will feature an Internet based service where patients and their caregivers will be able to monitor their progress and obtain useful advice and information for their recovery.

5.2.8 BodyLife

Intelligent system monitoring the body composition for better healthy life style and illness prevention. The BodyLife project is funded by the EC under the IST Programme with reference number "IST-2000-25410". It was started in January 2001 and was completed by the end of December 2004. There is a real medical need for non-invasive, but reliable and simple method for measuring the body composition since weight measurement is largely insufficient. The increase in the quality and type of data available for the determination of the actual status of the body is a key point for the optimization of these non-invasive techniques.

BodyLife aims at developing a system that will measure the body composition for the whole body and separately different parts of the body. The main objective of the project is the development and the validation of the body composition for better life cycle and illness prevention. These body measurements will be made using innovative ultrasonic and electromagnetic technologies. Sensors coupled with an intelligent platform or system with an appropriate representation of the data for non-expert end-users and interfaced with a medical multimedia database. Ultimately the body composition data combined with the overall clinical and psychological profile of the individuals will contribute to the improvement of their respective health provision and as well as their quality of life. Two kinds of intelligent systems were developed, on compact home PC to be used by the doctors and their patients in close collaboration with health care centers. The second system will be a battery-operated device that will enable patients to perform some measurements themselves at home. These systems are equipped with adapted software for easy interpretation by the patients and will have the ability to connect via an RS232 serial port with an external PC and printer.

5.2.9 CHS

CHS (Citizen Health System) .The CHS is funded by the EC under the IST Programme with reference number “IST-1999-13352”. It was started in January 2000 and was completed by the end of December 2002. CHS deals with the development of systems and services for the citizen. More specifically, it aims in the development of personal health services that can be used from home that communicate with the rest of the information infrastructure. These personal health systems are developed in the areas of diabetes, heart failure and post-trauma patients. The system architecture of the CHS is illustrated in the Figure 5.15.

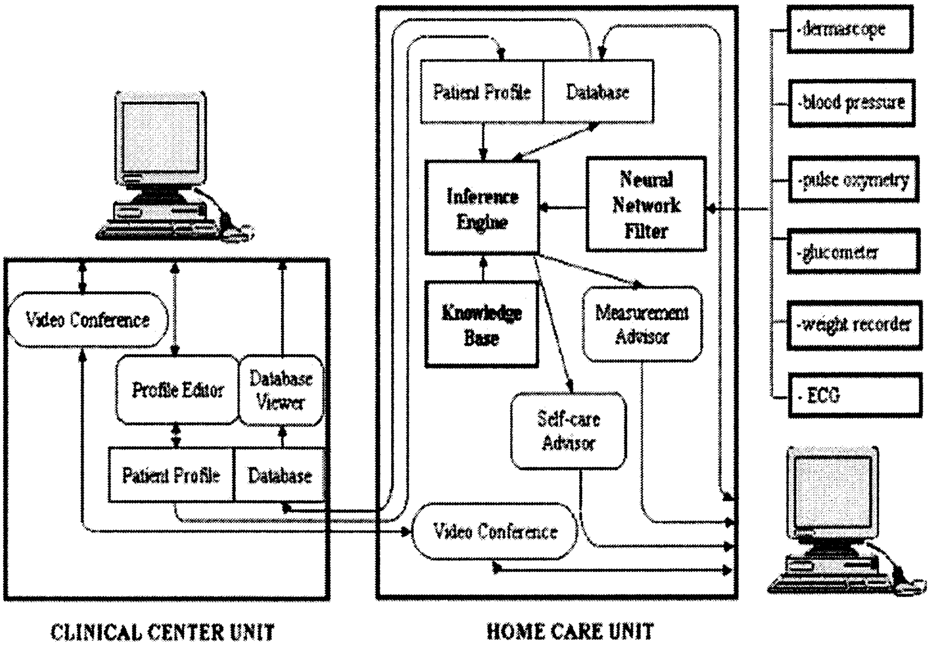

Figure 5.15 System architecture of CHS.

The CHS system consists of a clinical center unit and a home care unit at the patient's home. The home care unit will be a mobile personal computer equipped with telemedicine measurement devices, data management and decision support software, and connection with the hub unit of the supporting clinical center. It will provide a variety of care support functions including:

1. Reception of information from a variety of measurement devices.
2. Step-by-Step instruction for the patient to perform measurements.
3. Decision support system to identify and correct measurement problems.
4. Storage of collected information in patient database.
5. Forwarding and Downloading data to and from the clinical centre unit.
6. Decision support to treat simple clinical problems that do not require direct consultation with clinicians.

Data management will integrate the patient profile, a home monitoring database, and store forward technology while two types of decision support technologies will be applied in the home care unit of the system: neural networks to recognize artifacts and faulty measurement situations and a rule based decision support system for the management of measurement errors and assistance in correcting measurement problems. The clinical center unit will assist a variety of functions in co-operation with the home care unit through profiling of patients and identifying their particular health care needs, including monitoring, selecting and configuring the home care unit for the patient to use, educating patients about measurements and the sue of home care unit, providing on going support in form of regular home visits and telephone consultations.

5.2.10 CHRONIC

An Information Capture and Processing Environment for Chronic Patients in the Information Society. The CHRONIC project is funded by the EC under the IST Programme with reference number "IST-1999-12158". It was started in January 2000 and was completed by the end of June 2002. The main objective of the CHRONIC project was to develop a new model for the care of targeted chronic patients based on an integrated IT environment. The new model of care was applied to three highly prevalent chronic disorders that are predicted to become the top three causes of mortality in the year 2020 (cardio-vascular, neurological and respiratory disorders). The model and the role that the use of IT played were evaluated in a series of clinical trials during the life of the project.

The CHRONIC system allows the development of integrated services of hone care assistance. The complexity of the services depends on the clinical necessities of the patient or the organizational structure that supports the operation of the system. Thus, services can range from a simple follow up call to the acquisition of instrumental clinical data of the patient from a distance that can be evaluated at the control centre and dispatch it to the networked health care professionals. The system overview is illustrated in the Figure 5.16

The deployment of such system requires the use of different IT components 1) a call-center that could provide an effective entry-level for the system 2) an easy to use module for handling patient information 3) patient units that could support monitoring and transmission of vital signs (wired or wireless sensors) and 4) portable equipment that could support home interventions. The overview of an integrated care platform is illustrated in the Figure 5.17.

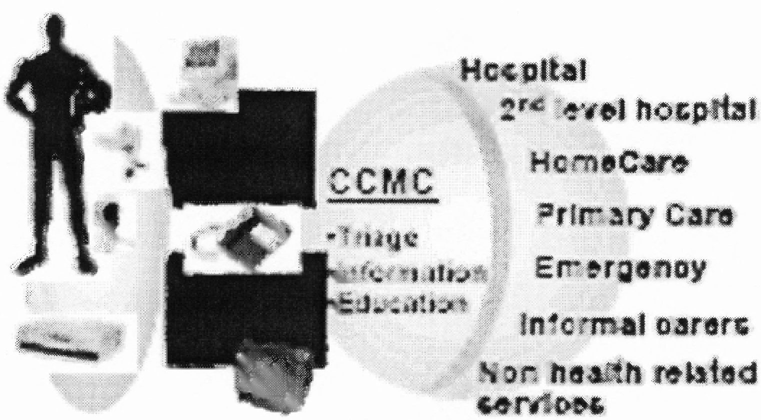

Figure 5.16 System overview of Chronic.

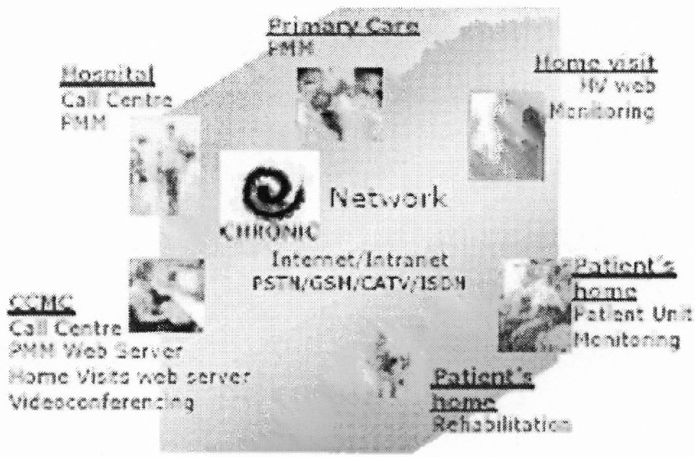

Figure 5.17 Integrated chronic care platform.

The Chronic care Management centre is the core of the whole system and is composed of two main modules: the Call-Centre and the Patient Management module. The centre can be placed inside a hospital or any other health structure, or it can e part of service centre from which requests and/or clinical data can be transmitted to the clinical reference centre of the patient. The call centre module is based on a high performance Web and Computer Telephony integration (CTI) server that can be accessed using different communication links (PSTN, GSM, ISDN, LAN). Users can access the call-centre in a variety of ways. The patient management module is a web based application running on a Windows Internet Information Server, and is implemented using ASP technology. It handles patient's clinical information and serves as a tool for the co-operative work among professionals from different health care levels. The information regarding the patient is organized in folders to simply its management. The home visit unit is laptop computer linked to the CCMC by mobile phone technology. Specifically designed for supporting home visit activities by health professionals, it includes the following basic features namely access to the patient's clinical data. In a selected group of patient of patient requiring closer follow up the Patient Units become the option of choice. The patient unit is illustrated in Figure 5.18

Figure 5.18 Patient unit.

5.2.11 MOBI-DEV

Mobile devices for healthcare applications. The Mobi-Dev project is funded by the EC under the IST Programme with reference number "IST-2000-26402". It was started in January 2001 and was completed by end of June 2003. Mobi-Dev addresses the long standing and increasingly demanding need of health professionals to effectively, accurately, securely, from anywhere, anytime communicate with patient's database located within hospitals, private offices, laboratories or pharmacies.

To this end, an innovative integration of state of art but also upcoming enabling technologies will be combined to combine the new generation mobile communication palm device for health care professionals. Natural language understanding, electronic signature, smart card reader and UMTS and Bluetooth transceiver technologies will be integrated.

CHAPTER 6

PROPOSAL OF ARCHITECTURE FOR A SMART HOME

6.1 Introduction

Having analyzed the sensor technologies, the commercial products and some of the research projects, here we present architecture to support these technologies. A technical overview of the system is followed by the proposed system design. A scenario to handle a elder suffering from diabetes is presented to support the above mentioned architecture.

6.2 Technical Overview

This section presents the technical overview of the system. At first, some of the medical parameters are measured on the occupant of the Smart Home through the use of sensors. A variety of sensors have been mentioned in the previous chapters. These sensors gather vital information using the sensor nodes. The data acquisition network is formed by various sensor nodes connected to each other. Specific sensors collect specific data. Then all these data is transferred to an access point. We assume that all the sensors nodes which gather data are BT nodes, since each of sensor is Blue tooth enabled, the sensor data is gathered at a Bluetooth access point in the Smart Home. After the acquisition of the sensor data, the data is transferred to the clinical database using one of the communication technologies discussed in previous chapters. This data is now stored in the clinical database and is available to e accessed by the clinic's computer systems. Medical professionals such as physicians or caregivers access these data based on the occupant of the Smart Home. If a patient needs a change in his daily dosage, an immediate care or is in a life threatening situation, the physician recommends an immediate action to be carried out for the particular patient. Thus from this system the occupant of the Smart Home benefits by an accurate diagnosis, health advice or medicine dosage adjustments.

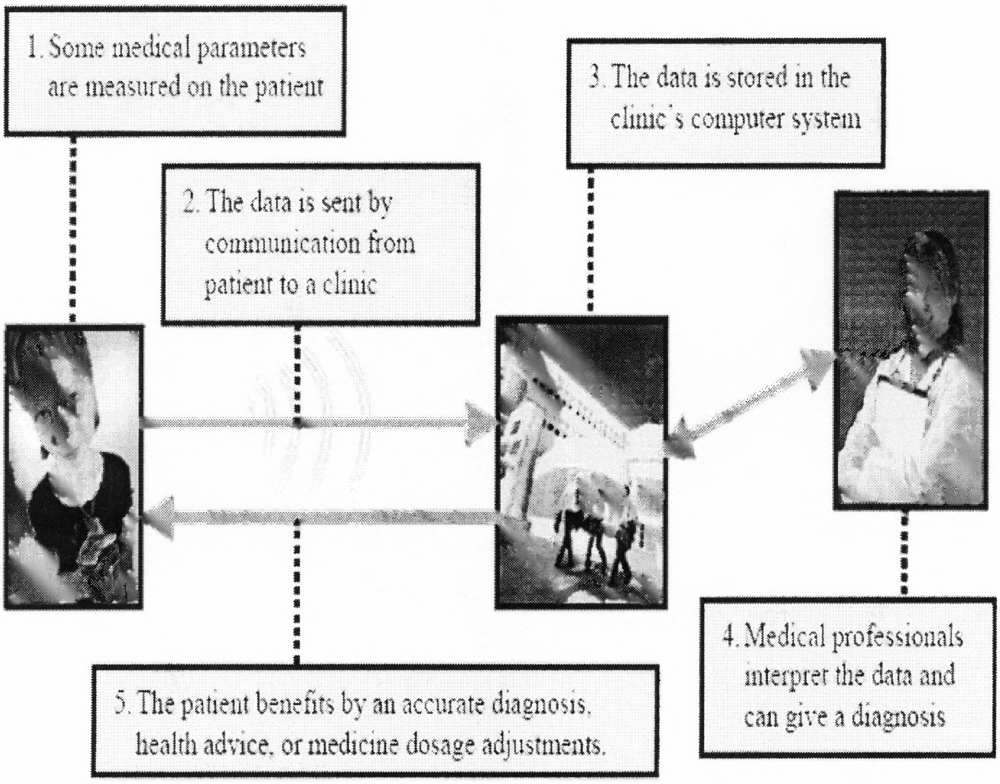

Figure 6.1 Technical system overview.

6.3 The Proposed System Design

A Smart Home medical monitoring system will use the power of sensors, Bluetooth transceivers, mobile telephones and computer networks to help elderly residents of the Smart Home to avoid or postpone institutional care and improve the quality of life by enhanced levels of independence. The proposed system design is been illustrated in the Figure 6.2.

6.3.1 Functionality Offered by the System

Using modern wireless communication technologies such as Bluetooth, residents and their homes are to be monitored. Medical and other data is collected from sensors with minimum personal intrusion and a communication device such as a mobile phone may be provided as a device of personal contact and confirmation of sensor alarm status. The central unit within the home transmits data to a remote center via the Internet. Here the operators keep a constant vigil and, if necessary, take the appropriate action in conjunction with colleagues such as takecarers and nurses.

6.3.2 Users of the System

The users of the system are identified to be one among the following

Elders: They are the occupants of the Smart Home. The health of the elders is being monitored in the smart home. They are equipped with Bluetooth enabled devices like cell phones where they can be reached immediately in case of emergency.

Doctors: Doctors or the Physicians are the people who monitor the health status of the elders in the Smart Home. A web portal is designed specifically for the doctors, where they can respond to any emergency alerts and correspond to the messages sent by operators and care takes or nurses.

Operators: Operators are the persons which remotely monitor the collected sensor data continuously and report any changes to the Doctors in case of any emergencies. A web portal is designed specifically for the operators, where they can escalate messages to the Doctors. Respond to the messages posted by the care takers or nurses. This portal would be basic call center specific portal with simple functionalities. Operators should have basic knowledge about medical terminologies. This operation could be outsourced to third world nations to cut down costs.

Care takers or Nurses: They would be monitoring the incoming data from the home network. This could be implemented by simple queries from the database providing a GUI (Graphical User Interpretation) representation of the actual information.

6.3.3 Functional Requirements

A Smart Home medical monitoring system may incorporate the following functions namely

- Act as an alarm or warden voice call system.
- Monitor if a person should fall to the ground.
- Record real-time monitoring data such as body temperature, heart rate and blood pressure using commercial available devices connected to Analogue-to-Digital Converters.
- Provide verbal or automatic medication reminders.
- Monitor a person's movement, location and personal safety using passive infrared sensors, pressure pads and switches.
- Store and maintain medical data in a private, secure and protected manner and yet permit authorized users to access the system remotely.

- Use technology that must be comfortable, convenient, easy to use and flexible to accommodate the way people actually live.

6.3.4 System Architecture

The system uses the wireless modem communication thru which the occupants of the Smart Home will be monitored. The sensors play an important role and form the backbone of the system. The sensor data is collected from these Bluetooth sensor nodes and is transferred to a Bluetooth network access point. These sensor nodes form the data acquisition network. There are two types of databases involved in the system design and each of them has its own use. The Short Term Database stores the data that is gathered from a Bluetooth Network access point. This database provides real time information to the Nurses and the Care takers. They constantly monitor this database for emergency alerts. The information is then transferred through a web server over the internet. The long term database stores the specific history information of all the occupants of a particular smart home. The web server is where all the data is posted to the internet. All the users of the system except the Elders have access to the web server based on their levels of priority and tasks. There are two types of web portals designed, one is for the doctors and the other one is for the operators. They access the web server data through these web browsers.

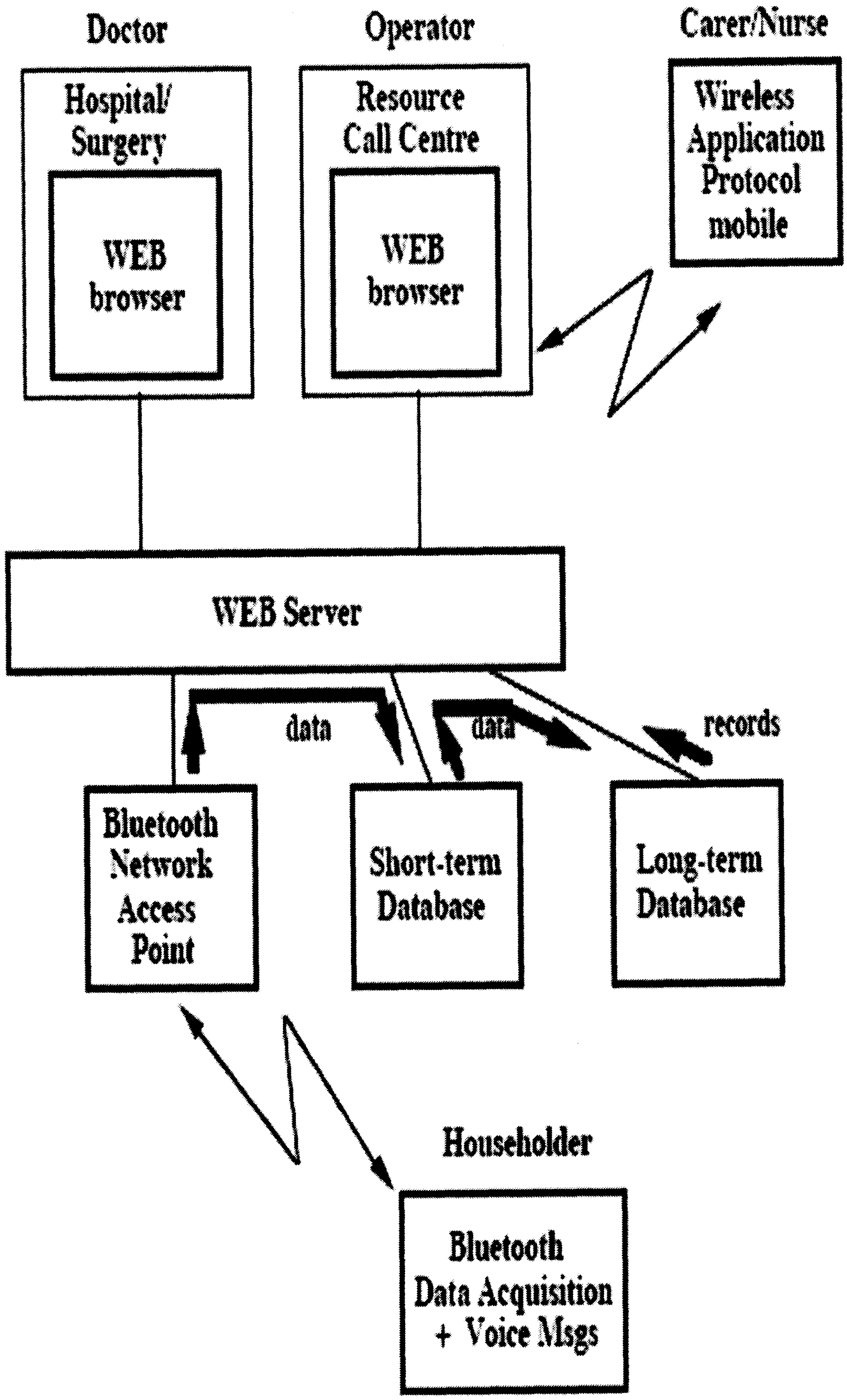

Figure 6.2 Proposed system design for smart home.

6.3.5 Scenario Illustration

Figure 6.3 illustrates a scenario with an elder in a Smart Home suffering from diabetes.

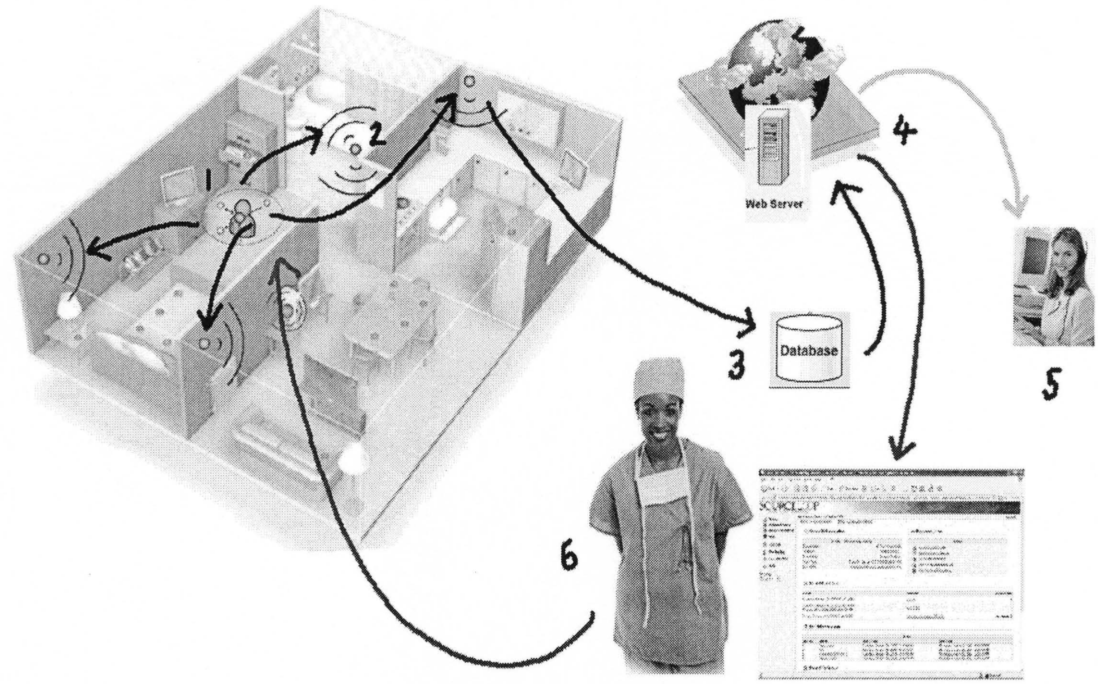

Figure 6.3 Scenario illustration for a diabetes patient

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