**International Journal of Electronics Communication and Computer Engineering**
**Volume 3, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209**

# Mobile Device for Health Care Monitoring System Using Wireless Body Sensor Network

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***Abstract* - Recent technological advances in sensors, low-power microelectronics and miniaturization, and wireless networking enabled the design and proliferation of wireless sensor networks capable of autonomously monitoring and controlling environments. One of the most promising applications of sensor networks is for human health monitoring. A number of tiny wireless sensors, strategically placed on the human body, create a wireless body area network that can monitor various vital signs, providing real-time feedback to the user and medical personnel. The wireless body area networks promise to revolutionize health monitoring. However, designers of such systems face a number of challenging tasks, as they need to address often quite conflicting requirements for size, operating time, precision, and reliability.**

**In this paper we present hardware and software architecture of a working wireless sensor network system for ambulatory health status monitoring. The system consists of multiple sensor nodes that monitor body motion and heart activity, a network coordinator, and a personal server running on a personal digital assistant or a personal computer.**

***Keywords* - Health Monitoring System, Mobile & Medical Sensor Technology, Wireless Technology in HealthCare System, Hardware & Software System.**

## I. INTRODUCTION

The aim of this paper is to investigate state-of-the art and emerging technologies in wireless communications and their applications in health care. The emphasis will be on recent technological developments for remote monitoring of vital signs, wearable computing and RF equipped implants, along with innovative new applications for the healthcare industry. Relevant standards that regulate the operation of such technologies will be addressed. Sensor nodes, systems, and networks with applications in the healthcare industry will be surveyed while studying and investigating algorithms, applications and communication architectures that allow for the remote health monitoring of the elderly as well as the chronically ill outpatients in their home environment. The emphasis will be on the continuity of tracking and monitoring based on combined communication technologies.

The healthcare industry all over the world is being confronted with many challenges including rising cost of healthcare delivery, a growing incidence of medical errors, acute shortage of staff and inadequate coverage of rural and less developed urban areas [1]. The reasons for this are not far-fetched current treatment paradigms hinge on sophisticated treatment models employing advanced and expensive technologies, and improved lifespan resulting in increases in the elderly population, most of whom are baby- boomers (those born in: 1946-1964), which in turn, put higher demands on resources and overall standard of living. As a consequent, there is an upsurge in prosperity and chronic diseases such as obesity, diabetes and cardiovascular diseases [2].

Healthcare (defined as the prevention, treatment and management of mental and physical well being through the services offered by the medical, nursing and allied health professionals [Wikipedia]) has been provided traditionally in an organized manner through a system of medical facilities and procedures by both private and public actors. In the traditional primary healthcare delivery model and visits a medical facility where a medical practitioner takes vital symptoms and uses them to diagnose the condition and then prescribe treatment appropriately. Apart from being a tiring manual process for the medical professional.

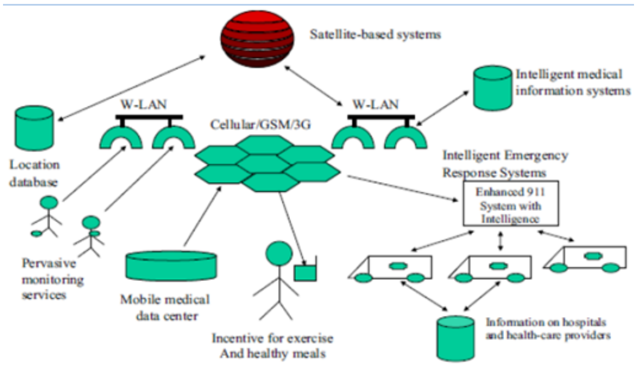


Figure 1-1: Several Pervasive Healthcare Applications [4]

The clarion call to apply existing and emerging wireless technologies to intervene in the healthcare delivery in both developed and developing countries was first heeded by extending the traditional model with communication infrastructure and devices that facilitate remote and preemptive checkup, surgery and visualization and imaging techniques to achieve continuous patient monitoring, automated diagnosis and treatment while utilizing medical facilities only in critical conditions. This gave birth to a remote monitoring model called the telemedicine model which is rather a centralized model and thus bereft of the full capability to address all the deficiencies inherent in the traditional model [3]. The expansion of the internet, the widespread adoption of digital communications, and the penetration of wireless devices and networks are making new relationships between physicians and the public possible. Along with traditional applications of wireless communications in telemedicine, a number of innovative new devices and applications have emerged that rest on wireless technology in order offer to the doctor quick and easy access to medical records and lab results from the ward enabling doctors and nurses to remotely access vital information and consult the medical files of a patient whether from the surgery room, the hospital, the patient's home or site of accident. Permit the remote monitoring of vital signs in clinical, emergency or outpatient situations. Reduce the cost of outpatient monitoring and in some cases, streamline the data logging process in medical facilities. This trend has introduced a new healthcare model, the pervasive healthcare model, which is proactive, automated, real-time, cost-effective and very efficient.

Defines pervasive healthcare as healthcare to anyone, anytime, and anywhere by removing vocational, time and other restraints while increasing both the coverage and the quality. Pervasive (or ubiquitous [4,5,6]) healthcare applications come in many forms including pervasive health monitoring, intelligent emergency management system, pervasive healthcare data access, and ubiquitous mobile telemedicine. Generally, pervasive healthcare requires a high level of security to mitigate threats posed to healthcare data, availability of reliable and usable user devices and wireless infrastructure that support prioritized communication and the right business model to bring synergy among stakeholders such as insurance payers, users and healthcare service providers. and getting people to embrace the use of wireless technology devices which are used to access these services. [4, 7, 8] noted that many a less technology-savvy people are willing to learn and use new technologies if that will allow them live more independently.

## II. Health Monitoring System

Wireless technologies have found use in healthcare in many forms including event-driven notification and messaging, web access, smart structures for assisted living and personal healthcare [5]. To be able to employ wireless technologies for healthcare monitoring, there is the need to measure the most important symptoms or signals on a patient that are necessary to make diagnosis. These signals, used by physicians as indicators of certain diseases, are referred to as vital signs. Examples of vital signs are heartbeat rate, electrocardiogram (ECG), blood pressure, blood oxygen saturation (SpO2, body core temperature, and acceleration. In most cases, vital signs alone may not be sufficient to enable the medical professional make a comprehensive diagnosis and need context information. Context is any information that can be used to characterize the situation of an entity, which can be a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves. The primary context types are location, identity, time, and activity. Context can consist of both implicit (where information is derived) and explicit information and can even be further divided among low level (such as time, temperature, and bandwidth) a high-level contexts (complex user activity) [8].

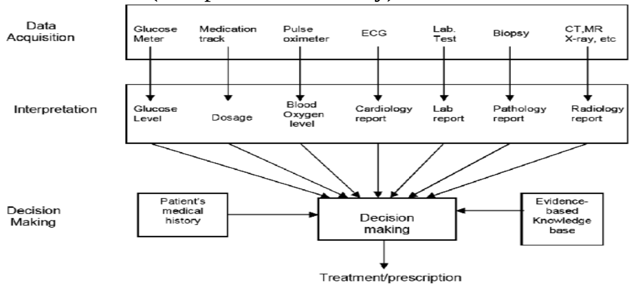


Fig.2.1. Stage Model of Medical Practice [9]

The context types in the healthcare environment include all that the physician require to completely characterize the health status of a patient, for example, whether the body temperature is too high or low, location, tress level, age, to mention just a few . In wireless health monitoring, healthcare professionals will make decisions based on knowledge derived from multiple set of informational items such as patient"s medical history, current vitalsigns, medical knowledge, and specific patient conditions [4]. The use of contexts in health monitoring reduces incidences of false positives. Figure 2-1 shows how different types of information – vital signs, context data, etc – are used by the medical professional to make a diagnosis.

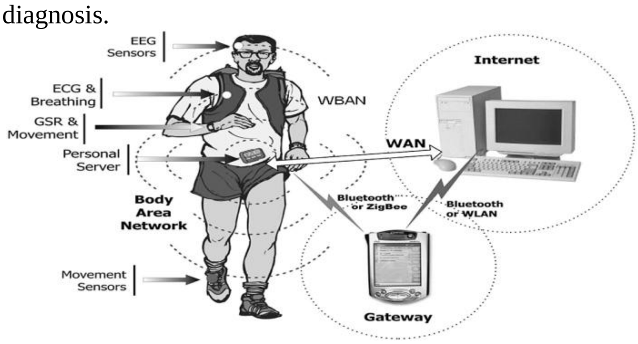


Fig.2.2. Health care Monitoring System

A system is considered context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task [8] and may include both "passive" context awareness where the system become aware of, but does not adapt to the changing contexts, and "active" context awareness, where the system adapts to the changing contexts. Vital signs and most contexts are measured by medical sensors and have different characteristics. Monitoring itself may be active or passive. Active monitoring involves generation, transmission and analysis of live vital signs and context information whereas passive monitoring entails recording the vital sign for a subsequent analysis by healthcare professionals. Active monitoring can also be continuous or event-driven depending on the nature of the event. Table 2-1 shows the vital signs and the sensors used to measure them while the information characteristics of vital signs.

| Vital Sign | Medical Sensor | Description / Usage |
|---|---|---|
| Temperature | Temperature sensor | Body core temperature |
| Blood Pressure | NIBP | Non-Invasive Blood Pressure (Cardiac) |
| Acceleration, | Accelerometer, e-AR sensor | Fall detection |
| Heartbeat | Pulse Oximeter | Heart pulse rate (Cardiac) |
| SpO2 | Pulse Oximeter | Blood oxygen saturation or level |
| Glucose Level | Glucometer | Glycemic control, Diabetes |
| ECG/EKG | ECG sensor | Electrocardiogram (heart activity) |
| EEG | EEG sensor | Electroencephalography (brain electrical activity) |
| EMG | EMG sensor | Electromyography (muscle activity) |
| Trunk position | Tilt sensor, Gyroscope | Angular position |
| Respiration/ Breathing | Breathing sensor | Monitoring respiration or breathing rate. |
| Gait phases | Smart sock or e-AR sensor | Detects steps while walking |

Table 2.1. Vital Signs and Corresponding Medical Sensors

### *2.1 Health Monitoring Networks*

In many applications, the vital signs obtained from medical sensors have to be communicated to either a medical center or a physician remotely. The remote medical/hospital server then determines whether to contact a physician or not. In other applications, the physician is contacted directly. There are different network architectures for remote health monitoring but the principle is similar. Healthcare monitoring networks consist of a hierarchical arrangement of heterogeneous networks consisting of short - (WBAN, WPAN), medium - (HAN, WLAN) and long range (WMAN and WWAN) wireless technologies. Figure 2.3 shows the wireless device technology map [5]. It shows the relative distances of the network coverage area from the human body starting from the shortest to the longest. It is a hierarchical arrangement of BAN, PAN, LAN, MAN and WWAN network types with overlap in usage depending on the interface capabilities of the gateway between the BAN and other networks in the hierarchy.

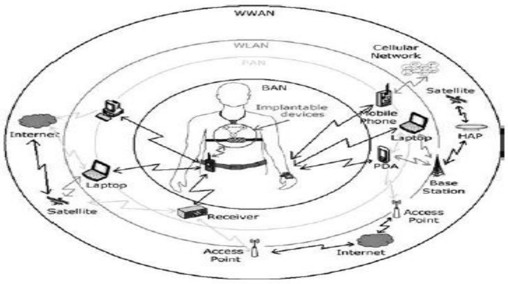


Fig.2.3. Wireless Technology for Health Care Network

*2.2 Body Area Networks:-* Zimmerman is credited with inventing the concept of body area networks [17]. A Body Area Network (BAN) is a network of devices in, on and around the body [7, 11, 12]. The devices are either sensors and actuators and other processing and communication facilities. Sensors measure vital signs such as ECG whereas actuators provide feedback control mechanism to the body. For example, an insulin pump or robotic prosthetic [7] is an actuator which pumps insulin to the body whenever the sensor-measured glucose level exceeds a set threshold. BANs may be used for different purposes. When a BAN is used for health purposes it is called a health BAN. Health BAN is assumed throughout this text. Prof Yang of Imperial College first coined the term Body Sensor Networks (BSN) in 2002 to describe a network of body connected devices while [7] used a combination of the above as Body Area Sensor Networks (BSN). All these terms refer to the same phenomenon. The network so formed is ad-hoc in nature and can be used for medical -, sports -, entertainment monitoring, gaming and specialized use cases as in Laparoscopic training [20].

*2.2.1 BAN Communication:-* [12] Describes two types of communication in BANs namely intra-BAN and extra-BAN communication. Communication between entities within a BAN is called intra-BAN communication and may be wireless (e.g. Bluetooth, ZigBee, UWB), wired, or a mixture of the two. In order to use a BAN for remote healthcare monitoring, its vital signs have to be communicated externally through a gateway. This type of communication, which is always wireless, is called extra-BAN communication. Short range wireless technologies such as Bluetooth and ZigBee can be used for intra- and extra-BAN communication depending on the application scenario [12, 22]. Common extra-BAN communication protocols are GSM, GPRS, UMTS, WiMAX, Satellite and the new and emerging femtocell systems. The gateway between the BAN and external networks is referred to variously: [11] refers to it as a Local Processing Unit (LPU), [22] and [12] as Mobile Base Unit (MBU), [15, 23] as a Personal Server (PS), [7] as body area aggregator (BAA) and [24] local gateway. Whatever the name, all these refer to the same concept of data fusion and will be used interchangeably. The difference between this and that of a conventional wireless sensor network is that there is only one fusion center or aggregator in any one BAN whereas in the latter there may be more than one. In effect, the personal or BAN server acts as a multi-sensor data fusion before transmitting the data through a network to the central server or a physician.

*2.2.2 BAN Classification:-* BANs can be classified according to the location of the sensor with respect to the body. An inbody area network (i-BAN) involve networking of implantable sensors with a gateway (located outside the body) to communicate to the outside world. An on-body area network (o-BAN) consists of wearable sensors positioned on the body while an 1exo-body area network (e-BAN) consists of a set of location or ambient sensors. A complete BAN may consist of a combination of any of these three categories. Irrespective of the composition of a BAN, the current state- ofthe- art is to have the BAN server very close to or at a distant from the body. BANs are not limited to Patients (patient BAN). Paramedic BANs are BANs worn by a health professional and consists of multimedia devices that provide real-time communication between the paramedics and a support team at a health center/hospital. BANs can be classified depending on what it is used for such as epilepsy BAN or trauma BAN [7, 11, 12, 19, 22].

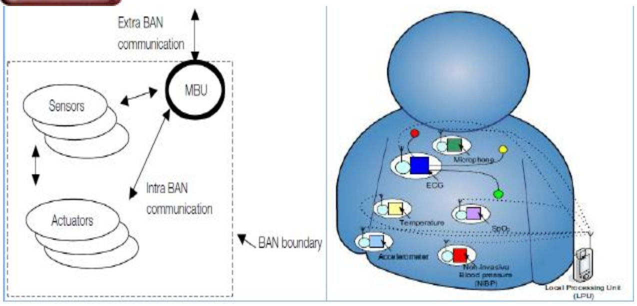


Fig.2.5. General BAN architecture & BAN Design [11]

### *2.2.3 Towards an Intelligent Personal Server (IPS):-*

The Personal Server (PS) can be implemented on a normal Desktop -, Laptop or Tablet PC, 3G mobile phone, a Smartphone, internet-enabled PDA or custom-made devices such as Mini Gate [32]. It serves many purposes in a BAN, depending on the focus of the application. Its interface capability addresses issues of interoperability for BANs and determines the network types through which to connect to the final recipient of the medical data. For example, a personal server with Wi-Fi and cellular capabilities could use any of them to connect. It can communicate with remote upper-level services in hierarchical type architecture. However, whether a medical data traverse all the tiers in this network depends on many factors including: the distance of the end physician from the body, the network architecture and the capabilities of the Personal server. Many an author have written about only part of its functions [7, 11, 12, 19, 23]. In this section, we characterize the Personal Server, which is formalizing its general functionality in a BAN and explore the notion of an intelligent personal server.

- It acts as a fusion center for data measured from medical sensors in, on or around the body and performs intelligent processing. Thus it processes and integrates data from the sensors thereby reducing data to be transmitted in order to make a more efficient use of bandwidth.
- If all aspects of intelligent processing are left to the individual sensors, this may require higher memory, complex signal processing and higher power consumption. The intelligence in the BAN such as implementation of QoS requirements is usually found in the PS.
- It acts as a gateway for extra-BAN communication, serving as the router between the BSN node and the central server,
- Multiple interface server to be able to connect to different networks
- Serves as a user interface (GUI for user), acting as a viewer for user
- Security algorithms can be implemented more simply at the PS
- Stores (limited) amount of data especially in personal alarm monitoring
- Includes the platform for context-aware implementations at the BAN side
- Control and monitor operation of WBAN nodes
- Collection of sensor readings from physiological sensors
- Secure communication with remote healthcare provider
- Initialization, configuration, and synchronization of WBAN nodes

Most of the SRWTs implement some form of security stack. However, this may not be enough since the PS may have to send medical data over heterogeneous networks and might compromise integrity and confidentiality. The IPS must be able to encrypt the information and the recipient must be able to decrypt it successfully.

### *2.3 Components of health Monitoring Systems*:-

A system for monitoring the health, wellness or fitness status of people should consist of a number of non-invasive and unobtrusive implantable or wearable sensors or computing systems for detecting a user's vital signs and context. The measured vital signs and context data are transmitted over the a body area network to a local processing unit such as a Smartphone, which aggregates the sensor data and connects to an external gateway to transmit the medical data over a network to a caregiver, a medical or emergency center, or a designated physician. The Smartphone (mobile phone that blends the capabilities of a phone and personal computer represents the local gateway which communicates the vital sign over a variety of networks to the healthcare professional. The medical data transmitted across the network can be stored in a database on a PC at the receiving end or be received on a Smartphone, a PDA, Mobile phone or Tablet PC. These devices are suitable because they have the advanced capabilities of modern computers, multiple communication capabilities (Bluetooth, Wi-Fi, cellular) and user friendly interfaces such as sleek design, portable, miniature keyboards and multi-touch screens.

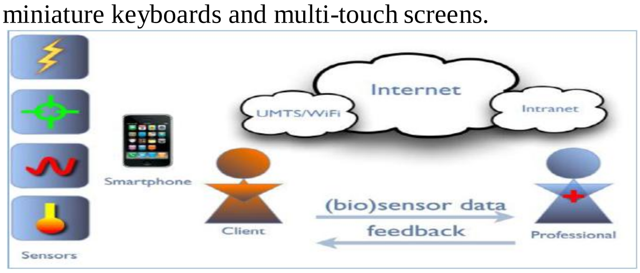


Fig.2.6. Components of Health Care Monitoring System

## III. Mobile and Medical Sensor Technology

*3.1 Mobile Technology:-*Wireless communications and Mobile Networks on Mobile- Technology Mobile Care offer the ease of mobility for patients with cellular wireless connectivity. A Mobile Care clients acts as the central unit to serve or connect to a nearby communication gateway using a public 2.5G, 3G cellular network or even a WLAN network. High speed mobile connectivity is readily available in most cellular handsets, and network support to handle transmission likes.

*3.1.1 3G and Beyond Networking:* The evolution of current 3G wireless communication and mobile network technologies will be the major driving force for future developments in Mobile Health systems. 3G wireless technology represents the convergence of various second-generation wireless systems. One of the most important aspects of 3G technologies is its ability to unify existing cellular standards, such as code-division multiple-access, global system for mobile communications (GSM), and time- division multiple-access, under one umbrella.

*3.1.2 Other Advances in Mobile Networks:* In recent years, other mobile network technologies such as have become popular [10]. These technologies are implemented as an extension to or as an alternative for wired LAN to make the communication more flexible and powerful. WLAN allows users to access a data network at high speeds of up to 54 Mb/s as long as users are located within a relatively short range (typically 30–50 m indoors and 100–500 m outdoors) of a WLAN base station (or antenna). In the U.S. WLAN operates in two unlicensed bands [11], [12]: a) 802.11b and 802.11g operate in the 2.4GHz band, together with many other devices including Bluetooth and cordless telephones. b) 802.11a (Wi- Fi 5.2 GHz) operates in the 5.2 GHz band, which at this point is relatively free of interference from other electrical devices operating in this band. WPANs are defined with IEEE standard 802.15 [10]. The most relevant enabling technologies for Mobile Health systems are Bluetooth [11] and ZigBee [12]. Bluetooth technology was originally proposed by Ericsson in 1994, as an alternative to cables that linked mobile phone accessories. It is a wireless technology that enables any electrical device to communicate in the 2.5-GHz ISM (license free) frequency band. It allows devices such as mobile phones, headsets, personal digital assistants (PDAs), and portable computers to communicate and send data to each other without the need for wires or cables to link the devices together. It has been specifically designed as a low-cost, low- size, and low-power radio technology, which is particularly suited to the short range personal area network (PAN). The main features of Bluetooth are: a) Real-time data transfer usually possible between 10–100 m. b) Supports both point- to-point wireless connections without cables between mobile phones and personal computers, as well as point-to-multipoint connections to enable ad hoc local wireless networks. c) 400 kb/s of data symmetrically or 700–150 kb/s of data asymmetrically. ZigBee (IEEE 802.15.4 standard) has been developed as a low data rate solution with multi month to multiyear battery life and very low complexity. It is intended to operate in an unlicensed international frequency band. Potential applications include home automation, industrial control, and personal health care. The standard uses 16 channels at 2.4 GHz, ten channels at 902–928 MHz, and one channel at 868–870 MHz. The maximum data rates for each band are 250, 40, and 20 kb/s, respectively.

*3.1.3 Beyond 3G Technologies and the Fourth-Generation (4G) Vision:* It is expected that 4G will integrate existing wireless technologies including UMTS, GSM, wireless LAN, Bluetooth, ZigBee, Ultra wideband, and other newly developed wireless technologies into a seamless system. Some expected key features of 4G networks are stated as follows:

a) High usability. 4G networks are all IP-based heterogeneous networks that allow users to use any system at anytime and anywhere. Users carrying an integrated terminal can use a wide range of application services provided by multiple wireless networks.

b) Support for multimedia services at low transmission cost.

4G provides for multimedia services with high data rate, good reliability, and at low per-bit transmission cost.

c) 4G provides personalized services, in order to meet the demands of different users for different services.

d) 4G systems also provide facilities for integrating services.

Users can use multiple services from any service provider at the same time. The main technological characteristics of 4G systems are expected to be as follows:

a) Transmission speeds higher than in 3G (min 50–100 Mb/s, average 200 Mb/s).

b) system capacity larger than in 3G by ten times.

c) Transmission costs per bit 1/10 to 1/100 of that of 3G.

d) Support for Internet protocols (IPv6).

e) Various quality of service (QoS) providing many kinds of best effort multimedia services corresponding to users demand.

f) User-friendly services where users can access many services in a short time span as compared with other wireless systems of longer waiting times for response.

4G advances will provide both mobile patients and citizens the choices that will fit their lifestyle and make easier for them to interactively get the medical attention and advice they need. When and where is required and how they want it regardless of any geographical barriers or mobility constraints. The concept of including high-speed data and other services integrated with voice services is emerging as one of the main points of future telecommunication and multimedia priorities with the relevant benefits to citizen-centered health-care systems. These creative methodologies will support the development of new and effective medical care delivery systems into the 21st Century. The new wireless technologies will allow both physicians and patients to roam freely, while maintaining access to critical patient data and medical knowledge.

*3.1.4 Technological challenges include:* User acceptance issues, such as lightweight implementation, long battery life or battery-less sensors, biocompatibility, maintainability, usability, and reliability.

- Seamless and secure integration of increased amounts of data from recording sessions.
- Smart medical sensor design integrating sensing, processing, communications, computing, and networking together into a reduced volume for wearable devices.
- Protocols for wireless medical sensor networks.
- Support for QoS in wireless medical sensor networks.

*3.1.5 Economical issues include:* Proof-of-principle challenges as required by approval agencies, such as FDA.

- Availability of physicians for monitoring /consulting, or development of new services for prolonged monitoring in Mobile Health systems.

- Price of preventive care versus savings from early detection.
- Standardization of protocols and interfaces that will significantly decrease overall cost.
- New business opportunities for cheap, small, and possibly disposable sensors.

*3.1.6 Social issues include:* Health-care coverage and patient's participation and reimbursement.

- Liability issues, particularly the cost of lawsuit abuse and fraudulent lawsuits.
- Promotion of healthy lifestyles (diabetes, obesity, chronically ill patients).
- The advantage of social networking of peers and interested parties.
- Privacy and security of patient's records and transmissions.

All these issues present significant challenges as well as research opportunities in the field of Mobile Health.

*3.2 Medical Sensor Technology:-* A basic wireless sensor node (WSN) is a micro-electromechanical (MEM) device comprising a sensor/actuator unit (SAU), a microcontroller unit (MCU) and a radio transceiver as shown in Figure 3-1 and 3-2. The sensing unit (also called sensor), consists of a transducer that measures or detects a physical quantity (such as temperature), converts it into an electrical signal and conditions this signal through amplification, filtering and other forms of signal processing. While sensors measure real-world phenomena and convert them to electrical form using ADC for analog sensors and I2C or SPI interfaces for digital sensors, actuators convert an electrical signal to some action. The MCU, the brain of the WSN just like the CPU in a PC, coordinates the activities of the WSN by controlling signal processing, storage, input-output, digital signal processing and network protocol functions, power management, operating system functionality and programming. The radio transceiver is responsible for establishing communication with other nodes using different communication protocols such as ZigBee and Bluetooth. The node has a power supply (battery-operated) and input-output ports for external and/or access. Besides the basic function of sensing, computation and communication, some nodes have storage and feedback functionalities [7].

Different types of wireless sensor node and network platforms have evolved including the Berkeley mote and Free scale ZigBee nodes. Free scale's acceleration sensor node (Accelerometer). Irrespective of the platform, wireless sensor nodes are characterized by small size, low cost, small memory footprint, energy problem and low computational power, and can be deployed in large quantities to form an ad-hoc network called wireless sensor network. Wireless sensor networks have found application in areas such as environment monitoring and healthcare.

*3.2.1 Types of Medical Sensors:-* Medical sensors can be classified based on type of vital sign, mode of power supply or location of the sensor with respect to the body. Figure 3.1 shows the various categories. Based on the type of vital signs being measured, there are three categories of medical sensors [7], namely physiological (bio-), bio-kinetic or motion (activity) and ambient or environmental sensors. Physiological sensors are used to measure physiological vital signs such as blood pressure, body temperature and blood oxygen saturation. Bio-kinetic sensors measure acceleration and angular rate of rotation derived from human movement. Since these sensors also indicate whether a person has fallen or not, they can be termed context sensors. Ambient or environmental sensors are used to measure environmental phenomenon such as temperature, light and contexts such as image using a camera and floor vibration sensor. Ambient sensors are located outside (but in the vicinity) of the body and may also be used to measure context. For example, a floor vibration sensor used to detect fall in the home [13] may either determine a Fall or Not-a-Fall state, or a value that can be used to determine if an elderly person has fallen or not. In terms of power supply, we have self-supporting and front-end supported sensors [14, 15]. A self-supporting sensor is one that has a power supply, signal processing and communication facilities and act as an independent unit or building block within a highly configurable body area network. The independence of these sensors requires synchronization among them in order to function in harmony. On the other hand, a front-end supported medical sensor is one that shares a common power supply, signal processing and communication facilities with other sensors. In other words,

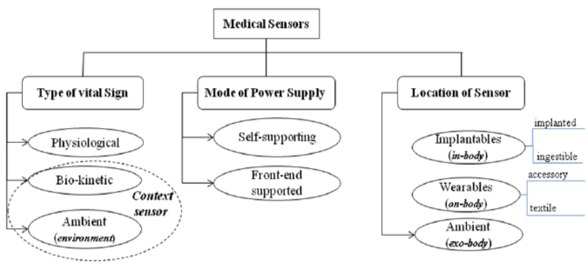


Fig.3.1. Categories of Medical Sensors

The sensors are connected to a sensor front end or "sensor- box" which powers the sensors and performs some signal processing and filtering. Since multiple sensors share common resources, they tend to operate on the same front-end internal clock and produce a single data block from multiplexed sensor samples.

*3.2.2 Types of Application Scenarios*:- Applications of wireless sensors and networks for effective and pervasive healthcare have been categorized in many ways [18, 19] as shown in Table 3.2 The monitoring applications are generally in the areas of wellness, fitness, remote outpatient, sleep disorder [15], recuperation, and emergency or disaster response. Other classifications are based on the place of monitoring – hospital, ambulatory, care centre and home monitoring for the elderly or the chronically ill. [2] presents the most comprehensive grouping of health monitoring applications scenarios including chronic disease monitoring (CDM), personal wellness monitoring and personal fitness.

| Function-based Classification | Object-based Classification | Application-based Classification |
|---|---|---|
| ❑ Preventive<br>❑ Predictive<br>❑ Assistive<br>❑ Emergency | ❑ Patient monitoring<br>❑ Activity monitoring<br>❑ Safety monitoring<br>❑ Event capture | ❑ Chronic Disease management<br>▪ *Episodic*<br>▪ *Continuous*<br>▪ *Patient alarm monitoring*<br>❑ Personal Wellness Monitoring<br>▪ *Activity*<br>▪ *Safety*<br>❑ Personal Fitness Monitoring<br>▪ *Monitoring and Tracking Fitness*<br>▪ *Personal Fitness schedule* |

Fig.3.2. Different Ways of Classifying Remote Health Monitoring Scenarios

In [18], the classification was based on the function being performed in the monitoring process as shown in the first column of Table 3.2 Preventive health monitoring seeks to prevent people from having problems while the aim of predictive monitoring is to guess if a person is going to be ill by analyzing a trend in vital signs collected. Assistive monitoring tries to help people in their everyday life by providing notification services based on monitoring context, for example reminding an elderly person at home to take their pills. Emergency monitoring involves using technology that will help people in the case of an emergency e.g. fall sensors, alarm buttons.

An object-based classification which considers the type of object – patient, activity or event being monitored was used in [18] as shown in the second column of Table 3.1. In patient monitoring, vital signs such as heart rate and temperature, and disease indicators, such as blood pressure and blood glucose levels are checked and transmitted to a network gateway, updating the staff or notifying them when a certain threshold is passed or cause an a response from an actuator . For example, blood glucose levels could be monitored and recorded at pre-set intervals. If the glucose level rises above a specific threshold, insulin could be delivered automatically. Activity monitoring records daily activity and uses the logged data to interpret changes such as tracking movement data from an acceleration sensor during daily activity or an exercising session. This reading can be compared with vital information from patient monitoring, such as the heart rate, to determine the extent of effect that a certain amount of physical activity has on the body. This activity can be tracked over any length of time and then compared to historical data to identify certain trends. Activity monitoring can even be used to remind the patient when to perform an activity or alert the caregiver if the activity has not taken place. Safety monitoring targets the notification of events, or potential events, that have affected, or could affect, a patient's safety. It can be tied to both patient monitoring and patient activity to provide notifications of such events. For example, if a patient leaves a certain area, an alert can be sent to the caregiver so the patient can be located. Event capturing records events associated with the patient and caregiver responses which are regarded as critical information for health care records. This proactive approach ensures that information on events and actions are quickly retrieved and reviewed.

## IV. Wireless Technology in HealthCare System

Wireless technologies (SRWTs) cover limited distances due to inherent design and operation at low power and data rate. There are a plethora of short range wireless technologies that are either in use or being considered for use in the healthcare infrastructure. This is because they operate at power levels low enough to be tolerated by the body. They offer low interference and ensure the security of the vital signs since their area of operation is very limited and close to the body [29]. They are needed for transmitting vital signals from the body to a fusion center, the Personal Server. Some of them may be used for remote monitoring in close proximity. However, the various technologies are not equally suitable for all applications; standards are required to ensure interoperability, which is key to the smooth deployment of solutions. An overview of the SRWTs and standard issues are addressed in this section.

*4.1. ZigBee :-* ZigBee came from the notion "Zigzagging path a Bee follows to get from flower to flower (node to node) [39]. It is a standard that defines a set of communication protocols for low-data-rate short-range wireless networking and is developed by the ZigBee Alliance (formed in 2002) which has hundreds of member companies, from the semiconductor industry and software developers to original equipment manufacturers (OEMs) and installers [27]. ZigBee is targeted mainly for battery-powered applications where low data rate, low cost, and long battery life are main requirements. In such applications, such as in in-home patient monitoring, the total time the wireless device is engaged in active use is short; the device spends most of its time in a power-saving mode, known as sleep mode, giving rise to duty cycles of less than 1%. Figure 4-1 shows the protocol stack. The ZigBee standard has adopted IEEE 802.15.4 as its Physical Layer (PHY) and Medium Access Control (MAC) protocols and defines only the network, application, and security layers. IEEE 802.15.4 defines a robust radio PHY and. MAC layers but it does not specify any requirements for higher layers. Three RF Bands specified: 2.4 GHz (16 channels) for global use, 915 MHz (10 channels) for North America, Australia and a few additional countries, and 868 MHz (1 channel) for EU countries, providing a total of 27 channels. Table 4-1 shows details. Two devices types are defined Full Function Device (FFD):

A device that is suitable for any topology, implements complete protocol set, talks to any other device, relays messages and can be PAN coordinator. Reduced Function Device (RFD): A device with a very simple implementation, reduced protocol set, limited to certain topologies and talks only to a network coordinator. The standard also defines three device roles as follows:

**International Journal of Electronics Communication and Computer Engineering**
**Volume 3, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209**

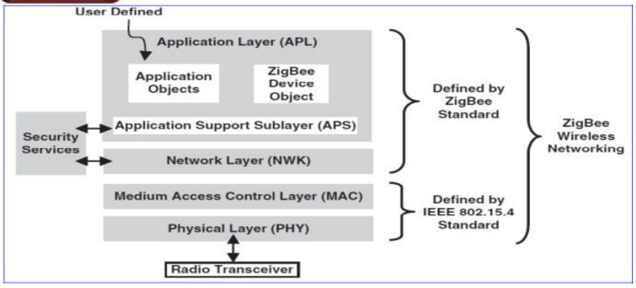


Fig.4.1. ZigBee Protocol Stack [30]

A. Network Device: An RFD or FFD implementation containing an IEEE 802.15.4 medium access control and physical interface to the wireless medium.

| Band | Frequency Band | Bit Rate | Symbol rate | DSSS Spreading Parameters | |
|---|---|---|---|---|---|
| | | | | Modulation | Chip Rate |
| 868 MHz | 868-868.6 MHz | 20 kb/s | 20 ksymbols/s | BPSK | 300 kchips/s |
| 915 MHz | 902-928 MHz | 40 kb/s | 40 ksymbols/s | BPSK | 600 kchips/s |
| 2.4 GHz | 2.4-2.4835 GHz | 250 kb/s | 62.5 ksymbols/s | O-QPSK | 2 Mchips/s |

Table 4-1: IEEE 802.15.4 Frequency Band and Modulation Parameters [30]

B. Network Coordinator: An FFD with network device functionality that provides coordination and other services to the network.
C. PAN Coordinator: A coordinator that is the principal controller of the PAN. A network has exactly one PAN coordinator and communication is done through it.

ZigBee devices (nodes) can form self-organizing (ad-hoc) and self-healing dynamic mesh network consisting of thousands of nodes. There are three device roles in a ZigBee network:

A. ZigBee router (ZR): It is an FFD that acts as an IEEE 802.15.4 coordinator. It is responsible for discovering and maintaining the routes in the network.
B. ZigBee coordinator (ZC): It is an FFD which acts as a IEEE 802.15.4 PAN coordinator.
C. ZigBee end device (ZD): It is an RFD which is neither a coordinator nor a router and cannot perform route discovery; either ZR or ZC performs route discovery on behalf of the end device. It is the least expensive device in the network and has the least memory size and fewest processing capabilities and features.

ZigBee supports two main types of network topologies – star and peer-to-peer which can further be classified as tree, mesh, cluster and cluster-tree topologies as defined by IEEE 802.15.4 protocol. The network formation and routing is managed by NWK layer which interfaces between the MAC and the APL. The NWK layer of a ZigBee coordinator is responsible for establishing a new network, selecting the network topology (tree, star, or mesh) and assigning the NWK addresses to the devices in its network.

To ensure data confidentiality and data authentication the IEEE 802.15.4 standard supports the use of Advanced Encryption Standard (AES) to encrypt outgoing messages. The encryption algorithm modifies the message using a security key so that only the intended recipient will be able to recover the original message. The lower layer of the APL layer (APS) and the NWK layer are responsible for the security implementation.

*4.2 Bluetooth :-* Bluetooth [31] is robustness, low power, low cost and open short-range wireless technology intended to replace the cables connecting portable and/or fixed electronic devices, creating a personal area networks. The Bluetooth core system consists of an RF transceiver, baseband, and protocol stack and offers services that enable the connection of devices and the exchange of a variety of data classes between them. Figure 4-1 shows the Bluetooth Protocol Architecture. The IEEE 802.15.1 standard includes the layers from L2CAP and below. Only the Radio and Baseband functions are described in this text.

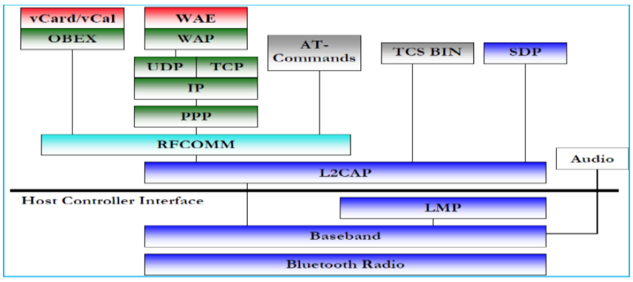


Fig.4.2. Bluetooth Protocol Stack [32]

The Bluetooth Radio (physical layer) operates in the unlicensed ISM band at 2.4GHz with 79 frequencies and employs a frequency hopping spread spectrum (FHSS) transceiver to combat interference and fading. RF operation uses GFSK and/or DPSK modulation to minimize transceiver complexity. The symbol rate is 1 Mega symbol per second (Msps) supporting the bit rate of 1 Megabit per second (Mbps) for basic rate and a gross air bit rate of 2 or 3Mb/s for Enhanced Data Rate. Every Bluetooth device has a native clock that is derived from a free running system clock. For synchronization with other devices, offsets are used that, when added to the native clock, provide temporary Bluetooth clocks that are mutually synchronized. During typical operation, a physical radio channel is shared by a group of devices that are synchronized to a common clock and frequency hopping pattern. The device providing the synchronization reference is known as the master. All other devices are known as slaves. The basic hopping pattern is a pseudo-random ordering of the 79 frequencies in the ISM band. The hopping pattern may be adapted to exclude a portion of the frequencies that are used by interfering devices. The adaptive frequency hopping technique improves Bluetooth technology co-existence with static (non-hopping) ISM systems when these are co-located. Bluetooth technology provides the effect of full duplex transmission through the use of a time-division duplex (TDD) scheme. Frequency hopping is used during packet transmission or reception. The Bluetooth Baseband specifies or implements the medium access and physical layer procedures such as Enhanced data rates between Bluetooth devices. Data is transmitted over the air and between devices in packets that are carried in single slots or a number of consecutive slots. Each Bluetooth device is allocated a unique 48-bit Bluetooth device address (BD_ADDR) obtained from the IEEE Registration Authority. Physical channel are defined by a pseudo-random RF channel hopping sequence, the packet (slot) timing and an access code. The hopping sequence is determined from the Bluetooth device address and the selected hopping sequence. Each device is classified into 3 power classes as shown in Table 4-2: Bluetooth offers an ad-hoc wireless communications technology comprising two types of network topologies: piconet and scatternet. A piconet consists of two or more devices that share the same physical channel. One Bluetooth device acts as the master of the piconet, whereas the other synchronized device(s) act as slave(s). Up to seven slaves can be active in the piconet. A scatternet is a larger network formed by joining multiple piconets together [33].

| Device Class | Range | Maximum Distance | Maximum Output Power |
|---|---|---|---|
| Class 1 | Long | 100 m | 100 mW (20 dBm) |
| Class 2 | Medium or Ordinary | 10 m | 2.5 mW (4 dBm) |
| Class 3 | Short | 10cm or 1 m | 1 mW (0 dBm) |

Table 4-2: Power Classes of Bluetooth Devices

Devices in a piconet use a specific frequency hopping pattern which is derived from the clock and Bluetooth device address of the master. Within a common location a number of independent piconets may exist. Each piconet has a different physical channel.

*4.3 WiBree (Bluetooth Low Energy):-* While Bluetooth has been a successful and widely deployed technology, it has problems of high power consumption and interference from technologies that operate in the noisy and congested spectrum at 2.4GHz. This is partly because it is designed to handle high data rate as a cable replacement technology. The Bluetooth SIG, championed by Nokia and other phone vendors, hasembraced Wibree, also known as Bluetooth Low Energy [33], as an additional strand of the established Bluetooth family of wireless specifications that takes care of small data rates – microdata – to produce a low cost and low power technology that can compete effectively with technologies such as ZigBee. Wibree [34] offers low power similar to other SRWTs; it has the unique feature that it can cohabit with a Bluetooth radio in a new generation of wireless chips, squeezing its small, complementary protocol stack in the same Bluetooth radio circuitry. This will enable quick and large volume Wibree deployment. Also, every Wibree-enabled mobile phone becomes a ready built, wide area gateway capable of transferring data from a peripheral Wibree device to a remote network or service.

Wibree is suitable for applications that transfer small amounts (a few tens or hundreds of bytes) of data occasionally such as a TV remote control, a glucose monitor, flight information at an airport or collecting data from health and lifestyle sensors. Low cost, Wibree only chips will find their way into a whole new range of accessories, such as watches and lifestyle devices while dual-mode Wibree plus Bluetooth chips give added functionality to the phones themselves. The advantages are low power, long battery life, low data rate that can handle short range communication as well as be adaptable to use for long range communication which allows a well designed RF circuitry an open field range in excess of 100m with very low battery consumption. Wibree can transmit at powers up to 100mW, but in mobile phones, where it shares the same transceiver with the Bluetooth chip it reside in, it will typically transmit at around 2mW with a receive sensitivity of better than -86dBm.

The Wibree specification deals with interference in 2.4GHz band by using advertising channels to ensure it is not inadvertently jammed by Wi-Fi or other transmitters in the band. To attain extended battery life, it implements a data transfer scheme that lets it rapidly wake up from deep sleep when it has something to say and then fall back asleep again. At the interoperability level, the standard defines a number of basic profiles that concentrate on efficiently sending attributes or values between devices.

*4.4 Ultra wideband (UWB) and Wireless USB (WUSB):-* UWB communications uses a low peak power which is spread over a wide (typically an octave or more) using extremely narrow impulses (typically between 0.2 and 0.5 nanosecond pulse width) to provide the communications link. This produces a „carrier free" system known as „impulse radio" (IR) since a conventional carrier frequency is not present. More recently multiple sub-band systems have been developed using more conventional narrow band techniques occupying a number of sub bands, which together utilize the available UWB spectrum. Ultra wideband is a bandwidth exceeding 500 MHz in the RF band: 3.1 – 10.6 GHz. UWB signals are inherently robust against jamming, offering a high degree of reliability. The physical and medium access control operations are specified in IEEE 802.15.3a. UWB systems have been targeted at two application types: HDR applications over short distances and very LDR applications over longer distances. In general, UWB technology is application area as follows [35]:

- It can be used as wireless peripheral interface.
- Applications requiring efficient energy operation as in battery-driven handheld equipment which makes it perfectly suitable for medical monitoring.
- High data rate transmission and possibility to process a large amount of data. This is good for the transfer of vital information anytime and anywhere using UWB wireless body area networks, and In addition, the ability to have controlled power levels would provide flawless connectivity between body-distributed networks. It can also be used for Internet access and multimedia services.
- Location based services involving the location and tracking of moving objects within an indoor space to an accuracy of a few centimeters or less; GPS may be too costly for this.
- Provision of accurate information and reliable transmission of patient's health data in a highly

obstructed radio environment since UWB is power efficient and jam- resistant.

- Application to imaging in medical applications since UWB has good penetrating properties; with the UWB body sensors this application could be easily reconfigured to adapt to the specific tasks and would enable high data rate connectivity to external processing networks (e.g. servers and large workstations).

Currently, researchers are performing studies and analysis on potential UWB antenna systems that could be applied to body-centric networks [35]. For example, Klemm and Troster designed a new ultra-wideband (UWB) textile antenna for UWB wireless body area network (WBAN) applications which offer a direct integration into clothing due to a very small thickness (0.5 mm)and flexibility [36]. In [37], a low data rate ultra wideband ECG monitoring system was designed and tested successfully.

*Wireless USB (WUSB) [38]* is a short-range, high-bandwidth wireless radio communication protocol created by the Wireless USB Promoter Group and based on WiMedia Alliance's UWB common radio platform. Intended to replace the cables from USB based PC peripherals, Wireless USB has found use in game controllers, printers, scanners, digital cameras, MP3 players, hard disks and flash drives transferring parallel video streams.

The WUSB architecture allows up to 127 devices to connect directly to a host. Because there are no wires or ports, there is no longer a need for hubs. However, to facilitate the migration from wired to wireless, WUSB introduced a new Device Wire Adapter (DWA) class also called "WUSB hub" which allows existing USB 2.0 devices to be used wirelessly with a WUSB host. WUSB host capability can be added to existing PCs through the use of a Host Wire Adapter (HWA), a USB 2.0 device that attaches externally to a desktop or laptop's USB port or internally to a laptop's Mini Card interface. WUSB also supports dual-role devices (DRDs), which in addition to being a WUSB device, can function as a host with limited capabilities. For example, a digital camera could act as a device when connected to a computer and as a host when transferring pictures directly to a printer.

*4.5 Radio Frequency Identification (RFID):-* RFID [39] is a short-range wireless technology that detects and identifies objects using radio signals. An RFID system comprises two basic components: tags and interrogators ("reader"). A tag has a unique identification number (ID) and memory to store the data (manufacturer name, product type, patient name) which enables the entire system to identify items whilst the interrogator can read and/or write the data from/to the tag. There is a backend database that stores the ID and the matching data [40]. The mechanism for encoding, storing (writing), reading (accessing), changing and transmitting the data depends on the tag manufacturer and may be guided by standards (e.g. ISO 14443 and ISO 15693) which offer different levels of security. Both the reader and the tags come in different shapes, styles and sizes. A tag may be passive or active depending on its power supply mechanism. The common frequency ranges of operation of RFID systems are: Passive (125 KHz – 148 KHz, 13.56 MHz and 915 MHz) and Active (433 MHz (and 2.5 GHz). The function of a reader and its tag is analogous to a barcode scanner and the barcode label in a barcode system respectively. In a typical RFID application, tags are attached or embedded in objects that must be identified or tracked. By reading nearby tag IDs and then consulting the backend database that provides mapping between IDs and objects, the reader can monitor the existence of the corresponding objects [40]. While RFID systems maintain their core role of identification, a recent research direction which involves a bringing synergy between the complementary nature of RFID networks and WSNs is making their use in medical healthcare monitoring in location tracking. The ways that the two systems can be combined meaningfully are presented in [40] [41].

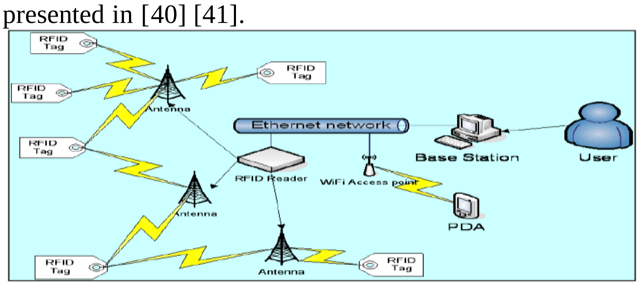


Fig.4.3. An RFID System

*4.6 Z-Wave:-* Most common in the US and standardized by the Z-Wave Alliance, Z-Wave [41] is a low-power, mesh networking wireless communications proprietary standard, designed by Sigma Designs of Zensys, for remote control applications and is used in energy conservation, home safety and security systems, home entertainment and healthcare. The low-power RF radio is optimized for low-overhead commands such as on-off (as in a light switch) and raise-lower (as in a thermostat), with the ability to include device metadata in the communications. It may be embedded or retrofitted into home electronics devices and systems, such as lighting, home access control, entertainment systems and medical devices such as blood pressure monitors.

It has a bandwidth of 9,600 bit/s or 40 kbit/s, fully interoperable and GFSK modulated. Its range of operation is approximately 30 meters in open air (reduced indoors) in the 900 MHz ISM frequency band as follows: 908.42MHz (United States); 868.42MHz (Europe); 919.82MHz (Hong Kong); 921.42MHz (Australia/New Zealand). In Europe, the 868 MHz band has a 1% duty cycle limitation, meaning that a Z-Wave unit can only transmit 1% of the time. This limitation is not present in the U.S. 908 MHz band, but U.S. legislation imposes a 1 mW transmission power limit, as opposed to 25 mW in Europe. Z-Wave units can be in power-save mode and only be active 0.1% of the time, thus reducing power consumption dramatically.

Z-Wave uses an intelligent mesh network topology, has no master node and can consist of up to 232 devices with the option of bridging networks if more devices are required. Devices can communicate to another around household obstacles or radio dead spots that might occur. The mesh network can begin with a single controllable device and a controller. More devices, multiple controllers, including traditional hand-held controllers, wall-switch controllers and PC applications designed for management and control of a Z- Wave network can be added at any time. Therefore a Z-Wave network can span much further than the radio range of a single unit, however with several of these hops a delay may be introduced between the control command and the desired result. In order for Z-Wave units to be able to route unsolicited messages, they cannot be in sleep mode. Therefore, most battery-operated devices are not designed as repeater units.

A device must be "included" to the Z-Wave network before it can be controlled via Z-Wave. This process (also known as “pairing” and “adding”) is usually achieved by pressing a sequence of buttons on the controller and the device being added to the network. This sequence only needs to be performed once, after which the device is always recognized by the controller. Devices can be removed from the Z-Wave network by a similar process of button strokes. This inclusion process is repeated for each device in the system. Because the controller is learning the signal strength between the devices during the inclusion process, the devices themselves should be in their intended final location before they are added to the system. However, once a device has been introduced into a network, it can become troublesome to remove the unit without actually having the functional unit present. This is a huge disadvantage of Z-Wave.

*4.7 Near Field Communication (NFC):-* NFC [42] is a short-range high frequency wireless communication technology which enables the exchange of data between devices over about a 10 cm (around 4 inches) distance. The technology is a simple extension of the ISO/IEC 14443 proximity-card standard (contactless card, RFID) that combines the interface of a smartcard and a reader into a single device. An NFC device can communicate with both existing ISO/IEC 14443 smartcards and readers, as well as with other NFC devices, and is thereby compatible with existing contactless infrastructure already in use for public transportation and payment. NFC is primarily aimed at usage in mobile phones. NFC has shorter set-up time and can be used to configure and initiate other wireless network connections such as Bluetooth, Wi-Fi or Ultra-wideband.

NFC communicates via magnetic field induction, where two loop antennas are located within each other's near field. It operates within the globally available and unlicensed radio frequency ISM band of 13.56 MHz, with a bandwidth of 14 kHz, and support data rates of 106, 212, 424 or 848kbit/s. With compact standard antennas, working distance is up to 20 cm. NFC communication may be active or passive. In passive mode, the initiator device provides a carrier field and the target device answers by modulating existing field. The target device may then draw its operating power from the initiator-provided electromagnetic field, thus making the target device a transponder. In active mode, both the initiator and target devices communicate by alternately generating their own field and need own power supplies. A device deactivates its RF field while it is waiting for data. NFC technology is currently mainly aimed at being used with mobile phones in three main ways:

- Card emulation: the NFC device behaves like an existing contactless card
- Reader mode: the NFC device is active and read a passive RFID tag (interactive advertising)
- P2P mode: two NFC devices are communicating together and exchanging information.

*4.8 Infrared Data Association (IrDA):-* The IrDA [43] defines physical specifications communications protocol standards for the short-range exchange of data over infrared light, for uses such as personal area networks (PANs). IrDA is a very short-range example of free space optical communication. IrDA interfaces are used in medical instrumentation, test and measurement equipment, palmtop computers, mobile phones, and laptop computers. IrDA specifications include IrPHY, IrLAP, IrLMP, IrCOMM and many more. For the devices to communicate via IrDA they must have a direct line of sight similar to a TV remote control. Infra Red is used in vital sign sensors [44] and camera sensors.

The mandatory IrPHY (Infrared Physical Layer Specification) is the lowest layer of the IrDA specifications. The most important specifications are: Range: standard: 1 m; low power to low power: 0.2 m; standard to low power: 0.3 m; Angle: minimum cone ±15°; Speed: 2.4 kbit/s to 16 Mbit/s; Modulation: baseband, no carrier; Infrared window and Wavelength: 875 +- 30 nm. IrDA transceivers communicate with infrared pulses (samples) in a cone that extends minimum 15 degrees half angle off center. IrDA data communications operate in half- duplex mode because while transmitting, a device’s receiver is blinded by the light of its own transmitter, and thus, full-duplex communication is not feasible. The two devices that communicate simulate full duplex communication by quickly turning the link around. The primary device controls the timing of the link, but both sides are bound to certain hard constraints and are encouraged to turn the link around as fast as possible. Available data rates are 9.6, 19.2, 38.4, 57.6 and 115.2 kbps. More detailed IrDA specifications can be obtained from [43].

*4.9 MICS and WMTS:-* MICS/WMTS [17], [45] stands for Medical Implant Communication Service/ Wireless Medical Telemetry Service. MICS (402-405MHz), has 10 channels of 300kHz (i.e. 3 MHz bandwidth), adaptive channel agility, transmit power (-16 dBm) while WMTS (608-614 MHz, 1395-1400 MHz, 1429-1432 MHz) has a bandwidth of 6MHz, transmit power (>= 10dBm and < 1.8 dB)). The ranges of operation are: MICS (0-10m) and WMTS (>100m) [57]. The major application is in medical implant communication due to negligible interference in the RF range.

## V. Hardware & Software Technology

In order to better understand various issues in designing a wearable wireless sensor network for health monitoring, we ventured into the development of a prototype system aimed to satisfy the above-mentioned requirements for small size, low power consumption, secure communication, and interoperability. Our WWBAN prototype consists of multiple ActiS sensor nodes that are based on a commonly used sensor platform and custom sensor boards [47,48]. The initial WWBAN setting includes a sensor node that monitors both ECG activity and the upper body trunk position and two motion sensors attached to the user's ankles to monitor activity. Such a WBAN allows one to assess metabolic rate and cumulative energy expenditure as valuable parameters in the management of many medical conditions and correlate that data with heart activity. Fig. 5.1 shows heart activity and acceleration data collected by our prototype during normal walking with a motion sensor attached to the right ankle.

*5.1. Hardware platform:* The ActiS sensor node features a hierarchical organization employed to offer a rich set of functions, benefit from the open software system support, and perform computation and communications tasks with minimal power consumption. Each ActiS node utilizes a commercially available wireless sensor platform Telos from Moteiv [50] and a custom intelligent signal processing daughter card attached to the Telos platform. The daughter boards interface directly with physical sensors and perform data sampling and in some cases preliminary signal processing. The pre-processed data is then transferred to the Telos board. The Telos platform can support more sophisticated real-time analysis and can perform additional filtering, characterization, feature extraction, or pattern recognition. The Telos platform is also responsible for time synchronization, communication with the network coordinator, and secure data transmission. Telos is powered by two AA batteries and features an ultra-low power Texas Instruments MSP430 microcontroller [51]. a Chipcon CC2420 radio interface in the 2.4 GHz band [52]. an integrated onboard antenna with 50 m range indoors/125 m range outdoors. a USB port for programming and communication. An external flash memory and integrated humidity, temperature, and light sensors. The MSP430 microcontroller is based around a 16-bit RISC core integrated with RAM and flash memories, analog and digital peripherals, and a flexible clock subsystem. It supports several low-power operating modes and consumes as low as 1 lA in a standby mode. it also has very fast wake up time of no more than 6 ls. Telos Revision A features a MS430F149 microcontroller with 2 KB RAM and 60 KB flash memory. Telos Revision B (now Tmote Sky) features a MSP430F1611 with 10 KB of RAM and 48 KB of flash memory. The CC2240 wireless transceiver is IEEE 802.15.4 compliant and has programmable output power, maximum data rate of 250 Kbs, and hardware support for error correction and encryption. The CC2240 is controlled by the MSP430 microcontroller through the Serial Peripheral Interface (SPI) port and a series of digital I/O lines with interrupt capabilities. The Telos platform features a 10-pin expansion connector with one UART (Universal Asynchronous Receiver Transmitter) and one I2C interface, two general-purpose I/O lines, and three analog input lines. We developed two custom boards specifically for health monitoring applications, an ISPM and an IAS (Intelligent Activity Sensor). The ISPM board extends the capabilities of Telos by adding two perpendicular dual axis accelerometers (Analog Devices ADXL202), a bioamplifier with signal conditioning circuit, and a microcontroller MSP430F1232. The ISPM's two ADXL202 accelerometers cover all three axes of motion. One ADXL202 dismounted directly on the ISPM board and collects data for the X and Y axes. The second ADXL202 is mounted on a card that extends vertically from the ISPM and collects acceleration data on the Z axis. The user's physiological state can be monitored using an on- board bioamplifier implemented with an instrumentation amplifier and signal conditioning circuit. The bioamplifier could be used for electromyogram or electrocardiogram monitoring. The output of the signal conditioning circuit is connected to the local microcontroller as well as to the microcontroller on the Telos board via the expansion connector. The ISPM has its ownMSP430F1232 processor for sampling and lowlevel data processing, selected primarily for its compact size and excellent MIPS/mW ratio. Other features that were desirable for this design were the 10-bit ADC and the timer capture/compare registers that are used for acquisition of data from accelerometers. The MSP430F1232 also has a hardware UART that is used for communications with the Telos board. The IAS board is a stripped-down version of the ISPM with only accelerometer sensors and signal conditioning for a force-sensing resistor that can be used as a foot switch.

*5.2. Software organization:* The system software is implemented in a TinyOS environment [53]. TinyOS is a lightweight open source operating system for wireless embedded sensors. It is designed to use minimal resources, and its configuration is defined at compile time by combining components from the TinyOS library and custom-developed components. A TinyOS application is implemented as a set of component modules written in nesC [54]. The nesC language extends the C language with new constructs to facilitate the component architecture and multitasking. By adding direct language support for task synchronization and task management, it allows rapid development and minimizes resource usage. Fig. 5.2 shows a generalized WWBAN software architecture, and from top to bottom, it shows the network coordinator software, WWBAN node's Telos software, and WWBAN node's daughter card software.

*5.2.1. Network coordinator:* The network coordinator is also implemented on a Telos platform. It feeds the PS application through its USB connector and manages the WWBAN – transmits the messages from the PS that establish a session, assigns the individual sensor ID, distributes keys if secure data are encrypted, and assigns communication slots. The network coordinator autonomously emits beacon messages for time synchronization. After the initial setup, it receives data from individual sensors, aggregates the data, and forwards it to the PS application.

*5.2.2. Telos software:* The Telos application software is implemented as multiple TinyOS components encompassing the following high-level functions: wireless communication, extended flash storage, messaging software, board-to-board communications, and signal feature extraction. Telos serves as a master controller, and it requests data from the daughter sensor card every 40 ms (25 Hz) by raising an interrupt request line. The daughter sensor card sends preprocessed data via an asynchronous serial interface. The received data can also be processed and analyzed. For example, motion sensors can analyze acceleration signals to identify the moment when a step has been made. A step detection event and the corresponding time stamp are sent to the personal server. As an alternative, we can upload raw data from accelerometers at the price of increased power consumption. The processed data set can be stored in an external serial flash memory in the case of autonomous operation or if the wireless channel is not available. It should be noted that the flash memory, CC2420 radio interface, and the daughter sensor card all share a single serial interface of the MSP30 on the Telos platform. This presented its own set of challenges since the Telos platform is tasked with reliable communications to multiple devices using this single serial interface. For example, to communicate with the daughter card, the software must configure the serial interface as a UART running at

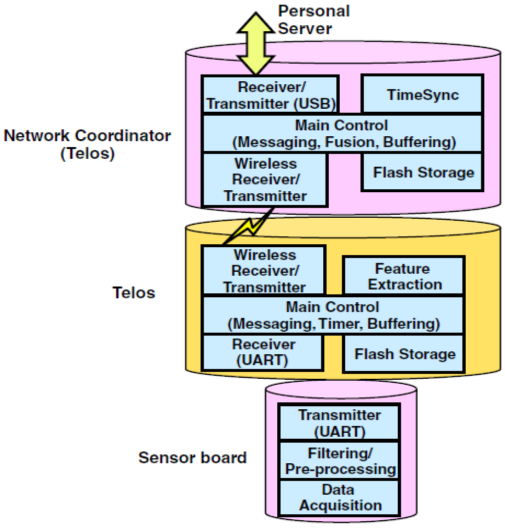


Fig.5.2. Network Coordinator Architectural

115.2 kbps. Once sensor data is received, the serial interface is dynamically reconfigured for SPI at 500 kbps, allowing communications to both the on-board radio and flash. Because events are recognized asynchronously, accurate event time stamps can be made, but often the messages must be buffered and queued for transmission when the serial interface is available.

*3.2.3. Sensor software:* The sensor boards handle acquisition of physiological signals and pre-processing. For example, the ISPM samples three independent accelerometer axes each at a rate of 200 Hz. The raw accelerometer data is filtered and preprocessed. The filtering includes moving an average filter to eliminate high frequency movement artifacts, and separation of low and high frequency components of the acceleration signal. Sensor orientation can be calculated as the angle between low frequency accelerometer components. User activity is estimated with a function based on the sum of the integrals of the AC components in each channel [49].

## Conclusion

We have studied and investigated the use of wireless technologies in the healthcare infrastructure. Out of the ten technologies, Bluetooth/Wibree, ZigBee and RFID have been found to be currently in common use. Besides, the short-range wireless technologies are used in combination with medium – and long-range wireless technologies to enable remote health monitoring. A study of the future trends in remote health monitoring points towards an increasing miniaturization to achieve the “disappearing–BAN” status and evolving network architectures that support ubiquitous connection and ambience intelligence in a robust and secure manner. The vast opportunity in the ‘point-of-care’ access and the capture and transmission of patient information will continue to drive the healthcare industry towards increased mobility. The importance is in the shifting awareness that mobility in healthcare settings increasingly refers to – the mobility of sensor/actuator devices, the healthcare providers (health ‘outsourcing’) and of the patient (users) themselves.

Secondly, we have proposed an E-Health architecture and tested for the in-home monitoring of the elderly and laid a solid foundation for its full implementation in the near future in the B-WiSE lab.

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International Journal of Electronics Communication and Computer Engineering
Volume 3, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

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