TELEMEDICINE AND ITS APPLICATION IN

Telemedicine Management

HEALTHCARE MANAGEMENT

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PREFACE

Telemedicine can be defined as the extensive depiction of providing medical and healthcare services by using telecommunications structures. Information Technology (IT) which covers controlling, interactive media, pattern recognition, knowledge management, image and signal processing: have empowered an extensive array of telemedicine applications to be supported. The joined consequence of the expansion of the global population and maturing populace in most advanced countries offers ascent to an increasing interest on the public health system. The effect on public health systems in various nations were further empowered by a change in the lifestyle and environmental contamination which further increases the demand for health systems. This is obvious from the pattern of perpetual ailments and complication arising from obesity-related conditions which attack youthful individuals over the previous decade. Currently, the financial prosperity which blesses the present generation is a result of the diligent work done by our fore fathers and the rapacious exploitation of the natural resources that will eventually cause various issues to the upcoming generation. Therefore, we should seize the responsibility of caring for the elderly who tirelessly sacrificed their time for the betterment of the current generation. Nevertheless, we are attempting to upgrade medicinal technology to enhance our well-being, and to furnish a supportable healthcare system for the upcoming era. Telemedicine is poised as a means of fulfilling our obligations to the adolescents and the elderly. There is significant awareness among the government authorities, healthcare service suppliers, the scholarly world, medical technology and supply industries, to upgrade the quality of medical services thereby significantly improving the patient's medical experience in terms of time and cost. The feasible use of telemedicine and associated technologies can help with although not constrained to:-

- aiding more range of services
- providing services to more people in many areas
- making healthcare more affordable to the senior citizen and the poor
- enhancing healthcare for all ages
- on-scene treatment for medicinal experts on the move
- offering preventive care notwithstanding emergency services
- monitoring remote rehabilitation care
- caring for a chronic illness and recovery
- sorting out service reliability and eradicating human errors
- protecting patients' data and medical history

In order to cope with the developing pattern of telemedicine arrangement in both rural and urban areas nationwide, this research will discuss diverse technologies and requisitions regarding telemedicine and the difficulties confronted. Besides, it will also take into account how the different signs of a human body are caught and then processes so that they could be generally utilized for providing therapy and health monitoring. Medicinal science has the tendency to administer cures according to symptoms. In addition, investigate procedures will be carried out to show how advancements in telemedicine can optimise general health by looking into its fundamental root causes.

BOOK OVERVIEW

Chapter 1 acts as an introduction to this research. This chapter will deliver a comprehensive explanation of what are telemedicine and its major role in delivering quality healthcare in various medical practicing sectors supported by telemedicine technologies. Fundamental ideas in diverse sectors will be discussed briefly yet comprehensive and will be further explained thoroughly throughout the research. The existing legal and regulatory restrictions made by related authorities of a country and currently available technology which will affect individual applications will also be dealt with. An in depth understanding on the relationship between medical and IT professional through technological development should be understood by the readers. IT and telemedicine not only complement each other for a better development but also enhancement of the health and medical services enjoyed by the general public.

Chapter 2 is more towards technical context on what telecommunication technology is, and how it can be implemented, aiming for a better healthcare. Rest assured that the engineering and mathematical detail will not be further explain in depth as the main objective of this research is to relate current technologies to medical and healthcare applications. Nevertheless, sufficient description will be given in explaining the fundamentals of communications technology for healthcare. Various alternatives that are currently available and the process of determining the suitable network for a specific telemedicine application will be presented. Examples will be provided to show the application of technology. Factors affecting the wireless communication system, for example the unpleasant outdoor environment, will also be evaluated. Basic restriction of technology will be analyses to discuss on what is allowed and what is prohibited.

Chapter 3 will first discuss on the advancement of technology for emergency rescue in accomplishing lifesaving. The writer will then focus on remote patient monitoring by utilizing wireless communication system as this is a crucial implementation in aiding the elderly and rural areas. Similar technology can also be utilized in rehabilitation as it enables patients to be properly monitored and recover from the comfort of their home after they are discharged. Diverse topics on the body network will also be discussed, including the body sensors, the types of wearable monitoring devices, difficulties that are will be faced and the data communication between devices.

Chapter 4

This will be a discussion on the theory of effective portrayal of numerous medical information with binary bits. The writer will first look into the different alternatives in collecting information from patients as different capturing devices will be utilized by different application. For instance, it would require a different kind of equipment to measure a person's electrocardiograph (ECG) and heart rate. Lastly, the required precautions for medical data transmission and storage will be analyzed and this leads to the storage applications namely: electronic pharmacy and electronic patient records.

Chapter 5

Matters involving system deployment are considered when working on the development of wireless telemedicine system. A number of possible alternatives will be analyzed and significant of assuring reliability and quality is something of utmost importance in the critical mission of life saving. The research will be concluded with an abstract of the distinct variety of wireless networks that is compatible with a diversity of telemedicine applications, and with the development of industrial standards which will affect the development of telemedicine systems and the services that are related over the next few years. The advancement of telemedicine system has developed extensively over the past few years as a result of the progress in information technologies. As such there are various publications on telemedicine and related technologies.

ACKNOWLEDGMENT

Alhamdulillah, through months of commitment and perseverance, we managed to complete this study which will be most beneficial to those who seek compact and exhaustive information regarding advancements in telemedicine. A word of thanks to our parents, for their tireless efforts in supporting our study. Without their confidence in me, we would have not been able to persevere through this ordeal. The support from our family has been the source of our strength and inspiration to push through the challenges that were obstructing me. Our parents who themselves are in need of medical healthcare, inspired me to pursue this study more avidly. The thoughts and information that we have recovered will be most beneficial to them and also pave way for future research on the subject matter.

Medical services stand steadfast to the aspirations of providing its services to a larger population and region, so that those in rural areas can gain access to health services as well. It is hope that the findings in this study will be able to shed light on healthcare services and promote advancements that strive to further improve the standards of healthcare today. Healthcare services may not be able to reach its fullest potential if the patients are denied treatment due to affordability or accessibility. The dreams of extending healthcare coverage in my community have driven me to complete our study, in hopes of contributing to the efforts of enhancing telemedicine technologies.

We would also like to extend our gratitude to our lecturers who sacrificed their time in an effort to guide me throughout the duration of this study. The experience of working with them has been most fruitful and enlightening. Their guidance shall be forever remembered and cherished. Lastly, we would also like to thank all our friends for their endless support. Their words of encouragement have kept our going when the times were though.

CHAPTER 1

INTRODUCTION

1.1 Healthcare Professionals and Information Technology

The history of telemedicine can be traced down since a century ago, during the time of the invention of the telephone. Physicians would give out medical advice through the telephone. As the name 'telemedicine' itself can be easily understood as using telecommunications in rendering supportive medical service. According to the ancient Greek, the word 'tele' means distance; hence directly translating the term telemedicine is delivering medical assistance from a distance. In medical application, telecommunication is transmitting medical information to a receiver. It could be as simple as a doctor being consulted on a complex data received from a human body. According to Circa (1924) the earliest documentation of the usage of telecommunication in medicine was known as 'The Radio Doctor', reported by Radio News magazine. Even though the application of information technology in healthcare has been used since then, the first formal scientific literature on the subject was reported by (Moore 1975), (Grigsby et al 1998), (Harrison et al 1996). The evolution of information technology has result in the support of diverse healthcare services. As an analogy to how vast the support system is can be seen if one is to count every single type of support service that is offered as it would result in volumes of books containing thousands of pages.

This research aims to cover in depth the subject, the utilization of wireless communication and other related technologies in medical services, the limitations and challenges faced from utilizing current technology in healthcare information systems. The paper will first focus on the function of simple wireless communication network and the components of telemedicine system. A few examples on primitive systems that are compatible with healthcare services will be discussed and then gradually more sophisticated system will be dealt with in detail. This chapter aims to provide a general summary on the assistance provided by information technology in the healthcare sector without indulging in the technical aspect of it. The concept of 'information technology' is usually related to computer science. Basically, information technology is widely understood as a merge of telecommunications and computing and hence the acronym ICT (Information and Communication Technology), also called as infocomm. All these are explanations to the application of technology in broadcasting information among entities through a secure and reliable method. In our daily lives, Information Technology (IT) has influence many areas for instance manufacturing, transportation, banking etc. and the list seem to be infinite. Since IT supports and is applied in our daily basis, it is easy to understand its application in supporting health and medicine too. Since the IT and the 'dot-com bubble burst' happened in 2000, the IT industry did not follow up closely. In March 2000, NASDAQ had sky rocketed to 5132 and then nine years later, decline to approximately one fourth of its peak. This shows the IT industry has experience major blows for years. IT professionals in finance would luxuriate in a few years till the subprime mortgage crisis in the early 2007. Therefore, despite the flexibility and wide application of IT in various aspects in our daily life it is greatly influenced. By the global economic. However, the medical service and healthcare is among the few sectors not affected and has a high steady demand, simply due to the fact that people are concerned with their own well-being. Nothing matter most to us than quality health. It is natural that health matters will be a vital part of our daily life for many years to come. Therefore, healthcare matters will remain in high demand. With the realization of the importance of healthcare, let focus on the applications of IT in medical and healthcare services.

A millennia ago, preceding the advancement of information technology, practitioners of herbal medicine have been using the most primeval type of communication method, a system that projects medical service messages. As documented by (Wang 1999), (TISTAERT et al 2011), (LITSCHER 2010) Shen Nong in 2735 BC had made use of information exchange to treat respiratory syndrome. Although this case might not be the earliest but it proved that the association of medicine and communication had been established for over 4000 years. Moreover, with the passage of time the development of IT has become more complex and can support a variety of medical services. IT has been used in medical services and healthcare to prescribe drugs, publicize pandemic modeling, establish medical database, perform distant operation, monitor patient and others. Although this is not a comprehensive list, the writer will also cover other examples throughout the research. It is obvious that high-end IT can benefit health professionals from various areas such as precision, ease of information retrieval, improve reliability and efficiency, enable users to remotely accomplish the task and improve organizational management. These improvements make healthcare much more accessible and efficient. The writer will look into details of the way technology assist healthcare professionals, with the expectations that readers only possess General IT knowledge and most likely not understand anything on the subject of underlying technologies.

1.2 Health care for patients

Apart from assisting medical practitioners in performing their tasks, healthcare services provided to the end users meaning the patients is a matter that need to be taken seriously as their comfort in receiving the treatment must be given top priority. Providing a practical solution is not the only challenge faced as the important issue that must be addressed is the acceptance and receptiveness of the patients. Providing patients with healthcare solutions by utilizing IT from the viewpoint of providers and patients is a challenge to endeavor. However, some patients are not receptive in compliant to technology to maintain good health, especially the elderly and children. An effort to persuade the patients in accepting the advantages of IT in healthcare assistance might take account of security, privacy and liability issues. For instance, patients must be assured that their personal home monitoring and tracking records at home are secured and their records are not accessed in any way without their permission. It is worth to briefly note the advantages of telemedicine technology to the elderly. As the issue of an ageing nation has become a global phenomenon affecting a lot of countries, naturally, more care and monitoring should be given to this particular age group. The utilization of wireless communication in the care of the elderly has multiplied rapidly during the last few years and is directly proportional to the maturity of related technologies. The evolution of technology has produced more affordable, portable, compact and user-friendly devices which has made services more affordable. According to (Stanford 2002), (SAHA et al 2003), (ALEMDAR et al 2010. as technology advances extensively, services that are more automated and comprehensive will be made available to the population of senior citizens in the near future. New innovation would result in unnoticeable and comfortably worn interconnected devices and sensors. Apart from that, the device can also be worn without restricting the user's movement and wearing condition will not affect its reliability. Another crucial aspect of the design is it will be user-friendly as the training and technical difficulty in using the device will be kept minimum especially for children and elderly. This will be a simple 'plug-and-play' device. The system can be installed by a technician in the patient's home and from then onwards, the device will be fully automated apart from scheduled maintenance that are unavoidable for example replacement of battery and calibration.

As an end user, a patient's perspective on telemedicine is to deliver medical services remotely. Telemedicine would be an advantage and provides convenience to patients as it reduces clinical visits. Patients can be given full medical attention at the comfort of their own home through the utilization of IT. As a whole, IT has benefited the general public tremendously in providing medical support over the past few decades. The recent development in technology has produced faster computers and wider bandwidth which enabled a wider range of services to more users. As an example, during the early days, a request for medical assistance can be made by dialing a physician in a clinic through a fixed telephone line. Nowadays, Voice over Internet Protocol (VoIP) technology enables a video call to be made anytime, anywhere and both the caller and the physician are not needed to be at fixed locations in order to facilitate communication. This is an example of the advancement of IT in assisting healthcare and further examples will be discussed throughout the research. Even though, there are many advantages, there are also problems faced by different sectors for instance the developers, healthcare management, authorities and practitioners etc. in serving the patients.

The following paragraph will discuss challenges faced by different people; from the initial planning stage, continuing maintenance and to the final rollout stage. The IT perspective is more concerned with the feasibility as to the capability of the current technology in assisting the end users, next the practicality and cost considerations. As an example, a program that decreases back pain issues among school children by ensuring their back packs are ergonomically prepared. Although the advantages of the program are obvious as it reduces the chances of the participating children from suffering from back pain the question that arises is whether the entire program is practical. In solving this simple question, an in-depth understanding in the technology involved is required. The standpoints and concern from various affecting parties should also be given due considerations. The parties concerned include participants' parents in granting approval to their children's participation, the children participating in the study, engineers who developed the monitoring system, funding bodies that provide necessary resources and clinical staff who analyze the captured data.

1.2.1 Technical Perspective

Figure 1.1 illustrates an example of a system consisting of sensors and data communication network which can be developed by biomedical engineers based on the prerequisites suggested by the clinical staff. This system consists of numerous sensors that form a network which is linked to an analysis system through a facility and stored in electric patient record (EPR), monitored by mandatory networks and system administration tools. This enables the extraction of various patient data.

This section will provide insights into what is involved sparing the in-depth technical details. The evaluation of the technical practicality and feasibility is done by the engineers. The main technical challenge to be addressed is whether the data captured is usable. Factors such as the origin of the signal detected by the sensors, signal transmitted and lastly received influences the usage of the data obtained. Therefore, it is upmost important that the sensors be correctly and securely attached to the participant's body at relevant points. The sensors used should be precise enough to detect even the slightest leaning of the body. However, it should not be too sensitive to the extent of detecting vibrations from unknown or irrelevant sources.

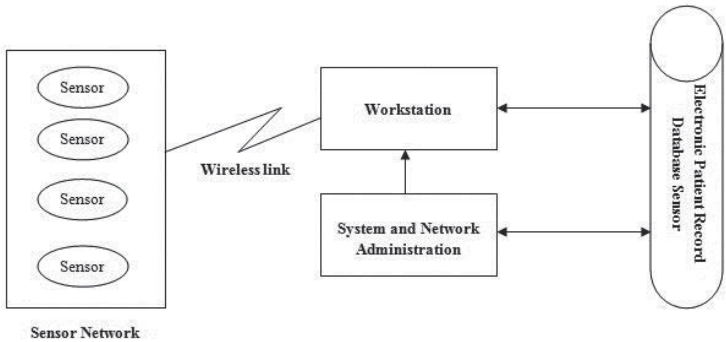


Figure 1.1: simple biosensor network (FONG *et al* 2011)

Then, we need to assess the compatibility of the sensors in performing specific applications. Examples of some challenges which are related to the sensors will be whether the size of the sensor is too large to be attached to a child or whether it will cause discomfort. Another question to be asked is whether common items in between the children and the backpack for example: clothing can affect the readings. What is the method that can be used for sending out the recorded data to be processed and analyzed has to be thought of carefully. Moreover, will distance between sensors because interference of one another if the sensors are placed too near each other has to be investigated. Assuming the sensors are well-design and can overcame all the questions listed, the system is now capable of capturing data that would describe the behavior of the children while carrying the backpacks.

Next, a brief insight on the utilization of telemedicine in a biosensor network will be explained and a detailed explanation will be dealt with in 3.5. In order to deliver the captured data, there are two alternatives namely wireless or via direct connection of sensor through wires. There is no clear indication to which one is better. It depends on the compatibility of the method to the system and this particular topic will be covered throughout this research. To sum up the discussion, there are many challenges related to the implementation of what is meant to be a simple health monitoring system. Therefore, although it appears to be a simple system to the patients, the implementation and design might not be as simple as it may seem, in addition to the many limitations involved.

1.2.2 Providers of healthcare

It should be made clear the objective of technology is to provide an easier and a safer routine for healthcare professionals. Although some might still prefer the traditional alternative, just as some prefer using pen and paper over using a technological aided personal digital assistant (PDA) to write down notes. It is clear that utilizing a PDA has many advantages but the user is required to be familiar with the user interface. There is also a risk of losing the stored data as a result of system failure. Some people might not be so keen in welcoming new methods as they have the habit of using the conventional way. Therefore, a little bit of persuasion might be required in convincing them of the advantages of the change in order to successfully implement new technologies. Therefore, an easy to use interface is strongly required whereby the whole process is fully automated yet very reliable. Different needs require different application. For instance, real time high definition imaging details and ultra-high precision controls is a vital requirement for tele-surgery; however a less rigid requirement is enough for tele-consultation. Unless the practitioners have fully mastered the functions made available to them, the advantages of utilizing IT will not be all that appealing, regardless if it may be more error-free, efficient and enables multi-tasking to be carried out quickly and reliably with the development of technical advancement. Adapting to unfamiliar things may be difficult; more so when handling critical tasks in particular. It is vital that constant adjustment are made to enable all the applications can take full advantage of the available technology.

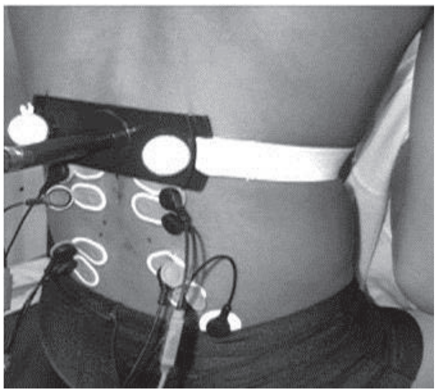


Figure 1.2: Biosensors attached to the back of a patient
(FONG *et al* 2011)

1.2.3 End of Users

Patients are individuals who receive medical services or treatment including schedule check-ups and are the system's end users. However, patient does not reflect that a person is in poor health condition. Individuals in good health can also be regarded as patients. Regarding our case study, a group of patients participated in the backpack study on children. The backs of the patients wearing backpacks of various load will be attached to a set of sensors. Figure 1.2 illustrates the means of attaching the sensor to the back of a patient. Examination of Figure 1.2 enables us to discuss the patient's first impression. Each sensor that pools into a network of sensors attached to the back is directly connected by wire to a data collecting device. This method is affected by movement; therefore we can clearly see the advantage of utilizing wireless sensors. Therefore, the question in hand would be, why not go wireless? There are 3 main reasons for using the wires. Firstly, the sensors should be made small as it will be attached to a child's back. However, it would be difficult for it to be small as for the sensor to be wireless requires an installation of a battery. Next is the issue in wave coverage by default which makes it a problem in going wireless as the body and the bag will cause disturbance. Lastly, due to physical separation of the sensor the number of movements would affect the accuracy of the measurements. Therefore, for the stated reasons, it is unfeasible to utilize a wireless solution and the patient will need to withstand using the wires throughout the experiment.

1.2.4 The authorities

Cost effectiveness is usually what concerns the authorities and funding agencies. Therefore, benefits to the community in the long run must be clearly stated as it might be difficult to gain funding for this case study, regardless of the advantages as stated earlier. This is because it will take a long time for a clear reduction in back pain trend to be attained and the realization of its benefits. The political issues will not be explained as it is not within the scope of this research. In obtaining capital for technology based projects, a rule of thumb is to provide immediate results. This describes the general issue of inadequate financial funding for the utilization of technology in inventive healthcare solutions.

1.3 Development of Healthcare Information

This segment will focus briefly on the evolution of bioinformatics and healthcare over the past few decades. For thousands of years, medical science has gone through constant development compared to IT which is a relatively newly emerged topic that commenced from the invention of the first computer in circa 1936 by (Konrad Zuse). Right after the emergence of computers, comes in information storage devices. Computer networking whereby computers are linked together in a network made health informatics possible. It all started after World War II where technology is made more available and the health informatics concept just appeared. This provided an opportunity for connecting hospitals together in the cyber world and recent development of computational intelligence has made a variety of services accessible. The collaboration of information technology, multimedia technology and health has made health maintenance and life-saving easily achievable. Figure 1.3 depicts technology supporting a wide variety of healthcare and medical services.

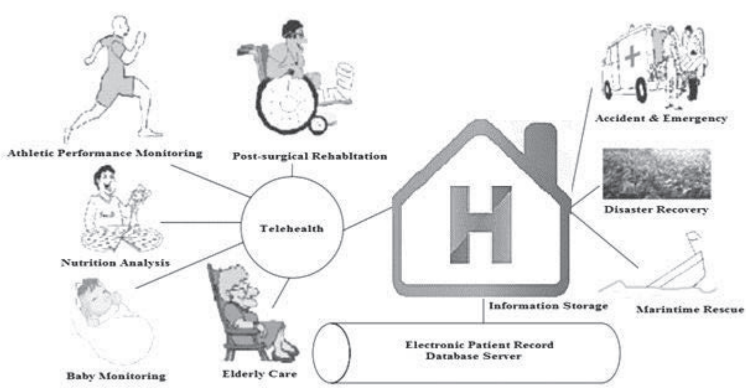


Figure 1.3 Telemedicine supports a range of applications
(FONG *et al* 2011)

Ever since The Radio Doctor was launched eight decades ago, there are various links between medicine and technology in almost all areas of healthcare practices. As the development of the health informatics from the first computer has been briefly explained we should now focus on recent developments that have the potential for further progress. Privacy and security are one of the major problems that many would be debated. Cases of personal information of patients being exposed are caused by security breach and lots of storage devices. The most crucial aspect of health informatics is making sure that the security and privacy of personal information including protection against information alteration or stealing and policy assurance that states that the information will not be abused by any parties including those who have access to the patient's records.

Apart from assuring the privacy and safeguarding the medical data, other matters need to be addressed also as health informatics involves a wide variety of topics that associate resources, people and devices which are developing and progressing independently continuously. In the USA during 1950s, (Robert Ledley) initiated a dental project, which marks the earliest record of modern informatics arrangement. It was done for the National Bureau of Standards which is now known as the National Institute of Standards and Technology (Ledley, 1965), (ZAHN et al 1972), (LEHNER et al 1998). The next couple of years saw more new medical information systems being developed in USA and most of the programmers are developed independently. Therefore, it is not feasible to develop a standard for health informatics systems. In 1967, the International Medical Informatics Association (IMIA) was founded to manage the progress of health informatics and associated advancement in technology. Shortly after the formation of IMIA, the Massachusetts General Hospital Utility Multi-Programming System language (MUMPS) was developed for the application for healthcare. Currently, MUMPS is still utilized in electronic health recording systems. Later in 1974, a standard was introduced as the demand for different programming languages for different computer platforms came into the picture. Nowadays the development of medical applications for different computer platforms are developed and used as 'Cach´e'. However, a lot of current electronic health record systems are developed by relational databases .Therefore, the development of healthcare informatics shows a wide range of areas which is associated with IT. It includes all features of technologies associated with caring, consulting, treating, preventing, monitoring and rehabilitating. Our discussion will now focus on networking and communication technology for healthcare purposes.

1.4 Types of Different Definitions of Telemedicine

Telemedicine aims to support various medical application and services through a combination of information and communication technology (ICT), multimedia and computer networking technologies. According to wiki, telemedicine is defined as an application whereby medical information is sent through the phone, internet and sometimes other network for remote medical procedures or examinations and consultation. It is similar to the definition given in Section 1.5. Also, Telemedicine Information Exchange (Brown 1996), (NG, H et al 2006) describe telemedicine as the transfer of medical data through the utilization of electronic signals from one site to another by telephones, the internet, PCs, videoconferencing and satellites that aim to improve health care. (Reid 1996), (MAHEU, M et al 2002),(JENNETT, P et al 2003) however specify telemedicine as utilizing the advancement in telecommunication to transfer health information and support health care services regardless of the geographical, social, time and cultural barriers. (Kantor's 1997), (BASHSHUR, R et al 2000) Telemedicine Report to Congress defined telemedicine as a way to obtain health care which has not been available before. Therefore, telemedicine can mean saving a live or losing a life while handling emergency cases whereby administrating immediate medical assistance in time and specialty care is crucial. At North Carolina University Hospital, a specialist detected a hairline spinal fracture of a rural patient at a distance via telemedicine video imaging. Subsequent treatment was then performed on the spot without the need of shifting the patient to the specialist's location and the patient was saved.

There are a few similarities that can be seen among the various definitions. All these definitions were made in the mid-1990s which suggests that telemedicine was recognized as a significant field only a decade ago. Other than that, all the definitions can simple be related to giving a wide range of medical services from a far via any type of telecommunication technology.

1.5 Telemedicine Overview

At the beginning of the research, telemedicine was explained. In short, it can be explained as the utilization of networking and telecommunication technologies in sending and receiving medical and healthcare application data. With the current modern telecommunication system data can be transmitted through various networks in various forms. It can be as mere exchange of ideas between two doctors via phone about a patient or as complex as a live feed of a surgical operation in a hospital transmitted through an advance network of global hospital enterprise controlled by surgeons from various parts of the globe. To further understand the wide description of telemedicine, a summarization of a few services supported by telemedicine is illustrated in Figure 1.4. It is clear that the list is incomplete. Nevertheless it displays the major and common services applied around the world. A common similarity can be seen in analyzing these services: emitting medical data between entities. Before we move on, as a reminder that this is just an introductory segment of the research, therefore the technical details and terms should not be a worry as it will be covered throughout the research. It is obvious that different applications involve different data. Each of these cases will be analyzed to understand the achievement of telemedicine. Even a simple usage of teleconsultation such as a transmission of usually verbal advice from an expert to people, requires medical data. Recently, the service is now made available through mobile devices. Experts can now perform diagnostics with medical instruments from afar via Tele-diagnosis simply by enabling communication connection between two locations.

Telemedicine can also be as sophisticated as tele-Accident and Emergency (tele-A&E) which is a service involving high definition imaging and vital signs of the patient collected at a remote location that must be transferred quickly and reliably to the hospital. Features like retrieving medical history at real time and video conferencing are supported by some systems. In addition, monitoring patients who are recovering at home or constantly on the move whereby they are not anywhere near the hospital can be done through tele-monitoring by the transmission of various types of data. Some monitoring application might require remote patients to attach compact wireless biosensors establishing a body area network (BAN). Individual data captured by each sensor is collected within the BAN before being transmitted collectively for further processing.

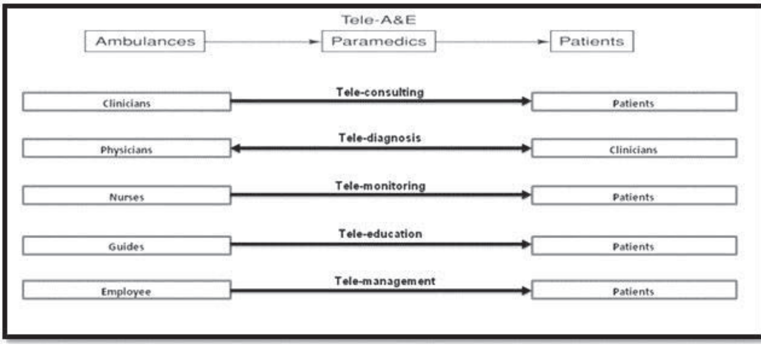


Figure 1.4 Subsets of telemedicine connecting different people and entities together (FONG *et al* 2011)

Various type of communication network might be needed for the telemedicine system in this particular situation. The in depth explanation of networking will be covered in Chapter 2 with particular focus on the applications of telemedicine as in Section 2.4. However, let us refer to Figure 1.5 for further understanding on the emergence of three isolated networks that are connected to form a telemedicine system. While moving around, the patient who is under observation is bounded by a BAN, carried by the patient. A nearby local area network (LAN) receives the data collected, and stores and processes the information. The LAN links the patient's home and the hospital attended by the metropolitan area network (MAN) effectively. LAN is a very typical and simple permanent home network fitted at the patient's home. A telemedicine system that supports tele-monitoring is feasible with the installation of the right equipment in correlation with the BAN, and a link to the hospital through the MAN.

Tele-surgery is perhaps the most extremely complex and difficult to follow application partly due to the precision required. Apparatus of very high degree of motion in every direction and un blocked view in high quality must be made available to the surgeon for the surgical operation to commence from a remote location. The following are essential requirements and must be satisfied in order to perform even the simplest operation:

- Sensors with extreme precision that is capable of detecting even the slightest shift of a surgeon's hand in real time.
- High definition cameras capable in delivering crystal sharp images of the patient without any interference. This is quite difficult to achieve as surgical tools movement should be considered and it is crucial to constantly maintain an excellent viewing angle of the patient.
- Actuators capable of replicating the exact 3-D hand movements as captured by the sensors in real time.
- A communication network that can rapidly transmit all types of data to and fro with a high level of reliability which is vital to make sure there are zero transmission errors throughout the whole process.

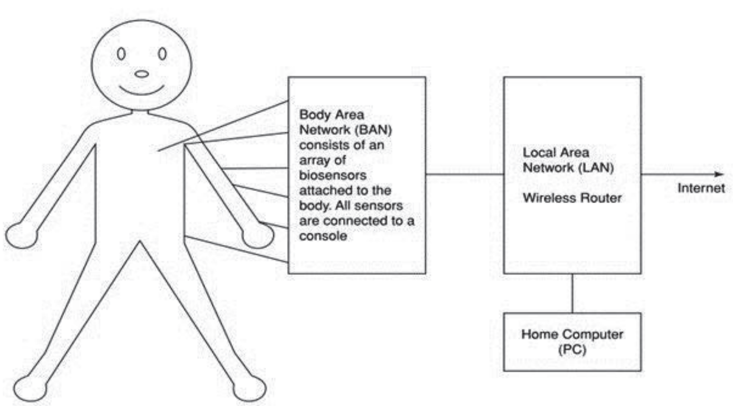


Figure 1.5 Simple network connections from the human body to the outside world (FONG *et al* 2011)

It can now be made clear that telemedicine has evolved to require more than mere simple POTS (plain old telephone system) which is just a verbal communication between two medical professionals. More telemedicine application and the basic technologies that are required for telemedicine to be made possible will be discussed in later chapters as the examples given previously is not ample in displaying the connection between the resources and people for an enhanced healthcare. Although the ways in which the general public can benefit directly from telemedicine have been described; other uses for instance linking appropriate authorities around the world in tracking outbreak of diseases or pandemic through epidemiological surveillance has been found effective in controlling crisis instigated by Severe Acute Respiratory Symptom (SARS) and Avian Influenza (Bird Flu) over the past years.

Tele-psychiatry, another obscure but significant application in assuring the safety of the community, enables psychiatrists to keep track of acutely anxious patient and avoid violent crimes via telemedicine, which addresses nearly all parts of daily life. Healthcare information is easily accessible with a touch of a 3G mobile device for example obtaining nutritional dietary information while dining out can be done so easily. Throughout this research we will be aware that telemedicine supports virtually all parts of healthcare in a everyday life of consumers, who have mobile devices such as mobile phones or notebook computers.

1.6 The Internet growth and Information on E-Health

The Internet is well known and utilized on a daily basis. We are commonly aware that the Internet enables us to download contents, video clips and pictures, video conferencing, accessing emails, email retrieval from websites etc. It allows information sharing worldwide without geographical disadvantage. Fundamentally, lengthy sequence of binary bits of ‘1’s and ‘0’s are delivered around the globe, at a rate of trillions in seconds. Even though there is only two possible states that can be delivered in the cyber world, almost virtually anything can be represented by these two states. The internet is an emergence of both information and devices.

To understand how telemedicine is supported by the advancement of technology, we will focus on the development of the Internet since the early times and how it supports telemedicine. As documented by (Licklider 1962), (SUTHERLAND, I et al 1964) the emergence of the Internet was most probably the Galactic Network,. Although the beginning of telemedicine is way earlier than the Internet, the internet greatly influences the development of telemedicine. Besides, internet is now the basic form of connection between devices and computers. According to Kleinrock (1961), the advancement of packet switching has changed the capability of networks in transmitting different forms of data through a single transmitting medium. Therefore, telemedicine can be supported by communication networks in many areas, for example:

- Reliability: Assurance in quality of service (QoS).
- Sharing of information: medical web pages online.
- Audio: tele-consultation, cardiac, pulmonary and respiratory sounds.
- Still Images: medical images, X-ray, scans.
- Video Images: tele-conferencing, medical education, tele-psychiatry,.
- Databases: electronics patient records, alternative medicine, e-pharmacy,.
- Vital Signs: EEG, ECG, analysis and storage.

Primal services like BBS (Bulletin Board System) and email were supported by the Internet during its early stages of development which was fairly sufficient to carry out Tele-consultation. Multimedia data traffic was only supported since 1984 as the internet integrated the Transmission Control Protocol and Internet Protocol (TCP/IP) (MILAD, A et al 2013). With all the advancement of the internet which supports a variety of telemedicine services as described above, threats towards the growth of telemedicine exists even today. It is interesting how the epidemiological control described above can be replicated by a computer virus, disseminated through the Internet. If a computer is infected by computer viruses it could obstruct the computer's normal operation. The viruses can be spread through many mediums through the Internet. The common medium would be through email attachments. They can also be concealed in many forms embedded in files or programs, as video clips or pictures. They can also be within unauthorized software, like a normal looking healthy person yet carrying hepatitis virus. There is anti-virus software that can be installed to protect the computer from viruses' attacks. Similarly, telemedicine systems can also function in preventing viral and bacterial infections from dispersing by actively searching the spreading and mutation pattern of viruses through signal processing abilities.

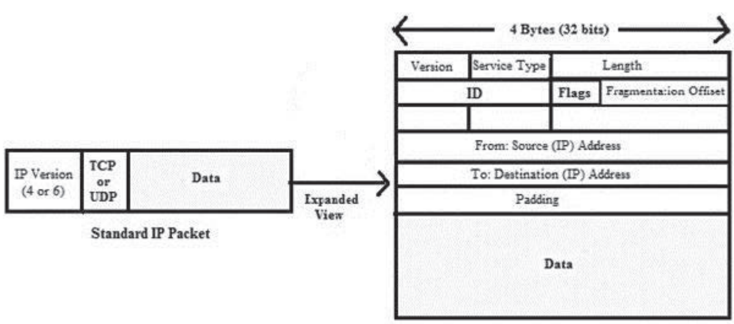


Figure 1.6 Simplified structure of a typical data packet
(FONG *et al* 2011)

A more versatile utilization of telemedicine in enabling off-site applications can be achieved through the advancement of wireless communication technology. As related technology for example batteries and antennas evolve, wearable technologies are now made accessible for various healthcare and medical applications. Therefore these development uncover more chances for development in telemedicine since data can now be obtain anytime, anywhere and on the go. With the emergence of various telemedicine applications that adapt to the internet, the question in hand is what the basic requirements to support telemedicine are? It is not factual to say that unlimited amount of data transfer can be done to almost anywhere in the world by the Internet. There will be a time when the Internet will be so saturated with too many data. Telemedicine is all about healthcare around the globe but this does not require all the medical information to be made available in the internet. Eventually data loss occurs as flooding the network with data causes malfunction and cease of speed. Since the internet is a shared medium and should be used responsibly, reducing overheads is a major responsibility of the system developers of telemedicine. Understanding data composition is required in controlling the transmitted information. Data is transmitted through the Internet in a form of packets. Packets are units of binary bits transmitted between entities (Mullins, 2001). A clear assembly of a common data packet transmission across the Internet is illustrated in Figure 1.6.

It displays that only a part of the packet contains the important data needed and the rest are overheads that help in the transmission of the data. It is just like sending a letter through the snail mail service. The actual message that is desired to be transmitted is put into an envelope that assist in sending the message to the receiver by containing the receiver's information which are Destination Address (recipient location), Sender's Address (source location), Postage Stamp (class of service) and Airmail Label (delivery method). The pair of flags is similar to the envelope itself representing the packet's attachment. Protocol is similar to the delivery method, and the type of service refers to the class of service. Lastly, there is the sender's and receiver's address and the all-important actual information that needs to be conveyed. The verification of the data upon receipt is checked by checksum, a service similar to the courier or registered post that is presented in the cyber networking world. Successful transmission is ensured by specific communication protocols. A variety of QoS programs can also be configured to emphasize on data traffic across the network (ALGAET, M et al 2013). As we are aware now, the actual information is not the only thing that is available in data packets. Nevertheless, we need to be wary that no changes can be made to the way data is structured as we are required to follow the standards of data sending across the Internet which is currently made available through IPv4 and IPv6. Minimal overhead has to be ensured in telemedicine services particularly during the usage of the Internet. The subject on transmission efficiency will be later covered in the next chapter.

As a conclusion, we can say that advancements of the Internet has presented a stage for developing telemedicine services which covers more sophisticated applications. However, it is upmost important that what is to be transmitted is carefully selected. Data security is also another aspect that should be looked into since the Internet is a globally shared medium and access can be gain by virtually everyone. Thus, it is important to remember the risk of security breaches as telemedicine require a high level of data security in both the privacy of the patient and accuracy of the information.

CHAPTER 2

SERVICES AND COMMUNICATION NETWORKS

Communication networks play a role in supporting a ample range of medical and healthcare services. Here, telemedicine applications make use of different type of networks so that doctors can pool their knowledge resources, surgeons from anywhere in the world can carry out an operation together regardless the location of the operating theatre, paramedics and nurses can recover the medical records of a patient anytime anywhere. The network is useful for hospitals and clinics in terms of inventory management, patient care and administrative work. This chapter deals with basic telecommunication technology with a focus on wireless networking, which provides flexibilities vital for most telemedicine applications.

2.1 Wireless Communications

In order to understand the basis of operation of telemedicine applications, an understanding of the telecommunications theory is required. Telecommunication is basically the transfer or exchange of data between different units. Basic communication, for instance, involves a conversation between two individuals, whereby the voice of the person who is talking which delivers information is disseminated through the air and the listener, is the individual whose ears receives the information. A communication system will be made of a channel which is a path whereby the information passes through, a transmitter (sender) and a receiver (recipient) as shown in Figure 2.1. The following is how it operates. The transmitter will send out information s(t), which is a function of time in which the content of the information changes with time. To make it simple, we may refer to this as 'sent' information at a given 'time'. The information will go through the communication channel and the receiver will is presented via the channel with r(t), the 'received' information at a given time. Although, this process looks very simple and that s(t) and r(t) are identical, in reality this is not always the case. The channel causes degradation of the information sent with distortion, additive noise and attenuation etc. Distortion refers to the warping of information which alters the information. The effect of distortion is usually considered being some form of noise. Anything that is added and becomes part of the information is referred to as additive noise. It means that additive noise is contamination of the original information sent to the receiver. When two individuals are talking, the listener might hear other background noise originating from various sources. The effect of distance travelled in weakening the signal is referred to as attenuation; the further away from the sender, the lower the intensity gets until it eventually fades out completely.

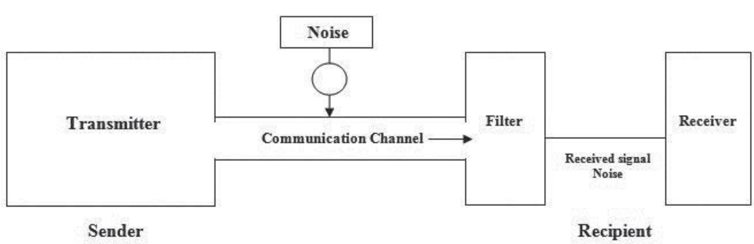


Figure 2.1 basic communication systems (FONG *et al* 2011)

In this chapter, we shall discuss in detail about communication degradation factors. Based on the fact that the data received is most likely not identical to what is sent, we will alter the basic communication system to what is shown in Figure 2.2 which illustrates that noise has been added along the channel. However, it does not mean that addition of noise at the transmitter or receiver end cannot occur. A simple equation to explain the process of communication can be written as:-

$$\mathbf{r(t) = s(t) + n(t)} \longrightarrow \quad 2.1$$

n(t) might be in different form but it will reduce the quality of information received. In extreme scenarios, the receiver might not be able to interpret the information received correctly due to severe corruption. A filter is normally added to eliminate the noise but its effectiveness will fluctuate according to the system used and the situation. Telemedicine systems can transfer information at varying distance. Information can be transferred within a gadget or within an integrated circuit (IC) chip by several micrometers. Information can also be transmitted a few hundred kilometers around the globe. The channel may be 'wireless' over the air or in the form of copper conductors that have connection with the transmitter and the receiver. Irrespective of what the channel is, the main concern will be maximising the speed of transmission as more data can be transmitted within a period of time. This situation is analogous to running a bus company whereby the organization accommodates as many passengers as possible to maximize its utilization. It will make a difference to the organization when there are 5 passengers and 50 passengers at a time. In the same manner, a communication channel should attempt to channel as much data as possible. (Shannon 1948), (WEAVER 1949), (CHIANG et al 2007) has examined the effects of noise on the maximum transmission speed of a communication channel. Shannon's research is worth mentioning to understand the effect of speed of transmission on the performance of telemedicine applications. Before we proceed further, we shall have a look at the ‘transceiver’- a gadget which can simultaneously act as a transmitter (**Tx**) and a receiver (**Rx)**, which will be used throughout this study.

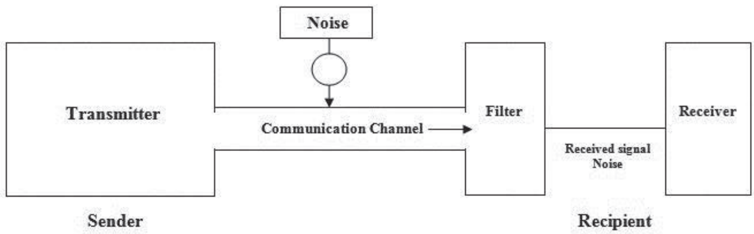


Figure 2.2 Communication systems with noise
(FONG *et al* 2011)

2.1.1 Communication (Wired vs. Wireless)

Technological advancements have solved various reliability and security problems which are traditionally associated to wireless communication. Therefore, wireless communication is no longer limited to low-cost critical application and thus it is gaining popularity lately. The choice of going wireless is driven by mobility and convenience factors. A comparison will be made between wired and wireless communications that is wide used all over the world. During the mid-nineteenth century, telegraphy was invented, which sparked the decade’s use of wired communications (Bellis, 2008). Bell and Gray invented the first telephone in which a microphone is used to attain an individual’s voice and a speaker will then reproduce the voice. Then, the audio signal which has been detected will be transmitted through a wire that joins two telephones. Such is the foundation for using electric wires for telecommunication purposes. Before the invention of telephone, telegraphs were visually sent through a line of sight (LOS) communication channel using wired communications by (Chappe C 1974). The 'line-of-sight' here means that the receiver will be able to 'see' the transmitter, unbarred; if you are at the receiving antenna, you should be able to see the transmitter's antenna either with your naked eyes. Depending on the distance that separates the transmitter and the receiver, you can also see by using a pair of binoculars depending on the distance that separates the transmitter and the receiver. Nevertheless, compared to visual LOS, radio LOS is slightly broader. This is because the radio horizon extends beyond the optical horizon since radio waves will move in a slightly curved path in the atmosphere. The combination of telegraphic and LOS communication technology pave the way for the beginning of optical communications. In the 1870s, Tindall J. found that light followed a curved water jet as it was poured from a small hole in a tank. This discovery led to the idea of keeping travelling light within a curved glass strand (Hecht, 1999, 2004). Subsequently, the efforts by these inventors become the foundation of wired communication technology which has evolved over an era. Currently, the reliability rate of wired technology is not less than 99.999% which means that rate of failure is not more than 0.001% each time or lower than 5.5 minutes per year. Section 2.1.2 will provide a comparison between the two main types of wires for communication; electrical conductors and fiber optic cables. According to (Garratt 1994),(BOWERS 2001) wireless technology was discovered back in 1887, almost as early as the first telephone. Hughes, D.E. and Hertz, H. had experiment by using a spark gap transmitter to generate and their research become the foundation of radio broadcasting by forerunners Faraday, M and Marconi G in the late 19th century. Television broadcasting began in the 1930s, thirty years after the discovery of the first radio. In 1941, New York and Pennsylvania were the first places where commercially licensed television stations were first introduced. In 1984, the first electromechanical television was used in Germany (Sogo, 1994). Both, television and radio broadcasting are 'simplex' communications; one way communication systems. During the

World War II, a two-way radio communication was utilized. However, it was only after World War II that commercial use of a two way communication system became popular.. Stubblefield, N.B has a US patent over his wireless telephone in 1908 but mobile phones became extensively accessible from the early 1980s after the Federal Communications Commission (FCC) approved the Advanced Mobile Phone Service (AMPS) system. However, till today the perceived development of wireless communication is not apparent to end users since it only allow users to verbally communicate among one another without any extra features.

In 1991, '2 G' Global System for Mobile communications (GSM) started in Europe. Since 1993, 2G technology supported text messaging. Not long after that 2.5 G and 3 G support many new functions such as Internet surfing, Multimedia Messaging Service (MMS) and video call. Therefore, over the past decade wireless technologies have developed tremendously and it is all related to 'speed' of transmission. Transmission speed will be discussed in sub-section 2.1.3. Hence both wired and wireless technologies have evolved over the past century and at present both are much more matured technologies. A summary of the elementary properties of wired and wireless technologies are listed in the Appendix.

Both wired and wireless technology is also categorized as 'guided' and 'unguided' media, respectively. As shown in Figure 2.3., information running along a cable is 'guided' through a fixed path which is the cable itself. On the other hand, in wireless communication, information does not under a fixed guidance, hence it is known as 'unguided'. In conclusion, based on its usage in telemedicine application, for short distance transmission, wired communication is more reliable and cheaper. Wireless communication is more convenient as it has a high mobility and flexibility in transmission. Telemedicine applications normally use wireless technology as mobility is highly sought after- everyone despises the idea of having wires tangling all over the body.

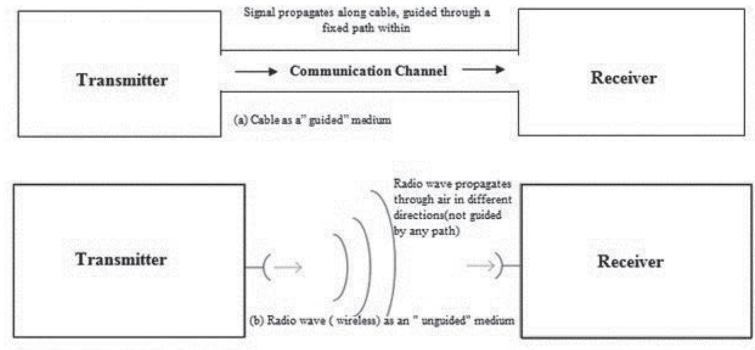


Figure 2.3 transmissions medium between Guided and unguided (FONG *et al* 2011)

2.1.2 Metal Conducting Cables vs. Optical Cables

Undoubtedly, mobility is a major concern for the governance of wireless communication in telemedicine applications. However, it is crucial to understand the principle properties of metal conducting cables and fibre optic cables as they remain highly utilized in particular sectors for instance the network backbone or relation between fixed devices. Now let us examine the way these cables transmit data and compare their properties to study how they are best suited for certain applications. By examining the 'twisted pair' cable as shown in Figure 2.4, we can briefly study the use of metal conducting cable. The figure illustrates two insulated wires coiled with one another in a helical fashion. Computer and telephone networks normally use this type of copper wires. Information is conveyed in a simple manner where a specific voltage means logic '1' and another voltage level represent logic ‘0’. The accurate exhibition relies on the specific encoding mechanism utilized but we assume a positive voltage denotes a ‘1’ while the absence of voltage (0 V) is represented as ‘0’. I. Therefore, transmitting information is fairly fundamental in which the cable carries a voltage that alternates between a positive voltage and a 0 V when relaying a sequence of ‘1’s and ‘0’s. Here, optical communications also operate in an identical manner. Figure 2.5 shows that if ‘1’ is transmitted, a light beam travels through the centre core. In contrast, ‘0’ is represented by the lack of light. As such, the light beam which is emitted at the fibre optic cables end will be in a succession of on and off. Usually, process of switching from on and off is too rapid to be noticed by a human eye. Thus, it may appear as always being on. Since the cable is bendable there must be some kind of mechanism for retaining the light within the cable’s core- a cladding that surrounds the centre core as depicted in Figure 2.5. The cladding is made of a highly reflective material which prevents light from escaping by reflecting the light back into the core.

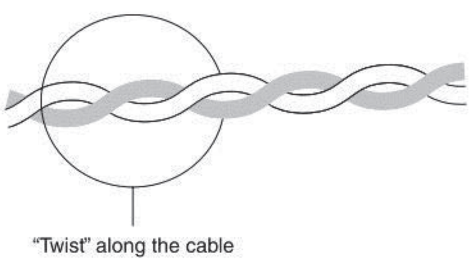


Figure 2.4 Twisted cables (FONG *et al* 2011)

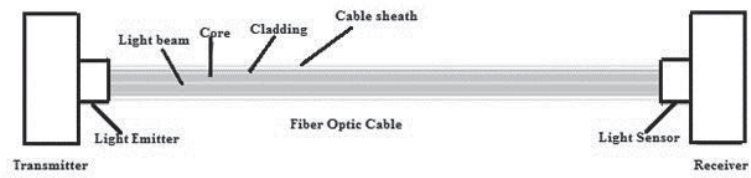


Figure 2.5 Fiber optic communication systems
(FONG *et al* 2011)

In the two scenarios, the presence or absence of a feedback determines the transmission of '1's and '0's across a cable. Nevertheless it must be noted that in reality what happens behind the scene may be complicated but the discussion above illustrates the process in which transmission takes place. There are some types of cables which are frequently utilized in wired telemedicine networks. One of the metal conducting cable is called the 'co-axial cable' which is no longer frequently used with telemedicine applications but will be mentioned briefly as it is still used in many applications especially in decoding boxes and TV antennas. Its main component is the centre core conductor, in almost the same structure as fibre optic cable, surrounded by another group of metal conducting strands and separated by an insulator. A major problem revolving this cable is that it is bulky. Other types of wiring include a couple of wires running in parallel. There are two major types of fibre optic cables namely glass and plastic fibres. The main difference is the cost and performance. Generally, glass fibres fair in terms of transmission rate and reliability but the plastic fibres are comparatively cheaper per unit length.

2.1.3 Transmission Speed of Data

'Bandwidth' specifies the quantity of data a particular channel transmits and it is crucial to fully understand it in any form of communications. The bandwidth is fixed for a channeled. A general guideline highlights that a higher bandwidth will support a higher information rate. As a particular transmission medium's bandwidth is fixed, data transmission rate can be increased by adding more bits into one 'band'. A tally of the number of changes of electronic states per second is referred to as a baud. For an instance, a copper cable of 1k baud changes the voltage 1000 times in one second. A crucial fact is it does not essentially mean that it just transmits 1000 data bits per second. This is explainable by examining several mathematics equations, even though we will not probe into the concepts. A specific number of distinct signal levels L is referred to each baud or shift of signaling state in one second. For instance, the voltage levels of 0.5 V and 1.0 V. These distinctive levels can be represented by combinations of binary bits. For example "01" and '11' represent 0.5 V and 1.0 V respectively. A direct relationship exists for the the number of bits (n) for every baud:

$$n = \log_2 L \longrightarrow \quad 2.2$$

Or:

$$L = 2^n \longrightarrow \quad 2.3$$

Thus, in this specific example, there are two bits (n = 2) and four dissimilar levels (L = 4) each one indicated as '00', '01', '10', and '11'. Moreover, the data transmission rate (or bit rate), counted in number of bits per second or bps might be expanded for a given fixed baud rate by utilizing more diverse signaling levels as more bits can be transmitted by every baud. Bandwidth is a significant term in illustrating the data transmission rate that is supported by a particular channel. It denotes the band of frequencies that an electronic signal uses while disseminating data over the channel. Thus, when measuring the bandwidth of a specific channel, it is often measured in hertz (Hz) which depicts the difference between the maximum frequency and the minimum frequency used. For instance, a phone channel transferring voice data between a maximum frequency of 3 400 Hz and minimum frequency of 300 Hz has a bandwidth of 3.1 Khz. Hence to explain the correlation between a channel bandwidth and data transmission speed, *SyQuest* theorem points out that the bit rate R b of a channel of bandwidth **H** is:-

$$R_b = 2.H \log_2 L \longrightarrow \quad 2.4$$

Hypothetically, this is highest data transmission rate a channel is able to reach. A real communication channel may have lower bit rate than this due to several factors. Previously it has been discussed that utilizing more diverse levels will enable more bits to be transmitted by each one change of signaling state to enhance the efficiency of the transmission. On the other hand, having more distinct levels would press the signaling levels closer together. For instance, in the example mentioned earlier, each stage is 0.5 V. We utilize eight levels to represent four bits for every level instead of representing two bits. This way, we may lessen the division between the levels from 0.5 V to just 0.25 V. The most critical issue here is that signaling levels may overlap due to the noise. The noise level **N** relates to the minimum division between two levels before the noise causes errors to cross the border of the neighboring level. The equation below gives the maximum number of levels L, in which refers to the maximum or peak signal power level.

$$L = \sqrt{\frac{S}{N} + 1} \longrightarrow \quad 2.5$$

Generally, the maximum data transmission rate R b is directly proportional to peak signal power S, and inversely propositional to channel noise N. An idea communication system must deliver the best possible transmission rate with the least power consumption with minimum noise. With reference to the equation above, a fundamental theory about the speed of data transmission has been attained.

2.1.4 Electromagnetic Interference

Wireless communications does have significant disadvantage which is EMI (electromagnetic interference) as the EMI impact is considerably more challenging than with wired cables. Here, wireless transmitting gadgets can drastically influence the manipulation of some sensitive medical gadgets. As such, the impact of EMI is especially dangerous in medicinal services applications. (Tikkanen 2005a), (tikkanen 2009b), (ho 2012) has explored different methods of managing the effects of EMI in healthcare services to guarantee reliability of the gadgets used. Some of the methods include using a suitable casing for medicinal instruments that can successfully shield the device from getting unwanted interference. A wide variety of composite materials may be useful to achieve this purpose. Metalized plastic materials are capable of being transformed into virtually any shape and possess the advantage of providing substantive shielding despite being light weighted. These qualities make them apt in housing numerous kinds of devices. There are three potential issues those results in EMI:-

- source radiating noise,
- receiver grabbing noise, and
- Coupling channel between source and receiver.

All wireless transmitting gadgets such as cellular phones and laptop computers are susceptible to EMI from proximate radiating sources. Such interference initiates capacitive coupling where energy is stored up inside the circuit and hence, affecting the electronic circuitry. This generates a wavering electric field that may be capacitive coupled to adjacent gadgets. There are two major forms of EMI; continuous and transient interference, which may be a result of thunderstorms provoking Lightning Electromagnetic Pulse (LEMP) or swapping of high current circuits. The continuous interference is initiated by emission of radiation in a consistent manner from nearby sources, for example, other medical devices or transmitting gadgets. Transient interference is intermittent, where sources radiates for a short time. These might be set off by thunderstorms initiating Lightning Electromagnetic Pulse (LEMP) or turning on high current circuits. The International Electro Technical Commission (IEC) manages standard regulations regarding EMI while the Comite International Special des Perturbations Radio Electriques (CISPR) or the International Special Committee on Radio Interference, manages concerns related to radio. The "CE" mark, which is often found on electronic items that include healthcare and medical equipment, denotes Conformit'e Europ'eenne (or 'European Conformity). Items bearing the "CE" stamp proves the item conforms to the European Directives that oblige Electromagnetic Compatibility (EMC) tests to be carried out to assure that a particular item fulfill the European Union (EU) directive 2004/108/ce prior to its legitimate release into the market in any component countries of the EU.

2.1.5 Modulation

Modulation is a process in which a 'carrier signal' which gives the energy needed for the data to be transferred to the receiver is modified somehow with conformity to the information to be transferred. This is basically a method of cramming information into a signal for dissemination. Certain parameter(s) of the carrier signal is changed to reproduce the information to be transmitted for instance, in FM (frequency modulation) radio broadcasting the frequency of the carrier signal is altered according to the voice information. The receiver (radio) interprets this alteration of frequency as the voice carried over. In its original form, criterions that could be altered are inclusive of the frequency (number of oscillations per second), amplitude (the signal level) or the phase (the signal's relative position to time). More than one parameter can be changed at a time in complex modulation procedure so that more data can be represented in every baud. Hence, this method will increase the efficiency of the transmission. Generally, a more complex receiver's electronic circuit structure is required for higher spectral utilization efficiency (SUE), as the difficulty differentiating between different possible categories of the signal increases. SUE measures the efficiency of a modulation scheme in transmitting a certain load of data for a fixed bandwidth.

2.2 Types of Wireless Networks

The development in the wireless communications has paved the way for many options to be opened. Different types of networks are developed for diverse purposes, with a coverage stretching from a few metres to thousands of kilometers. This segment will discuss the common networks that are used in telemedicine applications as well as explain the reason each network is best suited for particular circumstances. Table 2.1 outlines the key properties.

Network Type	Frequency Range	Speed	Maximum Range
Bluetooth	2.4–2.485 GHz	3 Mbps	300 m
IR	100–200 THz	16 Mbps	5 m
Wi-Fi	2.4–5 GHz	108 Mbps	100 m
ZigBee	900 MHz	256 Kbps	10 m
Cellular Networks	850–1900 MHz	20 Mbps	5 km
WiMAX (Fixed)	10–66 GHz	1 Gbps	10 km
LMDS	10–40 GHz	512 Mbps	5 km

Table 2.1 Properties of some common wireless systems
(FONG *et al* 2011)

2.2.1 Bluetooth

Bluetooth technology provides confined coverage in room mobile equipment connected in an ad hoc system known as "piconet”. The main advantage of Bluetooth is low power utilization and minimal cost requiring simple hardware. However, the disadvantage is the risk of spreading computer virus due to its flexibility in connecting gadgets which are close together. Bluetooth utilizes adoptive frequency hopping (AFH) which recognizes other gadgets in the range and hops between 79 frequencies at 1 MHz intervals to reduce EMI. By doing so, it keeps away from the frequencies used by close-by devices. Bluetooth innovation is directed by the Bluetooth Special Interest Group (SIG). Currently, there are three divisions which cover distances around 3 meters, 30 meters, or 300 meters. Despite the fact that it is generally used in hands-free units of mobile phones, it is convenient for tiny wearable bio sensors because of the use of cheap simple transceiver or low power usage which is 1 milliwatt for 3 meters or 10 feet, Class 3.

2.2.2 Infrared (IR)

Infrared waves are located between microwaves and visible red light in the spectrum. The sun emits an appreciable amount of infrared radiation that is associated with heat. An almost equivalent amount of visible light and infrared from the sun will hit the surface of the earth. Let us examine how these rays affect communications and healthcare. Generally, the application of infrared waves extends to detection by night vision which is significant in search and rescue operations. Common uses of infrared waves in wireless communication include the control of home appliances using a remote device. When we use the remote control to adjust the volume of a stereo, the controller discharges an infrared signal that conveys the instruction to the sensor in the stereo. The International Commission on Illumination (CIE) classifies infrared into three separate categories, of which near-infrared or IR-A is utilized in night vision applications while short-wavelength infrared (IR-B is used in wireless communications. Infrared waves of short wavelengths are used extensively in long range optical communications. However, this study shall not dwell into the details of this and concentrate only on wireless networking. The Infrared Data Association (IrDa) manages the IR wireless guidelines for gadgets that use the progressive "on" and "off" of an infrared Light Emitting Diodes (LED) for communication. A silicon photo-diode at the receiver alters the received infrared pulses to an electric current reproducing the sequence of "on" and 'off'. This is a developed innovation that has been used for years and quite simple to use without any interference issues. However, it cannot pass through walls. In addition, a direct LOS is prerequisite and the transmitter must be placed fairly near the center of the sensor with just + /- 15° offset possible. Even though the present IrDa compatible devices are only able to support speeds up to 16 Mbps, the adoption of Giga-IR offers a hypothetical transmission speed of up to 1 Gbps. It is frequently used in small ECG fragment transmission.

2.2.3 Wireless Local Area Network (WLAN) and Wi-Fi

The IEEE 802.11 guidelines are quite broadly used in wireless home systems, providing convenient access to the internet at minimal cost to the user. WLAN is different from Bluetooth and IR, and it requires a few deliberations in configuring the initial requirements before a communication link could be initialized. Popular IEEE 802.11 guidelines include a/b/g/n; these norm values describe the specifications for the physical layer 'PHY' that defines how raw data bits are transmitted over the air and the WLAN's Medium Access Control Layer 'MAC' that provides address and channel access control methods which permits numerous gadgets to correspond with each other via a single Access Point.

Besides the 802.11a which clocks at speeds of around 5 Ghz, the remaining three standards are running at 2.4 Ghz. Being confined to this frequency band, interference may occur due to other appliances adopting similar frequencies, for example microwave ovens, cordless telephones and other Bluetooth devices. Depending upon its usage, the coverage area of WLAN fluctuates enormously- namely indoor or outdoor usage ranging from 50 to 300 meters respectively. The construction of a basic WLAN connection generally comprises of one access point (AP) at the least, which one or several mobile client(s) (MC), tries to establish a communication to the network through the AP. MCs are fundamentally any mobile gadget that is able to establish this communication. A wireless networking infrastructure is formed when the APs are set in different locations throughout the broadcasting area. In a basic configuration of WLAN there is one AP in the focal point surrounded by one or more MCs. The network coverage zone could be expanded by fitting more APs or installing a relay device. In a situation whereby there are many Aps, a MC picks the closest AP that is able to provide the best signal quality when the connection is established. Wi-Fi, or Wireless Internet, provides a unified standard derived from IEEE 802.11 WLAN by the Wireless Ethernet Compatibility Alliance (WECA) for distinctive types of wireless devices. APs are also known as 'hotspot' which is generally functioning as connection distributors. Wi-Fi and Bluetooth are similar in numerous aspects, however differences exists because of tradeoffs between data speed, coverage and power consumption. As such, these lead to difference in device cost and size. In home networking, Wi-Fi technology is ideal and is quite adopted in situations of off-site patient monitoring for individuals who are recuperating at their own homes, whereby home networks can be conveniently utilized with little alteration.

2.2.4 Zigbee

ZigBee is a tiny digital device used for WPANS (wireless personal area networks) which complies with the standards outlined by IEEE 802.15.4. ZigBee is simple to use and consumes little power. However, it cannot be used for intensive information transfer because of its slow speed. As such, its functions are limited to wireless control and monitoring. As of now, a worldwide standard operating frequency does not exist for ZigBee. 950 Mhz is used in Japan, 915 Mhz in USA, 868 Mhz in Europe and 2.4 Ghz in many parts of the world. It is often seen as a basic adaptation of Bluetooth and is regularly utilized in System on Chip (Soc) implementations. It is extremely cheap to the extent that a transceiver can be purchased for less than US$1 for every unit. It is also usually utilized as a part of security mechanisms, for example in smoke detectors and remote control for air conditioner, as well as body area sensor networks (as stated in Section 3.5). Zigbee Coordinator (ZC) serves the communication network while the Zigbee Router (ZR) transfers information between the gadgets

2.2.5 Cellular Networks

Mobile phone system is usually identified as cellular networks since the coverage region is made out of radio cells whereby every single one is served by a Base Transceiver Station (BTS). The BTS functions as directed by the service operator and as supported by the cellular technology. Coverage area can be upgraded by creating additional cells. The use of cellular composition extends the capacity and lowers the usage of power during transmission besides enhancing the coverage area. One of the key features of cellular networking is the ability of the users to move across cells without breaking connections which is achieved by "handover" algorithms.

There are arrays of diverse technologies which are currently being used around the globe. We shall discuss briefly the technologies that are in use today, while omitting outdated frameworks for example Time Division Multiple Access (TDMA) and Advanced Mobile Phone System (AMPS) cellular technologies. CDMA1900 (1.9 Ghz) represents Code Division Multiple Access 1.9 Ghz. At the moment, USA still make use of an old digital cellular communication system as there are only a few operators who are authorized to operate at 800 Mhz before the FCC approval for 1.9 Ghz. CDMA can support multiple concurrent base stations which are on the same frequency channel.

2.5 G (900 Mhz): GSM Phase 2 + (Global System for Mobile communication) which is verified by the European Telecommunications Standards Institute (ETSI) is a system generally used all over the world as it offers easy roaming across the nations with one single cellular phone. General Packet Radio Service (GPRS) is an extension of 2.5 G which supports an extensive variety of multimedia services at a slow speed up to 114 Kbps. The type of services is legislated by an Access Point Name (APN) which define services for example Wireless Application Protocol (WAP) access, Multimedia Messaging Service (MMS), Short Message Service (SMS), Point-to-focus (PTP) and Internet access.

3 G (1.8 Ghz): Third Generation technology that is an improvement on the earlier 2.5 G version and has a maximum speed of 14.4 Mbps. The main characteristics of 3G are mobile TV broad casting and video calling. There are diverse interface networking systems that are accepted by the ITU (International Telecommunications Union) IMT-2000 as 3 G networks. The prominent ones are Mobile WiMAX and UMTS (Universal Mobile Telecommunications System) that is otherwise called W-CDMA where W signifies Wideband. The Mobile WiMAX is named under 'Worldwide Interoperability for Microwave Access' and is developed from the IEEE 802.16 Broadband Wireless Access (BWA) standard. UMTS is a substantially more developed and generally used technology and is an immediate upgrading of 2.5 G that basically developed from previous accessible mobile technologies. An enhanced adaptation generally denoted as 3.5 G was introduced in 2006 as High Speed Downlink Packet Access (HSDPA) which can support over 20 Mbps. In the year 2012, this is expected to be upgraded to 4 G with 100 Mbps and upgraded security features. In between the 2.5 G and 3 G version there is a technology frequently known as '2.75 G'. Although, this version is not regularly used but most people are familiar with CDMA2000 and EDGE (Enhanced Data rates for GSM Evolution). These are developed from CDMA1900 and GSM Phase 2+. However, these versions are often wrongly categories as 3 G because their expanded information capacities supports 2.5 G systems.

PHS (1.9 Ghz): Personal Hand phone System is popularly used in Japan only because of its low power usage and does not require a SIM card. The system is primarily intended for its voice calls with data support until 256 Kbps. Nevertheless, PHS is gradually being phrase out by 3 G networks.

2.2.6 Broadband Wireless Access (BWA)

BWA can support a wide range of services because of its ultra-high speed. Generally BWA is adopted for medium to long range distribution and the carrier frequency can vary between couples of Ghz to 40 Ghz based on local bylaws. The development of BWA is legislated by the IEEE 802.16 Working Group on Broadband Wireless Access Standards. However, IEEE 802.16 does determine the prerequisites of frequency bands or certification of equipment. Fixed or portable WiMAX operating at 2.4 to 5 Ghz ISM band is compatible with both IEEE 802.16e and ETSI HiperMAN wireless. A metropolitan Area Network (MAN) principle which covers several kilometers is gaining popularity as of late because of its high level of interoperability. Local Multipoint Distribution Service (LMDS) which is a common BWA operation is used for fixed networking which implies that mobility support is very constrained. The major distinction between MNDS and Fixed WiMAX is the operating frequency which paves the way to a significant enhancement in channel bandwidth. LMDS is able to support over 512 Mbps for transmitting large amounts of data. Since the radios possess a 90˚ field of view, it is practical to utilize four radios for omnidirectional 360˚ coverage. The features of LMDS make it especially suitable for telemedicine backbone support. The expression "backbone" denotes the medium which accommodates a major trunk line for interconnecting an array of local area networks (LANs) and also equipment over a vast area. For instance, an organization such as a hospital may have numerous buildings which represent different units that are interlinked to a network backbone as indicated in Figure 2.6.

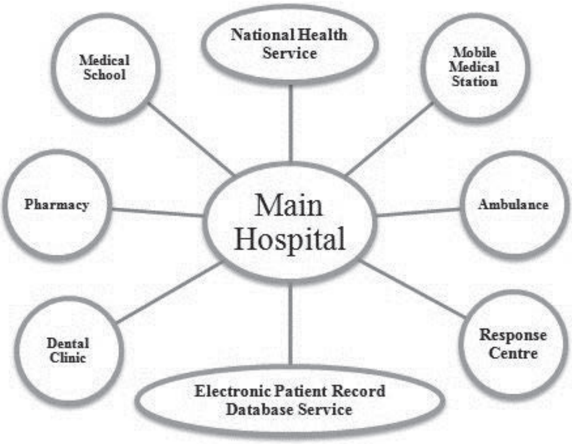


Figure 2.6 Network connecting the hospital

2.2.7 Satellite Networks

These are more advanced and costly networking as launching a satellite accurately above the earth is an expensive affair. However, its operating guideline is uncomplicated. A communication satellite or 'comsat' is placed into a pre-determined orbit above the earth. The orbit of the satellite will depend on the preferred coverage area. The comsat functions as a point-to-point microwave radio relay which facilitates a radio connection between two distinct Earth stations. Satellites are often utilized in WAN (wide area networks). Although a satellite cannot withstand natural interference for example solar storms, it is indeed very reliable and gives appreciable speed interfaces. Despite the fact that such features may seem apt for remote robotic surgery considering the endless amount of data which need to be transferred; it is not suitable since its integral long propagation delay will probably influence instantaneous operations. Therefore, satellite networking is mostly utilized for remote recovery.

2.2.8 Frequency Bands between Licensed and Unlicensed

Some networks utilize licensed bands while the other networks are unlicensed and they shared the band with multiple users. Hence the effect of licensed and unlicensed frequency on telemedicine operations is to be discussed further. Any telemedicine application can function in both licensed and unlicensed frequency bands and according to (Dekleva et al 2007), (yan et al 2010),(zhang et al 2011) which is a better option depends on the situation at hand. Firstly, an unlicensed network does not experience any delay or incur any cost in getting a license. Moreover, an unlicensed connection is easily created and can be done by anyone with no limitation on the kind of radio gadgets being used. However, since everyone can access the gadget is at high risk of interference and security breaches. On the other hand, licensed networks will function within designated bands with restricted usage so the devices can highly personalised to the exact requirements of the users. Licensed frequency bands have protection against inference although a 100% guaranteed bandwidth availability and 100% assurance against interference meaning an interference free environment cannot be attained. Therefore, one has to negotiate between convenience and cost with security and operating environment. In conclusion, there are several kinds of wireless networking which can be used for an array of telemedicine functions, each with its own benefits and drawbacks. A particular selection on the type of wireless networking will be based on its performance and features as the type of services obtained can extensive. Normally users will opt to make use of an existing network to reduce cost and time taken to set up. The advancement in communication technologies enables more selection to be made available in future and telemedicine application will be more accessible and reliable to be utilized by people with different needs.

2.3 Operating Outdoor

The impact of electrical noise emitted by the gadgets nearby may be very prominent as the signal strength will weaken in relation to distance travelled (attenuation), Transmitted signals can be lost or corrupted if the noise is very severe resulting in the data to be useless. At the same time, beside the noise and attenuation, distortion of the signal can be a problem as data travels through metal conductors. Distortion happens in many ways and is subjected to the kind of obstacles that lie along the signal path. Normally, the shape of the signal is distorted for instance when a square wave can no longer maintain its smooth pulse. Even though, the problem of signal propagation does happen indoors, there are more factors which are beyond control in the outdoor environment which makes more signals degrade severely.

The yardstick that measures the signal loss in a transmission link is the loss which is predicted to happen in a free space meaning the loss which happens along a path which is free of everything that might reflect or absorb signal energy. If a radio wave which is being transmitted hit a physical obstacle it will be subjected to the phenomena as in Figure 2.7: -

i. **Diffraction**: a signal will split into secondary waves. Diffraction will happen if a propagating signals strikes a surface which sharp edges. The waves emitted by the surface will be present in space and some fraction of the waves may penetrate behind the obstacle and create a power loss. A phenomenon of waves bending around the obstacle will occur.

ii. **Reflection:** a signal will be reflected back to the source, which is the transmitting antenna, using the same principle as a mirror reflects light. Reflection is cause by a propagating wave which is much larger than the wavelength of the carrier that hits a physical object.

iii. **Scattering**: a signal will reflect with different parts spreading in various directions if the signal becomes diffused upon encountering an obstacle. Scattering is different from diffraction. Scattering occurs when the propagating wave hits an object that is smaller compared to its wavelength for example air pollutant particles, dust, rough surfaces and other irregularities in the channel. As the signal scatters in multiple directions, it will provide extra energy as recognized by the receiver. Therefore the signal received will be more substantial than those affected by diffraction and reflection.

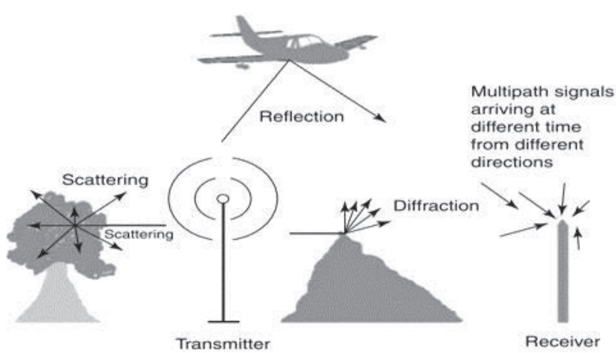


Figure 2.7 Factors in the spread of the wireless signal degrades different results (FONG *et al* 2011)

These will cause a lost in signal strength which is termed as fading. This impact can be overcome by utilizing numerous antennas to pick up different parts of the same signal which arrives from various directions. This kind of method is known as 'space diversity'. Using multiple antennas can solve the problem since different components of a signal are subjected to different phase shift, time delay and attenuation. An antenna may encounter severe fading and be unable to gather a signal efficiently but the usage of many antennas will boost the chance of gathering a clearer version of the said signal. Outdoor transmission faces more problems since the signals have to clear large physical objects for example trees and buildings. As for the visual line-of-sight, even in situations whereby a person can look from one position of an antenna to another, it does not necessarily mean a radio line-of-sight also occurs particularly in scenarios of long distance communication. Radio waves actually require some space to reach the receiver and the wave will not be able to "squeeze" pass a tiny hole drilled in the wall. It actually needs a clearance of the Fresnel zone which is a long ellipsoid stretched between two antennas. The first Fresnel zone refers to the spheroid space enclosed within the orbit of the path when the discrepancies between the straight line directly drawn between the two antennas and the indirect path that crosses a single point at the edge of the Fresnel zone, with half the wavelength. The area is a spheroid space required for the wave to be transmitted towards the receiving antenna centered along the direct straight line path between the antennas. For instance if the signal frequency is 30 GHz then by applying the formula (Equation 2.6):

$$v = f.\lambda; \qquad \lambda = v/f \longrightarrow \quad 2.6$$

If the speed of radio wave transmitted through free space is roughly 3×10^8 m/s, the wavelength λ would be $3 \times 10^8 / 30 \times x10^9 = 0.01$ m or 1cm. Therefore, half wavelength is 5 mm. The wave will reach the receiver by a direct straight line path and within a spheroid area of 5 mm. In order to achieve propagation in free space at least 60% of the first Fresnel zone should be clear of any physical obstacle. Besides that, in order to estimate the path loss or attenuation, the terrain profile around the spheroid area has to be taken into account and this can be carried out using well-established models such as the Longley-Rice Model (Hufford, 1999), (phillips et al 2011) whereby the median of the transmission loss can be projected using the geometry of the terrain profile and the refractivity of the troposphere. An Urban Factor (UF) can be used to calculate any additional attenuation caused by urban clutter encircling the receiving antenna. This model can be efficiently sued as an irregular terrain model (ITS) but the effects of buildings and foliage are not taken into consideration. In order to optimize the propagating path for long distance communication which exceeds 5 to 8 kilometers, the curvature of the earth has to be taken into account. The transmission loss varies according to how much power finally arrives at the receiving antenna. Attenuation has to be given due consideration as the signal will finally become too weak to be picked up by the receiver. At the same time, the reliability and range of wireless telecommunication systems are effected by weather conditions for example snow, rain or fog. In tropical areas consistent heavy rain exceed 100mm/hr and lasts for hours. Hence, the impact of rain on attenuation has to be considered as the dB/km. Measurement of attenuation shows the power loss in dB per kilometer of distance travelled. There are several factors that has an actual impact especially the rainfall and the frequency of the carrier. Generally, the higher the frequency and/ or the heavier the rain is; more power will be lost per kilometer. Nevertheless, attenuation induced by rain is not a main issue if the rainfall is below 20mm/hr if the r system is operating under 10 GHz. Figure 2.8 shows the comparison between the attenuation for 10 GHz and 50 GHz. It is important to take note that the signals of horizontal polarization will experience a higher degree of attenuation than vertical polarization under a similar situation. Figure 2.9 also shows that the difference between two polarizations also increases as the frequency and/or rainfall increases. A heavy rainfall on radio propagation path will reduce the availability of the system as the rain causes cross-polarization interference which will eventually reduce the polarization separation between signals of vertical and horizontal polarizations as they are transmitted in the rain. Radio link performance degradation can be measured by cross polarization diversity (XPD) which is calculated by the degree of coupling between signals of orthogonal polarization. (Bahlmann 2008) and (Fong 2003a) defined XPD as a measurement of the strength of a co-polar transmitted signal which is received cross-polar by an antenna as a ratio to the strength of the co-polar signal that is received which will normally result in a 10% reduction in coverage due to cell-to-cell interference. Although, it is logical to use horizontally polarized signals to evade unnecessary power loss, section 3.1 will explain why much system use both horizontally polarized and vertical polarized simultaneously.

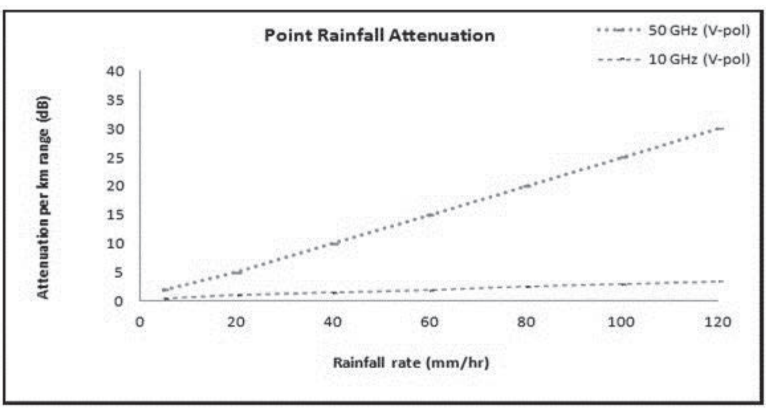


Figure 2.8 Effect of rain attenuation at different rainfall rate (FONG *et al* 2011)

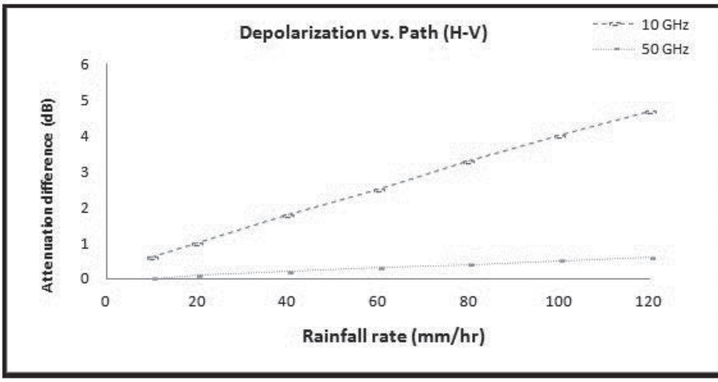


Figure 2.9 Horizontally polarized signals undergoes more severe attenuation than vertically polarization signals in a similar situation (FONG *et al* 2011)

Channel degradation that is caused by rain must be dealt with properly in telemedicine since accidents happen frequently due to heavy rain. Therefore, telemedicine systems which help during emergency rescue operations must be able to provide quality services. According to Fong (2003b) optimizing the system margins of the particular application will maximize the availability of radio link in related conditions. Multipath fading is a feature that results from multiple parts of a signal arriving at the receiver from different directions of arrival (DOA) at varying time because of reflection through various physical barriers along the propagation path that causes a varying amount of delay as shown in Figure 2.10. The straight-line unobstructed path having LOS will be the shortest path between the transmitter and receiver. When the propagating signal hits a barrier it will be spread out and take multiple paths which results in varying travelling time to reach the receiver that causes different amount of time delay. Multipath is normally a problem with signals below 10 GHz. On the other hand, attenuation due to rain is a critical factor at frequencies above 10 GHz. Therefore, lower frequencies are preferred in tropical areas whereby there are heavy and constant rainfalls. On the other hand, systems with higher frequencies are generally used in less crowded section of the range which has more bandwidth available. Besides that, Doppler Spread also causes delay in wireless communications whereby the fluctuations are caused by the movement of the receiver, transmitter or some physical objects which are in between them. Doppler Spread is predominantly significant in vehicular communications whereby signal reception is affected by fast movement.

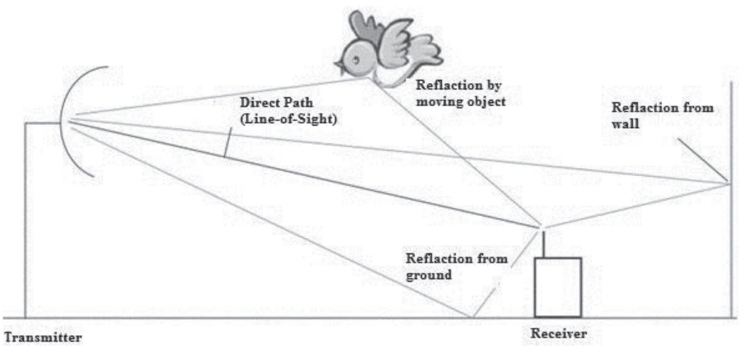


Figure 2.10 Multipath fading caused by different parts of a signal arriving at varying time through different paths
(FONG *et al* 2011)

2.4 RFID in wireless Telemedicine

Radio Frequency Identification (RFID) is an aged technology which was available since World War II but it has only been used widely in the past decade in many applications which are used daily in our lives. RFID can be used to identify things using radio frequency signals. Therefore, it is recognized as an 'electronic barcode' system. Currently, various types of RFID are utilized everywhere. Actually, RFID needs 'tags' to recognize an item and 'readers' to read and classify the information on the tags. The readers are available in different forms namely portable or fixed readers, active or passive tags which merely means whether an internal battery is required to activate a given tag so as to answer a reader. The purpose of the battery is to provide a longer reading range which reads an active tag from long distance. On the contrary, the passive tag obtains the power required from the reader as it receives the signal from the reader. As such, the passive tag is not equipped with a battery meaning it does not depend on a power origin. When this signal, which carries a certain supply of energy with it, hits the coiled antenna inside the tag it will induce a magnetic field. As a result, this triggers the electronic circuit containing information which is engrained within the tag including a special identification number. The passive tags are affordable, durable, and small and can be fabricated for less than 10 US cents each. It can also be mass produced because the tag is fundamentally a printed antenna with a small chip enclosed with paper. A common layout structure of a RFID tag is illustrated in Figure 2.11. Nevertheless, issues of using the RFID tag in telemedicine applications is not limited to short reading range alone. In fact, it is also unable to supply power to biosensors.

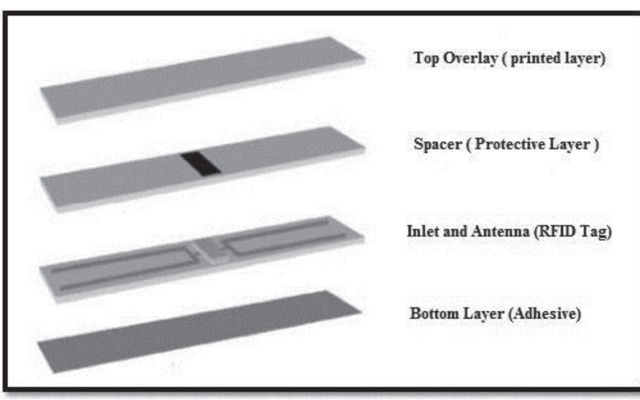


Figure 2.11 RFID tag (FONG *et al* 2011)

The main issue concerning the reliability of RFID is tag collision and reader collision. Tag collision refers to the scenario when a single reader energizes multiple tags which causes the tags to respond simultaneously. This results in reading failure. Reader collision refers to the scenario when the coverage area of one RFID reader and that of another neighboring reader overlaps. There is also an absence of security features since any reader within range can pick up the tag signals. RFID systems can function in different frequency range. The functions of different telemedicine applications may be affected by the RFID's propagation characteristics. With LF (low frequency: 135 KHz) and HF (high frequency: 13 MHz) systems, the power of the signal which is transmitted may be drastically reduced due to reflection of the signals as shown in Figure 2.10. Water can absorb the UHF (ultra high frequency: 900 MHz) systems signal. Hence, it is unfavourable for applications that involve administering tags on a human body. However, RFID is still used in many medical applications such as in drug dispensary for associating patients with prescribed or controlled drugs. Moreover, RFID is also used in tracking medical equipment, babies and patients.

Implanting medical gadgets into the human body is another significant aspect in healthcare, especially gadgets such as Biventricular Pacemaker and Glucometer. Due to the water composition in human tissue, UHF is not feasible to be used. Therefore, security reasons and lofty cost of the readers makes HF a more suitable selection for surgical implantation. The implantation of a biventricular pacemaker requires the implantation of leads through a vein into the ventricle and the coronary sinus vein for ventricle regulation purposes. Since its purpose is to assist patients suffering from severe symptoms of heart failure, any irregularities must be made notified to medical personnel promptly via telemedicine network in order to reduce the dangers of sudden cardiac arrest. Patients with insufficient ejection fractions may need an implantable cardioverter defibrillator

(ICD) and a pacemaker to maintain sufficient heart beats. ICD operates by detecting the rhythm and shocking the heart. As such, this can influence the operation of a RFID tag that is correlated with the ICD. Since the tags associated with an implanted device are closely packed to each other, there is a risk of tag collision. The barriers along the path of a propagating signal include, in order, the lung's anterolateral surface of the inferior lingular segment, rib bone and finally through the skin which is made up of epidermis, dermis, and subcutaneous fat leaving the body at the chest. Here, the barrier layers affect the signal path. The tuning of the antenna is affected by the capacitance between a tag and its housing. A solution to this would be tuning a tag away from resonating at the frequency of a reader. This eliminates mutual coupling with other tags. The use of RFID tags with tunable antenna can enhance the reading range.

The case study above is considerably complicated; we will examine an example that is less complicated such as an implantable glucose meter for overseeing a diabetic patient as documented by (Carlson 2007). Should there be any communication failure, this glucose meter will not have any immediate life threating issues. The RFID tag is able to transfer the readings from the glucometer for analysis. Data has to be immediately transferred upon arrival from the glucometer before it becomes saturated as the data storage capacity of the passive tag is less than 2KB. Hereby, the RFID tag is considerably alike to a mobile phone that utilizes a Universal Serial Bus (USB) cable to connect to a laptop computer as a wireless modem. Here, the mobile phone functions as a medium that delivers data to the outside world. Now that we have an understanding of the role of the tag, we shall examine the system involved. As a wireless transmitting gadget, the tag obtains energy from the incoming wave which is transmitted from the external reader; the received energy must be high enough to trigger the chip. When antenna of the tag returns the signal, it must be capable of making sure that the transmission power is sufficient for the reader. The hurdle is to implant the tag as close as possible to the patient's skin to reduce the distance of signal propagation, while at the same time, we should not allow any immediate contact between the antenna and any internal tissue that may fend off the signal. The selection of housing material for the tag is important as any housing which completely seals it off will avoid direct contact with internal tissue, but may influence signal penetration. Different materials which are suitable for implantation have been described by (Friedman 2001). The optimal wrap for separating the tag and surrounding tissue is polyvinylchloride (PVC) insulator of about 10 μm as it does not result in significant effect to signal propagation.

The glucometer system's structure is simple but the technicalities are challenging as it involves glucose sensing, biocompatible interface, and a gadget to change the input into an electrical signal that can be inscribed into the RFID tag for subsequent conveyance away from the patient's body to the reader. Simultaneously, the device should be set to ensure data stored is sent immediately and the memory content of the tag is emptied before the next set of measurement is taken. As such, the device linking the RFID tag to the glucose sensor must be able to both generate the signal from the captured reading and program the memory of the tag. This gadget must also be very small and consumes low power so that the reader can generate and hoard enough energy to last until the next reading operation. In short, the only thing required is to download the acquired data for consequent analysis and storage. The antenna and related circuitry for the chip must be designed to enable data from within the body is conveyed to the external world. Not only is RFID an identifier, it is also an extremely tiny, economical for implantation and supports short range wireless communications. Undeniably, RFID is versatile and has limitless usage, making it an important for telemedicine applications.

CHAPTER 3

THE WIRELESS TECHNOLOGY IN PATIENT MONITORING

Previously, we learnt there are a variety of wireless networks which can be used by telemedicine services. These networks are designed with distinct properties for specific circumstances. Since these applications may have different requirements, it is hard to determine which networks are the best for telemedicine. After studying different technologies, we know propagation is one major issue being faced by all wireless networks. Compared to wired systems, wireless telemedicine is considerably more popular since it is a fundamental technology which connects people and resources in terms of healthcare. For life threatening situations, technological advancements also enable reliable and secured networks to provide services. Now, we will look at different situations whereby wireless technology can aid patients to recover and rehabilitate. We shall see how it happens and the obstacles involved. The popularity of RFID in most applications allows patients and resources to be easily monitored and detected. The specific design of a network depends on the application it can support which means that it needs to meet the prerequisites that is required to transmit the kind of information involved effectively. As an example, consistent transmission of heart beat and ECG data is required to monitor a ventricular tachycardia (VT) patient in order to make sure that any possibility of a ventricular fibrillation can be detect immediately. This might involve at least 0.05s of resolving QRS complexes separation. Thus, the communication network used must be able to support the data rate needed in any telemedicine system.

Firstly we shall review the challenges and technologies involved in setting up a body area network (BAN) which can be utilized by both the healthcare personals and patients. Then, we shall review a few main applications that are able to monitor patient from afar by using wireless communication technology. Nevertheless, this is not the only deployment option; alternative solution may be available for some of the examples given. The main objective to review some examples to improve the understanding on how telemedicine technologies can contribute in various rescue operations and the obstacles that exist.

3.1 Body Area Networks

Body area network (BAN) or Personal Area Network (PAN) was invented lately when technology permits extremely mini radio transmitting gadgets to be safely implanted in a human. BAN is popular application in the healthcare, and also applicable in IT related stuffs due to its compatibility options. In the healthcare sector, BAN is small enough to be implanted in human body and could act as a detector and responder of various issues that are related to the human body. It could receive and transmit an issue detected in the body. In term of logging, daily chores of human body activities are logged accordingly and a set of requirement can be pre-defined to help in the monitoring of fitness, medical aids and others. This logging information can later be review through remote monitoring by the aid of biosensors that are attached to the user's body. The BAN is capable of monitoring, logging and tracking people who have serious illness or just wish to keep fit. The use of biosensors attached to the user's body will be able to detect potential issues. There are two major elements in the BAN namely:-

a) Intra-BAN for the internal communication - sensors and actuators were attached to a mobile based unit (MBU) functions as an information processing centre. The MBU could be practically any gadgets that we use generally such as hands free kit in the car, a hand phone, or the wireless modem which connects our computers to the Internet.
b) Extra-BAN for the external communication –to establish external communication with the units of the body surrounding and with the exterior world. Typical telemedicine adopts such framework which passes on data that has been retrieved data for analyzing and processing.

The advantages of BAN are power consumption lower than 10 m W and a low data throughput about 10 Kbps. Besides that, many problems have arise from the development of BAN. As for data security, no data protection is enabling in most of the cases thus QoS (quality of service) assurance need to be provided to ensure all devices are connected. The coverage area is approximately 2 meters from the BMU.

Few challenges are discovered when trying to design an antenna which is the most significant part of a wearable sensor. (Hirata 2010) mentioned that the antenna must have all angle coverage so that a better mobility and effect of human body absorption toward those transmitting signals can be achieved. Furthermore, it is more challenging with gadgets that are implanted. Currently no standards have been regulated for BAN transmissions but IEEE 802.15 Working Group for wireless personal Area Networks (WPANs) is looking into it and there is a possibility for various devices to be inter used on transmission medias. (Li 2008) has discussed the probability which might pave the way to develop a standard of IEEE 802.15 for BAN usage. At the moment, different media are assigned different group for instance 802.15.4 for Zigbee and IEEE 802.15.1 for Bluetooth.

Since specified sensor's flexibility has to be maintained at a high level of flexibility, BAN is equipped for observing diabetes patients, asthmatic patients, heart patients etc. Besides, tracking and keying in of relevant information can be effectively done to recognize any issues that might arise. In some sectors for example in the clinics and hospitals whereby there are most patients who need to be attentively monitored supervision, the main challenge is to have the capability of recognize every BAN system that is linked with each and every patient so that information gathered will not be mixed up. Despite the fact that numerous BANs can be built using sensors sold over the counter, there are various matters that arise pertaining to the use of the sensors for example:-

- **Standards**: specifications, operation, range of operation, communication protocols, , privacy and security matters.
- **EMC**: Prone to interference, amount of electromagnetic radiation produced
- **Calibration**: Precision, method for alignment
- **Integration**: networking, database connection, placement and mounting

As at today, no standard have been set in terms of design to oversee the improvement of BAN biosensors. There is no standardization on communication protocols regulating how information should be transferred or guidelines on power source prerequisites. The sensor's reliability and performance will vary when utilized under diverse circumstances. For instance, there is a probability that implanted sensors will not be suitable to function at above a certain elevation or during which an individual is immersed in water when swimming, snorkeling or repairing a boat. The distance to which an individual be away from the source of information need to be stated to guarantee that information could be adequately gathered if the gadget does not have any capacity to store internal data. Likewise just like all healthcare systems, security of the information and privacy is a paramount point to address. Most nations have rules and regulations pertaining to the usage of all wireless transmission with EMC conformity as one of the main issues that need to be adhered to. In settings of different countries, the health monitoring gadgets must be designed to adhere to all important administrative rulings related to EMC. Calibration is an imperative procedure that must be done for all gadgets that need precision in guaranteeing that the information obtained falls between the specified accuracy limits. It is advisable to be able to do self-calibration and diagnose the situation for a user free easy maintenance. When auto calibration could not be done, it is important to determine how regularly the calibration has to be done to ensure constant accuracy and whether calibration can be undertaken by the users themselves. Lastly, to guarantee the sensor's reliability, the linkage between the sensor and the MBU and the method of safe implantation on a user must be carefully handled. According to (Park 2003) and (Winters 2003), sensors could be embedded within the interior of a human and equipped with a fitting protective housing. Nevertheless, a large portion of them are connected to the body on a short-term basis, while some are attached on the user's clothes. To guarantee a high mobility rate, the sensors must be lightweight, tiny in shape and size. The form and weight of the sensors are basically controlled by the internal battery attached inside. Therefore, to ensure maximum durability and minimum size, the sensors must be produced to be particularly power efficient. Likewise, regular charging or changing of the battery might make the usage of the sensors impractical and inconvenient. Figure 3.1 shows how a BAN works. This example can explain a basic BAN which comprises of sensors for screening a heart patient who under attentive recovery. Here, the sensor's functions include gathering ECG information, movement sensors for gait stage detection, data on oxygen saturation, body temperature of a patient and the surroundings. Every sensor is linked with the MBU through wireless connection and information is sent at customized intervals. By using GPS (Global Positioning System) or through the position of Internet access point, the location of a patient can be determined. Information acquired from every sensor and existing home WLAN that is connected to the telemedicine system is passed on by the MBU. The acquired information can be used to immediately update a patient's electronic records. If a therapeutic condition that requires medical care is observed an alarm will be set off and the location of patient is known immediately so that essential care can be administered.

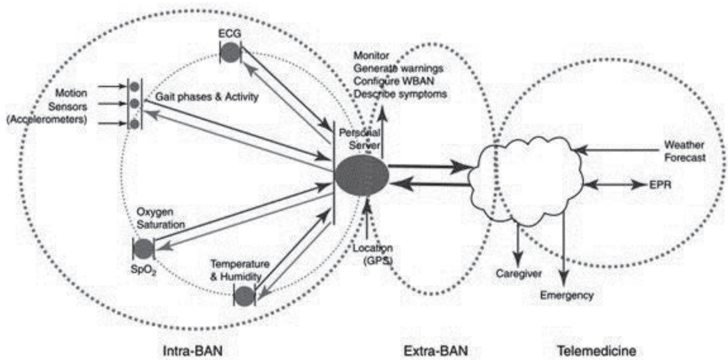


Figure 3.1 Body Area Network uses a telemedicine link to establish connection with outside world (FONG *et al* 2011)

The temperature and humidity of the surroundings whereby the patient is present can likewise be noted and recorded. A quantitative analysis of different patterns and conditions for issuing suitable proposals could be effortlessly attained. Information can additionally be saved anonymously for research proposes to enable the impacts of every parameter on a given medicinal condition can be examined. The by-laws in most nations limit the access of data related to identify patients. The sensors may encounter a range of bearings when they are fixed on a patient (Wang, 2009), (khaleghi et al 2010). When an individual moves, a few sensors might come closer to the MBU while some sensors might be moved further. (Welch 2002), (molisch et al 2005) examined attenuation and delay incited by the human body as a sign of degradation elements initiated because of assimilation, reflection, and diffraction. The electric characteristics of human tissues namely the electric conductivity and permittivity might be utilized to verify the conduct of radio signal transmitted through a human body. To make it simple, the relative permittivity diminishes when the conductivity builds up the increasing signal frequency. An itemized depiction of these electric characteristics of the human body on wave engineering is mentioned by (Means 2001), (beard et al 2006). It is typically important to confirm the network performance throughout the designing phase to guarantee its reliability. However, measurement can be carried out with suitable replicating models rather than utilizing human subjects,

3.2 Rescue of Emergency

No matter how careful people are, accidents do happens sometimes. Misfortunes can happen due to natural causes, deliberate or accidental human errors, machinery failure or due to a combination of all these. If a mishap happen and in the event of injuries, the most immediate action will be to render necessary treatment at the earliest possible chance. Normally, looking for help can be an extremely extensive procedure. Minimizing the time taken to give treatment is the most ideal approach in saving lives and emergency rescue mission can be carried out using telemedicine applications. How the use of wireless technology can help is evident as the usage of hand phones over the past few decades enables individuals to wipe out their handsets and make an emergency call for an ambulance regardless of time and location. While it was necessary to search for a fixed line phone, the time saved by using a hand phone today can mean life or death to the injured victim. Nevertheless this only applicable if the hand phone is inside the network coverage area. Therefore, expanding the coverage area will enhance the chances of saving some lives. If it is integrated with GPS, the location of the caller can be tracked immediately. Since, different various types of mobile devices are accessible, multimedia technology and wireless communication is linked in various ways for Emergency Medical Services (EMS). Thus, there are more functions available through the telemedicine. A number of deployment situations in which wireless telemedicine can serve various conditions in emergency cases has been identified (Ansari 2006), (wang et al 2010) had identified numerous deployment situations in which wireless telemedicine can be used to serve various conditions in emergency cases. Hand phones within built cameras can do a great deal more than merely calling for assistance from the emergency centre. As an example (Martinez et al 2008a), (martinez et al 2009b) reported of the utilization of hand phones to convey data regarding the changes in colors recognized from exposures to markers of infection. In this specific scenario, the victim is indicated to suffer from a particular kidney problem by sending the test strip images. As long as the 'color depth' is sufficiently recognizable between the variations in different colors that took place to reflect the properties of the fluid which are tested, the hand phone camera can be used to transmit the aforementioned data. Here, the number of binary bits which were utilized to signify every primary color- in particular green, red and blue of a given pixel in the picture controls the 'color depth'. A camera with n bit of color depth is equipped for taking a picture of $\mathbf{2^n}$ separate levels of shades of every primary color. Differentiation of slight change in color is not necessary to prove the existence or none existence of a substance. As such, a conventional hand phone is adequate for handling that application. Nevertheless, in different circumstances, for example, capturing pictures indicating a wound will require an image quality which far surpasses what a hand phone camera can take. Therefore, in responding to emergency rescue, it is fundamental for additional advanced devices. Telemedicine frameworks can capture a vast array of data remotely. Figure 3.2 shows a case study whereby the framework of an emergency rescue system which is equipped to furnish the paramedics unit a medium for sending a huge amount of data about an injured individual to the hospital so that essential arrangements could be done before the victim arrived at the hospital. We shall analyze the parts of this system. In circumstances whereby the fire engines are needed on location, a collaborative operation can be carried out as direct communication can be achieved for connecting the paramedics unit with the firemen. Every paramedic member can bring along various wearable units, such as sensors, communication gears and cameras. Likewise, a fireman can wear tracking mechanisms, oxygen level markers and gas detectors. A gateway for all paramedic's unit- ambulances serves to form a two-way communication connection between the paramedic unit and the hospital. Here, the electronic patient record saved in the hospital can be used by the paramedics unit to obtain the medical history of a patient. Therefore facts regarding health conditions and allergies can be obtained before first aid treatment is administrated as illustrated below.

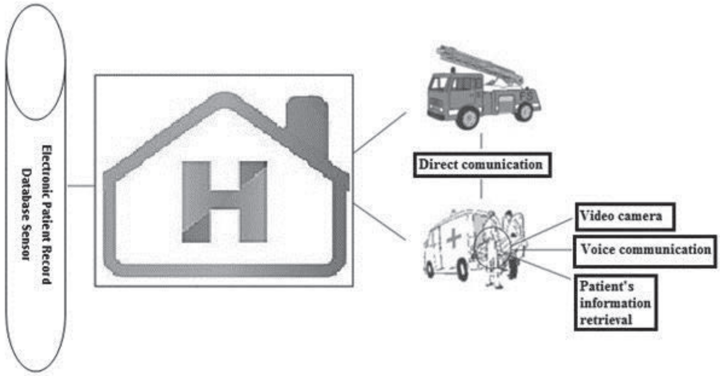


Figure 3.2 simple emergency rescue systems
(FONG *et al* 2011)

3.2.1 at the spectacle of an accident

In the event of an accident, a WLAN will serve the nearest ambulance. It can concurrently connect devices that are handled by a few paramedics so that information can be transmitted to the hospital. On the other hand, the electronic patient record archive within the hospital database can be used to recover the victim's data. IEEE 802.11n WLAN will typically be sufficient to cover the area encompassing a mishap scene unless the retrieval manoeuvre happens profoundly inside an elevated structure or a dense forest whereby it is impossible to park the ambulance close-by, The main advantage of WLAN is that sustaining a connection does not require the line-of-sight (LOS). WLAN system is able to execute the following:-

I. the injury sustained by the patient can be captured by using high resolution wearable camera
II. image processing algorithms which measures the volume of blood lost which is caused by the extraction of

an object that is approximately the volume of blood spilt with relation the volume lost

III. Different sensors evaluate different vital signs for example heart beat, SpO_2 level, respiratory rate and so on.

In giving prompt treatment, a paramedic may require immediately retrieval of the injured victim's medical history. Vital data for example drug allergies and being carrier of contagious disease is fundamentally essential to take necessary precautions to avoid harmful effect. Video conferencing technology enables the paramedics to consult the specialists easily particularly when the condition of the patient is sent to the specialists for rendering remote guidance. Thus, countless amount of information is captured by various mechanisms carried by every paramedic. Thus, there are different matters that must be tended to. Firstly, it is important to clearly identify every set of information clearly especially in circumstances whereby more than one victim is treated with on-scene. This simply means that the set of information that has been obtained must be efficiently linked to the patient concerned. Besides, in order for paramedics and the ambulance to be constantly connected, it is important to ensure that all the freely mobile paramedics are close to the ambulance. Therefore, constant checking must be done to make sure all the paramedics are within the boundaries of the network coverage area. Security of the data must be guaranteed to ensure no unauthorized personals close-by can access the patient's data. Simultaneously, in an uncontrolled scenario, data should not be tampered or altered throughout transmission. To have a perspective regarding the amount of information is gathered by each paramedic lets refer to Table 3.1. This may seem to be a low demand operation when compared to our daily use of the internet, but there is one crucial contrast between internet and telemedicine applications. If there is a system failure while surging the internet, we can simply reload a web page. In contrast, in the life saving telemedicine applications, there is no second chance of re-capturing the data or retransmission of data should a system failure happens. Thus, necessary precautions must be taken to make sure a certain edge for error is accepted.

Source	Format	Approximate data rate	Compression
Video Camera	25 fps 1280 × 720	19 Mbps	Yes
Still Image (each)	3000 × 2000, JPEG	1.5 MB	Yes
Voice	3 Hz bandwidth, 32 KHz sampling	525 Kbps	No
ECG monitor	12 leads ECG	12 Kbps	No

Table 3.1 Data requirements (FONG *et al* 2011)

Issue pertaining outdoor wireless communication have been examined in section 2.4. In some circumstances paramedics arriving at the scene of the accident will discover that the degradation factors to the connectivity of their gadgets are reflection and diffraction. We will look closely into Figure 3.2 and the subsequent Figure 3.3 that shows they are encompassing an ambulance. Confirmation that the transmitting gadgets will constantly provide a clear LOS to the AP's antenna in the ambulance is not possible since the paramedics unit is liable to be freely mobile throughout the rescue mission. Shape and size of the obstructing object and features of the signal- the amplitude, the level and polarization of the carrier wave at the point of hitting the object determines the amount of diffraction. Once in a while the wave might likewise be in part diffracted throughout the process of reflection. The polarization and the angle of which it hits is the major determinant of the degree of reflection and diffraction. Another influencing factor is the material of which the item it hits is made of.

Figure 3.3 Data communication in the vicinity of the ambulance (FONG *et al* 2011)

3.2.2 Supporting the ambulance

Paramedics may carry various wearable devices which depends on the type of the rescue operation and the nature of data that is being sought after. Figure 3.4 illustrates the type of wireless gadgets in which a paramedic puts on when treating an injured victim. Instead of directly connecting an individual gadget to the ambulance, it is advisable to set up a BAN by utilizing a Bluetooth since the design of the wearable gadget has to be tiny.

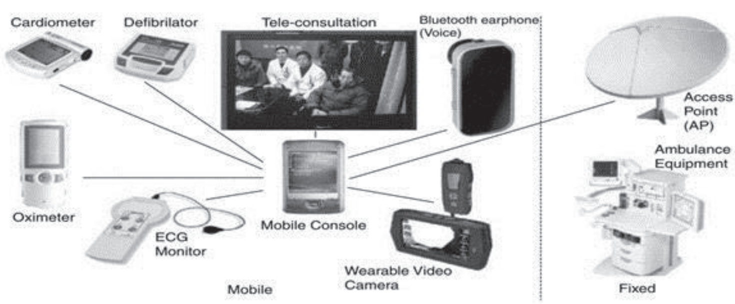


Figure 3.4 Wireless devices assisting an ambulance on the scene (FONG *et al* 2011)

In this case a modified PDA is used as a MBU that gathers information from all the cameras and sensors worn by the paramedics. A 2.4 GHz link connects the PDA to the ambulance network. (Baber 2007) has discussed about circumstances whereby wires might once in a while be favoured when attaching wearable devices. The posture of the paramedic and the desired interface of gadget might make the wires more ideal than wireless alternatives like Zigbee or Bluetooth. Generally, a tiny device fitted in a pocket and requires negligible connection throughout its usage could be linked through wires. Wires are normally more dependable and transmission of information will not be compromised by movement and orientation. However, it is preferable that the wires will not get entangled and the movement of the users will not be influenced in any way. Regardless of what is the capability of an individual gadget the design must be comfortable to wear and user friendly. Power consumption is a critical component to lessen the weight and size. Likewise, to ensure optimal operational dependability, reception properties with relation to orientation and movement have to be focused upon. Exceptional customization of the wearable medical gadgets is its most important feature; hence the current market does not offer many off-the-shelf devices. Its ergonomic design is an imperative credit to guarantee that gadget will not influence or hinder the paramedic daily chores in any case while capturing information as it is worn. A single type of processor is enabled to be customized to drive essentially any sensor through developments in programmable digital signal processing (DSP) chips. The conditions of each distinctive rescue mission determine the particular supporting gadgets which are worn. For instance, night missions require lighting which will consume more power causing a drastically shorter battery lifespan. For reliable missions in the event of a heavy downpour, majority of gadgets need waterproof housing. Nothing will drop whenever the paramedic run around, as long as the mounting is secured. Numerous gadgets are accessible depending upon the kind of data needed. Here, physiological monitoring in disaster recovery missions is even applicable whereby paramedics may need to work for long periods of time without rest.

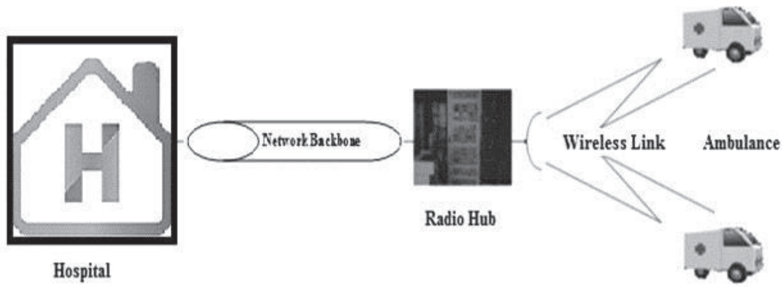


Figure 3.5 Emergency rescue networks (FONG *et al* 2011)

3.2.3 Backbone of the network

The backbone of the network can be practically any kind of wireless or wired networking which grants basic transmission bandwidth and coverage. In this specific case, we shall inspect the 17 GHz wireless system outlined in Figure 3.5. (Fong 2005a) has expanded Figure 3.2 to incorporate the features of a wireless interface system linking the ambulance to the hospital. This gives a two-way wireless connection between the radio center in the hospital and the ambulance.. This is an IEEE 802.16 point-to-point network that might function well if the ambulance remains static at the scene of the accident, however its functions will significantly weaken when the ambulance is on the move. Mobile WiMAZ might be a better choice for vehicles on the move if continuous monitoring throughout the journey to the hospital is required. Nevertheless, since most of the crucial data is obtained from the on the scene mobility support is basically not an important factor for accident recovery support system. Communications between the hospitals and the gadgets shown in Figure 3.6 which is worn by the paramedic may not be continuously accessible. Tall structures might leave no LOS path along the way from the scene of the accident to the hospital or near the scene of the accident Based on Chapter 2 there are a few problems to think about. The most ideal approach to guarantee network coverage is by analyzing the areas serviced by a particular hospital and develops a database for ground elevation which basically comprises of a computer topography map. The main function of the computer topography map is to gather data about the surrounding terrain to model the effects of trees and buildings in different areas on the communication link with the ambulance. Any given location (z) at a specific (x, y) position of the area represents the relative elevation of the ground above a fixed reference point for example, the rooftop of an elevated structure. A detailed database for the points (x, y, and z) might be seen as a grid for the whole coverage region. The topographic database need to contain all the information about the terrain of all the areas that a particular hospital serves so that whichever place the ambulance goes it will be connected. This communication link will require a high level of accessibility and reliability whereby a delay is normally not an issue. However, transmission needs to be error free since data of a patient not need reach the hospital in real time. Besides that, re-transmission of information is never a problem because if the information is corrupted or lost, it could be re-sent once more. Re-transmission ensures successful information gathering but at a delayed time frame. Heavy downpour is one of the main factors that cause severe accidents. Actually rain increases the probability of an accident; it likewise influences the reliability and functions of radio connections. Rain causes problems such as mainly attenuation and depolarization. Attenuation will weaken the strength of the signals which causes a decrease in coverage area. Depolarization will affect wireless link which uses both horizontal and vertical polarization signals. Depolarization causes the two signals to intercept with one another and inevitably produce no signal at all. Figure 2.8 shows how critical this problem is as the extent of rain attenuation depends on the intensity of the rain. A heavy downpour can influence the outdoor wireless networks that operates in an area.

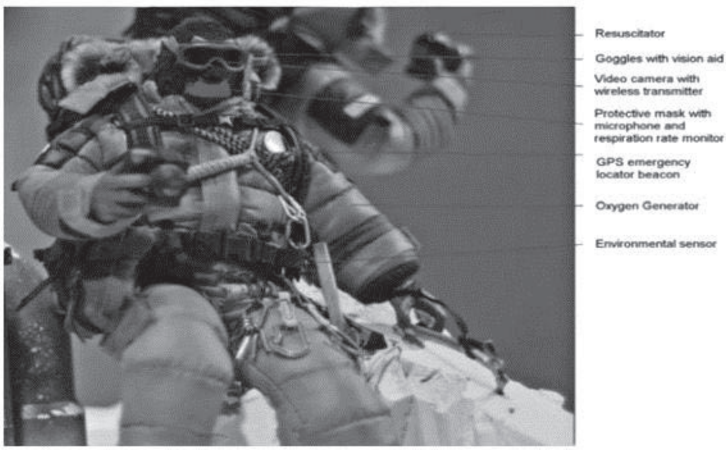


Figure 3.6 A well-equipped paramedic assisted by technology (FONG *et al* 2011)

We can observe the impact of a rainfall of 0 mm/hr and 120 mm/hr on 10 GHz and 5 GHz signals. From Figure 2.9, we see that a horizontally polarized signal is severely influenced by rain. Hence, depolarization will finally trigger off a phase shift to as much as 90◦ results the causes horizontally polarized signal intercepting the vertically polarization signal. As the two signals intercept, they join together and adequately contra one another. The entire network is a crucial factor for the telemedicine system since it provides a solid interface between the personnel's working on site of incident and the hospital. (Fong 2005b) has suggested in her research that generally when licensing of radio frequencies allows, a lower frequency of 10 GHz or below ought to be used for tropical regions whereby frequent rainfall level of over 20 mm/hr. is often possible. In general, any range between 25 and 40 GHz ought to be utilized for improving the network performance and staying away from spectrum congestion.

3.2.4 Accident and Emergency (A&E)

Surgeons in the Accident and Emergency (A&E) unit can get an exceptional decent idea regarding the condition of the victim when the ambulance arrives since data indicating the degree of injury suffered by the victim during an accident is sent to the hospital together with the vital body signs. The electronic patient record provides immediate patient medical history. Even though the benefits of telemedicine technology to the A&E unit personnel is clear, there are still various matters to be managed. Prior work by (Benger 2001),(guler et al 2002),(noland et al 2004) discovered various possible matters which emerge from the development of service capabilities. (Benger) has recorded are various human factors like reliability, and convenience and the issue of incorporating telemedicine technology into current practices. Medical practitioners and supporting staff are obligated to be clear regarding the system in terms of what it conveys and how it can be fully used. Possibly this involves training to guarantee data conveyed by the telemedicine framework is rightly deciphered. Since linking to a copyright framework might incur issues of compatibility and interoperability, integrating with an existing medicinal framework might likewise require exceptional consideration. Even though (Tachakra 2006),(duchesne et al 2008),(giakoumaki et al 2010) has reported that there are no recognizable interference between the telemedicine transmitting gadgets and sensitive medical instruments in A&E unit has been traced. Telemedicine is equipped to provide vital data of a victim before his or her arrival at the hospital. Vital signs like heart beat and breathing, pulse oxymetry (SaO_2 /SpO_2) and arterial blood oxygen pressure PaO_2 levels, diastolic arterial blood pressure (DABP), images of injury can be made accessible and updated as the patient arrives at the hospital. Despite the fact that an extensive variety of data could be sent, most of the information send are not large. Hence, channel bandwidth is not an issue. Moreover, there are a few systems that support live video conferencing but may require an information transmission rate of more than 1 MB/s.

3.2.5 The Authority

Privacy is an important matter for authorities concerned with any applicable lawsuit which demand for damages involving security breach as e-health involves constant supervision of the patients. Thus, the usage of telemedicine may be influencing liability issue. Usage of telemedicine application that crosses state boundaries can be involved in regulatory issues if the states use diversified by laws and licensing regulations. Initial setting up cost and shortage of funds may likewise be an imperative issue that constrains the use of telemedicine for A&E as officials in-charge might not be aware of the cost benefits in spite of the fact that valuable time can be saved in handling an accident victim and eventually save a life. Officials in charge normally make decisions from a business perspective; whatever funds invested can give high returns within a specified timeframe. Thus, the officials in charge have to be made aware of the benefits of telemedicine applications. Normally, it is not that difficult to overcome technological challenges compared to obtaining the endorsement from the government. Setting up a complete networking system for supporting emergency cases might require the co-operation from different sectors mentioned in this section. Additionally, the officials in charge might view the time required to provide training for medical professionals of various capabilities as time consuming. Even though, the long term benefit of saving lives is self-evident; gaining financial support from the authorities concerned and the required time investments are issues to be dealt with seriously.

3.3 Remote Recovery

Wireless telemedicine enables treatment to be given practically from anyplace; at the sea, on land and even in the air. (Mchugh 1997) stated that commercial airlines had started linking their aeroplanes to MedLink which is a service that offers healthcare support when the plane is in the air. Medlink provides essential life support service to train airline crews to give basic emergency treatment and diagnose a medical emergency to decide whether emergency landing is needed for immediate medical treatment. This technology enables better time and cost management by the airline industry which had to be incurred by making an impromptu landing to drop off passengers who actually do require quick medicinal attention. Through video conferencing, medical professionals from any nations can offer continuous medicinal counseling to airline crews who may not have any related training in healthcare. It is just a matter of providing suggestions on actions that need to be taken. In addition, telemedicine can retrieve a passenger’s electronic patient record so that any existing medicinal issues about that passenger will be known. Besides, rendering help to patients who are in the plane, telemedicine ensures recovery and treatment accessible from practically anyplace. Remote recovery frequently includes quick disclosure of the victim's actual whereabouts. Moreover any potential treat to the rescue team from the victim can be determined earlier by using telemedicine applications to avoid from placing the rescue team in dangerous situations. Remote recovery aid in these circumstances through telemedicine is made possible by technology. We shall examine 3 circumstances whereby telemedicine regularly serves to spare lives of ordinary layman and medical experts who endanger their own lives in order to save others.

3.3.1 At Sea

Maritime rescue is very demanding because cellular communication networks do not function at sea. Satellite signal is the only communication option that can be used at the oceans. Even though most modern ship has high technologically advanced GPS, communication might fail at times as unexpected thing can happen. The ship can sink or lost power, the individual who need to be rescued may be thrown overboard and GPS communication will fail. The development in technologies enables the rescue and recovery task to be done hassle free compared to before. Locating an individual in the big ocean is the crucial for the rescue operation but by the use of video extraction technology with high resolution makes the task easier to handle. Strategic coordination between the rescue boats, control centre and rescue helicopter are important and receive necessary support in real time as the waves may shift a person who need to be saved to new location. Satellite communication becomes the only option as need to cover the vast area of the ocean. Satellite signals use millimeter wave in GHz magnitude which are incapable for detecting sunken objects and ship. This was due to the absorption of satellite frequencies in the ocean water. Underwater communication is much more challenging than air communication. Underwater communication is accomplished by acoustic waves which travel 5 times faster in water than air. The study of acoustic waves was conducted back in 15th century; acoustic wave frequency has a range lower and average between 10 KHz to 20 KHz. This lead to the reasons why the acoustic waves are slower in the air and data transmission will be slower. Other factors that cause the underwater communication to be problematic are narrow bandwidth and high variation of multipath.

3.3.2 Mountains and Forests

Search and rescue mission is usually visually challenging in a forest area. Even with the aid of infrared camera, there are possibilities of failure of locating a person. The limitation of infrared camera can be influence by many factors. Another communication method that can be used is cell phone communication. However, areas at high terrain and covered by thick forest has less chances of having cell phone networks. Radio communication is not viable in these areas because of the economic factors as these areas are less inhabited by people. Hence these areas have less subscribers and utilization. Typical line-of-sight (LOS) link will not work due to the thick vegetation. Therefore, diffraction and reflection of a common radio signals are the degradation factors that lead to a better communication. Radio communication must be able to transmit signal to the receiver so that meaningful data or information can be transmitted for example the location of the receiver or images of the encircling areas. The clearing Fresnel Zone concept as shown in section 2.4 describes the effect of physical barrier such as trees while the signal is being transfer. This concept relates to the space encircled by an ellipsoid of two antennas between the ends of a radio link. Here, radio communication can always be established provided there was no disruption to the transmission of the signals as explained in Fresnel Zone, unless there is major diffraction or other factor. However, it cannot be concluded that failing to maintain Fresnel zone always result in communication error. Sometimes, communication relies more on the surrounding environment where it operates. Reflection of signal cause by objects that obstructs such trees, plants and lakes can be the main factor for any signal loss. Even though LOS path between the transmitter and receive is less likely to exist, there might be some gaps between the receiver and transmitter which enables one ground reflected path and one direct path through LOS to co-exist. Therefore, the loss of signal is much dependent on the physical properties such as the phase connection and relative amplitude between the signals transmitted through the 2 paths. The phase of reflected wave and signal amplitude depends on few variables namely frequency, permittivity and conductivity of the reflecting surface, polarization and angle of incidence which will overlap each other and have varying effect. The ratio of LOS signal path and the ground reflected paths having Fresnel clearance determine the relative strength of signal between those two paths. The 2 paths will have the same signal strengths if the ground reflected path lose a little because of reflection. This will cause an increase of up to 6dB of signal across the direct path or cancellation which may cause an extra path lost of at least 20dB which rely upon the relative phase shift of the 2 paths. A constructive interference is formed if the 2 signals combine in a phase without a relative phrase shift. Alternately, 2 signals combining as out of phrase (180◦ relative phase shift) causes 'destructive interference'. Techniques including multiple antennas and spread spectrum are usually used to solve this matter. Moreover, transmitting from a foggy environment can be done at a frequency of 20GHz and above. This can be used for communication system in a humid forests condition. According to Wiki "clutter" is excessive physical disorder which refers to vegetation that affect or disrupt signal transmission in wireless communication. Clutter causes deterioration and scattering of the transmission signal that strike on an obstacles surface such as branches and leaves because of the wind, thus forming variation of signal path. The extent of scattering depends on the characteristic and condition of obstacles such as the shape of the leaves, weight of the leaves, water content within the leaves and many more.

3.3.3 Fire in Buildings

Among the many types of rescue missions undertaken, fire rescue operations are the most challenging as the rescue team only has a very limited time to perform their rescuing mission. Fast spreading fire and thick smoke cause by it always result in the poor vision and difficulties in handling the situation such as exiting the place in time. Thus personals like the paramedic and fireman need highly reliable communication tools and systems that can help them complete their task successfully and return safely in a short period of time. A communication system that can lead them to a safe and quick response is a must. It is normal for people without special requirements not to have any transmission devices with them and this makes tracking fire victims who are trapped in building more challenging during a breakout of a fire. Therefore, locating a person through radio communication is not possible because the victim might not be having any kind of radio transmitting device which are fully functional. Thus the rescuers have to take personal risk when carrying out a rescue operation. They need to identify the safest route and grab the finest opportunity to save the fire victim. However, the floor directory or plan might not be made available to the rescue team. A normal building can change completely into a total messy place during a fire. Thus, when a rescue team enters a building on fire it does not mean it would be the safest and best path to take. On top of it, there is the risk of falling objects during the fire. Now we shall see how communication technology can help in locating the best path for the rescue team to be entered during fire emergencies.

Surrounding environment can be hardly visible when there is thick smoke during a fire. On the other hand, radio signals are also blocked by energy absorbing materials in the building. Metals are very common in buildings and it has undeniable usage in the construction and fittings but unluckily, the metal blocks radio signals. The rescue team will face tremendous challenges as visibility is blocked by thick smoke and radio signals block by the obstacles. Hereby advancement in technology enables the rescue mission to be carried out successfully. Technology helps to saves lives. In Chapter 2 we have seen that a signal with a frequency exceeding several GHz can easily pass through materials compared to those signals with lower frequency. Low frequency signals are blocked or jammed by obstacles. This is best explained in the scenario of interruption of phone calls in a lift as the metal cage blocks the 900MHz cellular signal. Thus, the firemen require a more efficient form of communication than a hand phone to lead them to safety and accomplishing their rescue mission. An essential and complete suite of a fire fighter is shown in Figure 3.6. This figure differs from Figure 3.4 as it comes with some changes in the equipment and with the transmission and reception of data capabilities. Communication devices that are provided have different functions in ensuring the fire fighter's safety. The suit is featured to protect both the fire fighter and the equipment itself from long term exposure to toxic gases and heat. Architecture of the communication devices must be designed to function within the suit at all time. Besides, suitable communication filtering should be fix to eliminate any surrounding noise that may affect communication. This is vital since communication should be established at all time during a rescue operation in a building on fire. Oxygen is very important in the scenario of a fire for a better chance of survival. Alert for the oxygen level need to be generated to allow the fire fighter have enough time to plan an escape or to have a supporting team bring in extra oxygen supply before the oxygen finishes. This alert should be designed to notify the fire-fighters in a subtle manner so as not to cause anxiety that could create a panic situation. It should ease the rescuing mission too. Beside the oxygen status, toxic and flammable gas detection equipment, video footage of rescuing task and on site scene is an option to be equipped too. This footage can aid the command center or offsite post to get a clearer picture of what happening in the building on fire. A reliable communication network is essential to ensure the safety of the fire-fighters and the task goes on well. The conventional Very High Frequency (VHF) radio range between 30–300 MHz utilized by US fire departments have been reported to possess several inefficiencies based on the TriData Corporation (2005) report. 800 MHz signal band for safe public radio communication has been implemented by the Federal Communications Commission (FCC) so that it does not interrupt the commercial broadcast signal and to reduce the spectrum from overcrowding and to prevent interference. However, the fire department uses different radio channels and interoperability becomes the main problem. Therefore, the question arises whether to standardize the communication system used by the fire department.

At a glance, satellite communication may fit the best since it has good coverage and perforation criteria. Satellite phone is a good solution for conventional communication with the offsite supporting team and the accuracy of determining the location prior to rescue is less demanding. Positional precision of global positioning system (GPS) that is aided by satellite varies on many factors such as position of the satellite and the dilute of precision (DOP) that is caused by nearby buildings. GPS is accurate up to a radius of several meters. So while carrying out a rescuing mission, a precise location is important than the range of location provided by GPS. GPS can generate a wrong analysis and mislead the rescue team to go to the wrong floor of the building and waste precious time. Thus satellite communication is an improper remedy for fire rescue.

Another solution is radio frequency identification (RFID) for short range path recognition and marking which creates automatic visible marking along the route used during the mission. The technology used need to be fulfil certain criteria such as being lightweight and user friendly, accurate tracking of location, able to penetrate through an array of materials liberally used in the construction of buildings and has the ability to withstand heat. Till today no single device has the technology to facilitate all the aforementioned criteria. Incorporating different solutions available but simultaneously being aware of the high level of interoperability is the most practical option.

We have reviewed three challenging circumstances for the rescue mission. Each of them has its own limitation and requirements. However, the common feature between them is the ease of the task and dependability. Technological development that happens in different types of communication tools and networks has enabled better wireless system to be developed and integrated to meet the growing need in the future and current usage. This will also help in the success of rescuing missions in critical situations.

3.4 At the Hospital

In the past few decades, the development of information technology has enabled a lot of automated and safety features to be used in the hospitals. IT has made a lot of improvements to the way a hospital manages its operation. An example of how the six distinct areas of IT results in a significant difference to a hospital has been discussed by (Felt-Lisk 2006),(schoenman et al 2007),(abdekhoda et al 2013). Since there is a wide range of possibilities whereby IT applications can be used in healthcare; it is impossible to include everything in a volume. Therefore, we shall focus on how communication technologies can aid to improve the condition in a hospital by briefly studying a case recorded in a magazine article named 'The Digital Hospital' by (Mullaney 2006),(terhune et al 2009). Then we will review in detail the role of telemedicine in the daily operation of specific departments of a hospital. For a start, this article documented a case whereby a physician was given an automatic warning after he asked to dispense a drug. The information system has discovered a possible the risk that may occur if this particular drug is taken together with another drug which has been prescribed earlier for the particular patient. As the physician had received a quick alert, a different drug was prescribed to avoid the possible risk. This is one case whereby the timely delivery of data saved a life.

The article also related about physicians who can remotely examine X-ray images and control a robot inside the hospital. Through telemedicine, all these tasks and many other became made possible. A hospital which provides complete healthcare services may consist of numerous departments with a central administrative unit. A simplified version of a few departments placed in a single complex of a typical hospital that is connected by information sharing and co-ordination network is shown in Figure 3.7. Apparently each department has different prerequisites on the type of information processed and prioritisation of data retrieval. As example, Accident & Emergency department need to get information about patients who are injured and need emergency treatment quicker than the Pediatrics department which is performing a general healthcare check up. Both these departments are involved in obtaining medical history of patients and updating new information. It is different for both departments in term of the tolerance to delay and the ease of examining the medical history. Section 3.2 has discussed the role of telemedicine enhancing the effectiveness of the Accident & Emergency department by updating the surgeon with the needed information about an injured patient even before the arrival of the patient. Now we shall examine another three example that proved that communication technology lends a hand in saving lives and costs.

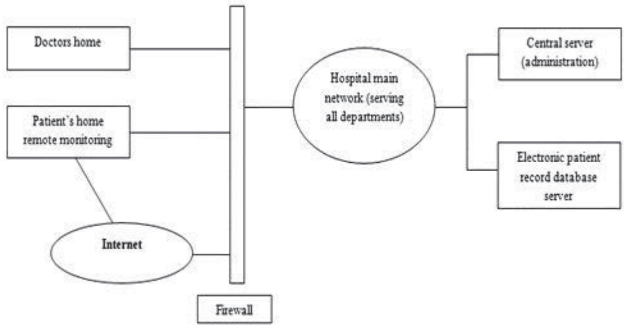


Figure 3.7 networking system in the hospital
(FONG *et al* 2011)

Below are three examples on the importance of telemedicine in a hospital based on different situations:-

- Measures that saves cost, coupled with timely and accurate info in radiology.
- Robots for surgery accurately controlled.
- Efficient detection of new born babies to prevent wrong identification.

These exemplars are chosen to demonstrate distinct sets of wireless communication applications such as remote sensing, quality assurance and surveillance. Many other situations with very similar basic technologies can adopt telemedicine.

3.4.1 Radiology Detects Abnormality and Cancer

Radiology is imperative for early treatment and diagnosis as it will safeguard that the surviving chances will be higher. In this application, communication between the staffs and the patients are important. Thus, telemedicine has expanded to more than the hospital network. A delay in receiving correct information may result in delay in treatment. This may cause legal repercussions. Radiology interprets medical images with precision. Explanation given by a doctor is a significant aspect of communication between the patient and the doctor since patients usually cannot understand the images by themselves. Due to that, reports are attached together with the images. A block diagram of the information contained in a radiology report is shown in Figure 3.8. To deter the chances of unauthorised access and modification of info, permission shall be given to hospital personnel involved only.

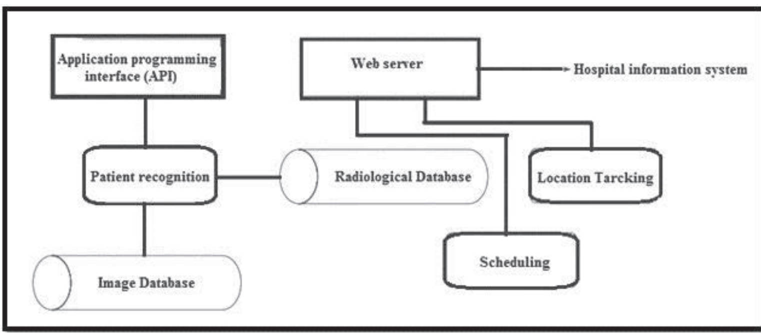


Figure 3.8 Radiology information systems (FONG *et al* 2011)

In this system, the patients will automatically receive an SMS (Short Message Service) text message as a reminder of the forthcoming scheduled check up. A RFID card will automatically notify the Radiology Department representative about the arrival of the patient and the electronic patient record. Besides, it will be used for tracking. Results obtained are analyzed by the hospital information system so that any appropriate actions can be taken. Images and radiological data can be stored in separate databases. Cost saving is a major objective of effective communication since proper delivery of information can cut cost as mentioned by (Brenner 2005),(singh et al 2007),(hardeep et al 2008) that the cost of a miscommunication can reach US$ 200 000 per case. Thus,

Figure 3.8 shows the whole process from capturing an image by the radiologist to delivering an extract of related reports to the patient without any errors to make sure accurate information is relied so as to decrease payout cases to minimum. A telemedicine system with proper design and well maintained can achieve such results. Figure 3.8 also shows a radiograph is captured by a radiologist who is serving many patients in every session at an X-ray facility. After the images are captured, they will be digitized and delivered to doctors handling respective patients.

Some possible mistake can happen during the process. The worst scenario will be a mix up of the images of different patients which can result in a wrong diagnosis. As an example, a healthy person is diagnosed with cancer while the cancer patient is discharged. Apparently, that wrong diagnosis will result in an adverse psychological effect on the patients and their respective families. A healthy person undergoes an operation while a cancer patient is left untreated. A proper filing system used of each image obtained during the entire process can make sure the images safe and correctly referred to related patient. Proper management of information can help to make sure the images are protected by stringent implementation of the proposed procedures. After each image is delivered correctly to the doctors, it will be examined and any strange signs which are tracked by two different ways;-

- manually detected by the doctors
- automated feature extraction by image processing methods

It is difficult to detect a tumour formation especially in the CIS (Carcinoma in Situ) at an early stage. This is an important phase whereby more treatment options are available before intrusive stage. It is important to produce high resolution images which are noise free without losing any specific details during the image transmission process. Since radiographic images are commonly transferred digitally, it is highly dependable on the 'bit error rate' (BER), which efficiently evaluates the amount of bits delivered if a bit in the data stream is corrupted. Conclusively, we want to avoid any undetected delicate signs displaying the tumour because of a few missing bits from the digital image.

3.4.2 Robot Assisted Tele-surgery

Tele-surgery is the surgical operation which can be carried out remotely by a surgeon without physically being present in the operating theatre. It is possible nowadays since we have high precision robots which use super reliable tiny sensors and actuators.

These actuators initiate the movement in the robot which is very precise. Actuator works on the instruction of the surgeon who operates it and is able to perform three dimensional movements. Figure 3.9 shows a surgeon performing a remote operation using telemedicine system with a robot in the operating theatre. Besides the options of hand control movements, (Randerson 2008) reported that there are eye controlled robots that can synchronize with the eye movement of the surgeon and monitor precisely the place which the surgeon is operating. These eye controlled robots can make a 3-D mapping of the tissue; automatically calculate the depth and thickness of tissues.

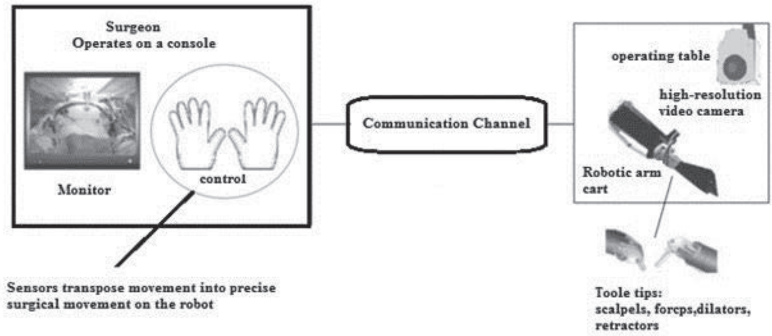


Figure 3.9 Tele-robotic surgeries (FONG *et al* 2011)

Tele-robotic surgery is performed using the professional skills and techniques of a surgeon without he or she being present in the operating theatre. However, this kind of surgery needs a lot of data exchange between the robot and surgeon. Firstly, the surgeon needs to have a view of the operation theatre. High tech cameras with high power zooming and rotation function should be installed in the operating theatre. The surgeon should be able to view the video image in real time without any hold ups so that the robot can be operated without delay. A minor delay in the movement will end up with tragic and irreversible damage on the patient. Thus latency (time delay) is the main problem with long distance tele-robotic surgery but sometime unavoidable as transmission delay happens especially when connection is established across continents. Besides, the user interface for controls has to be precisely engineered so that the entire system is synchronizing and work as the surgeon intended. Moreover, voice activated control will ensure there is minimal disruption so that the operation is hassle free. Speech recognition algorithm is also another matter that needs to be implemented precisely so that each command given by the surgeon is correctly interpreted. At the same time, it should be able to differentiate the voices of individuals in the operating theatre so that only the command given by the surgeon is acted upon. By having proper recognition of speech, the tele-robot will be able to differentiate the voice commands of surgeon from other supporting staff or surgeons in the operating theatre without a mixed up or wrongly carried out. Robotic control needs a high precision 3-D control over hand movement using a pair of virtual gloves. The sensors in the virtual gloves are describe as 'six dimensional'. Six dimension are the both negative and positive movement along the 'x','y' and 'z' axis that represents the three dimensional space away from any fixed reference point. as shown in Figure 3.10. The movement of sensor causes the respective actuators to make control of the robotic hand which holds a surgical tool. It also controls changing surgical tool held by the robotic hands.

Beside motion aided control, a voice channels should be provided for video conferencing between the surgeon and the supporting staff in the operating theatre. In conclusion, tele-surgery involves huge data transmission through real time videos images and also control signals of high precision. The transmission should be precise, with minimum time delay and highly reliable to perform a successful tele-robotic surgery. Portable robotic surgeon could be live savers in many remote rescue tasks as discussed in section 3.3 above. In fact the expensive robot can be written off without endangering lives if it is found to be malfunctioning. Robots are also capable of doing underwater task (Blackwell, 2006) and are even executed in high risk rescue operations.

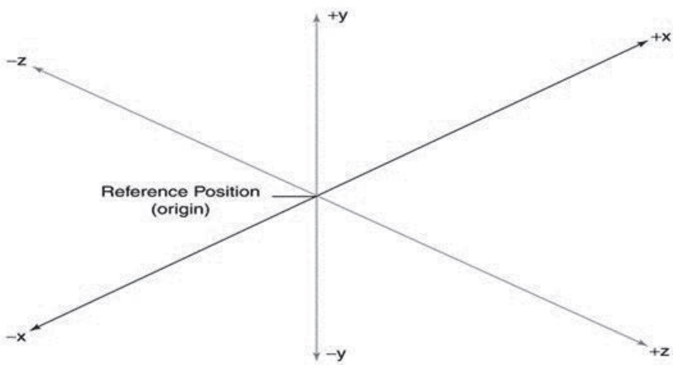


Figure 3.10 the 3-D space representing the 'Six-dimensions'
(FONG *et al* 2011)

3.5 Assessments of General Health

A Telemedicine use in healthcare goes beyond medical treatment for people with special needs. It also creates public awareness in the healthy lifestyle in their daily lives. Technology is always there to aid our wellbeing and lifestyles. Information technology fits well in many health evaluation tasks such weight management programs, skin care solutions, calculating calorie intake and burn out, nutrition monitoring, baby alarm and even automated reminder for medical follow-up etc. Technological development continues to provide sometime for everyone. Having said that, a conceptual design that makes us go easy on certain product is much associate with IT and healthcare since good product designs lessen the risk and hazard of using the product. Through weight management programs, telemedicine helps in the lowering the rate of obesity. The body weight of the participants in a weight loss programs can be automatically sent to a control centre for progress monitoring and evaluation. Before concluding, we shall examine the benefits of telemedicine in our daily lives since most of the time we just ignore the benefits and existence of telemedicine. A few examples of how telemedicine benefits us is explained below:-

3.5.1 Fitness Monitoring for Jogging

Accelerometers and gyroscopes are usually used for monitoring the movement as over the counter foot-contact pedometers can only calculate the number of steps taken. According to (Bouten 1997) a sampling rate of 18 Hz is enough for sampling human activities. A complete research was done by (Pappas 2004) and (Bamberg 2008) by installing Shoe Integrated Gait Sensors into the insoles of the running shoe complete with electric field sensors, resistive band sensors, accelerometers, gyroscopes and piezoelectric sensors as shown in Figure 3.11.

According to (Morris 2002) these sensors functions as a foot motion detectors. The data for analysis of the condition of the user and activity level can be sent by a small transmitter. Uneven wear on the heel of the sole and improper wearing patterns can be spotted by this mechanism in order to provide remedy for uncomfortable running. Technology helps us track the distance and speed of running and reduces uneven wear of our shoes. Telemedicine can also help those who want to lose weight by jogging. People feel hungry after running because the body metabolism rate increases with exercise. At one point while jogging for example a kilometer before reaching home, we can turn on a microwave oven to reheat our breakfast by sending an automatic signal to our smart home control console to make sure it is ready when we return home. Smart home automation can also activate a coffee brewer in the same. We do not need to do anything after remote or advance pre-programming through a cell phone, except if manual override is required. Therefore, communication technology can help us prepare breakfast while jogging. Jogging in the morning is a gentle cardiovascular workout that enhances our blood circulation, respiration and muscle strengthening. Digestive problems due to hectic work schedules can also be managed by jogging.

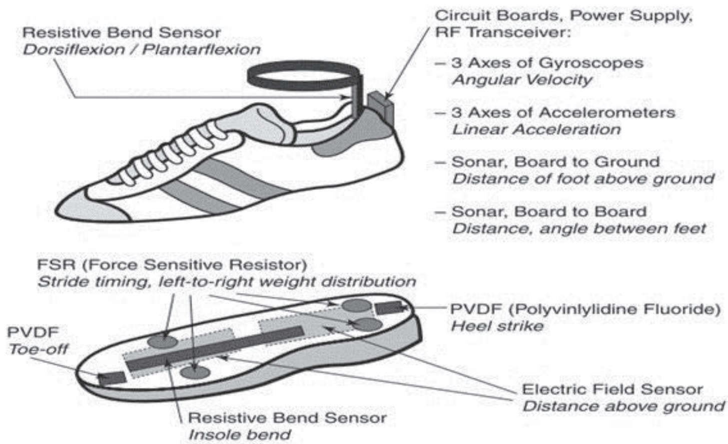


Figure 3.11 Schematic of the shoe-integrated gait sensors
(FONG *et al* 2011)

While we enjoy the benefit of jogging, technology help us realize the difference quantitatively and stores our progressive records by recording our daily jogging activity like the distance, duration, number of steps taken, respiratory and heart beat rates. We can buy a cheap pulse meter which can even be a watch that can help us monitor our heartbeats while jogging. A report of nutritional information of what we eat during each meal everyday can be monitored and generated by technology. Thus, the breakfast we take after jogging can be prepared depending on the number of calories burnt. We can also check our health progress daily and review a list of menu recommended based on the data obtained for maximum nutritional balance. This can be done by connecting the health monitoring device to a home desktop. Outdoor running in good weather might be more enjoyable than in a gym, but sometimes exercising in gym can be more attractive because there are many types of equipment for whole body workout and it is not affected by changes in weather. Hence, let us look at case study of healthcare monitoring in a gymnasium.

3.5.2 Workout in a Gym

Free WiFi Internet access is available at many gyms now although physical exercise usually not requires it. Even though, we rarely surf the Internet during a workout at gym, it can help us to keep track of our exercises. We can also wear small sensors all over the body during our workout to monitor distinct signs depending on the type of activities. The same technology used in jogging is used for walking or running on steppers or treadmills but downloading data can be easier since the wireless internet service in the gymnasium can support continuous downloading of data, thus, no memory storage is required in the BAN of sensors and relevant devices. In Figure 3.12 a layout of a gymnasium complete with fitness equipment that are usually available for example stepper, leverage bench press, exercise bike, seated rowing machine, treadmill, weights rack and elliptical trainers is shown. Even though there are a lot of equipment, the technologies that facilitates healthcare evaluation can be very similar if we sort them depending of their usage. As an example, leverage bench press and weights rack are identical in nature in terms of health assessment since these kinds of exercises uses the upper part of the torso to rise a specific amount of weights. The purpose of weight lifting is to build muscle. Thus, the results of the effort can be seen by the muscle growth which can be detected by evaluating the changes in body shape. Simple scanning of the upper body can be made and kept for reference. The users can compare the changes in their body shape when they return for the next session. Technology can also provide beginners with instruction on how to handle dumbbells to prevent injury. This can be accomplished by showing images to explain the proper ways to handle the dumbbells so that the users can follow every step closely.

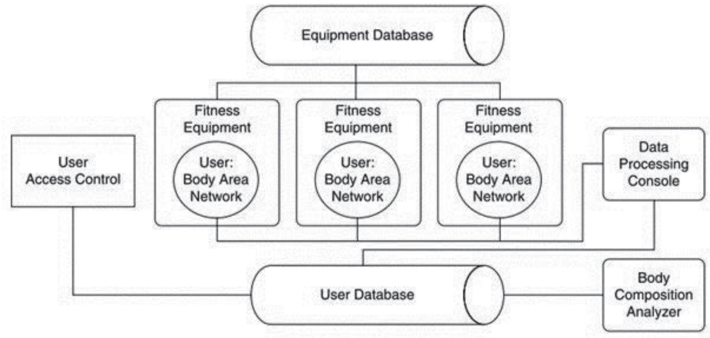


Figure 3.12 Block diagram of a gymnasium network
(FONG *et al* 2011)

Different users can be recognized in a lot of ways. The easier ways are either to install the user's subscription card with a passive tag or to set a RFID sticker on the shoe with readers on the mats that are connected to each equipment. It works in a very simple way; a particular identification number will be saved when a user steps on the mat and all data collected will be marked as belonging to the particular user when the equipment is used by that user. Besides being used to monitor health, it can also be used for billing purposes if the user is charged based on usage. When the user completes a session he or she has two choices. The user has a choice to either download the data and save it in his or her removable storage device or to sent to his or her respective home using the networking system of gymnasium. The identification procedure used can make sure the privacy of the data of each user is not compromised and there is not mix up.

3.5.3 Swimming pools and beaches

As explained before in section 3.3.1, underwater wireless communication always poses a big problem since the transmitter has to be immersed under water. Despite significant challenges, life can be saved beyond and above the capabilities of health assessment by using wireless communication like in a gym. This is an advantage to lifeguards on the beach who may not able to keep track of all the swimmers. A tiny waterproof transmitter can be useful to seek for help should an accident occurs. We also can use waterproof receiver that can accept signals from the shore if any emergency occurs for example the presence of a shark. However, a system that permits a swimmer to take along tiny transceivers can only function normally at a distance of not more than a few hundred meters as the radio waves are not totally block off by water absorption. An important matter here is the material to be used in the waterproof cover because it will effect signal absorption. Besides, the wave penetration properties in salt water and effect of bleach in swimming pool are different. Underwater Wireless Acoustic Network (UWAN) can also help since the data rate is usually not more than a kilobyte per second. A possible propagation delay that can be a second each kilometer is a big disadvantage of this kind of network. This major drawback should be considered while in the system design phase. It can be difficult to install an UWAN since the swimmers will be on the move and the transceiver will not be stationary. Below is a basic calculation that can explain the effect of changing speed. The total speed of swimming and water flow v is at an angle relative to the acoustic signal propagation direction θ, resulting in the effective acoustic propagation speed v' which is:-

$$v' = v . \cos\theta \longrightarrow \quad 3.1$$

Rationally, if the combined speed v is moving towards the same direction as the signal propagation, effective propagation speed v' will rise. However, if **v** moves in the opposite direction of propagation, v' will decrease. As the result of water flow, a narrow acoustic beam will bend slightly in the same direction. Nevertheless, the resulting effect is not significant. The propagation speed will change significantly if going through a different medium, for example from air into water or vice versa. This happen because of dielectric constant changes result in refraction just as light bends from air through glass or water. Thus, the direction of propagating signal will be changed by refraction. On a light note, in optometry the term 'refraction' refers to eye examination in the process of determining whether a prescription for spectacle improves a person's vision. This application is known as refractometry. Figure 3.13 shows that reflection also occurs when the signal touches the boundary between two media, then a part of the signal will be reflected back directly from the surface into water without going through the air. Reflection from the bottom of shallow water as with most swimming pools and beaches will also cause multipath effect

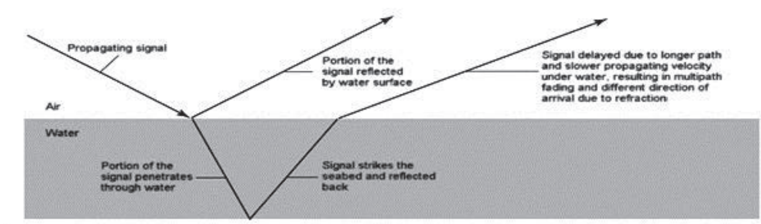


Figure 3.13 Water surface causes refraction and reflection
(FONG *et al* 2011)

In mathematics, the accepted signal r(t) can be written as:

$$r(t) = \sum_{n=1}^{N} \alpha_n . s(t + \tau_n) \longrightarrow \quad 3.2$$

in which the attenuation ceofficient α **n** indicates the decline in signal strength due to the absorption attenuation which can turn the signal energy into heat and loss because of reflection which depends on both distance and frequency while the original transmitted signal **s(t)** is subject to a delay of τ n resulting in **s(t +** $\boldsymbol{t_n}$ **)**. N is the number of incident acoustic signal paths which is caused by multipath effect. In most cases, n=3 in short range shallow depth due to three signal paths that occur which are

- a reflection from the bottom
- reflection from the surface
- Direct LOS between the receiver and transmitter.

Usually, there is an increase in **n** and $\mathbf{t_n}$ due to the increasing of range and depth since more reflections will occur and the time taken for the signal to reach the receiver will increase. Reflection loss because of water surface and bottom can be extremely different since the bottom may store deposits that make it uneven. The molecular movement of the water surface that is caused by the propagating signal is very minimal as the carrier wave most probably does not carry enough energy to move the water substantially. Hence, just a very small fraction of the signal will be sent into air from water. Almost all signals will be reflected back into the water. Acoustic pressure also does not match well with air just like an electrical current hitting a load with 'impendence mismatch'. The same situation happens in the case from air into water. This explained why we have difficulty hearing anything from above when our heads are soaked in the swimming pool. Usually, this coupling problem not happen at the bottom because deposited particles are 'more friendly' with the movement of water molecules. Better coupling will cause a certain portion to be reflected back into the water and others will be absorbed. This is good for communication because absorption will have a negative impact on multipath, the bottom efficiently acts as cushions to shield some reflected signals and thereby declining **N**. The actual efficiency will rely on the composition of the deposit.

We have seen signal propagation in respect to time. Let us now see the signal propagation in respect to distance. Consider a signal **S (d),** whereby d is the distance travelled by the signal. The signal **S** will definitely weaken if **d** increases. Below is a basic mathematics equation that explained their relationship.

$$S(d) = S(d=0).e^{-\alpha d} \longrightarrow \quad 3.3$$

Attenuation is usually indicated in dB, the signal loss is L is expressed as:-

$$\mathrm{L} = 20.\log_{10}\left(\frac{S(0)}{S(d)}\right) = 20.\log_{10}\left(\frac{S(0)}{S(0).e^{-\alpha d}}\right) = 20.\log_{10}\left(e^{\alpha d}\right) \longrightarrow \quad 3.4$$

Note : **L** is not to be confused with the notation in Equation 2.2 that represents the number of levels available:

It also can be simplified as:

$$L = 20.\log_{10}(e)\,[\alpha\, d] = 20.\,[0.434]\,[\alpha\, d] = (8.86\alpha)\,.d \longrightarrow \quad 3.5$$

The whole discussion provides an understanding into the complex situation of using telemedicine underwater in healthcare. Details of underwater wireless communication can be obtained from (Etter 2003a), (Etter 2003b). In this chapter, a number of cases whereby telemedicine can helpto save lives have been discussed. Besides that, telemedicine application can be used for monitering general health so it is benificial to healthy people. Wireless communication technology can be used to handle difficult challenges in rough surroundings. Baricades like plants and water can influence the reliability of the system, thus it is not totally problem free although technological developmments have enhance their capabilities.

CHAPTER 4

INFORMATION TECHNOLOGIES IN PROCESSING MEDICAL

There are numerous of examples telemedicine technologies that can save lives whereby these were not possible back in few decades ago. Today, these technologies are readily. Its wide-ranging series of technologies is able to facilitate almost everything ranging from search and rescue operation to general health checkups. These services include converting raw medical information into digital form. According to (Haykin 2006) there are many benefits of using digital data compared to raw information in analog form for instance the ease of transmission, processing and storing of digital data. Let us discuss the difference between medical data represented by a series of '1s' and '0s', and other digital things such as CDs and cameras. A common thread in all these applications is that data is sent and processed in binary form and we are only required to deal with **'1s'** and **'0s'**. Nevertheless, there are some differences between capturing medical data and capturing general data. First of all, the medical information is strictly private and confidential to an individual. Compared to losing normal documents or an MP3 file, the consequence of losing analysis results of a medical test is far more severe. For instance, it would cause a negative impact on the medical institution's reputation, patient unable to receive prompt medication and others. Also, misinterpretation of data also can be a serious issue. In comparison, if the MP3 file is misinterpreted and the music playback is disrupted, the worst consequence would just be the degradation of sound quality. However, in terms of medical information, the misinterpretation of data may lead to possible-life threatening consequences.

Figure 4.1 shows the way of using medical data is just like in any information systems whereby it acquires data from various sources for diagnosing and continuous monitoring. In related to telemedicine, most of the data come from patients who include a wide range of data from bio signals and surveys related to daily routines which are manually entered. Immediately as soon as the data has been captured, it must be transferred to a suitable location for further processing so as to know how the data relates about the patient. The processing of data requires different technologies such as multimedia, signal processing and data mining. The basis of processing the data is based on the nature of the data and the relevant applications. Once the data is analyzed and corresponding actions is taken pertaining to the situation, the data should be kept in the archive. This form of storage can be utilized for various purposes. For instance, information about a patient's allergy can be made known before receiving subsequent treatments.

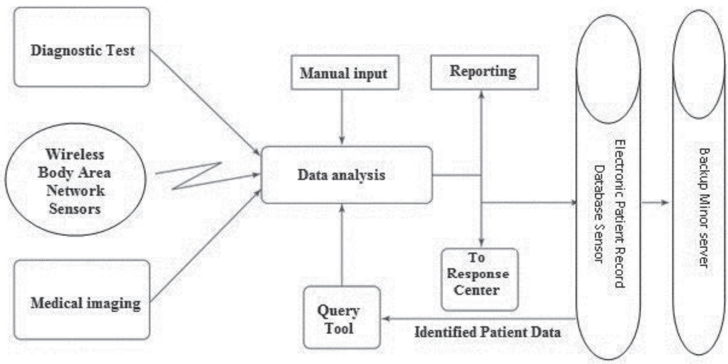


Figure 4.1 information systems of medical (FONG *et al* 2011)

In the case of disease control, the anonymous data can be utilized to perform statistical analysis of virus mutation and the pattern of spreading. The government agency can use the data for regulatory planning. Therefore, a method to store large amount of data and quickly retrieve the data is important. In this chapter, we shall take a look at the complete procedure of processing medical processing data and conclude the chapter by analyzing an Electronic Drug Store which uses medical data that is collected to ensure safe and efficient dispensing of drugs. It serves as an exemplar to showcase the role of advance technology in healthcare sector for aiding patients who require extra care, hence ensuring that dispensing medicine can be risk-free and easily accessible.

4.1 Data Collection from Patients

Data can be collected from a patient from every part of the body. In this section, we will focus on biomedical data that related to human anatomy and set aside the discussion on survey collection in order to deliberate on the technical issues. Therefore, we will discuss the types and methods in which information can be collected from a patient and the necessary precautions during data collection. However, the human body is too complex and as such it is not feasible to touch upon all measurable parameters in this volume. The main aim in this section is to cover the commonly used features and understand what happens when the medical data is being processed. The most important area is the vital signs of a human body as it reflects on the health status of an individual; a person without a vital sign is impossible to stay alive. Let's take a look of some of the attributes of vital sign and how it can be collected. For example, some of the vital signs can present circadian rhythms in 24 hour behavioral cycle which fluctuate due to temporary regulation of the environment.

4.1.1 Temperature Body (Normal Range: 36.0-37.4 ◦C)

The body temperature changes from time to time, it depends on the surrounding environment as well as which part of the body is taken to measure. More than that, gender can also differentiate the measurement of body temperature. Generally, body temperature able to indicate whether an individual has hyperthermia or hypothermia; in short, fever when exposed to extreme conditions. Body temperature that is above 40 Celsius can cause severe dehydration due to excessive sweating whereas body temperature that is below 35 Celsius can be considered as a cold. Both these situations can be fatal if proper medication is not administered. Abnormal body temperature can indicate fever which may cause permanent damage to the organs and death. Therefore, a monitoring of body temperature pattern and precise measurement is important issue to be concerned. There are various ways to measure body temperature ranging from the level of precision and time required to measure. We can take the measurement from different parts of the body, including armpit, tongue, ear, mouth, underneath the tongue and rectum. The age of the person can also affect the temperature measurement to be less predictable. For example, as a normal response; a child will generate more heat inside the body while playing hard whereas an elderly will not generate as much heat as a child under such normal circumstances as they do not have enough energy. To get a clearer picture about the temperature differences between people with different ages, we take an example of 3 perfectly healthy people- 5, 35, and 70 years old respectively as shown in Figure 4.2. Although the daily activities of each person are different, the circadian rhythm cities of all the subjects involved remain fairly consistent. The body temperature that we consider as a normal measurement can be quite unpredictable. Body temperature of a person can be gathered by different method and it will be affected by various environmental variables. A common example, the conventional way of measuring body temperature by inserting thermometer into mouth varies based on prior drinking of hot or cold drink. Besides, the measurement of temperature taken under the arm can be influence by sweat. Therefore, through advances in technology, more efficient methods are developed. One of the good examples is the infrared ear thermometer that can measure the amount of infrared energy radiated from the eardrum of the patient to measure tympanic temperature. This is much more reliable as the eardrum is located nearby the hypothalamus, the main temperature regulator of human body. The infrared ear thermometer is portable, affordable and gives a quick reading. This reading can be transmitted via suitable wireless technology to another terminal to update patient records.

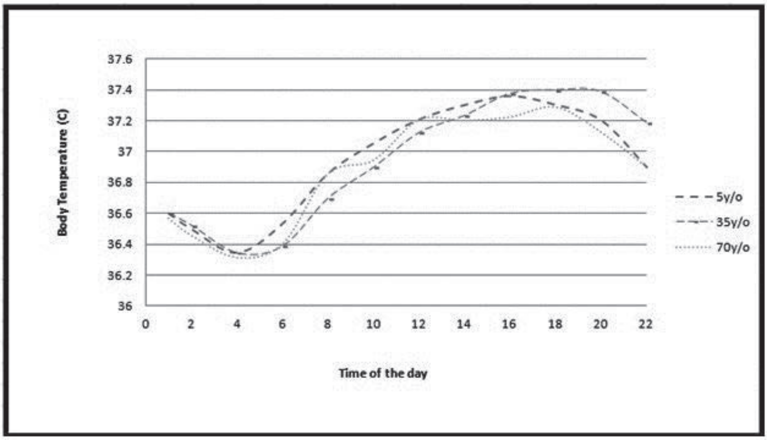


Figure 4.2 Normal variation in body temperature measured in a day (FONG *et al* 2011)

The best method for measuring a patient's body temperature is to use an ear thermometer as it requires inserting a probe into the ear. In order to prevent the spread of diseases, this type of measuring technique can be deployed at checkpoint where people must walk pass. It includes the use heat sensor camera that can show the core body temperature as color images immediately flashes as a person walks pass the camera. Infrared thermal imaging is widely used for this mechanism whereby a change in the color of an image of a person's body temperature indicates the abnormalities. Although this method is not as accurate as other methods, it is able to provide fast and efficient measurement and can be designed to trigger an alarm if abnormalities of body temperature among the people who are walking through the camera are detected. Next, forehead and spot infrared thermometer is also available in the market but it is not widely used for some reasons. The reason why forehead thermometer is not widely used is because the temperature at forehead can be affected by ambient temperature and some fever-relieve medication such as acetaminophen and ibuprofen. The spot infrared is dangerous as the laser beam may accidentally fall onto a person's eye. In the case of infants, high body temperature must not be neglected as it can cause permanent disabilities if proper treatment is not given promptly. Fever is caused as a human body response to infection (Cranston, 1975),(milton 1982),(dinarello 1984). Sometimes, parents that are over-protecting their children by making them wear too many clothes can cause temperature elevation to their babies. Technology can assist parents in monitoring their new-born baby by using a small heat sensing camera. The camera can be set to trigger the alarm if the body temperature of the baby exceeds 38 Celsius. An automatically alert will be sent to the medical staff if the temperature reaches 39 Celsius, signaling that the baby needs immediate medical attention. Such example shows that telemedicine system can be integrated with a simple thermometer to improve healthcare monitoring. Compared to the conventional mercury thermometer, advances in technology enable extra features such as automated updating of patient's record and alert signals if the temperature exceeds a certain threshold. The pattern of temperature variation can determine the cause which requires medical treatment. Hereafter, details of various methods of measurement methods which vary in terms of precision, speed and ease of operation are optimized for particular applications and surroundings.

4.1.2 Rate of Heart (Normal range at rest: 60-100 bpm)

The heart beat measurement and analysis can be utilized in many ways. Its uses can range from addressing life-threatening conditions such heart failure to general evaluation of fitness in a gymnasium as discussed earlier in section 3.5. Heart rate is unlike body temperature as the daily heart beat pattern of a human body shows a certain level of circadian rhythm as can be seen in Figure 4.3. Dismissing heavy activities, the heart rate is most likely to be 30% higher during the day time compared to when sleeping at night. The exact measurement would be around 70 beats per minute (bpm) where its range is at least 52 and at most 82 (bpm). The unit (bpm) represents number of beats per minute. Also, female subjects have 5% faster hear beat than male subjects under similar situations. The more mobile a person is, the more blood is pumped throughout the body. Sudden impulses resulting from strenuous activities during the day or nightmares during sleep can be eliminated by taking readings once every two hours. Compared to body temperature, the measurement of heart rate is less prone to environmental variables.

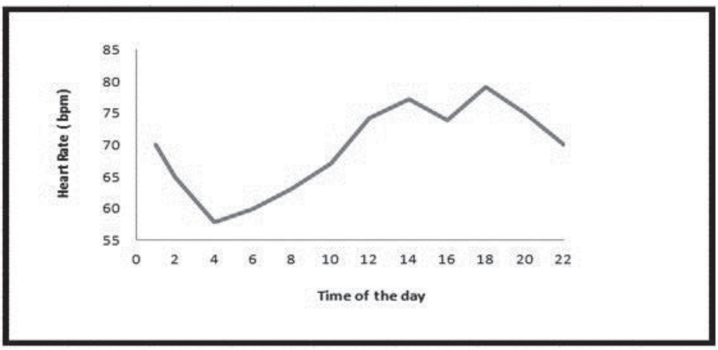


Figure 4.3 Circadian rhythm of heart beat
(FONG *et al* 2011)

Theoretically, the Circadian rhythm can be obtained from any part of the body that has an artery near the skin. The method of counting circadian rhythm is to count the number of pulse per minute. Usually, the measurement is taken at wrist and neck. Apart from that, some gym equipment targets the elbow for easier measurement during a workout. Some equipment in the gym are often equipped with heart rate sensor as shown in Figure 4.4. However, these designs are not flexible enough as we need to hold on to the sensor tightly in order to get the heart rate while doing exercise. This type of sensor has 2 limitations namely restriction of movement while gripping the handle and running and the inability to keep track of health condition (instantaneous reading may not relay much important information about health state). In order to overcome these problems, an electrical indicator is impelled through the heart muscle throughout compression as the heart beat. A reliable transmitter which can pick up the signal is placed at the 3 aforementioned body sites. With this deployment, the transmitter can send electromagnetic signal to receiver that calculate the time and then displays it in the form of number of beats per minute. According to research, the maximum rate of heart beat of a person decreases by **1 bpm** for every increase in age by one year. Technology ensures a safe workout as the user can set the gadget to alert him or her to slow down when the heart beats reach a particular predetermined level. Machines that are designed for elder people should not include measurements at the neck as it may cause light-headedness due to inappropriate exertion of force. For babies that are less than one year old, the heart rate is normally higher. Therefore, the type of application varies for different areas.

Figure 4.4 Heart rate sensors (FONG *et al* 2011)

Telemedicine technology should aid in providing necessary treatment when a sudden change of heart beat pattern may require medical attention. There are a number of causes of heart beat deviation including hypothyroidism. Other than that, it can also be influenced by medication that can lower down the heart rate. In contrast, the heart rate is increased by exercise, stress, caffeine and alcohol. The automated system shown in Figure 4.5 clearly shows that an elderly individual who lives alone can be monitored from time to time. This form of monitoring is very easy to install as it consists of a small pulse counter that is placed behind a wrist watch that can continuously monitor user's heart rate when worn. If the heart rate reaches certain level, it will send an alert to the corresponding centre to request for immediate medical attention. Before the medical team approach the user's location, they will first try to telephone the user to check whether the user is carrying out his or her routine activities. An unanswered call definitely needs immediate attention. It is vital to ensure that the threshold set has sufficient capabilities to reduce the chances of a false alarm, while at the same time ensuring that any serious problem will not be left undetected. Nevertheless, it is difficult to detect a weak pulse. A weak pulse can be due to a blood clot or heart disease which may lead to fatal. Therefore, it is very important to develop more method to measure heart beat for detecting palpitations. Besides that, the **ECG/EEG** that discussed in section 4.2 can be utilized to measure heart beat which can provide precise measurement and indication of the rhythm which co-relates to pattern and the strength. This information is useful when we use it to detect symptom of heart disease and abnormal blood vessels. However, just counting the number of beats per minute is not enough to determine whether there is a blockage of blood vessels. Palpitations might be unending or intense with shifting outcomes and each of them has diverse prerequisites for detection. Therefore, more advanced methods of analyzing heart beats are required.

Sometimes, the medical history of a patient can reveal a forthcoming problem. Additionally, in some circumstances a chemical analysis might be included for example when recognizing ingestions identified with reasons for palpitation. A laboratory diagnosis is required to detect the substance that may influence the changes of heart beat. Before a diagnosis is done no adjustments can be made. Both circumstances oblige interfacing the testing to a particular division of the hospital with a specific goal of accommodating outpatient observation of palpitation. It may even be important for the patient to use embedded mechanisms underneath the skin when continuous observation for certain conditions is needed.

Figure 4.5 Automated devices to assist the elderly
(FONG *et al* 2011)

4.1.3 Pressure of Blood (Normal systolic pressure range: 100-140 mmHg)

Blood pressure is a measurement of the pressure that exerted onto the wall of arteries. It is responsible for ensuring blood circulation throughout the body to deliver oxygen and nutrients to all organs. Plotting the blood pressure variation of an individual on a normal day will probably result in an untidy diagram that has little significance. Generally, the blood pressure of a person is usually higher when awake than asleep. Nevertheless, we cannot take this as a correct assumption for all case scenarios. A perfectly healthy adult will have a mean systolic (maximum) pressure around 120mmHg but it can fluctuate within a range of 20 mmHg above or below the mean systolic pressure while carrying out normal activities. The diastolic (minimum) blood pressure of a person is generally over half of the highest pressure in the arteries which is within a range of 80 to 90 mmHg. A spot measurement of an immediate reading cannot be used here due to the irregular variation experienced throughout the day. When we visit a doctor a sphygmomanometer is used to measure our blood pressure. This device will bind our arm tightly in a cuff and a reading is obtained by pumping the device. This refers to the most conventional method that does not involve any technology. Before we go in the technology aspect, we should understand the whole concept of blood pressure measurement first. Blood pressure is the measurement of the pressure which is exerted inside a blood vessel when our heart is beating and pumping blood throughout our body via arteries. This kind of measurement also can be called as systolic pressure, where this can be done anywhere that has of artery near the skin. Apart from that, the diastolic pressure is also important for us to measure as it is the pressure where the heart rest in between two consecutive beats. Hypertension is indicated when either of these parameters exceeded certain level. When measuring these parameters, the sphygmomanometer is used together with the stethoscope to listen to the heart beat so that the reading can be obtained at proper times; a pulse is for systolic pressure while the absence of a pulse refers to diastolic pressure. This method involves taking the reading corresponding to hearing. Therefore, this will definitely introduce errors. Moreover, this form of spot reading is inappropriate for ambulatory blood pressure monitoring (ABPM) as it is only taken at a particular time instead of a continuous reading. ABPM requires a wearable monitor which can retrieve blood pressure readings throughout the day. The data is then relayed to an external device so that the supporting medical team can run an analysis. ABPM is normally used to monitor abnormal blood pressure for patients having abnormal-ly high blood pressure caused by prescribed drugs or for patients who are undergoing prolonged anxiety psychological treatment. Here, technology provides patients with a wearable device for increased comfort .It is very useful for patients with hypertension and are resistant to pharmacotherapy. The whole process of blood pressure reading involves reading, scanning and analysis of the data obtained. There are different ways to perform ABPM whereby the measuring device can be remotely connected to the hospital to offer off-site measurement. This is useful when it necessary to obtain accurate measurements during normal daily activities while monitoring cardiovascular patients. In many cases, patients get nervous during a doctor visit which would lead to the recording of an unintentional rise in blood pressure. Here, the remote measurement technology will not face this kind of problem so accurate measurement can be taken. Different types of automated blood pressure meters are readily available in the market whereby measurements can be taken at various parts of the body.

Figure 4.6 Blood pressure meter (FONG *et al* 2011)

Measurements can also be obtained from the leg, wrist, and finger, apart from the arm. An example of the small monitor is in Figure 4.6. There are tons of similar devices that can be found in the market for just below RM299. The device adopts a design in which air is pumped into an inflatable wrap that acts similar as the manually inflated cuff of a sphygmomanometer. High and low reading which are based on the systolic and diastolic pressure respectively is recorded through a quick series of reading on the pressure exerted on the switch. With a built in clock, the time of reading can be stored for further analysis. Telemedicine technology grants much more than remote controlling and periodic blood pressure monitoring. It will alert the medical team when certain procedures which are not suitable to be performed on patients with special needs arise. For instance using a sphygmomanometer on a patient who is suffering from sickle cell anemia is not recommended as excessive pressure applied to the patient can cause intravascular sickling which may lead to tissue necrosis, intravascular thrombi and haemolysis. In order to avoid such consequences, checking the medical history of the patient can be done electronically prior to performing any treatment to the patient. As we have discussed briefly on the methods which technology can assist in the monitoring and measurement of blood pressure, we will proceed to the next vital sign which is the respiration rate.

4.1.4 Rate of Respiratory (Normal Range: 12–24 breaths per minute)

Respiratory rate is the most challenging aspect of measurement amid all the body vital signs because of its significant change over a very short lapse of time. The respiratory rate is most likely intertwined with heart beat since the level of intensity of activity would influence both parameters. Taking a deep breath might increase the duration of breath cycle and therefore cause the reduction of respiratory rate. On the other hand, heart beat would be less affected. The breathing rate of a healthy adult is 12-24 times per minutes, which is much lower than heart rate.

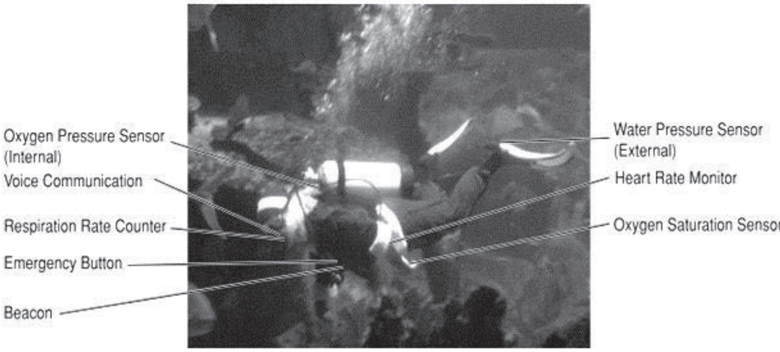


Figure 4.7 Underwater Telemedicine applications
(FONG *et al* 2011)

The breath rate is based on the age of the person; usually a newborn has more than 40 breathes per minute whereas a toddler has around 30 breaths. Compared to the three listed above, respiratory rate may give fewer significant information when examining the health state of a person. However, respiratory rate measurements can be utilized effectively for activities such as diving, in which the respiratory rate of a diver determines his or her length of time staying submerged underwater. Figure 4.7 shows the list of equipment for divers. Here, the most important device is button to seek for help. If used together with a beacon, the diver's position can be located easily. At this section, we will discuss about technology which measures the respiratory to provide a constantly updated estimate of the amount of oxygen remaining before the diver must decompress and resurface. Besides that, the alert will automatically trigger to ask for help if respiration abnormality is detected. Generally, respiratory rate is measured for patient who suffer from lung disease or patient who take medication to suppress respiration. The respiratory monitoring system can also detect asthma symptoms such as bouts of breathlessness. Apart from asthma, severe conditions such as tachypnea, caused by conditions such as fever, congestive heart failure and pneumonia which result in irregular increase of respiratory rate can also be detected. The breathing rate is easy to count because it is rhythmic and slow. The respiratory rate can be determined by counting the number of the increase and decrease of the thorax. The thorax motion during breathing can be measured by putting a pressure-sensitive switch attached to a counter inside a vest. The chest will expand when the diaphragm muscle contract and the chest cavity will shrink when the diaphragm muscle relaxes. The switch counts the frequency of this repeated motion.

4.1.5 Oxygen Saturation in Blood (Normal range:SaO_2: 95–100%, SaO_2 : 90–95 mmHg)

Blood oxygen saturation is the ability of the lungs to supply oxygen to the blood. In the blood oxygen is carried chemically by the hemoglobin and it dissolve physically in plasma.

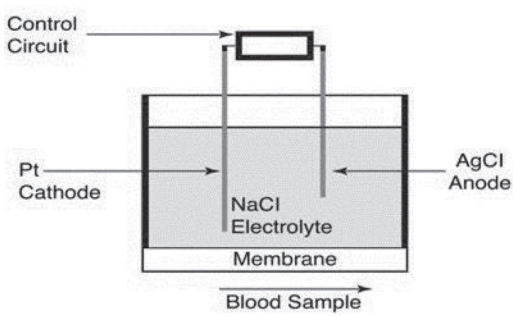


Figure 4.8 Partial pressure of oxygen in arterial blood (SaO_2) (FONG *et al* 2011)

Measurement is normally done to analyze the oxygenation and saturation of hemoglobin in the blood. There are a few variables used such as partial pressure in mmHg of oxygen in arterial blood (**PaO_2**), which refers to a technique to measure the arterial percentage of blood. **SaO_2** And **SaO_2** refers to direct and indirect measurement of the percentage in blood oxygen saturation level. The former is determined using pulse oximetry and the latter is measured using arterial blood gas sampling. Even though, **SaO_2** and **SpO_2** appear to be similar actually these two variables are different from one another. The reading that is obtained by arterial blood gas sampling can be affected by conditions such as anticoagulant medications and thrombolytic. These variables are linked to respiration as inhalation brings oxygen into the lungs and exhalation releases carbon dioxide out from the lungs. **PaO_2** Refer to a measurement of gas which can be determined using polarographic oxygen electrode as shown in Figure 4.8. Polarographic oxygen electrode contains a platinum cathode and a silver chloride anode in which generates an electrical current; the electrical current is proportional to the oxygen. The blood sample must be isolated from the electrode by a membrane to avoid protein deposition. The equipment must be kept in an oven that has a temperature analogous to the human body temperature which is approximately 37◦C. The membrane is should not contain any protein deposit that might accumulate on the surface over time. Pulse oximetry is a non-invasive method of continuous arterial oxygen saturation monitoring. The pulse OX meter is a tiny portable device which paramedics can carry to the site of an accident. It can measure the arterial oxygen saturation (**SaO_2**) of a patient. According to the formulae, the maximum amount of oxygen that can be carried by the blood is determined as:-

$$\boldsymbol{SaO_2} = \frac{O_{2\,content}}{O_{2\,capacity}} \, x \, 100\% \longrightarrow \quad 4.1$$

The formulae above will give an idea of an oxyhaemoglobin dissociation curve. In order to get precise measurement, it requires an oxygen meter that uses light source like red and infrared LED that able to shine through certain body parts where a considerably translucent area of blood flow can be exposed to light. Figure 4.9 show that oxygenated hemoglobin and deoxygenated hemoglobin absorbs infrared light and red light respectively. The measurement is usually taken from the fingers or ear lobe. The process involves light passing through the blood vessel where certain portion of red and infrared light beam is absorbed. The photocell will then receive whatever is left and then deduce the red-to-infrared ratio of absorbed light through blood.

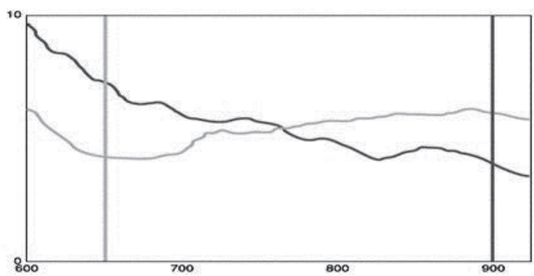


Figure 4.9 Infrared energy absorption by hemoglobin versus wavelength (FONG *et al* 2011)

Figure 4.10 shows the arrangement, where a 100% SpO_2 produces a received light ratio of about 50%. It is important to note that calibration is a must as the extent of light absorbed by skin and tissue varies.

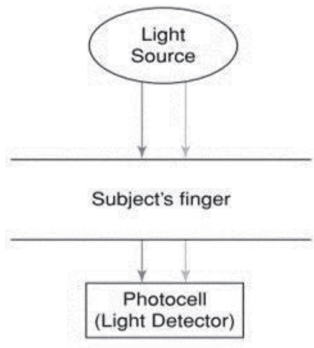


Figure 4.10 Pulse oximeter oxygen saturation (SpO_2)
(FONG *et al* 2011)

The accuracy of the measurement can also be affected as the amount of arterial blood flow is affected by the sequence of heart beat. Therefore, it is a must to measure for a sufficient period of time that covers two successive heart beats to get the average value. In the case of an accident, the measurement of oxygen saturation is a crucial step to detect hypoxia in order to facilitate emergency treatment when the victim arrives at the hospital. Hereby, problems such as tricuspid regurgitation, hypovolaemia and vasoconstriction affecting the blood flow may influence the measurement given by an oximeter. An oximeter is also unable to differentiate carboxy hemoglobin from normal hemoglobin in the case of carbon monoxide poisoning and it will also cause the reading to be of higher value than the actual value.

4.2 Processing and Bio-signal Transmission

Telemedicine functions to offer remote medical services whereby data must be transferred from the one site to another. For instance, the data from an accident scene must be transferred to the hospital. There are various types of information. Furthermore, the raw data that is received has to be processed before being used for analysis and storage. Some are self-explanatory but variables such as oxygen saturation require expert analysis before factors of the abnormalities can be established. To collect and process any type of data about a patient, a specific type of mechanism like Figure 4.11 is needed. The mechanism is extended from the basic communication system as shown in Figure 2.1 with the additive noise as seen in Figure 2.2.

Let's take a look of the block diagram that shows a biosensor capturing data such as those discussed in section 4.1. The sensor networking system that is linked to a transmitter via analogue-to-digital converter will transmit the acquired data to a remote. To ensure transmission security and efficiency, analogue data is converted into digital domain. This section will discuss transmission efficiency whereas information security will be discussed in Chapter 6. At the receiving end, the data that is acquired will then be analyzed and stored for analysis. This is a common information system that relates to basic information theory. For further discussion, it is necessary to refer to the work by (Shannon 1948a),(Shannon 2001b) which quantifies information in entropy, a term that relates to a particular expected data value in association with a data set.

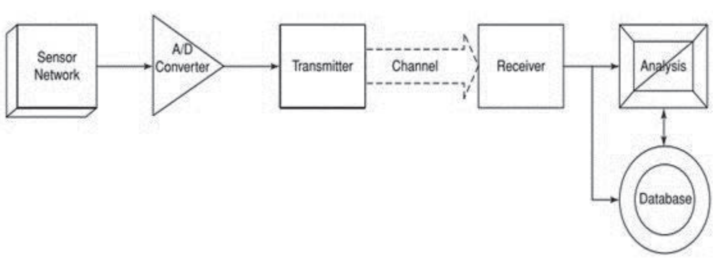


Figure 4.11 collecting a patient's information
(FONG *et al* 2011)

The Shannon entropy theory is used to measure the highest capacity of data transferable between communicative networks by using statistic modeling to describe the size of the network affected by unwanted noises during transmittance. However, the mathematical concept will not be further evaluated and readers who want to determine the concept should look it up from the references (Cover, 2006a),(Cover 2012b). The theory appears to be much simpler by excluding the mathematical concept. By using Figure 2.1 as a reference, we will look briefly into the fundamental communicative network equipped with a discrete source S. It has a measurable output values and uses R bits rate to calculate data. The discrete source has the entropy of:

$$\mathbf{H\,(S) \leq R} \longrightarrow \quad 4.2$$

According to the theory, the discrete source can be ciphered to another equivalent at the rate of H(S) bits, and the recipient can recover the initial code. This theory is applicable with the condition that the speed of transmittance is more than H(S). Hence, the bits rate is used as a measurement of the original data in the throughput of S. The Channel Coding will also be given a brief study by including the data transmittance bits $b \in \{0, 1\}$ across a network which includes q, a possibility of one failed bit from one million bits transmitted and C = C(q), where C refers to the capacity. A network cipher includes k data block which is mapped into n (where n is more than k ciphered bits) and introduces surplus. Data content of a deciphered bit r is referred as:

$$\mathbf{R = k\,/\,n} \longrightarrow \quad 4.3$$

An estimated ˆb of the actual data bits is produced by recipient prior to the transmission of deciphered chain c, with a failure possibility of:

$$p_b = \Pr(b \neq \hat{b}) \longrightarrow \quad 4.4$$

Hence, the value of **p** can be brought to the lowest at **r** < **C**. It is obvious that **C** is an estimation of network strength and the level of noise. By understanding the fundamental theory of network strength, the next subject of transmission and the process of medical data will be explored.

4.2.1 Imaging Medical

The science of diagnosis image is commonly applied in x-rays, physical scans and the study of bodily structure, distant operations as well as in recovering accidents. The simplified procedure of diagnosis imaging is depicted in Figure 4.12.It shows that the common procedure involves the capture, transfer, analysis and the storing of images. For usual diagnosis, image is copied and kept in archives.

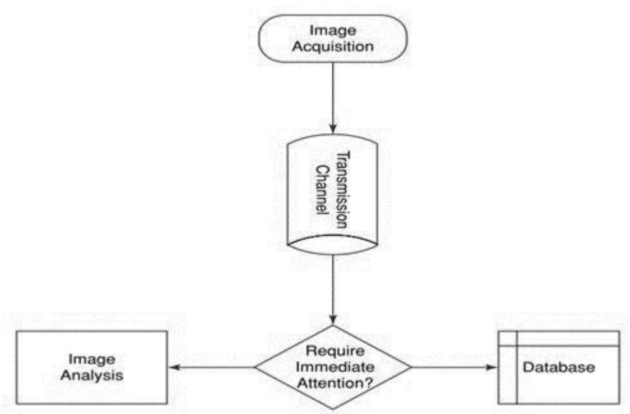


Figure 4.12 Process of Imaging Medical (FONG *et al* 2011)

Even though priority is normally given in the imaging of emergency cases, there are also other urgent cases that require the service of diagnosis imaging such as magnetic resonance imaging (MRI) performed at operations and images to show the state of injury at accidents. In the following subsections, the processes of different diagnosis imaging will be evaluated before proceeding to the process of transmittance.

4.2.1.1 Magnetic Resonance Imaging (MRI)

Figure 4.13 shows the similarity between a MRI device and a horizontal human's figure with the surrounding of huge round magnets equipped with RF and gradient coils. Protons are aligned in hydrogen atoms due to a hi-energy magnetic field generated from the magnet. Like small magnets, the protons are lined adjacent to the field. Protons are knocked away by radio signals emitted from the scanning device directed at the object, which is being slid into the device for scanning procedure. Protons are realigned to their actual positions when the magnet stops emitting magnetic field. Radio waves are also emitted during this process, and image is produced from the spectrometer that receives these waves radiated at different rates according to different bodily regions. Figure 4.14 illustrates the image of normal human brain acquired using the MRI device and the organ's structure is represented by tones of grey with different densities.

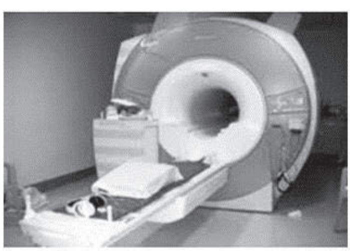


Figure 4.13 Magnetic resonance imaging (MRI) scanners
(FONG *et al* 2011)

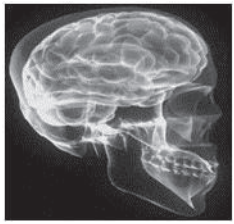


Figure 4.14 MRI scanned image of a healthy human brain
(FONG *et al* 2011)

4.2.1.2 X-ray

As with the MRI device, X-ray operates via radio signals directed at the object to be scanned. Images taken using X-ray is diagnostic in nature and normally regarded as radiographs. This scanning device is believed to be among the diagnosis scanning technology pioneered in the late 19^{th} century by Rontgen whom later awarded the Nobel Prize for Physics (Koeningsberger, 1988),(zabinsky et al 1995). A year after the device was introduced; mobile version of the X-ray scanner is manufactured, approximately 100 years after the invention of lithography by Senefelder. In X-rays, atoms are ionized through hi-energy incursion and produces positive ions that are able to destruct human tissues. Radiated electromagnetic (EM) emission with the frequencies above the range of visible light is captured in the radiograph as shown in Equation 4.5.

$$E = h.f$$
$$h \sim 6.63 \times 10^{-34}\,(J\,s) \quad \longrightarrow \quad 4.5$$

According to relation of Planck's constant (h) to the energy level in a quantum, the incident energy (E) equals to frequency (f) when calculated via electron-Volts (eV). The high content of energy can damage tissue cells by changing their chemical configurations. However, the energy level of radio waves is not enough for these alterations hence MRI is potentially less harmful than X-rays. The underlying theories of X-ray radiographs are not as hard as one thinks. As shown in Figure 4.15, energy is radiated by X-ray emission to ionize atoms and causes electrons to descend to a lower energy level. Excess energy is released during this process, producing photons called characteristic energy source or fluorescents. It is essential to know the processes of X-ray scanning to comprehend fully how an image with high resolutions is obtained. These characteristics produce Compton scattering during the deflection of X-ray photons by electrons. Compton was granted the Nobel Prize due to his discovery of this important process. Different than the stated condition above, the X-ray beam causes only a portion of energy from photons to be transferred to electrons, emitting photons with lower energy via different paths. This result in the change of energy level and the alteration of **λ** (where v = fλ) are dependent scatter angles as depicted in the equation below:

$$\Delta\lambda = \frac{h}{m_e v}(1 - \cos\theta) \longrightarrow 4.6$$

$$\Delta\lambda = \lambda' - \lambda$$

The diffused photon contains energy **E`** in relation to **E** as shown below:

$$E' = \frac{E}{1 + \frac{E}{m_e v^2}(1 - \cos\theta)} \longrightarrow 4.7$$

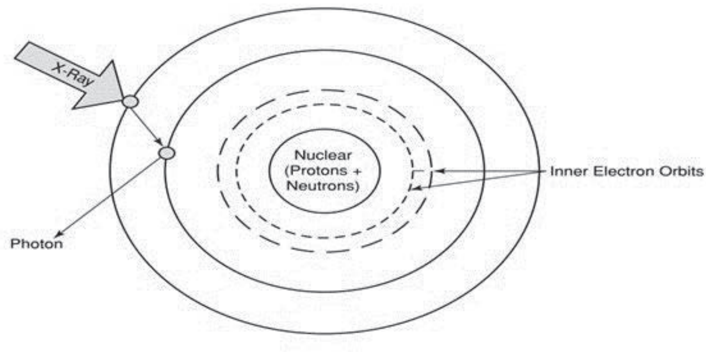


Figure 4.15 X-ray radiography (FONG *et al* 2011)

In Figure 4.16, the constant mass of electron is represented by m_e, θ for the scatter angles of photons and λ for the diffused wavelength. When electrons are knocked out from atoms, some energy is released. The theory of Compton scattering is crucial to understanding the unwanted noises in X-ray radiography and damages done to tissue cells. In Equation 4.7, low incident energy results in the independence of scattered energy from θ. Therefore, m_e with sufficient energy continues in a similar angle as X-rays. Even though the use of X-ray is potentially harmful, it produces a clear image. The damage is prevented or lessened through the adjustments of doses exposed, which is calculated in energy absorbance per single units of tissue cells. Detailed information regarding the doses of X-ray can be acquired from the 2009 report by the Radiological Society of North America.

Disruptions can be caused by cosmic and nuclear radiation as well as radio-activities from the surrounding environment. Section 8.5.3 discussed the potential harm associated with the overdosage of radiations. X-rays is used to scan cancerous cells and other irregularities of bodily functions through different tones of greys. Images converted and kept in digital formats are generally more reliable than silver-based photos. Therefore, abnormalities such as cancerous cells can be detected through the maintenance of these vital procedures that involves digital image technologies, as X-ray radiography can be ruined such as with the addition of noise. More comprehensive information of these mechanisms is shown in section 4.2.2.

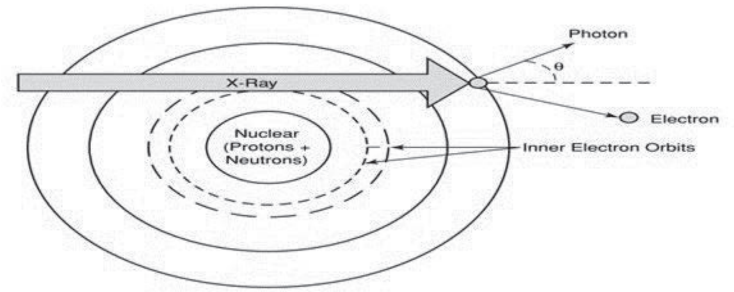


Figure 4.16 Photon scattering (FONG *et al* 2011)

4.2.1.3 Ultrasound

The estimation of ultrasound is dependent on various parameters such as sound propagations that comprised dispersing velocity, wave attenuation, the change in phases and acoustic impedance mismatch. Sound propagates across tissues and hence the bodily structural can be identified (Tempkin, 2009),(gillespie et al 2010). The propagation has frequencies higher than that of audible ranges and can propagate across liquid and cells which is then echoed back as images. Lighter images are produced when sound propagates through cells with higher densities, creating images with different shades. To produce an image, a probe is placed on the surface of the body. Ultrasounds are emitted from the probe and echoes are received. For the generation of echocardiogram if human's heart, ultrasound is propagated through blood, and echoed back as it stroke the valves. Figure 4.17 shows an image produced from the reflection of sound waves. A monochrome is used to diagnose the health and irregularities associated with the heart. The same procedures are used in different diagnosis, such as detecting the growth of cancerous cells and renal calculi in the kidneys to prescribe treatment as early as possible. Another common use of ultrasound is the monitoring of foetus. Figure 4.18 shows an ultrasound image of a 21 weeks normal foetus. The use of the device is important in this area to identify the gender of the foetus and whether there are abnormalities with the unborn baby.

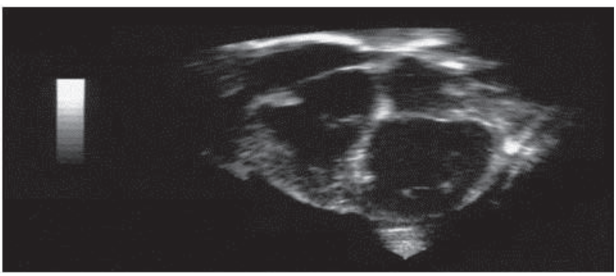


Figure 4.17 Ultrasound image of a beating heart
(FONG *et al* 2011)

4.2.2 Analysis and Transmission Medical Image

So far 3 main devices in diagnosis imaging have been evaluated. Next, the procedures in developing these images will be discussed such as Positron Emission Tomography (PET) and Optical Coherent Tomography (OCT). Certain similarities concerning process algorithms are exhibited by these models with the categories of images that have been discussed previously.

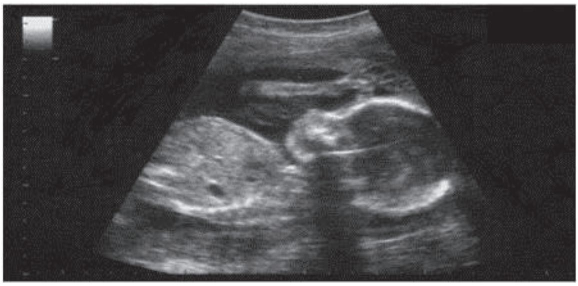


Figure 4.18 Ultrasound image of a healthy fetus
(FONG *et al* 2011)

Technology revolving around the transmittance of diagnosis imaging between different locations is almost identical to that of transferring an image taken via 3G mobile devices and transferring it to the Internet. Even though the mechanisms are almost identical, what mainly distinguishes one procedure from another is the purpose why an image was taken in the first place. For example in medical imaging, an image is taken with the important purpose of identifying the cancer cells, and this can be done so through the different tones of grayness produced. A case study is evaluated in order to comprehend the process of transmitting the diagnosis images. In this case, X-ray radiograph is transferred to a remote specialist (Maintz, 1998),(zitova et al 2003). Take note that the image is a 2-D representation of 3-D properties of X-ray attenuation formed by exposing tissue cells to a certain dosage of X-ray. During the beaming of the X-ray to the target object, the cross-section of the ray and tissue atoms is represented by *A* and *S* while cell's atomic density is represented by N. Therefore, the whole cross-section is N x S and the total atoms stroke by the ray is A x N x S as shown in Figure 4.19. Rate of changes in ray strength during penetration is shown in the equation below:

$$\frac{dI}{dx} = -N.S.I \longrightarrow \quad 4.7$$

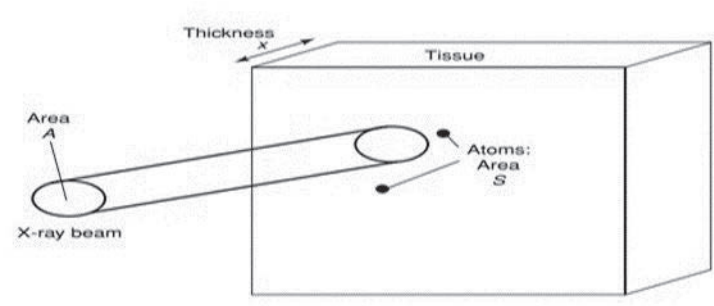


Figure 4.19 X-ray beam strikes the tissue
(FONG *et al* 2011)

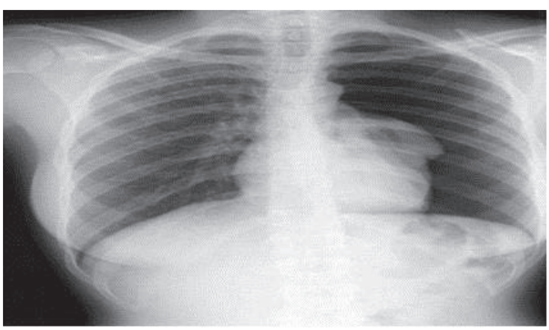


Figure 4.20 Radiograph showing tumour in the lung
(FONG *et al* 2011)

This characteristic is crucial to deduct the attenuation of coefficient **μ**. This coefficient is an entity of the strength of photons in every location of cell which is named as **I(x)**:

$$I(x) = I.e^{-\mu x} \longrightarrow 4.8$$

The formation of images from radiography is essentially a mapping of photons through the object which comprised of different densities, such as organs and bones. As an example, cancerous cells can be identified as these cells show distinctively different shades of grey compared to other structures. Figure 4.20 shows an image captured using radiography where darker masses can be observed on the left of patient's lung cavity which indicates the degradation of internal lung cells. This is a condition called spontaneous pneumothorax induced by pneumonia. Without this image, it would be impossible to identify the condition and to prescribe the correct diagnosis. The degradation of the left lung cells is compared to the right lung which looks lighter and normal. However, it must be ensured that all data must remain intact during image transfer as the loss of any information will halt the effort of diagnosis. Analogue images can be observed everywhere in the surrounding environment. This is particularly true as our observation and interpretation of the surroundings is comprised of a collection of various spectrums with uncountable distinctive features, and it is not possible to transmit images with infinite features. Hence, to enable an image to be transmitted, it has to be converted to a finite or exact size, such as the bitmap (arrays of colored or grey dots known as pixels). Next, to transmit an image, a network bandwidth with sufficient data rate is required. For instant, a considerable sized image with 3000 × 2000 pixels at 6 megapixels of resolution and 256 different grey tones will contain the size as shown below:

$$Uncompressed\,bitmap\,fil\;\; size = H.W.2^{b} \longrightarrow 4.9$$

It excludes insignificant features such as check errors and surplus data of the image, which include the types of file and date when image is taken. From the equation, b represents the amount of bits per pixel which results in the intensity of colors, H represents the height and W represents the width. Using the value of pixels given above, the total uncompressed bitmap size of 5.72MB is obtained. It is a fairly simple calculation; first the number of pixels is obtained by multiplying H with W. Next, the unit is converted to bytes through the division of the value with eight binary bits. Finally, the value is expressed in kilobyte (KB) by dividing the value by 1024. To express the value in megabytes (MB), the value has to be divided twice by 1024. This calculation exhibits the amount of data in managing digital images, and can easily be reduced for the ease of transmittance.

4.2.3 Compression Image

To ensure an efficient transmission and in order to reduce the space required for storing, images are compressed and shrunk. This is known as a loss compression. However, there will be some loss of data when the compressed image is decompressed back to its initial size due to the loss of some algorithms. This can be prevented via lossless compression. Using this form of compression, the decompressed image will have the exact properties as its original form. Take note that a digital photo is constructed of matrix of pixels with strings of 0 and 1. The evaluation of this topic will start by analyzing the advantages and disadvantages of the two compression methods (Tobin, 2001),(seeram et al 2008). It is necessary to compress diagnosis images to ensure its efficient transfer via medical channels and to decrease the amount of space needed for data storage, thus lower the operating cost. In digital photos, primary colors with consisted of different intensities of reds, greens and blues are used to construct the pixels. These colors however do not include secondary or subtractive colors like cyan, yellow and magenta which are resulted from the mixture of any two of the primary colors. The constitution of colored pixels in digital images is identical for other digital illustrations in different gadgets such as camera, mobile phone, television and computer. The addition of different intensities of primary results resulted in enormous possibilities of shades known as additive colors. The pixels in a regular color bitmap are comprised of 3 numbers each (one byte for one primary color) which resulted in different densities of colors constructed from the primary colors in overall. Therefore, a total of 24 bits are required to form one pixel (1 byte equals to 8 bits) for storing the color data. To get an idea about the enormous possibilities of color formations, an equation as shown below is used to calculate the number of color formations: $\mathbf{2^{24} = 16\ 777\ 216}$ (more than 16 million of possibilities!). In computer language, digital images with 24 colour bits are called true colour images.

$$Number\ of\ Colours = 2^b \longrightarrow \quad 4.10$$

From the equation, ***b*** represents bit-depth or bits number. A camera with between 12 and 14 bits is required to produce images with higher intensity of colors. To compress images, regions with identical colors are identified and regions that contain gaps and unnecessary fields are eliminated. In telemedicine, the compression of images using loss compression is not acceptable as loss of information cannot be tolerated. This is especially true as the identical shades of grey may marked as identical regions during compression, and some regions may be eliminated. For most diagnosis images, abnormalities present in the body may not be distinctive or refined enough to be identified even though it is absolutely crucial to the patient's condition. This may be due to conditions such as the initial stage of cancer of abnormal foetus formation, and the use of lossy compression might cause the elimination of crucial information. The strength of image is widely known as quality factor. The comparison of different compressing ratios with an original MRI image is shown in Figure 4.21. In (a), the image after a being compressed at 1:20 is shown and (b) shows the compression at 1:100. Using careful observation, the image in (b) is noticeably clear while the other image appears more blurry.

(a)

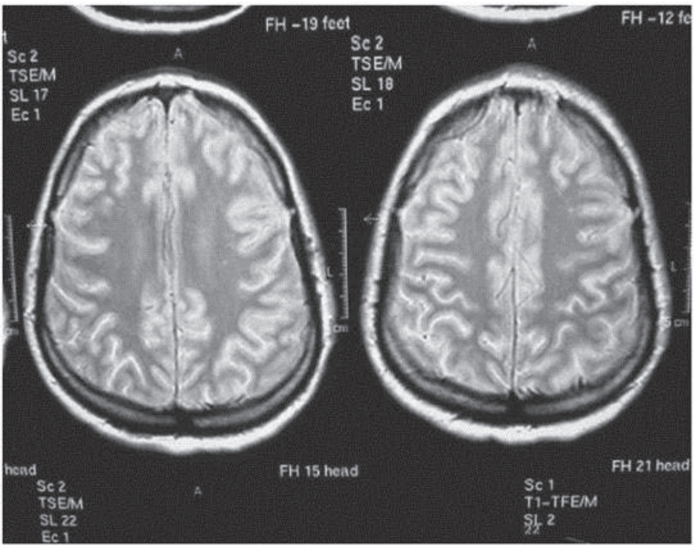


Figure 4.21 MRI scanned image. (a) Without data compression (FONG *et al* 2011)

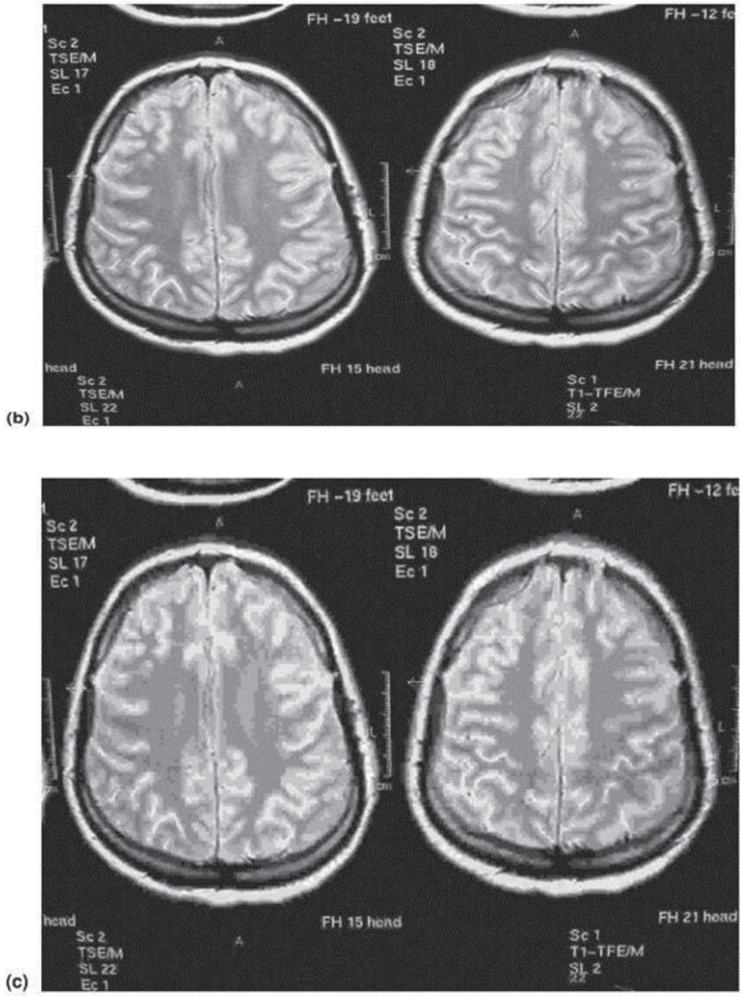


Figure 4.21 (Continuation) (b) moderate compression of 1:20; (c) compressed to 1:100 (FONG *et al* 2011)

4.2.4 Bio-potential Electrode Sensing

To measure the rate of heartbeat and the behaviors of other vital organs such as the brain or even sleeping patterns, the Electrocardiogram (ECG), Electromyography (EMG) and Electroencephalography (EEG) graphic hypnograms are used. The devices measure the electrical activities associated with nerve stimulation and muscle contract of the related organs, which can be illustrated as the generation of waves with the plot of electric currents over time. To have a good idea of the procedure, only the mechanisms of ECG will be focused as other devices exhibit the similar properties. The mechanisms of the devices are shown in Figure 4.22. The most significant property that is similar in these plots is that asymmetrical amplitudes are emitted throughout the measuring period. The heartbeat is measured via the electric potentials generated by the heart and not by transferring electrical currents to the organs. The rhythms of the heart are plotted via impulse generation which is used to identify a wide range of abnormalities associated with the vital organ. However, as with other devices, the measurement can be disruption by noise waves and significantly impair the diagnosis process. Other causes of disruption include some diagnosis protocols. For example, patients are required to exercise on the treadmill to measure the shrinking of the artery using ECG. If patients are not able to perform the task, the measurement would nevertheless be useless. Movements and shocks that incurred during the measurement process may also result in discrepancies of the result as electrical conductors are placed on the chest. The period of measurement varies based on the nature of the diagnosis. A brief diagnosis tends to be more advantageous as it is less likely to be disrupted by unwanted noises. The analysis of ECG diagrams is normally conducted manually by doctors. As with the storing of images, there is a possibility of data loss while transmitting or storing graphs. The graphs must be restored to its exact features to prevent any loss of crucial information. However, there is a certain difficulty as signals are required to be separated from its grid. Therefore, the use of colours is encouraged instead of black and white to help in extracting the signals even though it is represented by monochrome lines. In addition, pink grids in the plot can be eliminated through the elimination of red components.

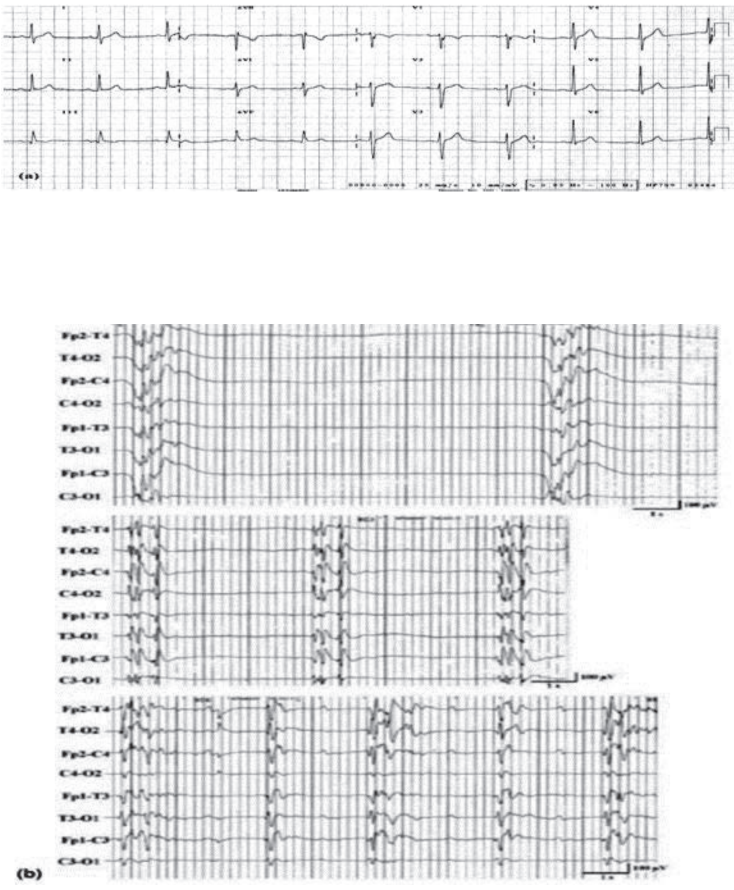
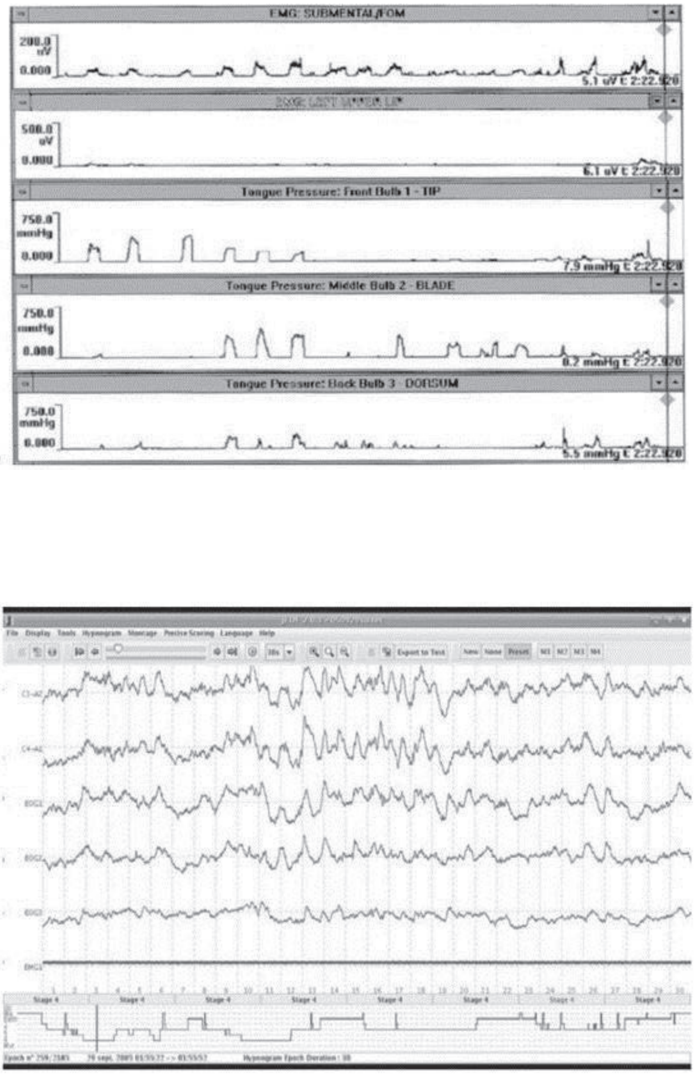


Figure 4.22 Electrical activities. (a) Electrocardiogram (ECG); (b) Electroencephalography (EEG)
(FONG *et al* 2011)



(c)

(d)

Figure 4.22 (Continuation) (c) Electromyography (EMG); (d) graphic hypnograms (FONG *et al* 2011)

4.3 Data Mining Applications and Patients' Medical Records

Keeping patients' medical records is long been practiced. This can be observed from the archives of visiting cards kept in clinics that contain the medical history and diagnosis of patients. The reason of keeping the medical history is to enable the tracking of patients' health and to serve as a warning to doctors about the existing medical issues of patients such as allergies. In addition, medical records show the pattern of patients' health and may alert doctors if there is something suspicious that requires medical attention. This enormous amount of data is the reason many physicians refuse to transfer them into digital forms as it requires a lot of manpower and resources, not to mention the change required in the whole operations in dealing with electronic systems. The use of manual data entry can be observed from a visit to the clinic; first the administrator would retrieve the visiting card of a patient, pass it to the doctor, and new records will be made to the card after the diagnosis. Even though this procedure appears unproblematic, it will result in long-term problems the first being the preservation of enormous amount of records that consume a lot of space. Another common problem is the intelligible hand writings that cannot be understood by another physician and the loss of valuable medical records crucial to the descendants of patients or new physicians due to migration of passing of patients. A small clinic operates in suburban may serve up to hundreds of people, while this figure can easily exceed hundred thousand in major health institutions. This results in a large volume of medical records when diagnosis details of each patient are combined with their personal information. The medical data of every patient could easily require megabytes or even gigabytes of data storage. It is easy to imagine the database of one hospital moreover the collective data bank of all citizens. This leads to the question of using a reliable database that allows the keeping of enormous amount of information and at the same time enables them to be extracted easily. Those are the basic enquires made on data storage. Even though it is not comparable to the collective data of the Internet, the database is still comparatively large. For example, the epidemic condition of swine influenza in the Mexico City in 2009 resulted in the influx of more than 10 000 patients in health institutions in a day. This coupled with other cases such as suspected and confirmed A (H1N1) infections has resulted in the built-up of vast amount of data in as short time. This paves the way for mining technology which enables clustered extraction from the database for the related information to study virus mutation such as in the case of influenza in a highly populated city.

Similarly to search engines and Internet browsers, statistics are employed to rapidly retrieve specific information from an enormous data bank. A browser links to the pool of data on the Internet and to retrieve related information, a keyword is entered which subsequently extracts the data that contains the keyword at a very high speed. To aid and simplify the study, a keyword is used. For the computer, phrases are long words with spaces in between strings of words which form specific meanings. These words are comprehended by computers as ASCII codes (abbreviation for American Standard Code for Information Interchange) where characters are constituted by 7 bit codes. From this code, computers understand A as 1000001 which equals to the numerical figure 65. Therefore, words or phrases entered as keywords are recognized as a sequence of 7-bit codes or ASCII codes. In data mining, data is extracted from an enormous database through pattern or strings of code recognition. At the same time with advancement in increasing the capacity for data storage, efficient statistic tools are developed for retrieving data with an incredibly fast speed. In current Internet browsers, by keying in the keyword "data mining" as an example, a staggering 21 million founds are obtained in just 0.18 seconds. The data retrieval mechanism is based on the enquiry of users that forms the search patterns. In general, 4 different processes are involved in data mining as shown in the charts of Figure 4.23. Even though every digital search applies the similar technology, the retrieval of medical data may involve more complicated codes, especially in diagnosis images which are highly distinctive among patients. We have already known this when searching for images on the Internet where results are often not related to the search keywords. Basically, four associations are involved in the process of data mining:

- **Associations**: Connection is identified from data extraction. For instance, diabetes is highly associated with obesity even not in every single case as diabetic patients are mostly overweight.
- **Classes**: Grouping of data based on categories, such as the group of diabetic patients.
- **Clusters**: Grouping of data based on logics, such as groups of patients based on locations or demographics. This type of association is especially helpful in analysing patterns of diseases.
- **Sequential patterns**: Predictions and patterns are made through the extraction of data. For instance, obese patients can be predicted to suffer from other chronic diseases than non-obese patients.

Next, a case study involving the digital records of a diabetic patient will be examined. The record contains not only the diagnosis history but other personal information such as demographic information. From the age of the patient, doctors are able to make precise assumption whether this patient suffers from Type 1 or Type 2 diabetes. This illustrates the usefulness of the data as a whole, even though most of the record is comprised of in-depth diagnosis details such as the amounts of glucose prescribed in its units.

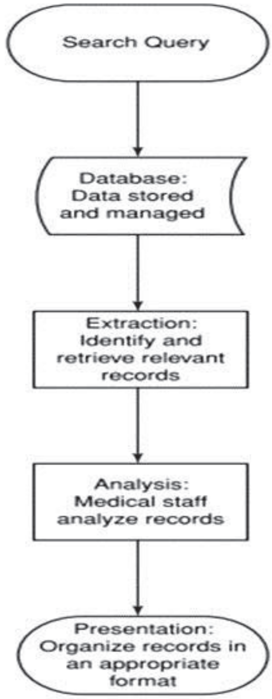


Figure 4.23 the information retrieval process
(FONG *et al* 2011)

The names of various nations, its respective measurement units and corresponding remedies are shown in Table 4.1. Besides patients' in-depth diagnosis details as mentioned above, other forms of data such as images and audio files from X-rays and ECG diagnosis may be included. To extract data that involves ambiguous natures and patterns, specific procedures is required (Elmaghraby, 2006),(kantardzic 2011).

mg/dL	mmol/L
Argentina	Australia
Brazil	Canada
Caribbean Countries	China
Chile	Ireland
Israel	The Netherlands
Japan	New Zealand
Korea	Russia
Mexico	Scandinavia
Most EU States	Singapore
Most Middle East Countries	Slovakia
Peru	South Africa
Taiwan	Switzerland
Thailand	Ukraine
USA	UK
Venezuela	Vietnam

Table 4.1 Blood glucose units (FONG *et al* 2011)

In addition, there are various procedures and the efficiency will be affected by the capacity of the computer to process the search, which is in turn affected by the extent of database and the nature of the enquiry made. Procedures widely employed consisted of:

- **Neural Networks**: Models based on prediction which makes a replication of the neurons. The efficiency of this model increases with time as it will be equipped with more processes much like long-term training.
- **Data visualization**: Graphic determination of complicated interactions in data which included the visual deduction of data.
- **Decision Trees**: Decision derived from the extension of themes that determine the procedure in data categorization. Classification and Regression Trees (CART) and χ-Square Automatic Interaction Detection (CHAID) are

the commonly applied procedures to extract disorganized data.

- **Genetic Algorithms**: Heuristic algorithms interdependent on the theory of evolution such as combining, recombining and mutating of selections to come up with a pattern. Initially this method was used for data mining by Holland (1962).
- **Nearest Neighbor**: Or known as k-NN method where every data is classified by combining categories of k number containing the highest similarities in history. It is commonly applied to recognize the patterns from ECG diagnosis as the device uses the same principle in identifying patterns. The algorithm is monitored where new search will be categorized based on the most probable k-nearest neighbors. The operation can be easily understood. The search mark looks for object with k number nearest to search mark as the learning location using the most probable votes. Finally, the value of new search will predicted using the classified neighbor clusters.
- **Rule induction**: It is the least complicated procedure relying only on the execution procedures of observed 'if' and 'then'.

Even though we have looked at the significant role of data mining in recording the medical data of patients, its role in the retrieval of diagnosis imaging and structured data has not been discussed. To search for images, keywords related to the image are used. In the case of medical images, keywords associated with the image are used and a set of organized image labels is required. The existing technology to extract images is still in its early stage. In common consumers' electronic devices, a number of characteristics such as colors and textures are used by in algorithms which are not adequate for the application of images from telemedicine.

4.4 Knowledge Management for Clinical Applications

In most nations, digital information of patients is recorded for numerous reasons, such as statistic studies and health insurance. It is stated by researchers that most doctors preferred data retrieval by searching from the databank of medical history (Dawes, 2003),(hersh 2009),(straus et al 2013). As the data contains not just medical record but other information such as demographic data, a more efficient way is required for data retrieval, particularly when the operations of health institution is constituted of different departments such as management and clinical operations. The complicated nature of medicine database across different applications is shown in Figure 4.24. A vast amount of data exchange can be observed from the system which comprised of different categories of information. Detailed information of a doctor is depicted in Figure 4.25.

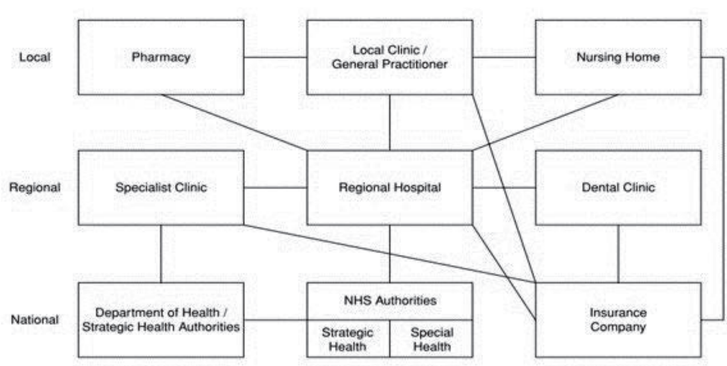


Figure 4.24 Clinical knowledge systems (FONG *et al* 2011)

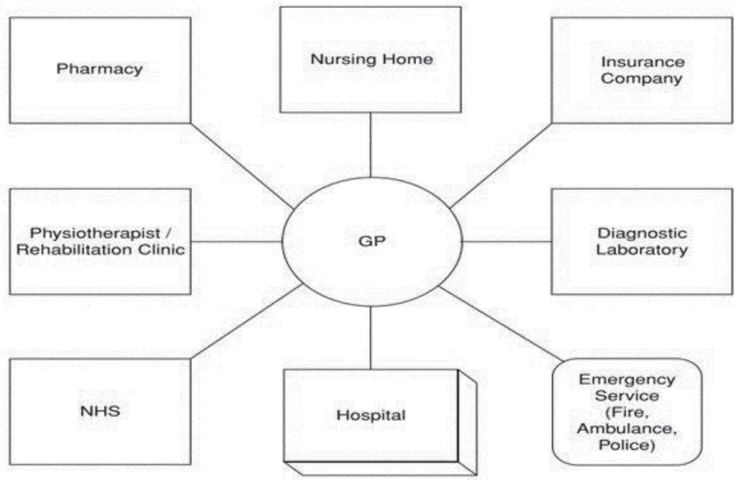


Figure 4.25 System linking a doctor to the outside world (FONG *et al* 2011)

In local health institutions, doctors frequently interact with related parties. Figure 4.25 shows the interactions that takes place outside the institution. Figure 4.26 shows the internal interaction that takes place in the local institution operated by only one general practitioner and how information is obtained and shared. There are various channels to obtain information from even though it is just a small-scale clinic. In managing knowledge, useful data is being created, transferred and identified. Conversing information is essentially a continuous process by preserving and enhancing information. The process is the same as creating information system, followed by its transfer and contribution to other parties to improve information sharing in general. For a continuous development, information throughput can be recycled for other processes. In the context of telemedicine, managing knowledge mostly involves creating and maintaining procedures that can improve medical service for the benefit of the society. Given this, knowledge management is undeniable advantageous to provide patients with the best possible diagnosis and prescription. Figure 4.27 shows that the digital record from a continuous monitoring contributes towards the development of medical services based on experience.

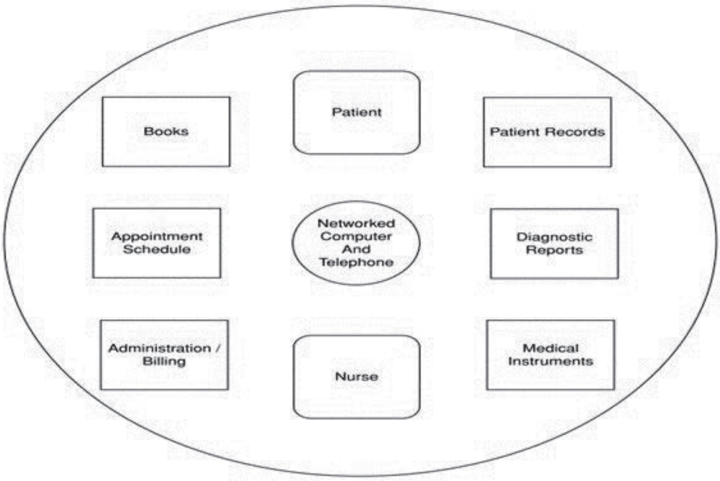


Figure 4.26 inside the clinic (FONG *et al* 2011)

Following a certain symptom, diagnosis is often accompanied by other more concrete results such as a series of tests from the laboratory and clinical evaluations. However, this often takes more time than permissible especially involving emergency situations. Therefore, knowledge management using medical history serves as an important support in prescribing an efficient treatment at the shortest duration possible. For example, a case study involving the use of ultrasound to eliminate tumour will be examined. When directed to target cells, the beam heats the cell quickly to above 70°C and result in hypoxia and stop oxygen to reach to the cell thus killing the tumours. Despite its effectiveness, there is a certain risk associated with this method such as the possibility of damaging epidermis tissues. However, by referring to medical records of previous patients, a database can be built which comprised of tumour categories and sizes along with its subsequent treatments. The case study illustrates the importance of knowledge management especially in storing and sharing of data. Various categories of data are comprised in patients' digital medical record such as diagnosis details, treatments issued and records of appointments. These records are also important as references for the treatment of similar conditions.

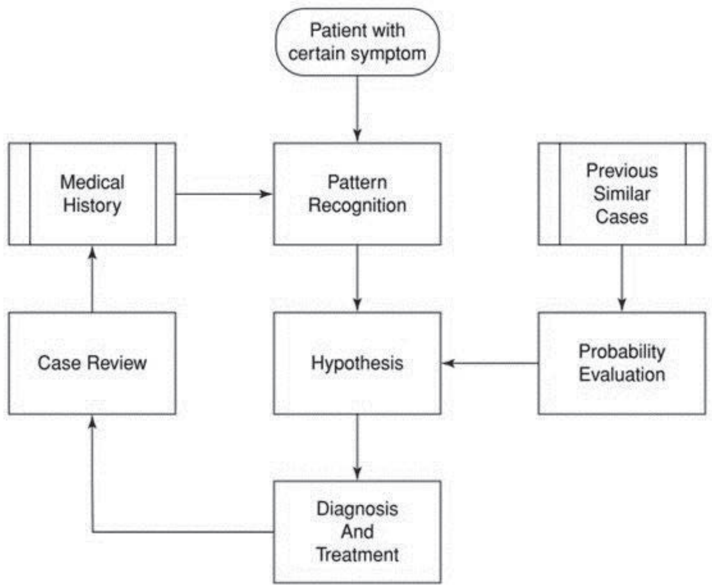


Figure 4.27 Knowledge management for electronic patient records (FONG *et al* 2011)

Several hazards and challenges have to be overcome to develop an effective digital database of medical history. Firstly, the well-known SOAP procedures will be referred to (schimelpfenig, 2006a), (schimelpfenig 2013b):

- **Subjective:** Medical nature of patients and the symptoms exhibited and reported.
- **Objective**: Diagnosis of vital conditions of patients such as heart beats, blood pressure and other tests to identify irregularities and prescribe necessary clinical examinations.
- **Assessment**: Summarization and analysis of the collected data as mentioned above.
- **Plan**: Devising the appropriate prescriptions and treatments as a follow-up plan.

The ultimate purpose of these procedures is to aid the diagnosis process using information management and lay the pathway for an effective interaction between patients and medical personals. It is often applied as a set of standardization in hospitals and clinics to systemize their medical records. Ultimately, medical information is sensitive in nature and the storing of this data must be reliable and accurately conducted and the distribution of the information should be regulated.

4.5 Electronic Drug Store

The chapter is concluded with a discussion on the sharing of medical data within an e-commerce medicine supplier. In fact, the term “telemedicine” might be derived from the distribution of clinical drugs. Via technological advancement, these firms can reach out to more patients particularly communities in far remote areas as well as patients incapable of travelling. Even though clinical drugs must eventually be delivered to these destinations, the improvement of telemedicine enables medical services to reach out to more remote locations and higher treatment efficiency through information sharing. One of the main responsibilities of e-medicine distributor is in assisting the distribution and dispersion of clinical drugs based on strictly regulated procedures to comply with standards and in reducing operation expenditure. This implies that the distribution of clinical drugs is not merely like a drug vending machine that distributes over-the-counter drugs. Note that in this discussion, the word "dispensary" is omitted to avoid confusion since this term is used in the US to describe agencies that are licensed to trade intoxicating or narcotic substances such as cannabis and alcohol for clinical purposes (Martinez, 2000),(iversen 2003). The examination of medicines is another main practice that aims to improve the efficiency of drugs and to reduce the unwanted side-effects of drug consumption. This practice aims to build a database that contributes to the development of new drugs. However, perhaps the most important role of e-medicine distribution is information sharing of the function and accurate prescription of certain drugs, information of drugs regarding its current usage in the medical field as well as the accompanied side-effects of each drug. Besides, these websites enable direct interaction among users and the drug distributors which enable consumers to obtain first-hand information regarding potential side effects. In addition, the practice of recalling products, obtaining information regarding their expiry dates or licenses enables pharmacist to be well-informed about the current drugs they handle with. For the end-users from the public, the availability of information in extensive networks means that they can inform themselves regarding the effectiveness of each drug and prevents risks associated with the mixture of high-risk medicines. Drugs prescribed to patients are in turn recorded in their medical history. Through extensive telemedicine networks, the medical records of patients are integrated into the network and enable information sharing among doctors and pharmacists as well as to patients themselves. This also results in much convenience where patients can obtain the drugs required from pharmacies without the need of a written document from hospitals, as pharmacists can easily retrieved this information from the network. The main concept of the establishment of e-medicine distributors is the ability to distribute drugs irrespective of time and location by referring to medical data of patients made available to them. The medical record enables pharmacists to issue medicines with an authority from healthcare institutions and acknowledge the adverse effects associated with the consumption of various drugs such as allergy and reactions occurred from drug mix-ups before distributing the drugs. In addition, the data network informs healthcare institutions about the insurance coverage of patients, and reminds patients to consume their prescriptions at the instructed time. In the network, the procedures associated with diagnosis and treatments prescribed are recorded automatically. Mobile monitoring devices can be established at the home of patients who have mobility problems such as senior citizens and blind patients. Figure 4.28 shows that these devices and be installed like a software on computers or any devices equipped with RFID reader. The software contains information about the medicines issued such as consumption instructions and the record of drug consumption by patients. This illustrates that the application of e-health and e-medicine distributions doubles as a device to update patients' drug prescriptions besides help them to obtain their medicines more conveniently. The record of medicines usage is especially crucial in diseases outbreaks such as the spread of A (H_1N_1) influenza virus. The drugs inventory informs healthcare institutions and pharmacies regarding the amount of stick available to meet the unexpected demands during the outbreak. The amount of influenza vaccines must be ensured to be adequate at all times to avoid the risk of inadequate supply especially in high-risk regions. Under telemedicine networks, drug suppliers can have a direct communication with manufacturer to initiate the transfer of the vaccines to high-risk regions immediately when a high rate of suspected cases of influenza is reported.

CHAPTER 5

DEPLOYMENTS OF WIRELESS NETWORKS IN TELEMEDICINE

From the previous chapter, it has been stated that patients' medical records can be obtained from different channels according to the nature and format of these data. The information is also subject to different requirements prior to data transfer and utilization. Procedures to obtain the information have been discussed along with their subsequent requirements for data transfer via e-health networks. The transfer of information such as patients' vital signals and physical scans are different as they are subjected to different requirements. Numerous ways in acquiring data result in the estimation for both immediate and longer intervals in order to suit various health monitoring situations. One of the main obligations is an effective and dependable communicative channel to support patient caring. The establishment of channels is considered via the support of specific applications to fulfil the specific requirements to comply with the nature and format of the data. As an example, the transfer of X-ray radiographies is subjected to distinctive procedures in the aspect of transmission capacity compared to the transfer of a text document that contains the information of treatment prescribed to patients. Each network possesses its own functional limitation on the capacity of information transferable in both wired and wireless transmission. The channel transmission capacity determines the amount of transferable bits can be sent to another network per second. Therefore, a communication channel must be selected that can transfer the information and at the same time do not result in data overflow (overflow of data happens when excessive of information is transferred to the same channel rapidly). To understand this situation let us take an example using the analogue network to send a HD video with a channel transmission capacity of 3100 Hz. Without doing any calculation, we obviously see that the capacity of transferred data exceeds the transmission capacity. A MHz-capacity transmission capacity is still required to send HD videos even if the files are compressed. Information is obtained in the format of block or stream in digital networks. Due to the expansive nature of information, prediction cannot take place even in the case of random one-off measurement as there are no fixed patterns. Therefore in every data analysis, a discrete data block is received and additional data will not be accepted until the arrival of next reading. The A&E department is a very good example that shows randomized cases where at times it will be overflowed with patients and empty in others. Poisson distribution modeling is the most effective model to manage the discrete likelihood in acquiring information (Shmueli, 2005),(lord et al 2010). On the other hand, a constant observation such as in gathering information of mobile healthcare devices results in a continuous influx of data. Hence, information is managed in a limitless time frame until monitoring is interrupted, such as the handling of audio and video information. To have a better understanding on how discrete and continuous information are managed, we will examine the previous example of transferring HD videos.

As the file is received in an influx in the time frame of five seconds followed by no file transfer, the transfer of the total file can still be completed in a prolonged period as there is enough time to process the data as in the situation of pouring a large amount of liquid down a funnel through a pipe with a narrow passage. It can still get through without spilling over if there is sufficient capacity in the funnel to buffer the flow before overflow occurs. However, if the water keeps flowing in continuously like a stream, it will not be able to get through. Imagine the consequences a tap is left on and causes water to flow continuously towards a narrow passage that could not retain the whole volume. Obviously, the water would spill from the funnel due to excessive water volume. The same concept can be applied in information transfer if too much data is transferred to a network without the sufficient transmission capacity to retain the data.

Communicative channels are important in the current medical industry particularly in data sharing. From the previous chapters we have learnt that these channels were established with the main purpose of supporting a wide range of functions to support the extensive medical services. The following sections will show the methods to overcome the obstacles associated with network development and highly resilient channel equipped with the ability to incorporate new features made available from research. The knowledge obtained in Chapter 2 will be used to examine the basic mechanisms of channel planning and the requirements to future expansion. The major topics covered include the outsourcing and its associated advantageous and disadvantageous and finally the quality assurance of network.

5.1 Strategies Involved in Network Deployment and Planning

In order to get a clear picture of the concept of the planning of telemedicine networks, the underlying concept must be understood. The most basic structure of network basically refers to peer-to-peer (P2P) framework as shown in Figure 5.1 which consists of two PC interrelated with each other. Each computer is equipped with a network interface card (NIC) which provides them the capability to communicate with another PC. However, the intermediate mediums which use to connect both PC make are the same as long as data can be transferred between them. P2P's main characteristic network there is no central region and all users (other PCs) have identical status. The overall picture of information sharing via Open Systems Interconnection (OSI) will be examined before proceeding to the mechanisms of communicative channels.

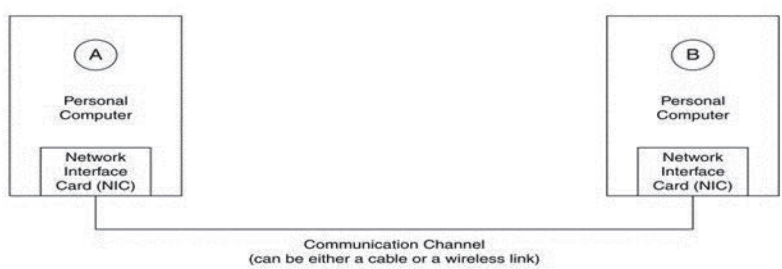


Figure 5.1 Simplified P2P network (the fundamental form of any network) (FONG *et al* 2011)

5.1.1 The OSI Model

The OSI reference model equips a layout for channel interactions. The objective of this model is to standardize channel designs as a descriptive model for tiered interactions. For example, channel configuration is categorized into various tiers and with its own specific functions. Figure 5.2 shows the seven tiers consisted in the model. Every tier or layer is assigned to the handling of different tasks. Communication between any layer and the next is referred as 'direct'.

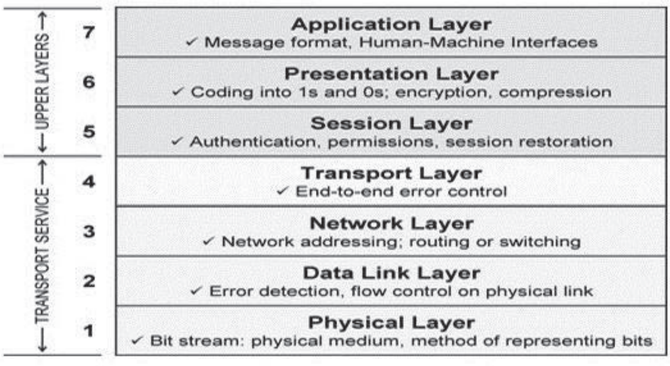


Figure 5.2 Different layers in OSI model (FONG *et al* 2011)

This includes the exchanging of data blocks via a port of a layer called service access port. They are usually grouped into two categories, where the top 3 layers referred as host layers and transport layers for the bottom 3 layers out of the seven layers. From the literature, the middle layer is categorized into either host or transport layer. However, the name of this particular layer is called 'Transport', therefore it would be more logical to classify it into the layer of lower transports. Basically, the entire communication process is categorized into different functional areas by OSI model. The illustration of Figure 5.1 shows that the communication process of PC A is maintained with PC B. In a simpler sense, any layer of PC A talks to the layer of PC B can be referred to any layers in the OSI model. Any process carried out by a particular layer can be classified as its entity. Since there is no direct connection link between the two PCs, the communication between these 2 layers can be classified as virtual.

Communication can be succeeded through the conversion between Protocol Data Unit (PDU). PDU is considered a shell that holds information identified as Service Data Unit (SDU).

Hence, SDU is the entity of PDU that containing the header of data. The entity that belongs to any n layer is managed by n protocol. These entities use the manage data in constructing SDU header to create a PDU that can be transferred to **'n - 1'**. The main objective of layer n is to receive the PDU from upper layer **'n + 1'** and deliver to the subsequent layer below. If the size is not enough to carry the data, the segmentation and assembly process will be carried out to break the data blocks into smaller units at the sending end and reassembly at the receiver. Next, we take a look at the overall picture of the layers of OSI model beginning from the top:

- **Application Layer**
  Application layer refers to the top layer among the 7 layers in OSI model. It takes establishes the communication between users and the application of software. For example, when a staff wants to perform stock count, update of the database will be performed and any notification must be sent if there is any missing of stock. The staff enters the stock quantity into the system and the system updates the database. For any changes made to the stock count, system will auto-generate an email to the top management. All these processes are handled by application layers which include the database, email, browsers and so on.

- **Presentation Layer**
  Presentation layer is known as a converter in the application layer for data from human users. Information is converted into appropriate code for system processing. Individual devices use different operating systems (OS) and hence different codes to present the information. Therefore, the presentation layer changes this information into a suitable format for data transfer. For example, smart phones and computer have different

application for information display. Presentation layer functions as a converter to convert a smart phone readable form into computer readable form.

- **Session Layer**
  Session layer establishes dialogues between two nodes and allows data exchange either in the form of simplex, full duplex or half duplex methods. Besides, it also supports error recovery services to ensure the data can be exchanged without error. It is useful to manage a flow of data such as ECG readings.

- **Transport Layer**
  Transport layer mainly handles end-to-end delivery of messages to ensure the messages can be sent properly. If the size of the message is too big, transport layer will perform segmentation and reassembly to break the message into smaller parts at the receiver and reassemble the message. This layer utilises the service from the core channel to impart quality of service (QoS) as an aid in transferring data, monitoring of segmented data and retransfer when necessary.

- **Network Layer**
  Network layer handles the delivery of packets from source to destination by referring to the IP address. Other than delivery of packets, it also handles the routing of packets to the correct destination using the correct routes. The packets will be en-capsulated at the receiver and when the packets reach the receiving end, decapsulation will be performed to remove the header attached to it.

- **Data Link Layer**
  The purpose of is categorized into 3 processes referred to media access control, error control and message de-

lineation. It also establishes an exchange of data frames between nodes. Originally, the frames are data blocks that have been converted. The media access control handles the transmission of frame into the communication medium, and performs the error control process by checking the data bits. Once they have passed these stages, the frame will be transferred to the correct destination without any disruption.

- **Physical Layer**
  It is the model's underlying layer that manages, activates and de-activates physical connection for bit transmission. All the data and information will be converted into bits like '1' and '0' and then they will be transmitted through the communication medium. Therefore, this layer only concerns about the network hardware and the type of circuit to be used to transmit the messages.

5.1.2 Site Survey

It is one of the most crucial steps to initialize the planning of networks. It is because this is where the decision of "how many radio station or wireless access point to be placed?" made. Even though it seems to be simple, this step cannot be taken lightly. Site survey is carried out to perform stress test in identifying problematic issues such as poor reception, network interference and so on. This procedure must be given an emphasis because it could reveal useful information to perform "what-if" analysis. "What-if" analysis generates a lot of questions solutions can be provided to address the question before we engage in the real plan. Some sample of questions include "what if an object block downs the wireless signal?" and "what if the signal coverage needed to be expand as far as to the road across the other building?" Hence, the locations of wireless emitter should be studied including the extent of area covered, the capacity of network, interference problem as well as possible obstacles. Coverage area basically refers to the signal strength. To check this signal, we can connect our PC to a wireless network and observe the 5 bars icon of bottom right of the PC. More green bars indicate stronger signal strength. If we move our PC further away from the access point, we can observe a reduction of green bar immediately. If we move the PC further away, the wireless connection will be disconnected. There is a formula for this measurement:

$$\boldsymbol{S(d) \propto \frac{1}{d^2}} \longrightarrow 5.1$$

However, this applies by assuming that there is no obstacle in between wireless access point and the device connected. The second element refers to the capacity of network. It mainly controls the user limit. Besides, the amount of data transferred by all users at the same time can be regulated. When it reaches the maximum capacity, any other users who attempt to connect to the wireless access point will be denied. Interference refers to the degree of distraction towards the wireless broadcast signal. This can happen when the wireless access point shares the same frequency band with others. For instance, there are a few wireless routers in the same place that broadcast the signal using the same channel and such situation results in interference. Interference can cause a reduction of the data speed and reduces the connection quality. Apart from interference resulted from channel conflicts; physical obstacles can be one of the major causes to interfere the signal transmittance. For instance, thick walls with steel beam can absorb or block the wireless signal. Another example is glass panel which have the capability to reflect the wireless signal. In order to get accurate data and information from site survey, a lot of work has to be done. For instance, we can install a network management system into a laptop to capture the measurement of signal strength and its interference in different locations. Access points are often moved around different locations in order to find the best signal strength. Modern surveying software can also be used to measure and analyze signal from the access points just by walking around with the laptop. In the case of the hospital, the coverage extent must be estimated as it is not possible to search through every corner. Site surveys can only provide the signal to be expected but the outcome doesn't mean that the real channel functions exactly the same as what we performed during survey. Additionally, the authorized risk assessments must also be given a consideration on the possibility of interfering with sensitive medical devices.

5.1.3 Comparison of Standalone Ad Hoc and Centrally Coordinated Network

The deployment of wireless network is categorized into two methods which include standalone ad hoc and centrally coordinated network. The network entry is an independent operation and configuration to prevent congestion and device failure. Moreover, it does not have centralized control on data flow and user access management, and each body network operates independently. In the situation of patient monitoring application, it requires an intense level of energy to meet the performance as it involves continuous data streaming. With this configuration, the issues of power management, packet loss and security may arise and can cause performance degradation on network.

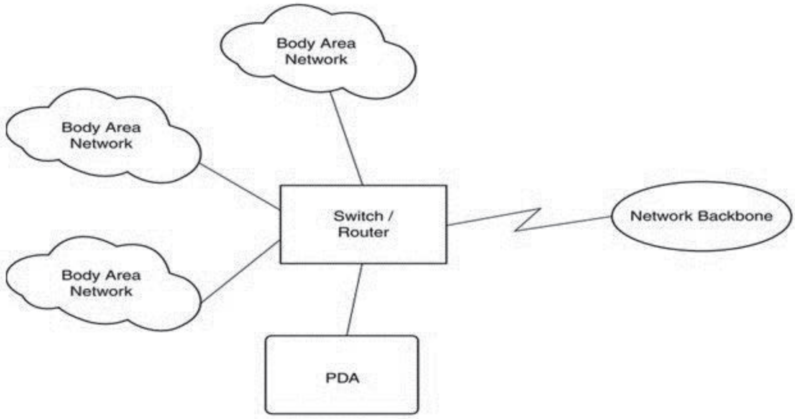


Figure 5.3 an ad-hoc network (FONG *et al* 2011)

In centrally coordinated network, each access point is no longer required to perform most of the management task as it has been taken over by the central controller. Hence, the observation of channel efficiency for the whole channel can be centrally conducted. With such configuration, it is very easy to expand the coverage area. All we need to do is just plug in more entry points to the central control and the user-traffic can be monitored among access points. Apart from that, we also can program the central controller to re-configure the access point independently if the network condition changes such as programming the central controller to disable failed access point and re-route traffic for load balancing. This provides the network with the abilities of self-recovery. This configuration topology is shown in Figure 5.3. Instead of using a switch or router, it uses controller. In conclusion, standalone ad-hoc network is more suitable for smaller network with small coverage area and small number of access points, while centrally coordinated network is more suitable for network with dynamic changes from time to time.

5.1.4 Assessment of Link Budget

It is a crucial procedure to identify the extent of coverage through a margin to prevent any unwanted problem. For outdoor wireless network, rain can be one of the factors that reduce the signal propagation. Other than that, regulations and polarization too can significantly impact the signals. The gain and loss in the whole communicative network is described by the link budget as shown in Figure 2.2. This is very simple and requires the calculation of P_R after it passes the whole system include air, obstacle and so on. Other than that, it also takes account into the cables that used to connect device such as antenna and demodulator. The formula is shown in the following:

$$\boldsymbol{P_R = P_T + G - L} \longrightarrow 5.2$$

In the formula above, P_T represents the transferred **dBm** signal, whereas **G** and **L** represent the total dB gain and loss. Equation 5.2 should be re-evaluated for link coverage expansion. Radio waves spread as it travels through air. If we double up the propagation distance, it can cause the receive power to reduce to a quarter as shown in the formula below:

$$\boldsymbol{L = 2 - \log 10\left(\frac{4\pi d}{\lambda}\right)} \longrightarrow 5.3$$

A link budget measurement is invented by NIST to estimate the ambient link budget. It is essential for us as both signal of link budget as the transferring and acquiring characteristics of transmitter are different from each other. In the situation of telemedicine network, a minimum of 10 dB of link margin is needed to overcome the reflection problem that can cause the reduction of signal strength. Furthermore, another additional of 30 dB is needed in case polarity mismatch happens. Hence, link margin becomes one of the elements that show the difference between telemedicine from wireless network for a general purpose. Besides that, we also need to ensure that the wireless network is able to perform well under consistent heavy rain. Extra link margin is estimated mainly based on the transmitter design and the site environment. In addition, if we maximize the link margin, it will ensure the system reliability to be maintained at the optimum level.

5.1.5 Antenna Placement

It is tiresome to decide the location to place an antenna. Sometimes a location offers the best performance is not feasible to be used. Impedance matching is also one of the major elements to be considered to effectively transmit signals between antennas, radios and cables. Also, cable connected between antennas and radios must be the same to prevent losses caused by mismatch. As many antennas are not identical with cables connected, impedance matching circuitry is crucial to transform the antenna impedance to the cable. To measure the impedance match, Voltage Standing Wave Ratio (VSWR) is applied. The optimal value must be below the ratio of 2:1 so that more energy can be sent with minimum reflection. O the other hand, a VSWR with high ratio shows that the power is either lost or retransmitted and the percentage of bandwidth relates to carrier frequency $\boldsymbol{f_c}$:

$$\boldsymbol{BW = \frac{f_H - f_L}{f_c}\, x\, 100\%} \longrightarrow \quad 5.4$$

$$\boldsymbol{f_c = \frac{f_H + f_L}{2}} \longrightarrow \quad 5.6$$

$\boldsymbol{f_H}$ And $\boldsymbol{f_L}$ represent the maximum and minimum band frequencies. Since most of the antenna does not support 360 degree omni-directional coverage, the angle of coverage needs to be considered to place an antenna. Omni-directional coverage can be applied horizontally. The directivity of antenna is mainly referred to the power focused when sending or acquiring signal from other antennas. Even though most of the wireless router that we use at home provides cylindrical monopole antenna which can beam for 360°, many antennas are designed for only high-focus beam in a few degrees. This is known as beam width. Antenna with narrow beam width is for longer coverage to direct the energy. The concept is the same with the radiation from regular bulbs and spotlights with identical energy capacity. Spotlights concentrate its lights in a more specific region with more intensity than bulbs. This difference shows the relative strength of the radiated field in various directions from the antenna in the coverage area close to the antenna apart from that of the pattern over long distance. The phenomena introduce the term near and far fields. A "near-field" refers to the induction field and "far-field" refers to the radiation field. "Far-field" measures the radiated energy of an antenna. The measurement use to determine this is:

$$\boldsymbol{d} = \frac{\mathbf{2.}\boldsymbol{l}^{\mathbf{2}}}{\lambda} \longrightarrow 5.7$$

d represents the minimum distance and **l** represents the longest dimension while λ represents the wave length of the carrier frequency. For antenna placement, "near-field" is not as significant as it only reduces the minimum safe distance which is normally related to health issue.

5.2 Network Scalability for Network Development

The degree of the channel which can be expanded for a larger capacity, better performance and larger coverage area is termed network scalability. In short, the degree of future expand is important for any communication network. Network expansion often involves setting up new hardware to the existing network and extending coverage area. During the expansion, the network should not be interrupted as the availability of network is very important especially if that network supports life saving operations. In the case of telemedicine, availability is far more important compared to the other purpose as accidents could be happen and it will not wait until the network service resume. Therefore, a network should not be shut down temporarily. In terms of wired network, expansion usually involves adding of new cables. On the other hand, in terms of wireless network, it requires some adjustment of the infrastructure. Therefore, modifications are more feasible for wireless compared to wired network. According to (Fong 2004), the transmission path is hard to be altered. However, the transmitter can be enhanced to ensure receivers to process the incoming stream of data if there is an increase in data input. The main aim will be to maximise the use of available resources in the system and minimize errors so that it is not necessary for re transmission.

5.2.1 Modulation

The conversion of digital signal to analog signal is termed modulation. For example, a modem has the capability to transmit computer digital signal into analog signal so that the signal could be transferred through the traditional phone line.

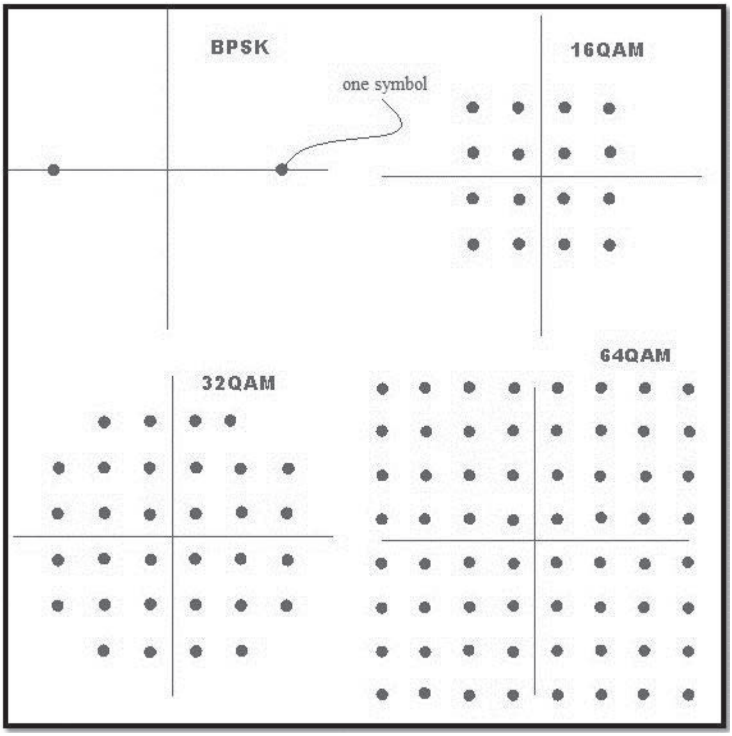


Figure 5.4 Constellation diagram (FONG *et al* 2011)

Based on the constellation diagram above, the cross section represents the amplitudes and phases of signal. More dots in diagram means that there is a higher modulation of above 64 and carries more data bits. Nearer dots mean that it is harder to identify individual dot. As resolving packed dots requires more complex recipients, there is a need to trade-off between the effectiveness if spectral usage and the framework of receiver. For example, with something as high as 1024; the amplitudes and phases difference between neighboring signals points may make them cannot be differentiated.

Compared to high order modulation, low order modulation such as QPSK is more receivable with the same transmittance energy. High order modulation always experience signal loss issue. Therefore, the 16-QAM is suitable to serve receivers that are close to the transmitter and at the same time QPSK can be use to serve receivers that are further from the transmitter.

5.2.2 Cellular Configuration

A wireless channels can be configured as single and macro cell. They have the technique of reusing frequency but in different methods. reusing frequencies is a technique to enhance spectral performance and expand channel performance by re-using the channel and frequency of the same network by separating and RF coverage area into segments. In the diagram, there is an example that shows the re-use different frequency. Although they belonged to identical bands, sufficient separation is required from adjacent segment to lower the risk of interference. All these frequencies are re-used at least two segments away from each others.

A wider coverage is normally achieved using high-gain antennas with clear line-of-sight to receive signal in single cell architecture. Similarly, different polarizations can be achieved in frequency re-use. Macro cell architecture usually uses structural frequency re-use that able to provide acceptable signal reception without clear line-of-sight. Therefore, it is clear that we can improve spectral efficiency by combining a high-order modulations and frequency re-use. However, it may results in the amplification of co-channel interference, where two neighboring channel shares the same frequency that interfere with each other which mainly caused by network congestion and bad frequency planning.

This causes the reduction of modulation order in the opposite way. The spectral efficiency, which is estimated in the unit of bits per second per hertz transferred. Co-channel interference mainly occurred through the scatter of re-use sectors in cells. As macro cell architecture adopts frequency re-use structurally separated segments and the sharing of frequency among neighbor segments can cause co-channel interference, Shannon's Theorem can be use to perform frequency re-use as shown in the formula below:

$$BHC \leq \frac{\log(1 + C/I)L}{K.m}. \longrightarrow 5.8$$

L represents the frequencies of network usage, **C/I** represents the channel interference ratio and represents the structurally re-use variable while m is the overhead assigned to guard bands which separates the frequency into different channel that shown in Figure 5.5. From Equation 5.7, the increasing of **L** or decreasing of **K** in macro cell architecture can perform frequency re-use at optimum level. Besides that, **C/I** in single cell and macro cell architecture can be approximated as Equation 5.8 and Equation 5.9 respectively (Sheikh, 1999),(love et al 2003),(celebi et al 2007).

$$C/I = \frac{c}{L}$$
$$\longrightarrow 5.9$$
$$C/I = c.K^2$$

In the equation, c represents the arbitrary constant that especially for a network deployment.

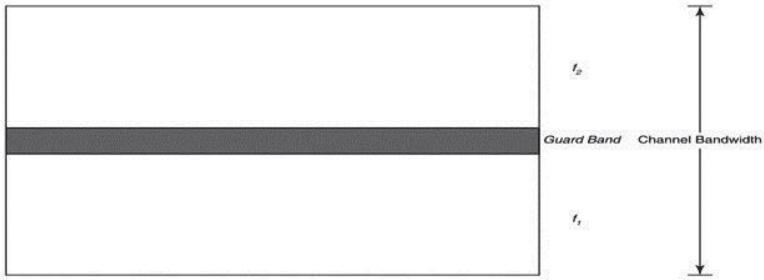


Figure 5.5 Sub-channels separated by a guard band
(FONG *et al* 2011)

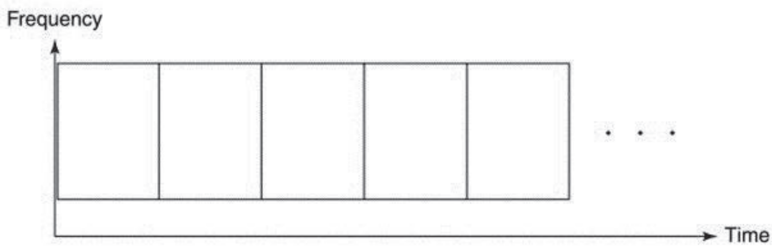


Figure 5.6 Time division multiplexing (FONG *et al* 2011)

5.2.3 Multiple Accesses

Multiple accesses or multiplexing is a process of breaking a high speed circuit into smaller logical circuit for sharing purpose. In order to perform multiplexing, two multiplexors are required; one for combination and the other for separation. There are two techniques that can be used to perform multiplexing namely TDM (Time Division Multiplexing) and FDM (Frequency Division Multiplexing).

Multiple accesses are common things in the early 90's during the boom of digital cellular phones. The working principle of multiple accesses can be easily understood by referring to Figure 5.6 and 5.7. A network is divided into individual time slots in Figure 5.6. In this scenario, the time slot happens to be equal but this situation does not occur most of the time. Every transmitting device has its own allocated duration and the next user will be allocated another duration. For instance, A, B and C are the devices allocated with 10ms time slot each. During the transmission process, device A will be given the first access and spend its first 10ms. After that, B is given the same time slot and followed by C. This means that at the time slot between 0ms to 10ms, A will have the transmission followed by B in between 10ms to 20ms and C in between 20ms to 30ms. As C completed its time slot of 10ms, it goes back to A and the entire cycle continues. In every 10ms the device is changing its sequence (A to B to C and again with A). The theory of the multiple accesses is well explained in the example of three devices above. However in real time, when switching between the devices, there is a lag time between them. There were no instantaneous transmission goes on when each device completes its time slot. Hence the lag time should be considered when switching the transmission cycle. Figure 5.8 describes the transmission process discussed earlier where a logical switch enable the devices to gain entry to the channel.

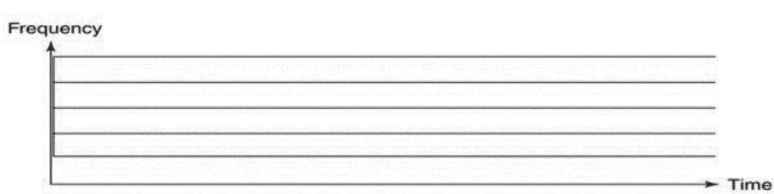


Figure 5.7 Multiplexing of frequency division
(FONG *et al* 2011)

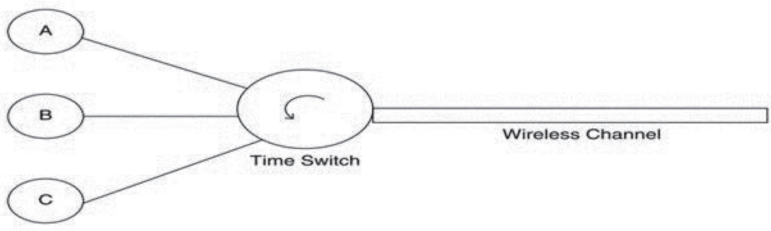


Figure 5.8 Time slots alternation (FONG *et al* 2011)

Rather than dividing network into time slots, the network is divided into unique frequency bands through FDMA. The channel is split according to frequency bands permitted illustrated in Figure 5.9. For instance, the split frequency is demonstrated by having a channel with a band of 100 to 400 MHz. The channel is split into three equal frequencies where each of them is capable of transmitting 100MHz. This means that all the three splits have the range of 100 to 200MHz, 200 to 300MHz and 300 to 400MHz transmission. Each split shares the one third of the channel bandwidth. However in real time, the one third of the bandwidth is hardly fulfilled by the splits. This is due to band pass filters (Figure 5.8 shows that each splits were attached to a band pass filter against the usual switch with TDMA) which are not able to immediately break the frequency for the next and also for immediate start up. The use of a guard band is required for the cut off so that it creates better accuracy of the filters. Figure 5.10 show a perfect filter with an accurate cut off of the frequency. In real time, such perfect filter cannot be found. As the disruption is progressive in nature, more effective filter with the accurate frequency cut off is needed so that the changes happen in quick time.

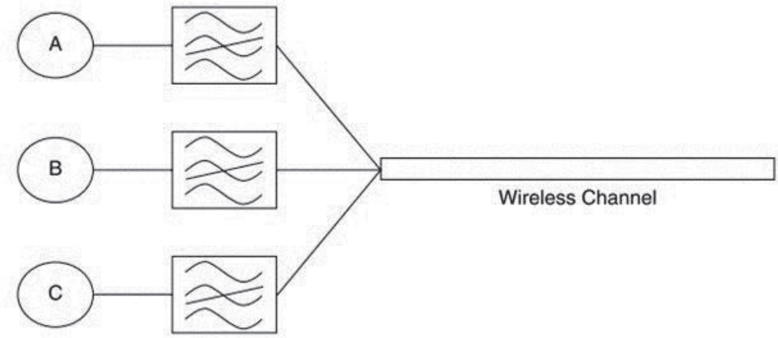


Figure 5.9 Filtering for different sub-bands
(FONG *et al* 2011)

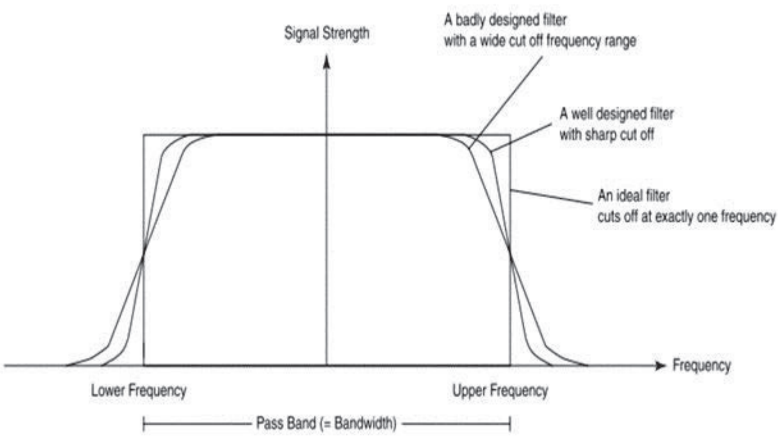


Figure 5.10 'Ideal' filter with sharp cut off
(FONG *et al* 2011)

Those accessible methods on splitting channels have a significant effect on a shared wireless networks. TDMA and FDMA methods are more commonly used for splitting instead of other methods such Code Division Multiple Access (CDMA). The main differences of TDMA and FDMA are well-fed bandwidths over a time frame and the continuous availability for bandwidth variation. Each method provides a distinct advantage where TDMA is more suitable for subsequent data traffic and FDMA for the severe data traffic as it have a continual access and is constant over a period of time. Allocating dynamic bandwidth increases the efficiency of the channel by providing more demand sources.

5.2.4 Orthogonal Polarization

Expandable data throughput is achievable by adjusting the configuration of antennas. For example, the signals of vertical and horizontal polarization can have separate channels through putting different antennas with orthogonal polarization perpendicular between the two signals. Based on earth's topography, vertical polarize antenna has a perpendicular electric field whereas horizontal polarize antennas has parallel electric field. Figure 5.11 shows an example of old style TV antennas placed on rooftops known as linearly polarized antennas. Those antennas on rooftops are always placed in parallel to earths topography, thus is known as horizontal polarization. Polarization can be increased by having more channels through the addition of antennas. Figure 5.12 show the existing antennas of circular polarization. In circular polarization, the polarization completes its rotation per wavelength as the plane rotate in a circular motion. For example, if the wavelength of polarization is **1** meter the circular polarization should have 360 degree rotation in a **1** meter. The energy in circular polarization it exerts on horizontal and vertical planes. The direction of the polarization is also flexible, where circulation can take place in either clockwise or anti-clockwise rotation.

Figure 5.11 Regular television antennas (FONG *et al* 2011)

Commonly circular polarization has higher adaptability in non-LOS scenario mainly because as it hits any barriers, the signal are reflected back to the transmission source and the difference sources of signal can be propagated.

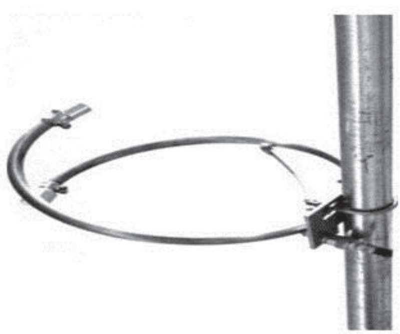


Figure 5.12 Circular polarization antennas
(FONG *et al* 2011)

To achieve scalability, sectorisation is performed whereby additional antennas are installed by request by increasing the number of sectors as illustrated in Figure 5.13 which shows that in the beginning, deployment is installed via the provision of omni-directional coverage. Additional three more antennas are installed to cover areas in a 90° angle as demand gets higher. Therefore, 3 more networks are provided in the same region. Development is possible through segmentation shown in the given example whereby there is an alternative of increasing to 8 segments from 4.

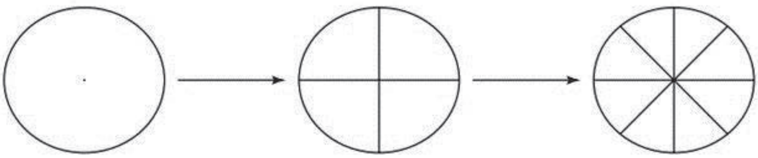


Figure 5.13 Sectorisation of an antenna (FONG *et al* 2011)

5.3 Integrating network with current IT services

Most of the e-health channels are established on existing IT services (Gibson, 2002),(borgmeyer et al 2005),(polak et al 2009) such as in the home monitoring of an asthmatic patient using the Internet. The only difference is the addition of asthma monitoring device telemedicine as shown in Figure 5.14. It shows that there will not be a severe disruption to the monitoring system even if the Internet is disrupted. However, an integrated channel is a much complicated system and a slight disruption such as the integration process will result in the disruption of the entire network. As a rule of the thumb, any maintenance work carried out in one part of an organization should not affect the daily operations of independent of the channel system.

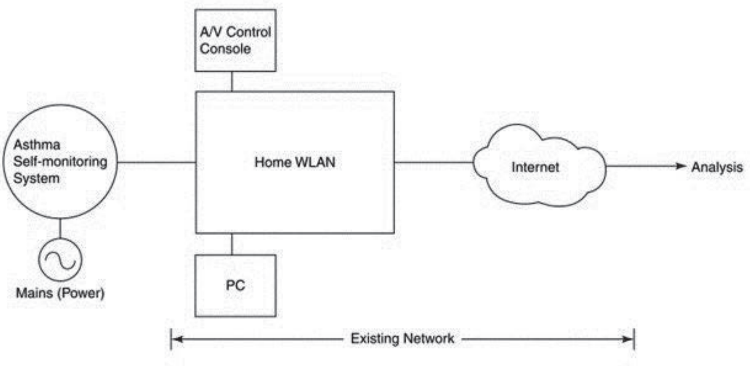


Figure 5.14 Self-monitoring system for an asthma patient
(FONG *et al* 2011)

In order to carry out the network maintenance successfully without effecting the entire system in an organization it is important to have a copy of the building layout map which illustrates the physical network of the building whereby wiring locations, access entries and related infrastructures. It allows the merging of all the latest gadgets in appropriate locations. Data networking and energy supply should be attached to newly-integrated gadgets since most monitoring devices could attain energy from cables. Effective integration includes configuring new portions into the system. All the existing networks might have different network architectures that need varied integrating demands. Existing communicative channels include IEEE 802.11 WLANs are IP channels that simplifies interaction through standardizations. However, several previous channels may require extra procedures due to network protocol.

5.3.1 Middleware

Middleware is a vital tool in network integration. It provides services that are able to communicate and link to any systems. The word middle in the name itself resembles its purpose as a medium of communication or link between application and operating system in a computer. According to (Krakowiak 2009),(tazari et al 2010a),(tazari et al 2012b), a detailed tutorial for middleware is provided. (Rimasss 2002) has come up with middleware abilities which can serve as a communication tool, providing data accessibility and utility control for the connected devices. Another use was discovered by (Sphani 1999) who stated that middleware is used for different healthcare purposes.

Middleware aims to aid the combination of different computational systems, medical devices, surveillance functions and database among others. As it supports the interactions of different functions related to Enterprise Application Integration (EAI) and describes the combinations of different functions in the healthcare network, the software is actively adjusted to facilitate its access into the database. Enterprise Application Integration addresses issues related to consolidation and connection, where the consolidation of data is conducted through the incorporation of application programming interfaces (APIs) for data adaption. To access to the OS or libraries of computational devises, an interface is provided according to functions.

5.3.2 Database

A huge volume of data is stored in different formats such as themes or subjects, files and records for a systematic organization and facilitates the retrieval of data according to user's objectives. Files refer to individual data while records are a collective data based on themes. In the application of healthcare, files contain single medical activities of patients such as the prescription of medicines, while records hold more comprehensive information of patients from health complications identified to the prescription of medicines as well as other personal information. The size of data varies according to healthcare institutions i.e. smaller database in clinics and pharmacies and enormous database in national health institutions. From this, the integration of database is essentially a very difficult task. For example, in Canada alone, one of the aspects that has to be taken into consideration in data integration include the differences in encoding schemes as a result of entries from different languages (French and English being the most spoken languages) and this is further complicated by the conformation of legacy databases of each system vendor. Each function is designed for different objectives in the healthcare institution and equipped with a unique database according to matching information. Through the integration of these functions, medical history and data sharing can take place which results in a good medical practice. Figure 5.15 shows an example of an integration of functions and database. The most important feature in data integration is consistency, where medical information from different healthcare institutes can be shared and renewed through a system.

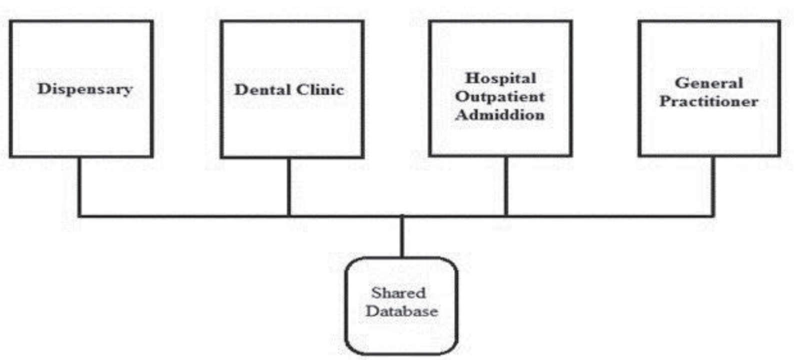


Figure 5.15 Data sharing in hospitals (FONG *et al* 2011)

5.3.3 Involvement of different parties

Like other systems, the healthcare information system must be complemented with various human-users such the technical support, system design and engineering teams. Different users result in different perceptions of the system. Hence, it is important to maintain the originality of the user interface, and changes in how the system is used are kept at a minimum level. This aspect is especially important with healthcare systems as any error cannot be tolerated and puts lives at risks. It is important to ensure that system operators can still use the system prior to changes. To ensure this, system maintainer must retain the original functions and system interface even after new ones are installed or upon integration of systems. The success of system management includes a good communication between users and system suppliers. During system maintenance, users must be informed in advance for the rescheduling or arranging for alternatives to avoid any complications in case of the occurrence of medical emergencies. To keep operational disruption at the minimum level, every procedure that can be conducted prior to system shut down is carried out earlier. System testing is conducted as a crucial part to identify and rectify complications following system integration. In section 9.1, system reliability will be examined. As the conclusion for this chapter, the function of system testing will be briefly reviewed. The extended function of unit testing is integration testing. In this function, individual functions will be examined before integration. Also during this process, unit testing is performed during system integration to ensure the detection of system error within functions and rectified before system integration is finalized to avoid further completion made to the whole system. This is important as sometimes errors only occur when individual functions have been integrated into the system. To ensure system reliability, these arduous procedures must be performed prior to and after system integration is finalized. The most common issue encountered in integration is function compatibility especially from various service providers. To solve this problem, standards are developed to optimize system compatibility. There are three similar interpretations of system integration abbreviated by CII:

- ***Common Integrated Infrastructure****:* A model for the integration of new and legacy applications in organizations for identical functions (Helm, 1999), which include the healthcare institutions.
- ***Compatibility, Interoperability, and Integration****:* Regulations developed to make sure the conformation of measurements as mentioned.
- ***Configuration Identification Index****:* A process to manifest and link files accordingly for different systems.

User acceptance test is the last procedure conducted to verify system's efficiency and applicability to make sure that system integration conforms to operator's demands. It is also important to inform users about the functions that have been added.

5.4 Evaluation of IT infrastructures and solution providers

There is a wide business opportunity offered in the healthcare for IT organizations due to the expansive applications of informational technology. There are various categories of business collaboration that can take place between IT firms and healthcare institutes in acknowledging numerous important issues. Given this, readers must have a good comprehension on the related issues as a preparation of the information provided.

5.4.1 Outsourcing

To save time and expenditure, IT firms outsource some of their services to other service providers. The outsourcing of services also enables third-party firms with more related expertise to conduct the task. However, it is not an easy task to have collaborations with the right firms as IT is a vast field and there are possibilities of the existence of firms offering mediocre services. For example, outsource in developing software is common as all it takes is to have Internet connection. In the healthcare industry, various operations namely tele-radiology, diagnostic images and e-payment can simply be conducted by third-party firms especially in developing countries with much lower operational expenditure. However, several risks are associated with outsourcing particularly in handling sensitive data of clients. For example, information may be disclosed to competitors in hospitals or other healthcare institutions that engages identical service providers. There are other indirect risks such as delay in providing service and communication problems. Therefore, before outsourcing, firms have to review a list of performance evaluation and identify the potential risks. Even though it is essentially a difficult task, guidelines are established to facilitate this procedure. For instance, features such as error rate (BER), rate of maximum data and effects associated with the number of network users should be given the foremost consideration when selecting service provider. Other guidelines include post-purchase services such as system maintenance; respond time and system substitutes offered during maintenance.

5.4.2 Adaptation with developing technologies

It is essential to have a sound knowledge on the latest IT development to ensure an efficient operation and profit generation. Latest innovations are more environmental friendly and sustainable in terms of energy consumption and where hazardous components are strictly prohibited (Jablonski, 2009). Such requirements result in the restriction of system design and conflict in management and applications. System providers should also bear in mind the indirect risk associated with regulatory compilations such as increased in expenditure and delay, and in devising a future plan regarding unexpected change in legislations. It is also vital for service providers to be in touch with the market condition to avoid offering outdated technologies. This is also due to the rapid change in the scene of IT development. For example, mobile glucose indicators were manufactured to be connected to computer a couple of years ago. Due to the availability of 'Vena' platform that enables the matching of information within strict procedures, this project was handed by third parties. Even though the platform did not result in any problem, the manufacturer was not aware that the standardization of IEEE 11073 was yet to be completed an as a result, the glucose meter did not conform to the standard. This occurs as it is common for manufacturers to ignore the requirement of standards. Given its importance, the installation of a system update is required to ensure IEEE 11073 compilation even though it results extra resources.

5.4.3 Reliability and Liability

The factor of reliability is measurable with either numerical measurement of qualitative attributes such as verbal communications. As a general rule of thumb, long-existing firms often have a high reliability, even though this cannot be applied in all conditions especially on vital health-supporting devices. For example, the lagging of computers is a normal condition and this is when reboot of the system is required. This is to emphasize that not all situations can be fixed by the simple act of system reboot particularly the ones that involve the resuscitations of patients. This issue will be given more attention due to its importance in the healthcare system. The reliability of healthcare devices will be examined via mathematical modeling and statistics. For the rest of the section, a focus will be placed on the reliability of system provider when signing a contract. Before signing the contract, it is the topmost priority of firms to believe that their business partners are reliable. Potential service providers are normally identified via the Internet or Yellow Page and further screened to a shorter list. To layout a list of reliable providers, the guidelines as mentioned in sub-section 5.4.2 can be observed, such as identifying the duration for prototype testing, compilation of standards, the overall costs and system maintenance and update among others. However, it is often helpful to come up with a longer list of potential suppliers in the first place to increase the probability of getting reliable suppliers. The elimination of listed suppliers should be carried out for firms without records of required functions. In overall, potential suppliers are identified after a screening process of the preferred products, performance in extending their services, area of operations and good financial records.

In the industry, request for a proposal (RFP) is often initiated when there is a list of service providers to be chosen. This process enables the investigation of demands in great details such as the lifespan of batteries in portable medical devices. The references provided from other institutions can be useful, provided that cautions are still practiced on the possibilities of biases. In the end, a ranked list of providers is obtained with a high probability of getting the supplier with high reliability. Even though it is almost impossible to obtain a provider that fulfils out budget, it is still ensure that providers are reliable and devices provided can be utilized without problems. This is to avoid serious ramifications such as mistake in diagnose and followed by a lawsuit from patients. Under this situation, it is important in the first place to define responsibilities so that a clear statement is available during the inspection by legal bodies. This certainly cannot be taken lightly as legal liability results in a major ramification in the healthcare industry, which can be observed from the long terms and conditions following the reclamation of health insurances. To avoid the risk of legal consequences, a liability waiver is often issued before the provision of healthcare facilities.

5.5 Measurement service quality

It is indisputable that quality holds the highest importance in the healthcare industry where services are now offered using wireless networks. Given this, potential problems regarding wireless networks will be examined for a high quality of service (QoS) (ALGAET et al 2014). Link outage is when wireless network is disconnected. Statistics are normally used alongside with the theories on communication to describe the possibility of network performance as shown in Figure 2.1, using a receiver. Data is transmitted via a wireless network, and the common issues that may arise pertaining transmittance are (Fong, 2003b):

- ❖ **Attenuation**: reduce in strength of transmission according to distance
- ❖ **Depolarization**: lowering two separated signals from varied polarizations caused by segment disruption
- ❖ **Interference**: disturbance of signals due to other causes
- ❖ **Noise**: undesirable extra energy joined to transmittance signal
- ❖ **Scattering**: random radiation of signals when blocked by physical objects

In addition, various factors that degrade the strength of signals are identified. This complicated process can be shown via the concept of interference. The reliability of wireless network can be affected by interference which includes (Stavroulakis, 2003),(alade et al 2010):

- ❖ Co-channel interference: or ‘crosstalk’ that resulted from the encounter of signals of other networks with identical frequencies.
- ❖ Electromagnetic interference: or ‘radio frequency interference’ (RFI) that resulted from disturbance of other signals. It is a common method applied in radio jamming for disrupting a wireless network through the emission of a similar frequency. It can also be resulted from wavelengths projected from the sun.
- ❖ Intersymbol interference: undesired communication among symbols that normally resulted from multipath, a resulted impact identical to noise from the same signal in different time phases.

These demonstrate that there are several types of signal interference. Various features are used to determine the strength of wireless network such as:

Bit Error Rate **(BER)**: indicates the errors occurred in bit stream blocks **($BER = 10^6$**) signifies that from statistics, one bit error is expected for a million bits transferred). However, higher strength is required in e-health (Schimizu, 1999) and **BER** must be improved by reducing the data rate or allocating sufficient link margin. Link margin is the additional power to rectify the disruption of transmittance due to signal degradations. For instance, a particular margin link is required for signal degradation cause by rain. As **BER** measures data bit error, this function also used to determine **E_b / N_0** (energy per bit to noise power spectral density ratio) of networks. It is digitally identical to Signal-to-Noise Ratio **(SNR)** of analogue communications networks or known as **SNR** per bit and usually ranged at 18–20 dB for a good transmittance.

$$\mathbf{SNR} = \frac{P_{signal}}{P_{noise}} \longrightarrow 5.10$$

$$\mathrm{SNR_{dB}} = 10\log_{10}\left(\frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}\right) = P_{\mathrm{signal,dB}} - P_{\mathrm{noise,dB}}, \longrightarrow 5.11$$

Its performance can be increased by adapting filtering algorithm at the user's end. The increase of $\mathbf{E_b / N_0}$ is parallel to **BER** and often a software packages are used to determine the value. Signal-to-interference ratio **(SIR)**: A measurement of signals and interference strength ratio in the network for measuring the signal strength at user's end. **SIR** is also known as 'carrier-to-interference ratio' and is identical to the **SNR** of propagating signals prior to process at user's end. Given this, it is mainly differentiated by the interference of **'I'** and noise **'N'** caused by interfering transmitter objects that can be managed via network resource management. Noise results from a mixture of sources including human and the nature. **SIR** is often measured by mathematical modeling (Wang, 2001) to develop an algorithm for analyzing the signal's strength at user's end before demodulation due to interferences. Carrier-to-noise-and-interference ratio (C/N + I) or CNIR): refers to the measurement of amalgamate effect of noise and interference in co-channel interference **(CIR)** and **SNR**.

Co-channel interference (CCIR): refers to adjacent networks with identical frequencies that result in network interference. However, an increase in **SNR** does not help in improving network quality. CCIR can be reduced through an increase of distances among co-networks (Chen, 1997). FCC controls the 'out of band' noises radios in United States to prevent sidebands which results in disruption. This issue is rectified by deploying filters with abrupt disconnection at user's end.

Link outage: refers to statistics pertinent to the duration of time (in the format of minute and second) of network disconnection. For instance, a network available at the rate of 99.99% usually results in 52 minutes of link outrage every year which is measured using an equation below. t refers to the highest link outage where there are 31 536 000 seconds in a year.

$$t = 31536000.(1 - availability\%) \longrightarrow \quad 5.12$$

Numerous main measurable features have been discussed to determine the strength of wireless network. In conclusion, strength indicator gives the assurance of wireless networks in supporting e-health devices. However, this is in contrary to reality as unpredictable factors might result in system disruption.

Peak signal-to-noise ratio (PSNR)

PSNR is generally used to analyze quality of image, sound and video files in dB (decibels). And PSNR is calculation of two images, one original and an altered image, describes how far two images are equal.

The maximum possible value of the pixels in image **I**. typically, this may be given as (2^n) - 1 where **n** is the number of bits that represent the pixel. Thus, an 8-bit pixel would have a maximum value of (2^8) - 1 = 255

$$PSNR(dB) = 10 * \log(\frac{255^2}{MSE}) \longrightarrow \quad 5.13$$

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N} \longrightarrow \quad 5.14$$

M and ***N*** are the number of rows and columns in the input images

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Appendix: Key Features of Major Wireless Network Types

The beginning of the era of the Internet marks the expansion of communication network to reach virtually every facet of the world including remote areas by wireless connections. It was Maxwell equations describing the basics of electricity and magnetism that developed wireless communication technology over a century ago (Huray, 2009):

Electric Field (E):

$$\nabla \bullet \overrightarrow{D} = \rho_v$$
$$\nabla \times \overrightarrow{E} = -\frac{\partial \overrightarrow{B}}{\partial t}$$

Magnetic Field (H):

$$\nabla \bullet \overrightarrow{B} = 0$$
$$\nabla \times \overrightarrow{H} = \overrightarrow{J} + \frac{\partial \overrightarrow{D}}{\partial t}$$

With interrelationship:

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

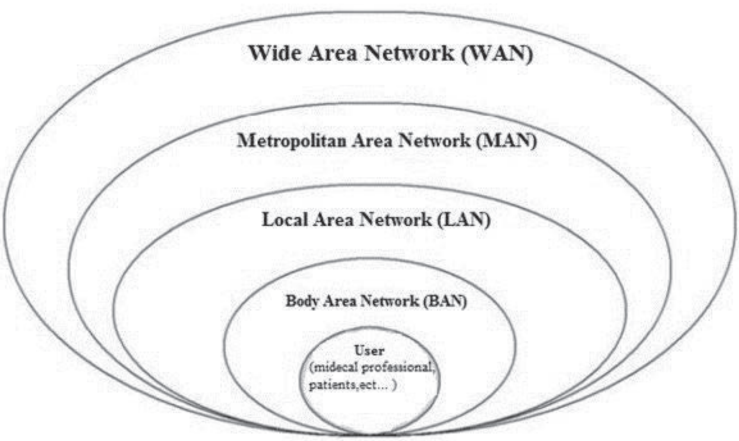

Figure A.1 Network classification based on coverage
(FONG *et al* 2011)

Without examining the mathematical details, we will study the fact that the Figure A.1 illustrates the process of forming the foundation of wireless communications using the relationship between magnetic and electric fields. Plenty of wireless transmission networks are possible for a limitless range of application thanks to the technical developments throughout the twentieth century. In this post-war era, billions of people worldwide use the television broadcast, which was likely one of the most common wireless communication system. Traditional broadcasting systems such as radio and televisions utilize simplex point-to-multipoint communications, which involves one way communication from a transmitter to multiple receivers. Nearly forty years ago, the proposed cellular concept led to the advancements of many wireless communication networks of today (Farley, 2007),(bii et al 2013). We shall examine the major components of main wireless network types and group them in accordance to their target coverage.

Body Area Network (BAN)

BAN is known as IEEE 802.15, and its purpose is to provide a standard for low power transmitting gadgets within or around the human body. However, BAN is not designed specifically for medical applications, as BAN related technologies also support certain entertainment functions for consumer electronics. Figure A.2 describes the different groups of BAN gadgets that have dissimilar power consumption requirements and bandwidth. Subsequently, we examine certain common specifications in Table A.1. IEEE 802.15 ‘Wireless Personal Area Networks’ include both Bluetooth and ZigBee that operates in the 2.4-GHz unlicensed frequency band. Table 1.2 describes the differences of Bluetooth and ZigBee.

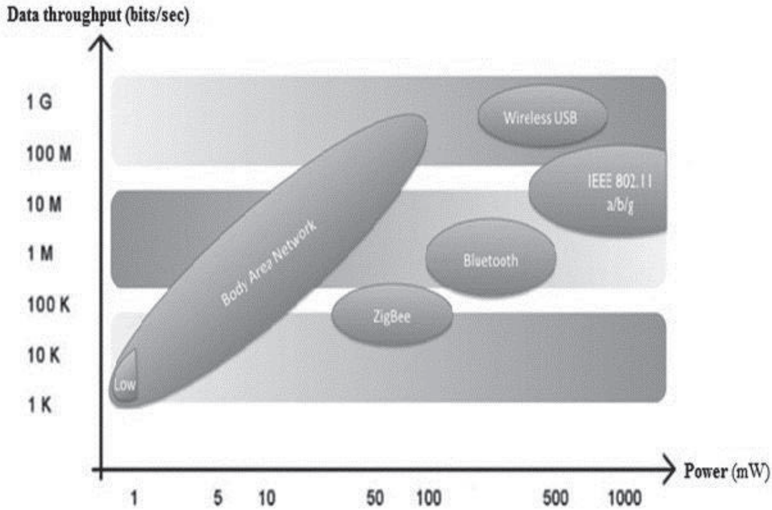

Figure A.2 Comparison of data throughput versus power consumption (FONG *et al* 2011)

Range	Up to 2 m, can be extended to 5 m
Maximum device per network	< 100
Network density per m^2	< 4
Power consumption (nominal)	1 mW / Mbps
Latency	10 ms
Device start up time	< 100 µs
Network set up time	< 1 s

Table A.1 Typical BAN specifications (FONG *et al* 2011)

	Bluetooth	Zigbee
Standard	IEEE 802.15.1	IEEE 802.15.4
Modulation	Frequency Hopping Spread Spectrum (FHSS)	Direct Sequence Spread Spectrum (DSSS)
Network throughput	< 1 Mbps	< 250 Mbps
Typical time to establish connection	3 s	30 ms
Protocol stack size	250 KB	28 KB
Battery charging mode	Intended for frequent recharging	High capacity, low usage for prolonged use

Table A.2 Bluetooth vs. Zigbee (FONG *et al* 2011)

		Data Rate (Mbps)	Indoor Range (m)	Outdoor Range (m)
IEEE 802.1	Bridging			
IEEE 802.3	Ethernet	100		
IEEE 802.11a	5 GHz carrier	54	35	120
IEEE 802.11b	2.4 GHz carrier	11	38	140
IEEE 802.11g	2.4 GHz carrier	54	38	140
IEEE 802.11n	2.45 GHz carrier	150	70	250

Table A.3 Local Area Networks (FONG *et al* 2011)

Local Area Network (LAN)

Table A.3 lists some of the collection of IEEE 802, including both wired and wireless networks. Basically, areas up to few hundred meters of wired networks are covered by IEEE 802.3. The magnitude of LAN differs in a range of a few computers in an office to thousands of gadgets across proximal buildings. Here, both cables and radio waves can make up a connection. A LAN can also be linked to the Internet or a Metropolitan Area Network (MAN) of larger geographical coverage.

Metropolitan Area Network (MAN)

Several geographically proximal LANs are connected together by a MAN to form a larger overall network. A MAN is usually utilized to provide a 'Last-Mile' Broadband Solution within a zone. As of today, the 802.20 and IEEE 802.16 standards, as distinguished in Table A.4, are utilized for wireless metropolitan-area networks. In conjunction with the respective IEEE groups and the WiMAX forum, ETSI HiperMAN, the corresponding standard of the European Telecommunications Institute, is developed (Yang, 2007).

Currently, the IEEE 802.16 and 802.20 standards, as compared in Table A.4, are adopted for wireless metropolitan-area networks. There is also ETSI HiperMAN, the corresponding standard of the European Telecommunications Institute, developed in conjunction with the respective IEEE groups and the WiMAX forum (Yang, 2007). ETSI and IEEE standards may be comparatively analogous. However, IEEE's fixed WiMAX specify carriers in the 10–66 GHz range while the European version targets spectrum access lower than 10 GHz.

	IEEE 802.16 Wireless Broadband	IEEE 802.20 Mobile Broadband Wireless Access
Latest version (as of January 2010)	IEEE 802.16j-2009	IEEE 802.20-2008
Maximum data rate	100 Mbps mobile/1 Gbps fixed	80 Mbps mobile
Spectrum	2–11 GHz mobile/10–66 GHz fixed	< 3.5 GHz mobile
Channel bandwidth	1.25–20 MHz	5, 10, and 20 MHz
Mobility	Supports adjunct mobility services	Full mobility at up to 250 km/h
PHY	Extensions to previous 802.16a	New PHY optimized for packet data and adaptive antennas

Table A.4 Metropolitan Area Networks (FONG *et al* 2011)

Wide Area Network (WAN)

Multiple distinctive groups of network are linked together by a WAN to cover a large area. A MAN and WAN differs not only in terms of coverage area, but also in a way that a MAN is commonly a dedicated network specially utilized by an entity or organization while a WAN is a pooled network that is usually leased through a service provider. WANs currently have no available standards, and differ in their implementation; through a leased line or a shared line by either ‘packet switching’ or ‘circuit switching’. A packet-switched network involves data fragmented into several packets with each packet containing a portion of the data. Here, each packet can travel across the network to the destination in several different routes where the packets are then reassembled at the receiver into the original data. On the other hand, the circuit-switched network is static in which a link is form from the sender to the receiver before the initiation of the transfer, hence establishing a ‘circuit’. During the entire transfer, the resources are dedicated to the circuit and all data goes through a similar pathway. The Internet is possibly the world leading WAN. One of the key features of WAN is scalability as it can be extended to reach more areas and more gadgets by different ways of network expansion which involves both dedicated and shared leased lines. The following summarizes the important characteristics of leased and shared lines:

Shared packet switched network (commonly best suited for smaller-scaled enterprise, e.g. regional hospitals):

- **Flexibility**: Access bandwidths and coverage expansion can be altered easily without disruption of service. Service is commonly provided by fixed-terms hence, ideal for temporary site coverage

- **Consolidation**: The same access service at each site provides network access that merges circuits to save cost.
- **Cost effectiveness**: Allocates network resources by on-demand basis. As such, utilization efficiency is optimized with little wastage.

Leased line (ideal for large enterprises, e.g. national system managing different states and provinces):

- **High data throughput:** Quality of service (QoS) assured connection speed in magnitudes of Gbps.
- **Management**: Network management for distribution of resources and performance monitoring.
- **Uncondensed**: Exclusive link with guaranteed bandwidth, stable and predictable

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