DESIGN REQUIREMENT CLARIFICATION FOR BODY AREA NETWORK (BAN)

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A project report submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering (Hons) Biomedical Engineering

Faculty of Engineering and Science
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DECLARATION

I sincerely declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project entitled "**DESIGN REQUIREMENT CLARIFICATION FOR BODY AREA NETWORK (BAN)**" was prepared by CHEAH EE LING has met the required standard for submission in partial fulfillment of the requirements for the award of Bachelor of Engineering (Hons) Biomedical Engineering at Universiti Tunku Abdul Rahman.

Approved by,

Signature : _____

Supervisor : Mr. Chuah Yea Dat

Date : _____

Specially dedicated to

My beloved grandmother, father and mother

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Although travelling around the private hospitals (particularly in Kuala Lumpur and Penang) can be quite tiring, I admitted that I gained a lot of precious information through the survey conducted, which cannot be retrieved on the textbook solely. This definitely helps a lot in aiding my understanding and further interpretation regarding BAN system. Based on the ascertained design requirements, we shall thereafter have a clear concept in developing a BAN based, human friendly, connected health system.

Last but not least, I wish to express my deepest thanks to my family for their unconditional love and support. Their sincere caring and support had helped me successfully completing my dissertation.

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CHAPTER 1

INTRODUCTION

Body Area Network (BAN) is one promising application in the integration of sensing and consumer electronics technologies which would allow people to be constantly monitored (Schmidt, A., Laerhoven, K.V., 2001). It enables a ubiquitous remote medical device which can provide patients with assistance everywhere, anywhere and at any time.

In the near future, healthcare will face major challenges as medical costs are rapidly increasing worldwide due to widespread chronic diseases and aging population. In such a case, the ageing population is due to the combined effect of falling birth rates and increasing life expectancy. Recent statistics showed that the percentage of ageing people in Malaysia was increasing. In 2000, the number of elderly people was 1.45 million or 6.2% of the total population but in 2009, the number increased to 2.03 million or 7.1% of the total population. Twenty five years down the line, Malaysia is likely to reach an ageing nation status by 2035 with the number of people above the age of 60 reaching 15% of the population. In such a case, the United Nations categorizes any country with 10% of its population above the age of 60 as an ageing nation. (The Star, 2010) On the other hand, chronic diseases are persistent or recurring conditions that require care for more than a year and that limit the patient's activities. Although there is no definite cure for a chronic disease, it can be managed to reduce its effects on the patient at a minimal level.

Also, there is a situation where hospital beds not being able to meet the number of patients to be admitted. Furthermore, chronic patients discharged from hospitals, elderly and the disabled are desperately in need of intensive monitoring at home. The cost of sensing nurses or medical doctors to attend patients at home is very high. Therefore, the rationale of my research is to solve the problems stated above to at least, a minimal level. In such a case, the traditional cable sensors however, often cause inconvenience to patients by restricting patient's mobility and disturbing them with the presence of cables. To overcome this problem, wireless medical sensors are developed and applied. (Guo, Kang, Cao & Zhang, 2008) Admist all the effects on biomonitoring, we see the potential of using low – power consumption, light weight and integrated physiological sensors for detection of sentinel events among in – patients and out – patients as well. In maintaining the general health of people, it can be useful to remotely monitor their health status in their daily lives as well too. (Togowa, 1998)

Well, the aim in this research is to clarify the design requirement which is needed for BAN. The scope of the research is to identify out the use cases of BAN and clarify specific vital sign sensors to be mounted on patients. In such a case, the functional specifications and design requirements may differ to suit different medical procedures. Thus, all these matters have to be discussed face – to face with medical doctors and biomedical engineering personnel from Malaysia's private and government hospitals.

In order to do so, the objective in this research is:

- To understand the application of connected health system in patient health monitoring.
- To understand the BAN architecture and its functionality
- To develop and apply interpersonal skills when conducting interview with medical doctors and specialists during interview session. In such a case, presentable soft skills are needed as to let them understand the concept of such system and to collect their medical point of view.
- To develop data analysis technique in analyzing data.

This BAN research is only mainly concentrating in hospitals around Kuala Lumpur and Penang. The participating respondent in this research were 30 people. They are consisted of 10 medical doctors and 20 biomedical engineering personnel. Based on the ascertained design requirement (which can be obtained from their professional knowledge), we shall thereafter develop a BAN – based, human friendly, connected health system.

The first chapter of this progress report is about the introduction of the BAN. The second chapter is about the literature reviews which have been done based on the journals and articles related with BAN. In such a case, one way of attaining information is through the current mass media and publications. These reviews are important in such a way that they provide the latest development especially from the biomedical field. Lastly, the third chapter is about the methodology to define the methods to conduct this research. The methods included here such as literature review, questionnaire survey and also data analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Body Area Network

The current common goal in medical information technology today is the design and implementation of telemedicine solutions, which provide to patients services that enhance their quality of life. Recent technologies advances in sensors, low – power integrated circuits, and wireless communications have enabled the design of low – cost, miniature and intelligent physiological sensor modules. These modules are capable of measuring, processing, communicating one or more physiological parameters, and can be integrated into a wireless body area network. (Rotariu, Costin, Arotaritei & Constantinescu, 2008)

In such a case, the healthcare BAN consists of sensors, actuators, communication and processing facilities. Patient data is collected using a Body Area Network (BAN). A healthcare practitioner can view and analyze the patient data from a remote location. In this setting, the BAN acts as a provider of patient data and the healthcare practitioner acts as a user of that data.

2.1.1 BAN Sensor Nodes Design

Depending on types of patient data must be collected, different medical sensors are integrated into the BAN. For example, an oximetry sensor is attached to the patient's finger to measure their pulse rate and oxygen saturation. In the case of an ECG

measurement, electrodes are attached on the patients' arms and chest. (Dokovsky, Halteran, Widya, 2003)

In bio – monitoring, the sensor nodes should be placed in close proximity of the subject's body. This constitutes a body – area network. The evolution of sensor node leverages all technology options available, from the every – shrinking standard microelectronic technology, to the emerging microfabrication processes (Benini, Farella, Guiducci, 2006). The evolutionary sequences of 4 sensor nodes generation are generally characterized by a decreasing level of obtrusiveness.

(i) Obtrusive

These devices are constantly perceived by the target subject due to their large size and weight. Many current commercial devices are obtrusive. For examples, holter ECG and body tracking systems based on wearable cameras and marker. Disadvantage of such device is such a way they are too bulky to be applied on the daily monitoring purposes. Also, they may constrain normal behavior on patients.

(ii) Parasitic

These nodes are still perceived by the subject as physical objects, but their size, weight and structure are comparably less than obtrusive node in first generation. In such a case, the physical volume of these nodes should not exceed a few cubic centimeters, and their weight should be in the order of the tens of grams. For examples, parasitic devices are bio – metric watches and body – tracking inertial sensors. Advantage of such device is such a way that it does not pose serious limitation to normal behavior if compared to obtrusive sensor node devices.

(iii) Symbiotic

These nodes are called symbiotic since they have a mutual advantageous relationship with the target organism. In such a case, the nodes are more aggressively scaled and should be in cubic millimeters. Also, it should be bio – compatible to enable in – body bio – monitoring applications. Advantage of such devices is such a way that they do not pose limitation to normal behavior since they are implanted within the target organism. They are not being able to be observed. However, disadvantage is such that the biocompatibility of this sensor node have to be considered since it is in-

body bio – monitoring applications. Once implanted, the device should not be rejected by the immune system by patients due to in – biocompatibility. The rejection here can be fatal, for sometimes.

(iv) Bio – hybrid

As an end point of out evolution trend, the physical scale of these devices approaches a few cubic microns (or less), and the interface between the sensor target and the sensor itself disappears. These devices operate autonomously, powered by chemical reactions inspired to biological systems. The construction process and the architecture of these devices will also resemble natural process in biology: bottom – up self – assembly, self – replication and self – repair. Advantage of such devices is such a way that they do not pose limitation to normal behavior since they are implanted within the target organism. They are not being able to be observed. However, disadvantage is such that the biocompatibility of this sensor node should be considered since it is in-body bio – monitoring applications. Once implanted, the device should not be rejected by the immune system by patients due to in – biocompatibility. The rejection here can be fatal, for sometimes. (Benini, Farella, Guiducci, 2006)

The trend and the fundamental characteristics of the 4 generations of sensor nodes are summarized in Table 1.

Table 1: Summary of Sensor Node Generations (Benini, Farella & Guiducci, 2006)

Node	**Maturity**	**Power (W)**	**Size (m^3)**
Obtrusive	Commercial	$1 – 10^{-1}$	10^{-3}
Parasitic	Prototype / commercial	10^{-2} to 10^{-3}	10^{-6}
Symbiotic	Research / prototype	10^{-5} to 10^{-6}	10^{-9}
Bio-hybrid	Concept / research	$< 10^{-7}$	10^{-15}

In this survey, the attention is paid on one specific sensor node application, which is parasitic sensor node. There are several reasons for the choice. Firstly, this sensor node is less obtrusive and does not pose serious limitation to normal behavior. Secondly, its design does not take consideration of biocompatibility. Also, the technical challenges posed are not causing major problem with the state of the art.

In general, a sensor network node hardware consists of several subsystems: a microprocessor, data storage, sensors, actuators, a data transceiver and an energy source. A sensor node is a multi – functional unit performing many different tasks, from managing acquisition to handling communication protocol schedule and preparing data packets for transmission, after filtering, synchronizing and signal processing on data gathered from sensors. Thus, each sensor node requires processing and storage capabilities. The choice of the processing unit not only decides the intrinsic "intelligence" of the node but also influences its size and power consumption.

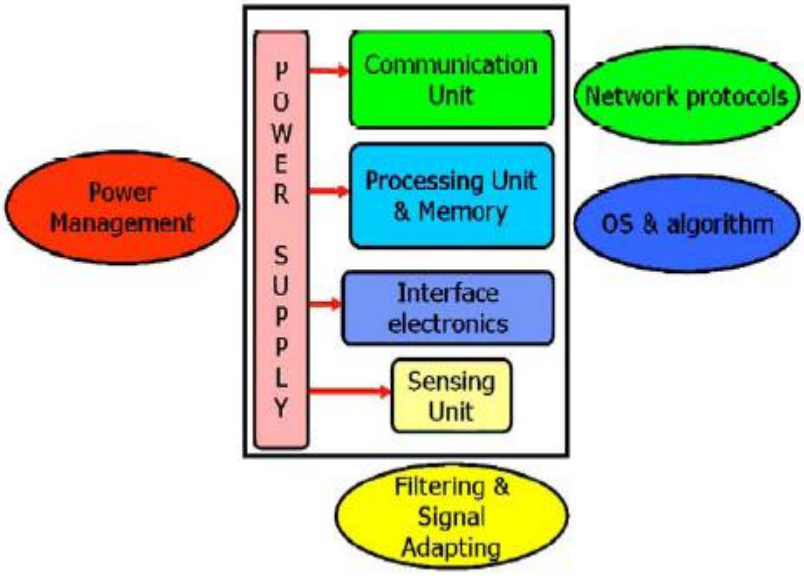


Figure 1: Sensor Node Functional Components (Benini, Farella, Guiducci, 2006)

2.1.2 BAN basic block diagram

Sensor nodes are designed to be small and power efficient so that their battery can last for a long time. They are designed to collect raw signals from a human body. A sensor node undertakes 3 tasks: detecting signal, digitizing / coding / controlling for a multi access communication and finally wireless transmission via a radio transceiver technology. They collect the signals from a human body which are usually weak and couple with noise. For a reliable information transfer, it is necessary that the interface electronics in the sensor nodes detect the physiological signals in the presence of noise. The signal – to noise (SNR) of the detected signal should be increased for a better processing.

Filtering process is to first remove the unwanted signals and noise. At such low frequency and low amplitude, amplification process is utilized to increase the signal strength. Then, an Analog to Digital (ADC) stage is employed to convert the analog body signals into digital for a digital signal processing. The digitized signal is processed and stored in a microcontroller. The microcontroller will then pack and transmit over the air via a wireless transceiver (Mehmet, 2010). Figure 3 shows a basic idea on hardware implementation of sensor nodes and the block diagram. (Mehmet, 2010)

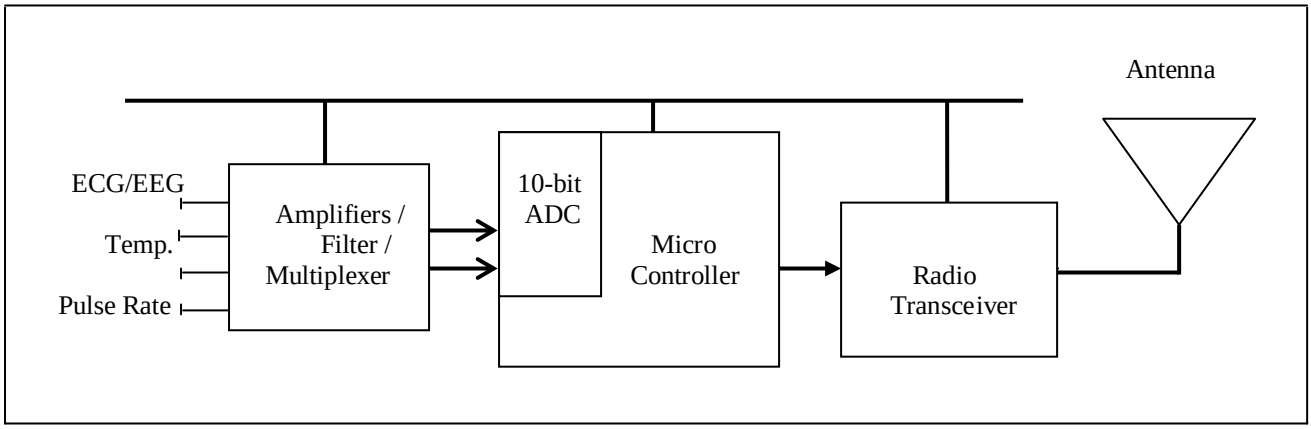


Figure 2: An Example of Implementation Block Diagram (Mehmet, 2010)

2.1.3 BAN data exchange

The data exchange may be done in one of two methods, which is real time or non – real time basis. In the case of real time basis communication, both users are simultaneously logged into the server. The data should be sent when the sensors are measuring vital signs. Though out such communication, both users are able to interact with each other in real time, establishing also video conference session, when is needed. On the other hand, in the case of non – real time basis communication, the users exchange messages and information in asynchronous mode. (Sachpazidis, Kontaxakis & Sakas, 2009) The data is stored and can be sent after vital sign measurement has been completed. For example, the data can be attached as a file to e-email.

In this research, the BAN data can be sent to hospital / Medical officer's office in either real time or non real – time basis. For the application of BAN within

the hospital (particularly for in – patients and medical tourists), the data is transmitted in real – time bases when the sensors are measuring vital signs. The advantage is such that medical personnel can be alerted when any sentinel events happens in real – time.

On the other hand, for home monitoring purpose on out – patients and health conscious people as well, non real – time basis data transmission is more applicable with the state of the art. Advantage is such that users can be monitored constantly if compared to the existing Holter system (which can only be used on monitoring purpose for 24 up to 48 hours). Rather than precise measurement, such BAN is useful for long – term monitoring on patients at home. The data is stored and analyzed by medical personnel or caregivers after a period of monitoring.

2.1.4 BAN communication

Communication between entities within a BAN is called intra – BAN communication. Our current prototypes use Bluetooth for intra – BAN communication. To use the BAN for remote monitoring, external communication is required which is called extra – BAN communication. Figure 2.1 below shows the architecture of BAN.

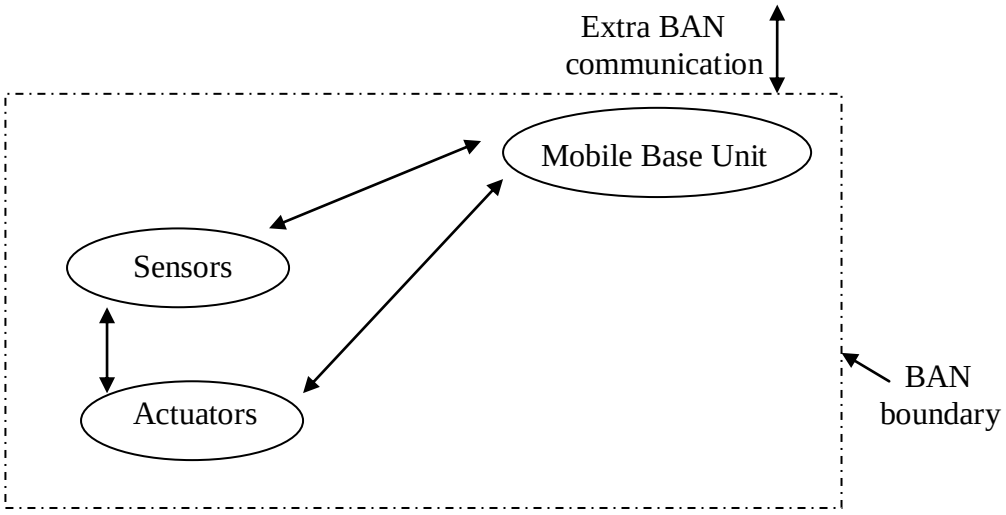


Figure 2: BAN Architecture (Dokovsky, Halteran & Widya, 2003)

The range and complexity of telecommunication technology vary with the specific medical application. Transmission of medical images would require more bandwidth. However, teleconsultations of ultrasound images require only a few

megabytes of data. On the other side, transmission of vital signs might also need adequate bandwidth. The bandwidth needed for vital signs is depicted in Table 2.

Table 2: Bandwidth Required for Real – Time Transmission (Benini et al, 2006)

Signals	Bandwidth
ECG 1 lead	3,6KBit/second
ECG 12 leads	43,2 KBit/second
Pulse oximetry (SpO_2)	72 Bit/second
Heart Rate	24 Bit/second
Blood Pressure	32 Bit/second
Ultrasound images	256 KBit/second
Video conference	25 KBit/second

In this research, the signal transmission is mainly concentrate on ECG, pulse oximetry, heart rate and blood pressure. Integration of vital sign measurements are depending on the specific uses cases of BAN, and yet such integration have to researched and discussed with medical officers and specialists from Malaysia's private hospitals. Signal transmission of ultrasound images and video conference are not included in this research.

2.1.5 BAN signals traffic

In BAN, traffic between the biosensor and the controller can be classified into 2 major types: periodic traffic and aperiodic traffic. Periodic traffic is physiological signals measured at every fixed period (such as every 2 seconds). On the other hand, aperiodic traffic has no constraint of periodicity. Aperiodic traffic can be divided into alarming packets and control commands. In such a case, alarming packets are usually time – critical, because an emergency must be reported before a worse case situation occurs. (Guo, Kang, Cao, Zhang, 2008) But in practical case of this research, the alarm have to be made sure that it must not be frequent false alarm caused by human error. Else, the alarm might be ignored by caregivers when it comes to critical one.

2.1.6 BAN Power Supply

The power supply block usually consists of a battery and a DC – DC converter. Although batteries in the last decade have become smaller and less expensive, battery energy density does not scale exponentially as other technologies. Nevertheless, batteries are still a reasonable solution.

Alternative power sources must be explored. Fuel cells are a possible chemical alternative to lithium batteries. Advantage of such cell is they are able extend a node lifetime up to several times compared to usual batteries. However, many open research issues still remain to be addressed before microfuel cells can be used to power up sensor nodes. (Dyer, 2007) The disadvantages are such that they are noisy and must be improved in terms of robustness. Moreover, they pose safety issues (Benini, 2006) Also, they are still not yet available in a variety of configurations at low cost.

For indoor environments, rechargeable batteries may be the solution. However, recharging the batteries may become burdensome especially for the elderly since they might tend to be forgetful at most of the time.

There are many options for harvesting energy from the environment instead of using energy stored locally on the node. The most common example is the use of solar cells for outdoor systems. Advantage of this source is that the solar cells can provide up to 15 mW/cm^2 under direct sun (Amirtharajah et al, 2005), which is proven to be quite a large energy amount. However, the disadvantage of this source is such that the power density decreases in cloudy days and drastically reduces in indoor environment. Also, it cannot be used with body – worn sensors since sensors are preferred to be placed under the clothing at most cases.

Power also can be harvested from human – body motion, temperature, explicit interaction such as squeezing, shaking, pushing and pumping objects. Electronic systems harvesting energy from ambient – radiation sources are another possibility. (Benini, 2006) However, disadvantage is such that they need to be close to the radiating source or benefit of a large collection area. Also, they collect only extremely limited power (less than 1 $\mu W/cm^2$).

Overall, there is no single energy source will fit all environments and applications. Thus, researchers must choose carefully one or a combination of power – sources depending on application requirements. Unused devices or components can be put into "sleep mode" and activated only when it is required. It is to optimize power consumption.

2.1.7 BAN Signal Measurements Principle

This research is mainly focusing on the signal measurements such as SpO_2 (or pulse oximetry), temperature, heart rate (ECG) and blood pressure. In such a case, the researcher has to identify the use cases of BAN and clarify specific vital sign sensors to be mounted on patients.

(a) Blood oxygenation measurement (SpO_2)

SpO_2 or pulse oximetry is the measure of oxygen saturation in the blood, which is related to the heart pulse when the blood is pumped from the heart to other parts of the human body. When the heart pumps and relaxes, there will be a differential in absorption of light at a thin point of a human body. Oxygenated hemoglobin absorbs more infrared light waves and allows more red light waves to pass through. On the other hand, deoxygenated hemoglobin absorbs more red light waves and allows more infrared light waves to pass through. This unique property of hemoglobin with respect to red and infrared light wave allows oxygen saturation to be detected non – invasively. In such a case, sentinel events are defined when SpO_2 is less than 85 %. (Francis Tay, Guo, Xu, Nyan & Yap, 2009).

(b) Temperature measurement (^oC)

Temperature taken at the ear closely matches the body core temperature compared to other pats of the body. This temperature is called is tympanal temperature. In such a case, the tympanal temperature gives us an indication of the state of the cognitive organ of a person – the human brain. Extended period of high fever can damage human organs, especially the brain. Thus, a precise thermopile was chosen in this application. Sentinel events are defined when temperature (^oC) is greater than 38.3^oC. (Francis Tay, Guo, Xu, Nyan & Yap, 2009).

(c) ECG monitoring

The standard ECG generally involves connection between 12 and 15 leads to a patient's chest, arms and right leg via adhesive electrodes. Disadvantage of such system is such that this device records only a short sampling of the heart's electrical activity which is not more than 30 seconds. Such short sampling time fails to capture cardiac activities that are irregular or intermittent, which is typical among ICUs and the elderly. (Mehmet, 2010)

Thus, a 3 – lead continuous telemetry based ECG is developed to evaluate a patient's cardiac activity for an extended period. Once a beat is detected, it is characterized by a number of features such as width, amplitude and R – to – R interval. Heart beat rate (HR) can be easily calculated by the R – to R interval.

(i) Heart beat rate :

Tachycardia : Heart rate > 90 beats/ min

Bradycardia : Heart rate < 60 beats/ min

(ii) QRS width :

0.1 – 0.12s indicates the Wolff – Parkinson – White syndrome or non – specific intraventricular conduction delay or incomplete right or left bundle branch block (RBBB or LBBB).

> 0.12 s indicates complete LBBB or RBBBB or ventricular tachycardia.

(iii) Q Wave

If Q wave's width is more than 0.04 s or/ and Q wave's height more than 25 % of R wave's height, it indicates myocardial infarction.

(d) Blood pressure measurement

Blood pressure measurement consists of the systolic and diastolic blood pressures. Conventionally, blood pressure is obtained by using a cuff method utilizing Korotkoff principle. Other cuff methods make sure of pressure measurement in an oscillometry system. However, disadvantage is such that cuff is not suitable method for wearable application. This is because complex electronics and mechanical components have to be employed with pressure sensors that need to detect signals that fall in the range of milivolts. (Francis Tay, Guo, Xu, Nyan & Yap, 2009).

Recently, a new cuffless method have been developed. The pulse transit time (PTT) is defined as time taken for pulsed blood, which is initiated from the heart, to travel to other parts of the human body where the plethysmogram (PPG) is taken. The PTT is then used to infer the systolic blood pressure, which provides enough information for decision of hypertension and hypotension. Sentinel events is defined as below :

(i) Hypertension : > 140 / 90 mmHg (systolic / diastolic)
(ii) Hypotension : < 90 / 50 mm Hg (systolic diastolic)

2.2 Prospective BAN contribution to patients and medical people

BAN has great potential in contributing to patients and medical people as well. First in place, it realizes connected health system. In such a way, patients can be connected to caregivers 24 hours via network according to needs of patients.

Secondly, BAN can be used to monitor chronic but stabilized patients ubiquitously meaning at home. Chronic patients discharged from hospitals are desperately in need of intensive monitoring at home. The cost of sending nurses or medical doctors to attend patients at home is very high. Therefore, remote monitoring of vital signs for home care becomes essentially useful especially for those patients. At the same time, it reduces chronicle disease patients' visit frequency to doctor's office.

Thirdly, there is a situation where hospital beds not being able to meet the number of patients to be admitted. BAN contributes in such a way that to monitor an after surgery patient vital signs (such as temperature and ECG) in a hospital wherever patient is located. In such a case, they are not critical as intensive care unit (ICU) patients but still require monitoring of vital signs. (Francis Tay, Guo, Xu,, Nyan & Yap, 2009).

Also, it can be in an automatic alert signal transmission from personal server to rescue centre by monitoring drastic vital changes in one's vital signs. The traditional cable sensors however, often cause inconvenience to patients by restricting patient's mobility and disturbing them with the presence of cables. To

overcome this problem, wireless medical sensors are developed and applied. The special caregivers dependability will be decreased. (Alemdar & Ersoy, 2010) In such a case, this system will be not only monitoring system in everyday life, but also be a convenient system without limitation of movement.

It can identify emergency situations like heart attacks or sudden falls by real – time monitoring as well. It will detect if patient fell and alert the doctors or caregivers to avoid cases of lack of attention or late attention. It will suffice for saving lives considering that, without them these conditions will not be identified at all. With remote monitoring, this system can save the time and cost taken to the hospital. Today, time is same as money and competiveness. So, the patient may feel more comfortable. (Bong, Yong & Sun, 2008)

2.3 BAN International Applications

In a wider international context, BAN application can be extended to an even broader extent. Table 2.2 below shows some of the in – body and on – body applications.

Table 3: In – Body and On – Body Sensor Networks Applications (Ullah, Khan , Saleem, Higgins & Kwak, 2009)

Application Type	Sensor Node	Data Rate	Duty Cycle (per device) % per time	Power Consumption	Privacy
In – body Applications	Glucose Sensor	Few Kbps	< 1 %	Extremely Low	High
	Pacemaker	Few Kbps	< 1 %	Low	High
	Endoscope Capsule	>2 Mbps	< 50 %	Low	Medium
On – body Medical Applications	ECG	3 kbps	< 10 %	Low	High
	SpO_2	32 bps	< 1 %	Low	High
	Blood Pressure	<10 bps	< 1 %	High	High
On – body Non – Medical Applications	Music for Headsets	1.4 Mbps	High	Relatively High	Low
	Forgotten Things Monitor	256 kbps	Medium	Low	Low
	Social Networking	<200 kbps	< 1 %	Low	High

The following part discusses some of the BAN international applications:

2.3.1 Cardiovascular diseases detection applications

Traditionally, Holter monitors were used to collect cardio rhythm disturbances without real – time feedback. However, transient abnormalities are sometimes difficult to capture. For instance, many cardiac diseases are associated with episodic rather than continuous abnormalities and their time cannot be accurately predicted. Such episodic abnormalities can be transient surges in blood pressure, paroxysmal arrhythmias or induced episodes of myocardial ischemia. The advantage of BAN system in such a case is such that patients can be monitored under natural physiological states, over a long term period for their heart activity. Also, the patient can be monitored for an ambulatory period without being constrained physically.

2.3.2 Cancer detection applications

Cancer remains one of the biggest threats to the human life. In such a case, sophisticated technology allows a set of miniaturized sensors capable of monitoring cancer cells to be seamlessly integrated in a BAN. This allows physician to diagnose without biopsy. (Ullah, Khan, Saleem, Higgins & Kwak, 2009)

2.3.3 Diabetes detection applications

A BAN network on a diabetic patient could auto inject insulin through a pump, as soon as his insulin level declines, thus making the patient ‘doctor – free’ and virtually healthy.

2.3.4 Asthma detection applications

A BAN can help asthma patients by monitoring allergic agents in the air and providing real – time feedback to the physician. Chu et al proposed a GPS – based device that monitors environmental factors and triggers an alarm in case of detecting information allergic to the patient (Ullah, Khan, Saleem, Higgins & Kwak, 2009)

2.3.5 Artificial retina applications

Retina prosthesis chips can be implanted in the human eye that assist patient with limited or no vision to see an adequate level. (Ullah, Khan, Saleem, Higgins & Kwak, 2009)

2.3.6 Sleep disorder detection applications

If monitoring is carried out during ordinary daily life, data have to be collected routinely and automatically without constraining the subject. It is expected that people will be in a stable physiological condition during sleep, and that the sleep period is long enough for physiological observations. (Ogawa & Togawa, 2000)

Example of existing project:

SleepScan is recently developed by Japanese Tanita company. It is a wireless sensor-equipped mat to measure the deepness and quality of sleep. In such a case, it is designed to monitor heart rate, respiration rate and motion in bed and to record these data during night time so that to help detecting sleeping disorders such as insomnia. The concept is as easy as slipping it under patient's mattress and based on information coming from the capacitor microphone inside the mat that tracks vibrations. The collected data is stored on a removable SD card allowing it to be uploaded and analyzed on a PC via an included piece of software. The advantage of such system is such that this system is a convenient system without limitation of movement. This, improves the quality of healthcare as well. In comparison, the traditional EEG method is an invasive method to diagnose any sleep disorders among patients. Rather than precise measurement, this SleepScan system can provide long term monitoring without disturb the sleep quality of patients.

2.3.7 Medication intake monitoring applications

Medication noncompliance is common in elderly and chronically ill especially when cognitive disabilities are encountered. Therefore, medication intake monitoring is essential. One of the early prototypes developed by Moh et al. (2005) aim to control the medicine intake of the elderly with the combined use of sensor networks and RFID. In such a case, the system is able to determine when and which bottle is removed or replaced by the patient and the amount of medicine taken. In such a case, the patient wearing an Ultra High Frequency (UHF) RFID tag is identified and located by the Patient Monitoring Subsystem and the system is able to alert the patient to take the necessary medicines.

2.3.8 Medical status monitoring applications

Monitoring the medical status of the people is the most widely studied application type of pervasive healthcare systems. The commonly used vital signs are ECG, pulse oximetry, body temperature, heart rate and blood pressure. The acceleration data is also used together with these vital signs in some studies. In maintaining the health of elderly people, it can be useful to monitor their health status through their daily routine in their own home, as well too. (Ogawa, Suzuki, Otake, Izutsu, Iwaya & Togawa, 2002)

Examples of existing projects:

(a) **MobiHealth** is one of the early projects that integrates all the wearable sensor devices such as PDA's mobile phone and watches that a person carries around during the day. MobiHealth is important in being one of the early studied proposing the convergence of different network systems like BAN, PAN and WAN to enable personalized and mobile healthcare.

(b) **CodeBlue** is a hardware and software platform developed at Harvard University. The design includes a mote – based pulse oximeter, 2 – lead ECG and a motion analysis sensor board. CodeBlue project is one of the most comprehensive projects in the literature which includes mote design, software architecture design, ad hoc network design and multi – hop communication together with location tracking.

(c) **LifeGuard,** which was developed for astronauts in the first place, can also used for general vital signs monitoring. The system is comprised of 3 components. The sensors part can support different types of sensors such as ECG, respiration, pulse oximeter and blood pressure.

(d) **FireLine** is a simpler prototype design. It is designed for monitoring cardiac measurements of firefighters for being able to take the necessary actions in the case of abnormality. The device is composed of a wireless sensor, a heart rate sensor and 3 electrodes.

(e) **MEMSWear – biomonitoring system** is developed by National University of Singapore. Microelectro – mechanical systems (MEMS) integrate mechanical elements, sensors, actuators and electronics through microfabrication technology. In such a case, MEMSWear is a wearable shirt,

which is equipped with physiological sensors for human physiological signs, which is ECG, SpO_2, body temperature and blood pressure. The advantage of such intelligent biomedical cloth is such that biosensors are embedded inside cloths for measuring physiological signals and to provide immediate diagnosis and trend analysis. Although embedding the sensors into the garment could provide a convenient wearable system for the patient, the disadvantage is such that it is not flexible for the addition or relocation of sensors. Different sizes of clothes have to be designed for different person, which can cause cost burden. (Benny Lo & Yang, 2008)

2.3.9 Predictive diagnostic applications

In the case of predictive diagnostic in maintenance health systems, there are many types of diseases but only percentage of them we can predict by technique.

With the help of embedded system capabilities, we can predict some life endangering situation like allergic reaction, coronary thrombosis, hypoglycaemic shock and sudden death syndrome. For example, the sudden death syndrome can be predicted from ECG signal, temperature, breath frequency and blood oxygen saturation. Also, prediction of blood pressure and blood glucose can prevent from hypertension shock and hyper or hypoglycaemic shock. (Srovnal & Penhaker, 2005)

2.3.10 Biomedical feedback control systems applications

It is well known that there are other indirect physiological parameters that can be measured. In such a case, BAN is to provide an indirect indication of the key parameters that require close monitoring or regulation. Examples of such indirect parameters include end tidal carbon dioxide tension, oxygen saturation in blood and glucose concentration in interstitial fluid. Methods of soft computing can be applied to combine continuous measurement of indirect parameters to produce sensors that can provide continuous estimation of the key physiological parameters. (Srovnal & Penhaker, 2005)

2.4.10 Location tracking applications

Location tracking for pervasive healthcare systems may serve both indoor and outdoor applications. In an indoor scenario, the location tracking system can be integrated for increasing the context – awareness of the systems and for efficiency. In an outdoor setting, it can be used for assisting people with cognitive disabilities or identifying the locations of people when an alarm situation has occurred like an epilepsy seizure. In such a case, the system works by placing passive RFID tags in important locations where patients need to make decisions about the next action to take, such as turn right or left. The visited positions are tracked and logged and in case of anomalies, alarms are raised. (Alemdar & Ersoy, 2010)

Examples of existing projects:

(a) **Ultra Badge System** is location tracking application that is used in a hospital setting. In Ultra Badge, a 3D tag system designed to realize the location of the patients. When a patient is in a specific area where a fall is most likely to occur (such as at the entrance of a toilet), the system alerts the caregivers.

(b) **ALMAS** project integrates location tracking technology with video analysis and wireless multimedia technologies to create an environment that provides healthcare for the elderly. It consists of a wireless wearable unit, RFID tag, wireless transceivers and video cameras. ALMAS' video cameras continuously record the activities of the patient and automatically detect if there is a situation that requires attention by the healthcare professional.

2.4.11 Battlefield applications

Other than in medical field, BAN can also be used to connect soldiers in a battlefield and report their activities to the commander. For example, the activities can be running, firing and digging. The soldiers should have a secure communication channel in order to prevent ambushes. (Ullah, Khan, Saleem, Higgins & Kwak, 2009)

2.4 Challenges

2.4.1 Hardware Level Challenges

2.4.1.1 Unobtrusiveness

When the patients have to carry sensors attached on their bodies, unobtrusiveness poses a major challenge. In such a case, the need for integrating different sensors into one solution makes it even difficult. For example, the body – worn sensor devices are heavy yet obtrusive devices, whereas the bandage type ECG sensors are much easier wearable devices (Alemdar & Ersoy, 2010). Hence, the design and development of wearable yet unobtrusively sensor devices is crucial. It is expected that the sensor nodes could become miniature in order to avoid activity restriction with new integration and packaging technologies. (Huang et al, 2009)

2.4.1.2 Sensitivity

Sensitivity of the sensor devices is important especially when the users wear the sensors under harsh environments like in a fire situation or exercising. In such a case, the transducer of the sensor devices can be affected negatively by the sweat, causing the sensitivity reduction of the sensors or requiring further sensor recalibration. It is expected that low – maintenance and highly sensitive vital signs monitoring sensors are developed in the near future. (Alemdar & Ersoy, 2010)

2.4.1.3 Energy

The lifetime of batteries becomes one of the bottlenecks of sensor devices. In such a case, the wireless communication link is the most power demanding part of the BAN. Reducing the power consumption of the RF transducer could significantly reduce the power consumption and extend the lifetime of the sensor node. (Benny Lo & Yang, 2008)

For indoor environments, rechargeable batteries may be the solution. However, recharging the batteries may become burdensome especially for the elderly since they might tend to be forgetful at most of the time. Apart from designing low – power sensors, we still need energy scavenging techniques (Yoo, Yan, Lee, Kim, & Yoo, 2010). In such a case, the solar cells can provide up to 15 mW/cm^2 under direct

sun, which is proven to be quite a large energy amount. But after all, it cannot be used with body – worn sensors since sensors are preferred to be placed under the clothing at most cases. Therefore, motion and body heat based energy scavenging techniques should be developed to prolong the sensor operating life.

2.3.1.4 Data acquisition efficiency

We have to pay special attention on the efficiency of data processing techniques. In some cases, a 3 – axes accelerometer may not be capable of classifying all activities of the people whilst 3 – lead ECG may be insufficient for identifying a cardiac disease. Thus, more sensors will be needed in order to increase the data accuracy. The real – time acquisition and analysis of the physiological data is essential. (Alemdar & Ersoy, 2010)

2.3.1.5 Reliability

The reliability of the system is important factor. In such a case, an undetected life critical signal could be fatal. The improvement of reliability can minimize sensing and read – out errors, avoiding errors in wireless communication as well. (Huang et al, 2009)

2.4.2 Layer Independent Challenges

There are some challenges that are not directly related with a specific layer yet they have to be solved for the improvement of BAN system. The challenges and their solutions are discussed in the following subsections.

2.4.2.1 Security / Privacy

The confidentiality, data integrity, accountability and access control are the fundamental security requirements of the BAN system. In order to protect patient's privacy, the security of BAN should be guaranteed into such an extent that the sensed signal from the body should have secure yet limited access. Also, the sensed signal from one person should not be mixed up with another person. (Huang et al, 2009) The privacy preserving methods should be developed for the comfort of the monitored people. (Alemdar & Ersoy, 2010)

2.4.2.2 User – friendliness

The development of natural interfaces between a diverse group of people and pervasive systems are crucial. In such a case, the system should be easy for patients to use with minimal training and minimal maintenance. The power consumption should be minimized to eliminate the recharging inconvenience. It should be portable so that patients can take the system anywhere, anytime. (Blount et al, 2007)

2.4.2.3 Cost

Cost is the most frequently discussed issue. Unless the system is affordable or it has cost offset, it may not be widely accepted and adopted even if it is deemed useful. (Steele, R., Lo, A., Secombe, C., Wong, Y.K., 2009)

CHAPTER 3

METHODOLOGY

3.1 Introduction

The aim of this chapter is to define the methods of research. In such a case, the process involves the source of data, research strategy, questionnaire design and the technique to analyze the collected data. The methods used to conduct this research are primary and secondary research. The primary research method used is questionnaire survey whilst the secondary research method used to support and to compare the primary results was intensive interview. A flow chart of this research is included at the end of this chapter in order to depict how the process of this study to be undertaken from the inception to the completion.

3.2 Source of data

Source of data is defined in which the required information can be obtained in order to compile this study in a more thorough way. It can be classified into 2 categories as following:

3.2.1 Primary Data

Primary data is the data to address the specific problem at hand – the research question. In this BAN study, the raw data are collected through survey questionnaire. The major advantage of primary data is accuracy of data since it is collected by the researcher. The disadvantages of primary data are costly and time consuming (Donald and Pamela, 2006)

3.2.2 Secondary Data

Secondary data are data originally collected to address a problem other than the one requires the researcher's attention at the moment. The data are ready made data which collected from references books, newspapers, journals, magazines and internet in order to realize the existing information and issue on current BAN technology. The advantage of secondary data is quicker and cheaper than primary data. The disadvantage is the information may not meet specific needs for this BAN study (Donald and Pamela, 2006)

3.3 Selection of Research Strategy

3.3.1 Literature Review

The literature review form part of this research. One way of attaining this kind of information is through the current mass media and publications. Reviews and analysis were conducted on articles, journals, reports and the internet. These reviews are important in such a way that they provide the latest development especially from the biomedical field. This method will increase the knowledge about this study and provide a better yet in – depth understanding. These reviews and analysis also helped in formulating the questionnaire survey, too.

3.3.2 Questionnaire Survey

In this research, method of acquisitive information used was questionnaire. In such a case, a set of questionnaire has been designed based on criteria of particular research paper in fulfilling objectives of this paper. In this survey, postal questionnaire is not chosen because it may take several weeks to collect the responses and normally response rate is usually less than 5 %. Also, phone interviews are not chosen as the respondents are obligated to the time slots provided by the researcher. Thus, the questionnaire was best conducted in a face – to – face interview form.

There are a variety of designs for scaled response and hence the design options need to be considered by the researcher. One of the most common scaled – response formats is the Likert scale. It is developed by Rensis Likert in an attempt to improve the levels of measurement in social research through the use of standardized response categories in survey questionnaires. A common form is an assertion, with which the person may agree or disagree to varying degrees. It is typically a five point scale, as shown in the following format:

a) Very important
b) Important
c) Average
d) Not important
e) Very not important

The major advantage is such that questions used are easy to understand and so lead to consistent answers. By using such likert scale, the researcher can avoid choices of "Don't Know", Neutral or Undecided response category. However, a disadvantage is that only a few options are offered, with which respondents may not fully agree. Also, a problem may arise where people may become influenced by the way they have answered previous questions. For example, they may continue to agree if they have agreed several times in a row. (Changing Mind Organization, 2010)

In this research, there are 3 main target end users, which are in – patients including medical tourism, out – patients and health conscious people as well. Thus, this questionnaire is mainly consisted of 5 parts to know the design requirements of BAN.

(i) Section 1 is related to the application of BAN to in-patients (including medical tourism)
(ii) Section 2 is related to the application of BAN to out- patients
(iii) Section 3 is related to the application of BAN to health conscious people.
(iv) Section 4 is related to the physical requirements for the BAN design.

After finalizing the entire research questionnaire, the photocopies of questionnaires are completed along with face-to-face interview. The answers are filled up by the researcher based on the participating respondent's response. The participating respondent in this research were 30 (medical doctor: 10, biomedical engineering personnel: 20). In such a case, the researcher has to identify the use cases of BAN and clarify specific vital sign sensors to be mounted on patients. The functional specifications and design requirements may differ to suit different medical procedures. All these matters have to be discussed with medical doctors and biomedical engineering personnel from Malaysia's private and government hospitals (in this BAN research, Kuala Lumpur and Penang are chosen as the main surveyed destinations). Based on the ascertained design requirements, the researcher shall then have a clear concept in developing a BAN based, human friendly, connected health system.

3.4 Data analysis

3.4.1 Importance Index

Qualitative data such as likert scale can be measured using a 3 points, 5 points measurement scales. In this research, the 5 points likert scale is being used.

Qualitative data can be converted to quantitative data using the following adopted from Lim & Alum (1995) (NTU, Singapore) published in the International Journal of Project Management (Lim, E.C. Alum, J., 1995).

Conversion Formula $= \dfrac{5N_1 + 4N_2 + 3N_3 + 2N_4 + N_5}{5\,(N_1 + N_2 + N_3 + N_4 + N_5)}$

N_1 = Number of respondents with strongly agree

N_2 = Number of respondents with agree

N_3 = Number of respondents with average

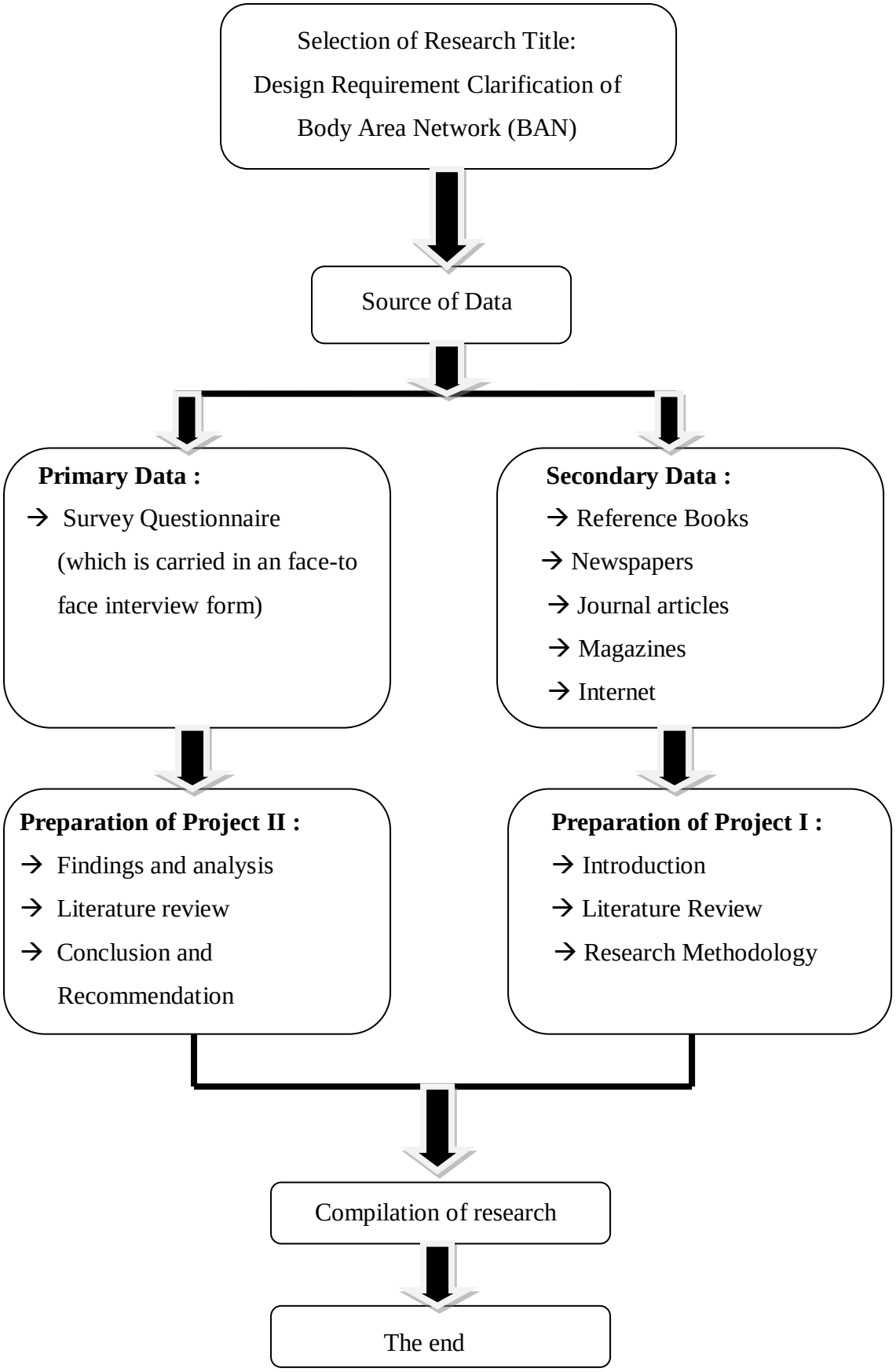
N_4 = Number of respondents with disagree

N_5 = Number of respondents with strongly disagree

3.5 Conclusion

Data will be gathered through primary and secondary data collection method with the purpose to find out the respondent's response on BAN design requirement.

3.6 Flow Chart of Research Progress



CHAPTER 4

DATA ANALYSIS

A total of 30 sets of questionnaire were carried out. It is mainly comprised of the hospital, biomedical companies and clinics which located within Kuala Lumpur and Penang area. The questionnaire was aimed to obtain ascertained design requirement which is important for us to develop a Body Area Network (BAN) – based system.

Eventually, 25 questionnaires responded were returned, it represents rate of 83.33%. Hence, this analysis is carried out based on the 25 completed and returned questionnaires. Following is the list of hospitals or companies or clinics which are included in questionnaire surveys :

Table 4: List of Hospitals and Companies Included in Questionnaire Surveys

No.	Hospitals / Clinics	Location
1	Gleeneagles Intan Medical Centre (GIMC)	Kuala Lumpur
2	Hospital Kuala Lumpur (HKL)	Kuala Lumpur
3	Hospital Tawakal	Kuala Lumpur
4	Hospital Pusrawi	Kuala Lumpur
5	Hospital Universiti Kebangsaan Malaysia (HUKM)	Kuala Lumpur
6	Tung Shin Hospital	Kuala Lumpur
7	Ampang Puteri Specialist Hospital (APSH)	Kuala Lumpur
8	Faculty of Medicine, Universiti Tunku Abdul Rahman (UTAR)	Kuala Lumpur
9	Hospital Pulau Pinang	Penang
10	Penang Adventist Hospital (PAH)	Penang
11	Gleeneagles Medical Centre (GMC)	Penang
12	Loh Guan Lye Specialist Centre (LSC)	Penang
13	Hospital Mutiara Pantai Timur	Penang
14	Klinik Lim Sungai Pinang	Penang
No.	**Biomedical Services / Equipment Companies**	**Location**
15	Healtronics (M) Sdn Bhd	Kuala Lumpur
16	Schiller (M) Sdn Bhd	Kuala Lumpur
17	Radicare (M) Sdn Bhd	Kuala Lumpur
18	UMC SrviceMaster (M) Sdn Bhd	Penang

4.1 Respondent's Demographics

This section evaluates working experience, occupation or position and the nature of service of the questionnaire's respondents.

4.1.1 Years of Working Experience Among Respondents

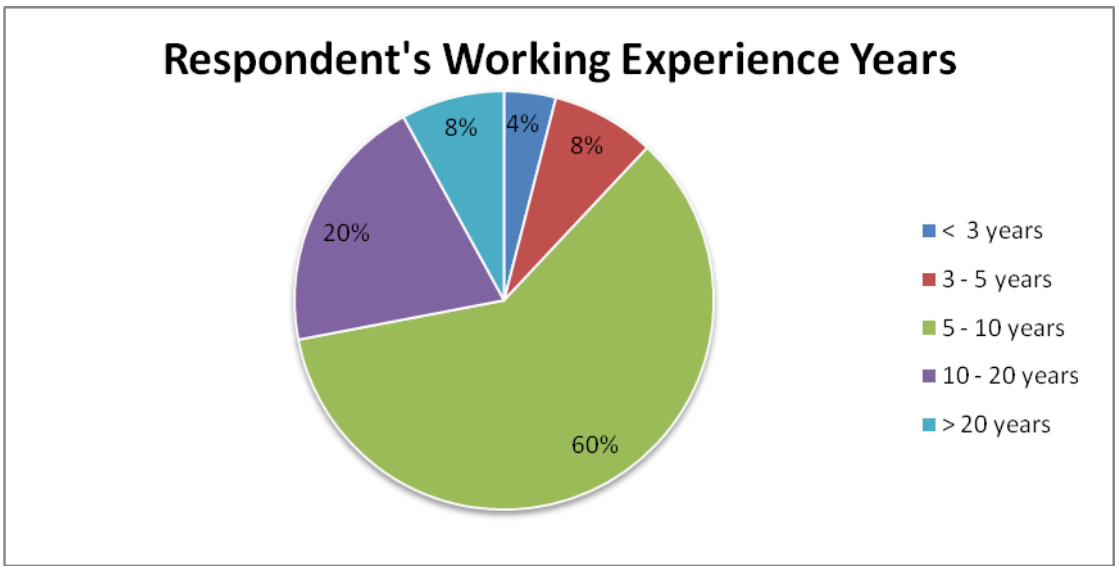


Figure 1: Years of Working Experience among Respondents

This data analysis examines working experiences among respondents. This is to ensure the reliability of data obtained from the questionnaires. Since this is a qualitative based surveys, respondent's working experience are important in contributing to the accountability and reliability of data obtained.

The data analysis was indicating the greatest number of the respondent's working experience is at the range of 5 – 10 years which consists of **60%** (15 respondents). On the other hand, the least number of the respondent's working experience is less than 3 years, which comprises only at **4% (**1 respondent**)**. Range of 10 – 20 years consists of **20%** (5 respondents) which is the second highest among all the categories. Besides, other range of working experience such as the range of 3 – 5 years and those more than 20 years both comprise **8%** of the questionnaires (2 respondents).

4.1.2 Respondent's Occupations

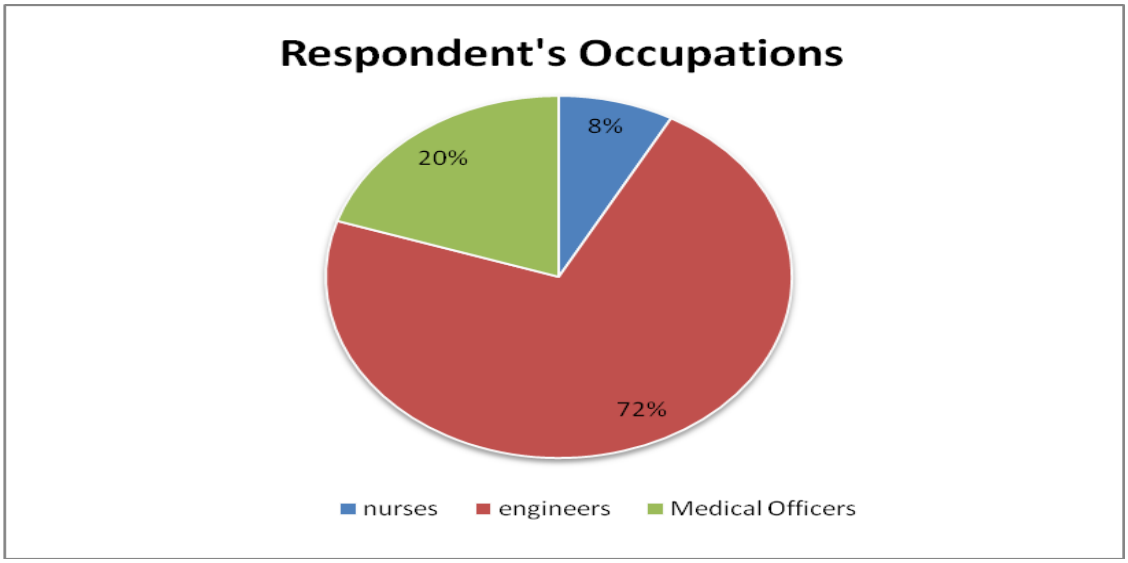


Figure 2: Respondent's occupations

This data analysis examines respondent's occupations. This is to ensure that the involvement of respondents in medical industry and to ensure their qualification to answer the survey questionnaire which related to medical field.

Out of the 25 questionnaires, there are a total involvement of 19 biomedical engineers, 5 medical officers and 1 nurse. In other words, the respondents are mainly consisted of **72%** of biomedical engineers, who actively involve in maintaining and repairing biomedical equipments within hospitals or biomedical companies. Their opinions are important in this design survey since they are the engineers who design, maintain and repair whenever any equipment that breakdown. Thus, they will understand more on the technical parts involved in the design of BAN equipment.

The other **20%** respondents are consisted of Medical Officers. In such a case, the scope of this research is to identify the application of BAN and to identify the types of sensors to be mounted on patients so that to capture specific vital signs. The functional specifications and design requirements may differ to suit medical procedures. With their in – depth medical knowledge, they would know and understand the needs of patient in using BAN equipment. For example, they would know in depth regarding the location to attach the sensor patch on patient's body.

There are another **8%** respondents which consist of nurses. Their opinions are useful as they are the end user of the medical equipments on patients.

4.1.3 Nature of Respondent's Sectors

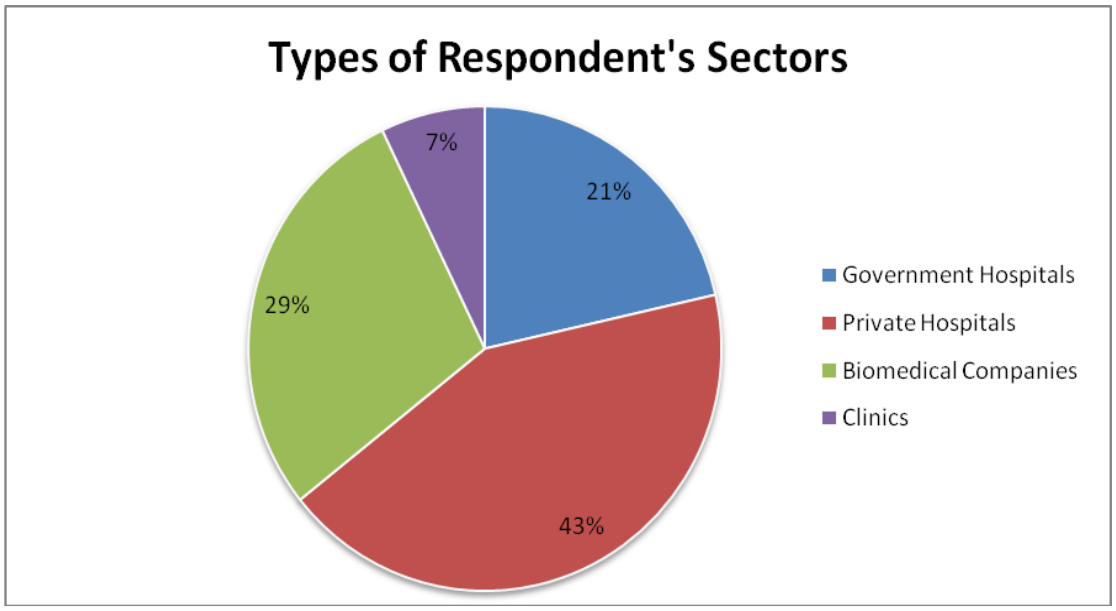


Figure 3: Types of Respondent's Sectors

This data analysis is to examine types of respondent's sectors. This survey is to ensure that the accountability of respondent's companies to answer the survey which related to medical field. Figure 3 above shows 4 types of respondent's companies which involved in the surveys. The result shows that majority of respondents are from healthcare sectors, which adds up to **64%**. Among this 64%, **43%** comprises of private hospitals and the other **21%** are comprised of government hospitals. On the other hand, **29%** of the questionnaires were carried out in biomedical companies which provide sales and service of biomedical equipments to private and government sectors. Besides, minority of **7%** are from clinics.

Part 1: Application to In-Patients

4.2 Findings from Questionnaire Surveys (Part 1: In – patients)

4.2.1 Response of Respondents towards BAN Implantation within Hospital

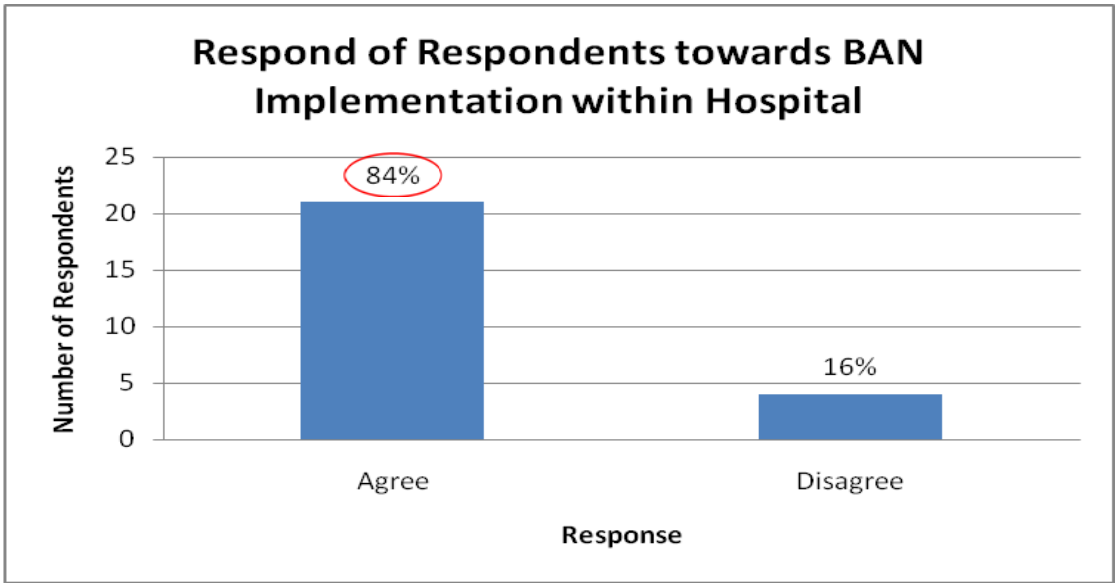


Figure 4: Response of Respondents towards BAN Implementation within Hospital

Based on collected response, **16%** respondents disagree on the idea of wireless BAN implementation within the hospital. They mostly satisfy with the performance of current cabled telemetry system in their hospital. Because through such cabled system, there is no risk of data lost. Besides, cabled system has been adapted quite some time and they feel get used of such system.

However, most respondents agreed on the idea of BAN implementation within hospital. They consisted mostly **84%** of the surveys. According to the statistics, they would agree and support the idea of innovating the cabled sensor nodes in current telemetry system into wireless form. This is due to the idea that current cabled sensors are always not in good condition after repeating usage on patients. In such a case, the cables may be detached, or even loosened after long term yet frequent usage.

Secondly, the nurses have to use tape to attach cables firmly on patient's body. This may leave the cables in sticky yet poor condition after each usage. Thus, this condition may be improved if it is replaced with wireless sensor. Cables are no longer in need. In such a case, wireless sensor is attached on the patient's body for automated

and periodic measurement of patient's vital sign. It is attached to the patient's body with the use of medical adhesive dressing. The sensor can pick up and transmit the biological data from patient body to a patient-worn transmitter. The data can be stored on a SD card or read in real – time basis by caregivers or doctors on duty. Any value above the threshold level will induce alarming signal so that immediate action can be taken to avoid any late of attention.

Another limitation of conventional telemetry using wired electrodes is that the patient is hard wired to the monitor, thereby limiting the mobility of the patient. The current cabled telemetry system allows patient mobility within certain monitored areas in hospital. However, patients definitely feel uncomfortable with all those cables tangled around on their body. In such a case, any sweating happen on those taped cables would cause a definite uncomfortable among patients. At this point, there is a set aim to deliver the obvious benefits, in which wireless BAN is to enable removable of restrictive and unreliable wiring, enhanced ease-of-use and everyday efficiency as well.

There are always some spaces for improvement in future medical field. Driven by a strong pressure to improve, the performance targets for the healthcare industry continue to rise. At the time where budgets and resources are restricted, new ways of increasing efficiency, productivity and usability are sought. With the Body Area Network concept, there is a possibility where for some innovative yet patient-friendly design here.

(i) The cabled telemetry system is suggested to be used in wireless form with all those sensor patches. As wireless sensors attached to the patient transmit data to the nurses' station or other centralized location, data can be sent on a continuing – instead of intermittent basis no matter where the patient is in the hospital. In such a case, wireless medical BAN also allows nurses to monitor multiple patients simultaneously.

(ii) The wireless BAN system can collect several vital sign at the same time with the network formed. For example, a newly innovated wireless BAN is a sensor network system which constitutes of different sensor that can read spO_2, heart rate and blood pressure at the same time. The current telemetry device can only record the patient's heart rate.

In fact in these few decades, there is always an escalating presence fuelled by changes in the wireless landscape. Firstly, there is a greater economy of scale through global standardisation. In such a case, cheaper, smaller and more reliable solutions incorporate higher levels of electronic integration. Also, there is an obvious reduced interference in protected medical frequency bands. Lastly, increased awareness and interest in public and especially in medical professionals lead to wider acceptance of wireless BAN system.

The main difference between a wired and wireless BAN infrastructure is the existence of physical cabling. In such a case, a wired network uses wires to communicate whereas a wireless network uses radio waves without any form of cable. The transmission of data occurs over radio waves just like cordless phones. Thus, wired networks are easy to set up and troubleshoot whereas wireless networks are comparatively difficult to set up, maintain, and troubleshoot. Also, wired networks is costly when covering a large area because of the wiring and cabling while wireless BAN networks do not involve this area cost. (Wifinotes, 2011) A wireless BAN network can also save our time and efforts in installing the lot of cables. (Solms & Marais, 2004)

Secondly, wired networks make the user to be immobile while wireless ones provide user with a definite convenience of movement, mobility and freedom. Within a wired network, a user does not have to share space with other users and thus gets dedicated speeds while in wireless BAN networks, the same connection may be shared by multiple users. (Rodriguez, 2005)

Another drawback in the wireless internet is that quality of service is not guaranteed if there is any interference then the connection may be dropped. (Rodriguez, 2005) But once again, a wireless BAN networking system can avoid the downtime, which may be induced in the wired network.

However, the healthcare sector has long been an eager adopter of wireless technology. In such a case, wireless solutions can radically improve efficiency and productivity. Today's solutions perform better whilst being smaller and cheaper. At the end, the final outcome of wireless BAN is at higher volumes, lower costs but greater functionality.

Comparison between Wired Medical System and Wireless BAN System :
From the comparison below, there are both advantages and disadvantages between the wired medical telemetry and wireless medical telemetry.

Table 5: Comparison between Wired Telemetry System and Wireless BAN System (Wifinotes, 2011)

Features	Wired Medical Telemetry System	Wireless BAN system
Networking	The networking of the wired telemetry is faster as compared to wireless networking devices.	The networking of the wireless networking is good and better for the future resources but it is not faster as the wired system. WIFI is the common types of wireless network that can provide the reliable working for BAN.
Pros	There are cables involved.	No hassles of cables.
		No need any kind of wiring for installation. Thus, save cabling time and cost.
	Transfer of data is secured.	Convenience of mobility, movement and freedom.
		Easy to expand to a wider coverage areas.
Cons	It cannot provide mobile network.	Not reliable when interruptions occur.
	Difficult to lay down the cables and it looks very messy with the cabling setup.	Transfer of data is not that secured as the connection is shared by multiple users.
		Quality of service is not guaranteed if interference occurs.

As a conclusion, there are always spaces for improvement and innovation in terms of BAN implementation within the hospital. The responses from engineers, medical officers and nurses are mostly positive towards the idea on wireless BAN implementation.

4.2.2 The Best Implementation Site for BAN within Hospital (According Importance Index)

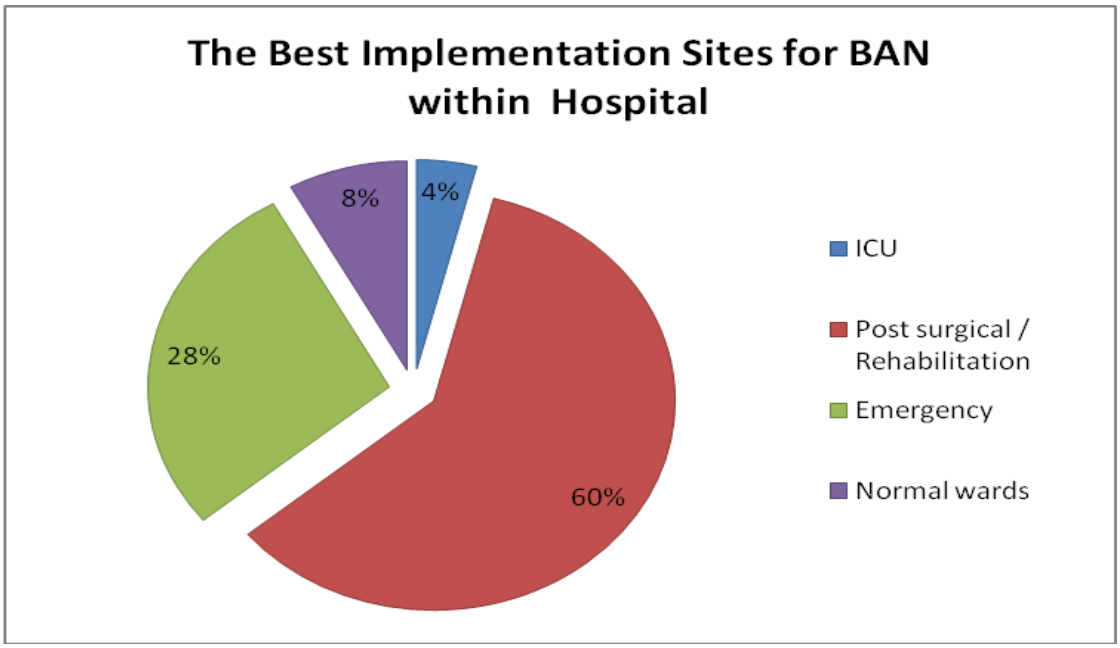


Figure 5: The Best Implementation Site for BAN within Hospital (According to Importance Index)

From the questionnaires, the best implementation site for BAN within hospital would be post surgical or rehabilitation departments. They both consist **60%** of the questionnaire responds. **28%** of the respondents feel that emergency department would be best served as the best implementation site. At last, there are a mere **8%** to be implemented at normal wards and **4%** at ICU.

While the acuity of patients increases, the healthcare industry is facing an inability to provide the traditional ratio of caregivers per patient due to a growing shortage of both physicians and nurses (particularly nursing care in the hospital environment). Although this trend is projected to continue in the foreseeable future, advances in technology are creating an evolution in health care services of the future.

For **60%** respondents, they feel that wireless BAN is suitable for post surgical and rehabilitation usage. They are not chronic as compared to ICU patient, however, they still in need of intensive monitoring on their health status. Any value above the threshold level will induce alarming signal so that immediate action can be taken to

avoid any late or lack of attention. With such wireless monitoring, patients under rehabilitation can walk around the hospital under close monitoring from nurse station.

In current state, remote cardiac monitoring is one of many important telemedicine applications available in today's healthcare environment. Remote cardiac monitoring provides additional surveillance for patients, typically at locations outside the care areas. (ECRI, 2007) This type of cardiac monitoring generates visual and audible alarm signals based upon condition changes that exceed established alarm limits for a specific patient. (Cale, 2007)

Thus, innovation can be made based on such situation. Among **28%** of the respondents, they feel that wireless BAN would be useful in Emergency department. In their perception, Emergency department is always full of crowd waiting for their queue up to be consulted by doctors. They may have underlying cardiac conditions or demonstrate unexpected symptoms and condition changes that require continuous or physiologic cardiac monitoring or transfers to a higher level of care, for which appropriate treatment may be delayed due to bed unavailability. Many facilities implement remote cardiac monitoring to facilitate alarm notification. (Patient Safety Advisory, 2009) In such a case, the implementation of BAN would be useful in monitoring their health status and to avoid cases such as late or lack of attention on those crucial patient with life – threatening diseases, such as heart attack and cardiac arrest. It may avoid further deterioration of patient conditions. For example, cardiac arrest is an abrupt cessation of pump function in the heart. The main diagnostic criterion to diagnose a cardiac arrest is lack of circulation. There are a number of ways of determining this. One of this is by determining their blood pressure. For example, cardiac arrest may cause blood pressure to drop below minimum levels of 50 mmHg systolic and 35 mmHg diastolic. If not treated immediately, this will lead to a coma shortly followed by death. (Chen & Hollander, 2007)

Also, non-intensive telemetry units are utilized for monitoring patients at risk for life-threatening dysrhythmias and sudden death. When 70% of the top 10 diseases admitted through the Emergency department are clinically indicated for telemetry, hospitals with limited resources will be overwhelmed and admitted patients will be forced to wait in the Emergency department. (Chen & Hollander, 2007) Wired telemetry is not suggested here, since wires would be tangled around the department

and it would make the emergency department look more messy and doctors would be sometimes get frustrated over this situation. However, telemetry is not indicated for patients requiring minor blood transfusion, low risk chest pain patients with normal electrocardiography, and stable patients receiving anticoagulation for pulmonary embolism. (Chen & Hollander, 2007)

At last, there is a minority of **4%** felt that ICU would be served as BAN implementation site. However, this is not supported significantly for serving ICU patients. In such a case, ICU units are for those patients who likely to require advanced respiratory support, and requiring support of two or more organ systems. Also, ICU units are for patients with chronic impairment of one or more organ systems sufficient to restrict activities and who require for an acute reversible failure of another system. (Cuthebertson & Webster, 1999) Thus, there is a perception that ICU patients would need more intensive monitoring with more complex monitoring systems (which is more than 3 vital signs criteria as mentioned in BAN architecture).

4.2.3 Main Concern about BAN System (Rated Responses)

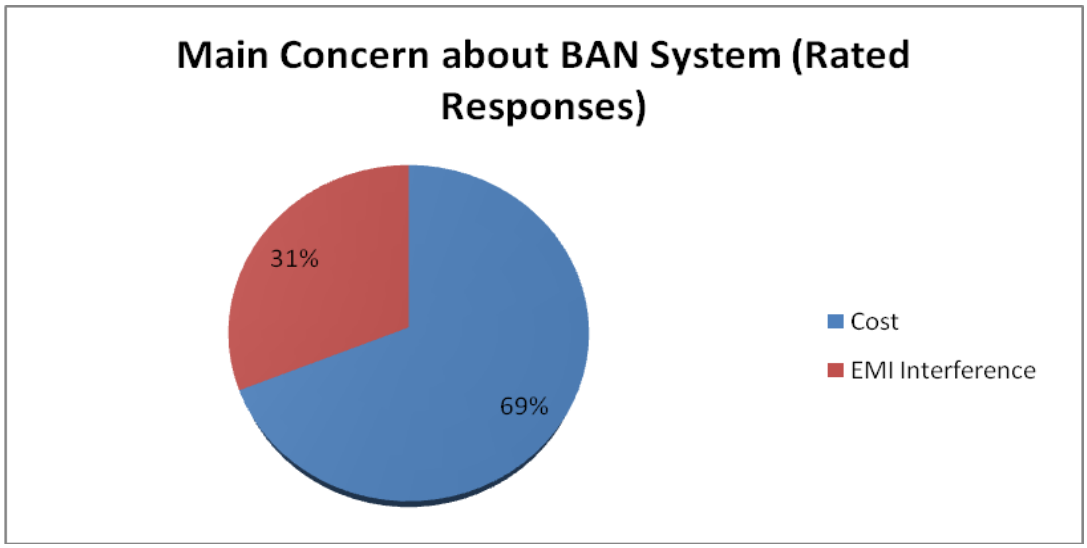


Figure 6: Main Concern about BAN System (Rated Responses)

There are several major problems to be considered in order to implement such BAN system in Malaysia context. One is low cost to consumers (patients). From the questionnaires, **69%** of the respondents feel that cost is the major issue to be considered in BAN implementation. Others **31%** feel that Electron Magnetic Interference (EMI) will be another problem instead.

With a growing per capita income and adoption of new lifestyles, healthcare services are rapidly changing, fuelling the demand for healthcare equipment across segments. Patient monitoring systems have become an indispensable part of all hospitals to ensure effective patient care. The patient monitoring market is expected to continue growing at a reasonably good rate with the products becoming more and more affordable. According to 2009 statistics, an estimated 18,000 units of patient monitoring equipment were sold in the Indian market in 2007. In 2008 an estimated 22,000 units of patient monitors were sold in India. The current unit-wise growth rate is 20 percent and the market 26,400 units of patient monitors are expected to be sold in 2009. (Medicalbuyer.com, 2009) Thus, there is a definite market value if we implement the BAN concept into the design of wireless patient monitoring system. In such a case, bulk production will help in reducing the production cost.

Secondly, a specific frequency transmission band is chosen. As users of medical devices, the radio signals transmitted from patient to the monitoring station are vulnerable to electromagnetic interference (EMI). In such a case, it can pose a real risk to patients. If these signals are interfered while the patient is suffering a significant adverse health event, the medical response could be delayed and serious patient consequences are likely to develop.

Because of the importance of these signals and the likelihood of EMI with these vital transmissions, the Food and Drug Administration, the Federal Communications Commission (FCC), medical device manufacturers, and the health care community banded together to examine the EMI issue with wireless medical telemetry and developed solutions. This is to minimize the risks to patients posed by EMI. These efforts in creation of the new Wireless Medical Telemetry Service, with its separate frequency spectrum and coordination, which is designed to reduce the risk of EMI to the vital patient telemetry signals from other frequency transmission operating in the same frequency bands. (Witters & Campbell, 2004)

4.2.4 Target Diseases for BAN System

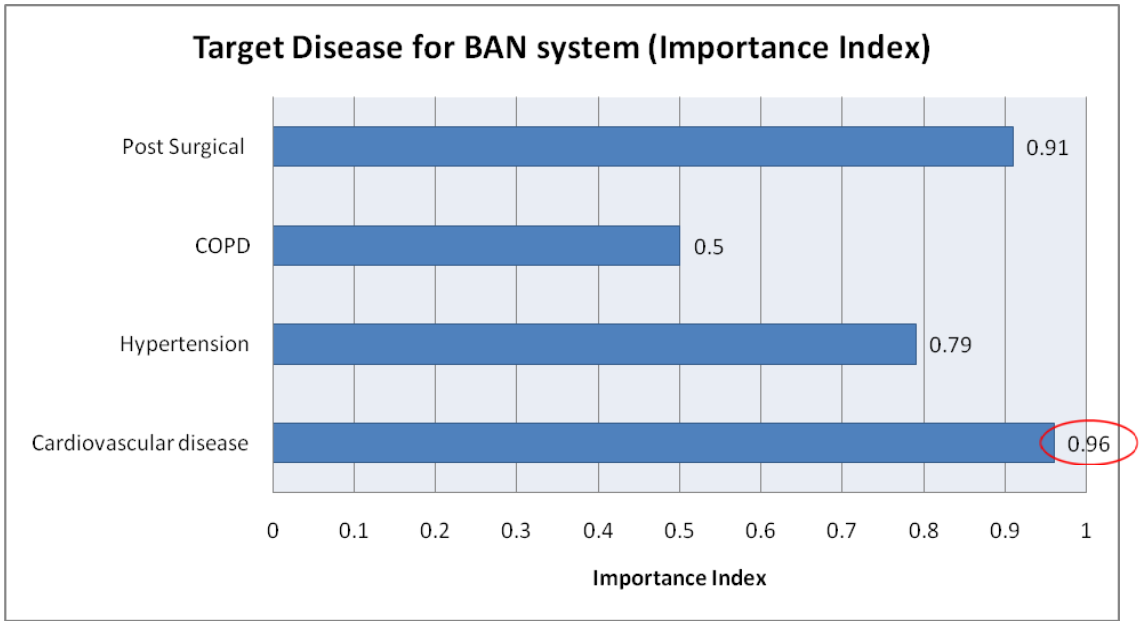


Figure 7: Target Diseases for BAN System (According Importance Index)

Figure 7 shows target disease for BAN system. The data collected from survey questionnaire shows that main target disease for BAN system would be cardiovascular disease monitoring which was ranked first with the importance index of **0.96**. Secondly, it is followed by post surgical complication with importance index of **0.91**. Hypertension is ranked at **0.79** importance index. Pulmonary disease such as Chronic Obtrusive Pulmonary Disease (COPD) is ranked as the least important, with its importance index only at **0.5**.

Cardiovascular disease is ranked the most important with a total of **0.96** importance index. In United States, heart disease is the number one killer of both me. n and women. The causes and cure for heart disease are now known and although many cardiovauscular diseases can be treated or prevented, an estimated 17 million people die of it each year. (National Heart Association of Malaysia, 2008) In Malaysia context, heart disease are on the rise despite improvement in health services and facilities. They were the second leading cause of death in 2006, accounting for 15.5 per cent of those who died in government hospital. In 2001, approximately 20 percent of all deaths at the Ministry of Health hospitals were due to heart attacks and strokes. Two thirds of these deaths were due to heart diseases and the rest to strokes.

By 2010, they are projected to be the leading cause of death in Malaysia and other developing countries.

Secondly, post surgical is possible, important and yet feasible to be included in wireless BAN system. It is ranked with **0.91** importance index. Patients recovering from surgery are at risk of complications due to reduced mobility as a result of post operative pain. The ability to monitor the recovery of this group of patients and indentify those at risk of developing complications is, therefore, clinically desirable and may result in an early intervention to prevent adverse outcomes. (M. Pallikonda, S. Radhakrishnan, P.Subbaraj, 2008) For current state, most hospital implements cabled telemetry system on those rehabilitation patients. However, this wired telemetry system is believed that it can be improved to wireless extent, in which it can be innovated into wireless BAN system for providing real-time monitoring. The function would remains the same, which is to send vital sign readings to central nurse station. However, BAN system in here, is a better yet innovated version. It would allow sensor patches to be attached on patients in wireless form. The most valued features of this system is such that there would be no wires constraint on patients, thus patients will feel more freely and comfortable.

Thirdly, hypertension is rated at **0.79** importance index. In such a case, high blood pressure usually causes no symptoms and high blood pressure often is labelled "the silent killer." According to Medilexicon's medical dictionary, hypertension means "High blood pressure; transitory or sustained elevation of systemic arterial blood pressure to a level likely to induce cardiovascular damage or other adverse consequences". (Monografias.com, 2010) Hypertension can be diagnosed by measuring blood pressure. If the pressure is greater than 140/90, the patients will be considered to have hypertension. If hypertension seems reasonable, tests such as electrocardiograms (ECG) will be used in order to measure electrical activity of the heart and to assess the physical structure of the heart.

Others such as Chronic Obstrusive Pulmonary Disease (COPD) are seen not as significant for BAN context compared to heart disease and post surgical disease. They are both ranked at importance index of **0.5**.

4.2.5 BAN Requirement for Cardiovascular Disease Patients

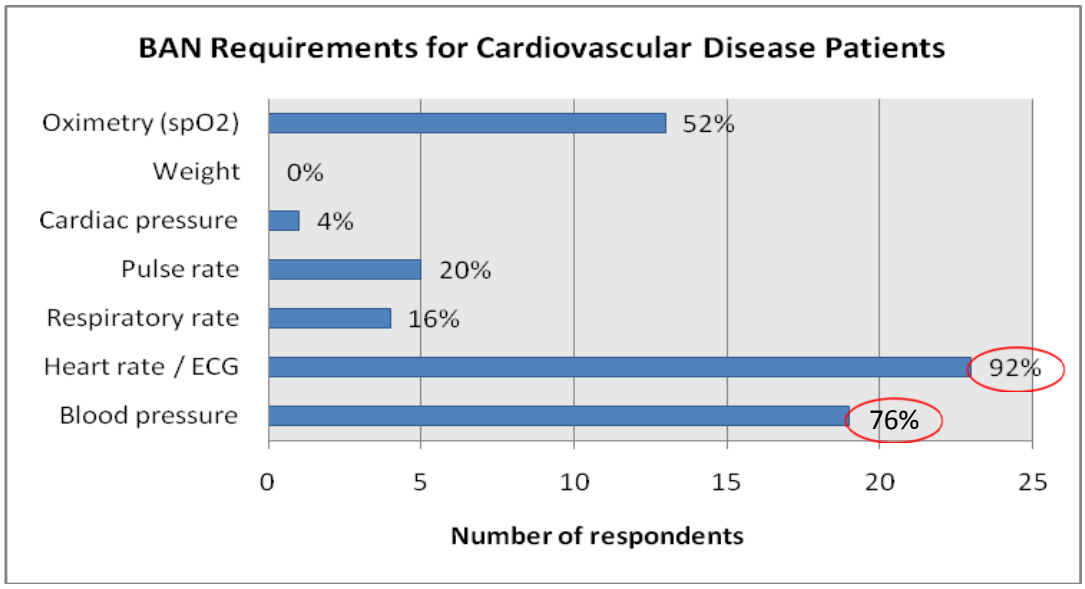


Figure 8: BAN Requirement for Cardiovascular Disease Patients (According Importance Index)

Above chart shows BAN requirements for patients with cardiovascular diseases. The data collected from survey questionnaire shows that if BAN is applied on patients with cardiovascular diseases, certain requirements are needed. Firstly, the main requirement would be blood pressure measurement which is ranked mostly at **100%** (25 out of 25 respondents). It was then followed by the measurement of heart rate / ECG at **88%** (22 out of 25 respondents). There are **40%** of respondents choose oximetry (SpO_2) as optional measurement. Other measurements such as pulse rate, respiratory rate and weight are seen as not significant in BAN measurement on heart failure patients.

For blood pressure measurement, systolic blood pressure is a readily vital sign that has been found to be a key factor in predicting mortality risk and revealing characteristics for heart failure patients, according to a team of academic researchers. Published in the Nov. 8 issue of the Journal of the American Medical Association, the new study found that the level of systolic blood pressure taken offers insight into different stages of heart failure, prognosis and disease development. (Champeau, 2006) In such a case, the heart rate increases as one of the compensatory ways of maintaining adequate cardiac output. A decrease in the resting heart rate with medical therapy can be used as a marker for treatment efficacy. For example, systolic blood

pressure demonstrates the maximum arterial pressure during contraction of the left ventricle of the heart, typically the first number in a blood pressure reading. Heart failure occurs when the heart is not working effectively, including when the heart's left ventricle cannot pump sufficient blood to the body's other organs.

Secondly, electrocardiogram (ECG) can be helpful as well. An ECG cannot diagnose heart failure, however, it is simple and painless to perform and can indicate heart problems by detecting the enlargement of the heart muscle, which may help to determine long term outlook. (Edward.com, 2006) In such a case, medical health evaluations often involve the use of ECG. An ECG is a highly useful tool in evaluating a patient's a cardiac activity, heart rate and rhythms. Each heartbeat is caused by a section of the heart generating an electrical signal, which then conducts through special pathways to all parts of the heart. These electrical signals, in an attenuated form, can be detected at the skin of the patient and recorded. Also, ECG helps to detect abnormal cardiac rhythms. In such a case, a rhythm pattern called a prolonged QT interval, for example, might predict people with heart failure who are at risk for severe complications and would need more aggressive therapies. In addition, the QRS duration is stable in the majority of patients during the course of their hospitalization. (Edward.com, 2006) Measurement of the QRS duration on an ECG has significant advantages as a tool in the clinical setting.

Oxygen saturation is another critical measure in those patients experiencing respiratory depression whether it is the physiological result of cardiopulmonary or respiratory distress. It is rated at **60%** in the questionnaires carried. In such a case, pulse oximetry provides a fast, accurate and non-invasive method to measure a patients' arterial oxygen level and is among the first patient vital signs to indicate physiological distress. However, it cannot be used in certain medical conditions like carbon monoxide poisoning and cardiac arrest situations. This is because it fails to detect any difference between the oxygen and carbon monoxide bound to haemoglobin in blood. (Karthik, 2010)

4.2.6 BAN Requirements for Hypertension Patients

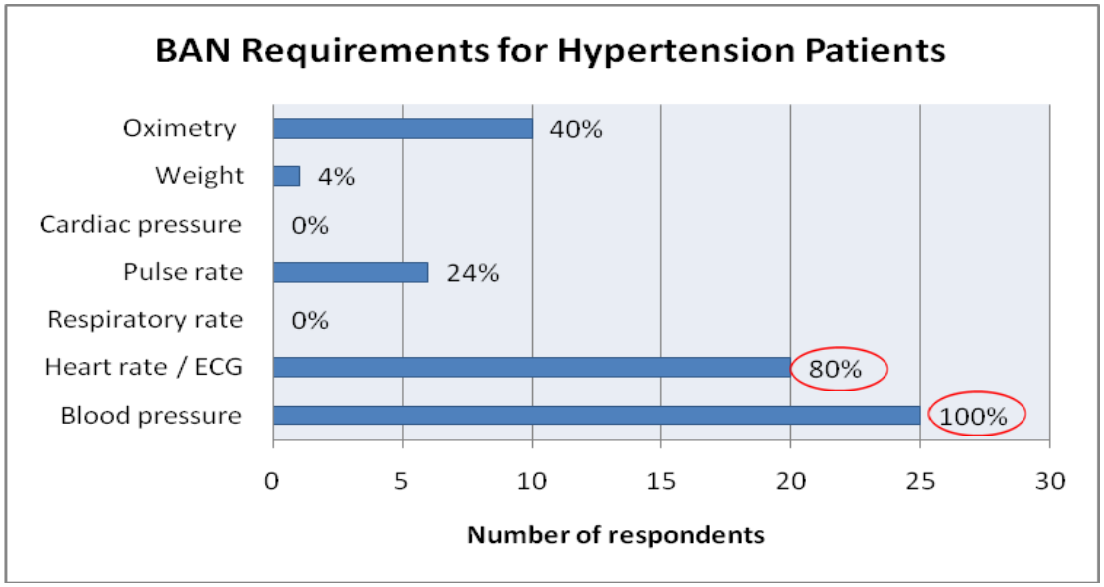


Figure 9: BAN Requirements for Hypertension Patients (According Importance Index)

Figure 9 shows BAN requirements for hypertension patients. The data collected from questionnaires show that if BAN were to be used by hypertension patients, certain requirements are needed. Firstly, the main requirement would be blood pressure measurement which is ranked mostly at **100%** (25 out of 25 respondents). It was then followed by the measurement of heart rate/ECG at **80%** (20 out of 25 respondents). Other measurements such as pulse rate, respiratory rate and weight were seen as not significant in BAN measurement on hypertension patients.

In such a case, hypertension is a cardiac chronic medical condition in which the systemic arterial blood pressure is elevated. It is generally diagnosed on the basis of a persistently high blood pressure. Thus, blood pressure measurement is significant for initial diagnosis of hypertension. Exceptionally, if the elevation is extreme, or if the symptoms of organ damage are diagnosed, immediate treatment and close monitoring is necessary. (Wikipedia.com, 2011)

4.2.7 Types of Post Surgery Patients Suitable for BAN Monitoring

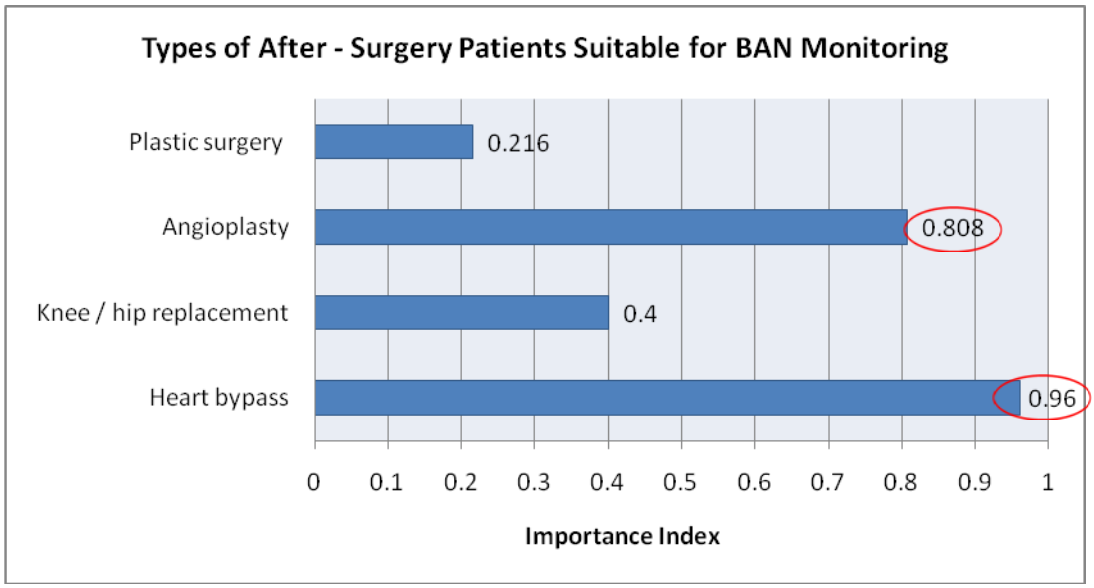


Figure 10: Types of Post Surgery Patients Suitable for BAN Monitoring (According Importance Index)

Figure 10 shows BAN design requirements for those patients who just went through surgery. For the current state, BAN might be mainly used for rehabilitation of patients after surgery (particularly for medical tourism). In this case, perhaps real-time sign transmission is not necessary, but all the data should be stored in memory in the BAN. After conducting surveys, a conclusion can be made where BAN is only applied on a few of surgery. Among several surgery list, heart related surgery are ranked at the top of the list. In such a case, it can be shown that heart bypass is ranked at first place with its importance index at **0.96**. It is then followed by angioplasty with a total of importance index at **0.808**.

For those patients who just undergone heart related surgery, most of them are required to be admitted in hospital for post surgery care. For example, after heart bypass surgery, the patient is moved to cardiac surgical intensive care unit. Current heart rate and blood pressure monitoring devices continuously monitor the patient for 12 to 24 hours. Thus with the current devices, innovation is proposed to apply wireless system so the patients are free from wire hassles, and still there are under closely monitoring with real time transmission. Any value above the threshold level

will induce alarming signal so that immediate action can be taken to avoid any late or lack of attention.

The same situation applies to after angioplasty surgery as well. The patient needs to be moved to a special care unit where they are required to stay there for a few hours or overnight. They must lie still for a few hours to allow the blood vessel in their arm or groin (upper thigh) to seal completely. While recovering, nurses will check their heart rate and blood pressure. In such a case, the situation can be improved where BAN idea can be incorporated into it. Where, the measurement of heart rate and blood pressure can be done by putting BAN sensor onto the patients. Although the patients are not allowed to move around, however, this BAN system can definitely reduces the nurses' workload and helps to alleviate nurses' shortage as well. Any value above the threshold level will induce alarming signal so that immediate action can be taken to avoid any late or lack of attention.

Others non heart – related surgery such as knee/hip replacement and plastic surgery are least ranked, both at importance index of **0.4** and **0.216** respectively. They are seen least important because at most of the cases, patients undergo knee/hip replacement surgery can just directly go back home and perform home rehabilitation. This situation applies to those plastic surgery patients as well.

4.2.8 Post Surgical Complications (Importance Index)

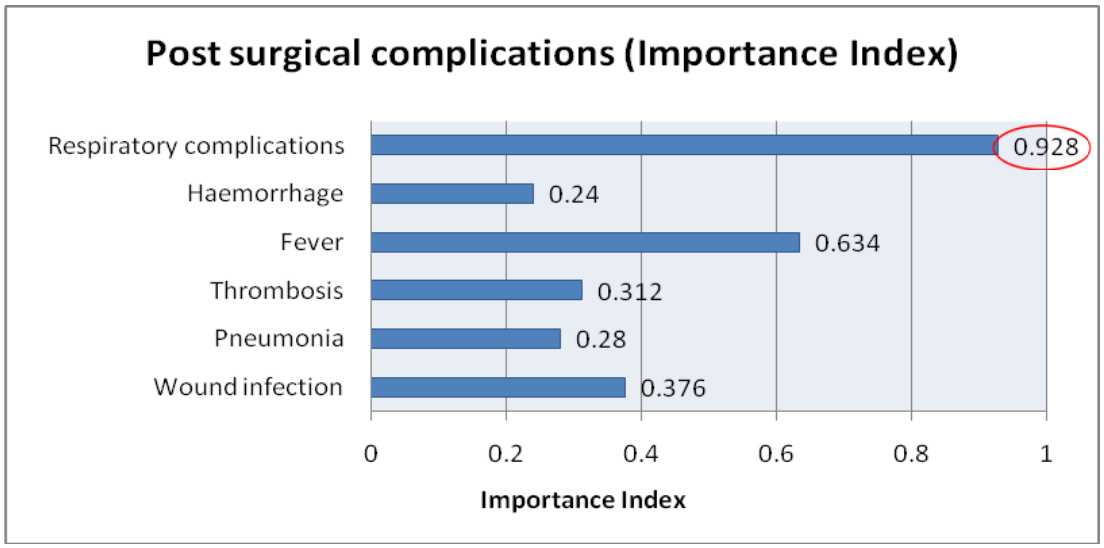


Figure 11: Post Surgical Complications (According Importance Index)

Patients just went through surgery process might develop several complications. Post surgical complications may either be general or specific to the type of surgery undertaken, and should be managed in time. Common general post surgical complications include post – operative fever, wound infection, embolism and deep vein thrombosis. The highest of post-operative complications is between 1 and 3 days after the operation. (Colin, 2009) If BAN were to be applied on such post surgical patients, it must be able and to consider to pick up the possible complications from the patients.

A series of surveys have been conducted. There are few important complications which are possible to be considered in BAN architecture and the statistics are depicted as in Figure 11. Among several post surgical complication list, complication such as respiratory complication is mostly ranked. In such a case, it is ranked at first place with its importance index at **0.928.** The data is then followed by fever with a total of importance index at **0.634**.

Other complications such as wound infection, thrombosis, pneumonia and thrombosis are seen as not important since they contribute the importance index which is less than 0.400.

4.2.9 BAN Requirements for Post Surgical Patients

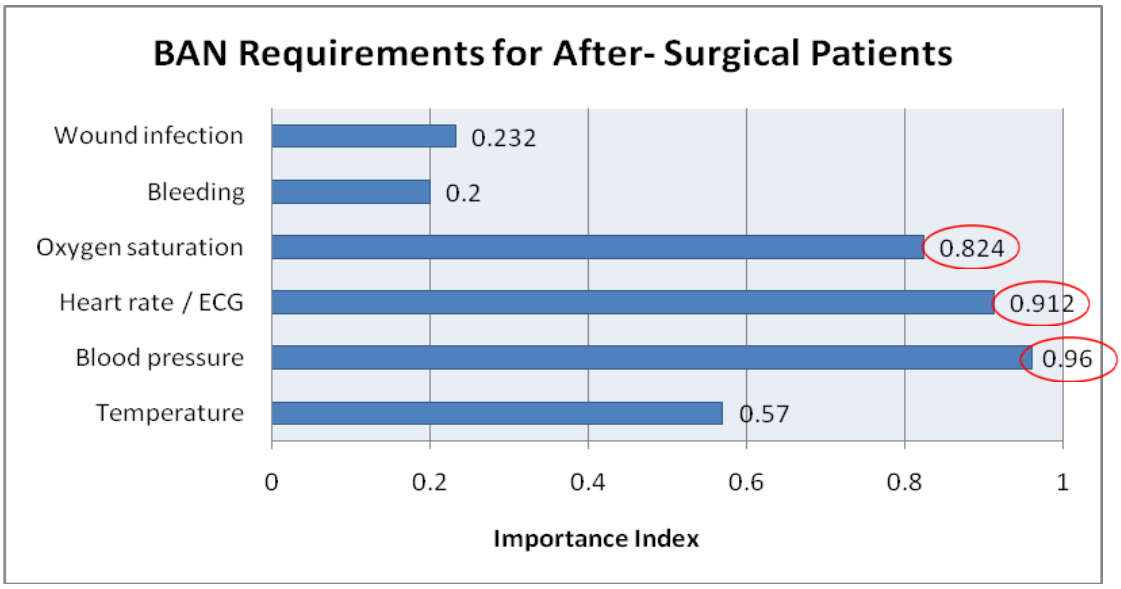


Figure 12: BAN Requirement for Post Surgical Patients

(According Importance Index)

If BAN were to be applied on such post surgical patients, it must be able and to consider to pick up the possible complications from the patients. It must be done so in order for nurses or doctors to take immediate yet necessary action to save life. We have conducted a series of surveys and found out that several of those possible post surgical measurements with BAN architecture.

Among several post surgical measurement list, measurement such as blood pressure is mostly ranked. In such a case, it is ranked at first place with its importance index at **0.96.** The data is then followed by heart rate/ECG measurement at importance index of **0.912**. Lastly, it is oxygen saturation (spO_2) which is rated at **0.824**. These are 4 vital signs which are equally important and yet possible to be incorporated into wireless BAN architecture.

Blood pressure is the pressure exerted by circulating blood upon the walls of blood vessels and it is one of the principal vital signs. For blood pressure measurement, systolic blood pressure is a readily vital sign that has been found to be a key factor in predicting mortality risk and revealing characteristics for heart failure patients, according to a team of academic researchers. Published in the Nov. 8 issue of the Journal of the American Medical Association, the new study found that the level

of systolic blood pressure taken offers insight into different stages of heart failure, prognosis and disease development. (Champeau, 2006)

Secondly, electrocardiogram (ECG) can be helpful as well. An ECG cannot diagnose heart failure, however, it is simple and painless to perform and can indicate heart problems by detecting the enlargement of the heart muscle, which may help to determine long-term outlook. (Edward.com, 2006) In such a case, clinical care and medical health evaluations often involve the use of ECG. An ECG is a highly useful tool in the evaluation of a patient's a cardiac activity, including heart rate and rhythms. It is a method of recording the electrical activity of the heart. Each heartbeat is caused by a section of the heart generating an electrical signal, which then conducts through special pathways to all parts of the heart. These electrical signals, in an attenuated form, can be detected at the skin of the patient and recorded. Also, ECG helps to detect abnormal cardiac rhythms. In such a case, a rhythm pattern called a prolonged QT interval, for example, might predict people with heart failure who are at risk for severe complications and would need more aggressive therapies.

Lastly, pulse oximetry provides a fast, accurate and non-invasive method to measure a patients' arterial oxygen level and is among the first patient vital signs to indicate physiological distress. Since respiration complication is rated highly among the post surgical complications that might develop, measurement of oxygen saturation is important for those patients in BAN context. However, it cannot be used in certain medical conditions like carbon monoxide poisoning and cardiac arrest situations. This is because it fails to detect any difference between the oxygen and carbon monoxide bound to haemoglobin in blood. (Karthik, 2010)

4.2.10 Other findings

4.2.10.1 Preferable Types of Battery Maintenance

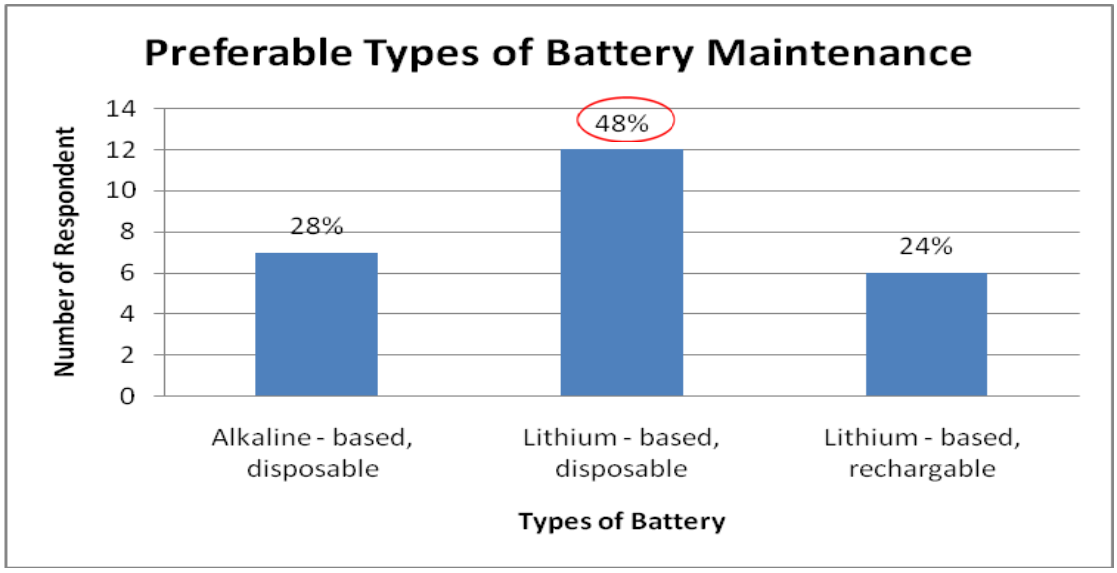


Figure 13: Preferable Types of Battery Maintenance

Figure 13 shows preferable types of battery maintenance among respondents. There are 3 types of battery maintenance listed, which is in alkaline disposable form, lithium disposable form and lithium rechargeable form. The data collected shows that for BAN architecture in terms of medical purpose usage, lithium based-disposable form is most rated at **48%** (12 out of 25 respondents), follows by alkaline-based disposable form at **28%** (7 out of 25 respondents) and lastly, lithium-based rechargeable form at **24%** (6 out of 25 respondents).

Although batteries in the last decade have become smaller and less expensive, battery energy density does not scale exponentially as other technologies. Nevertheless, batteries are still a reasonable solution. Among **48%** of the respondents, they felt that lithium disposable form of battery is most suitable for medical equipment purposes such as to be integrated into BAN architecture. In such a case, Lithium-Ion battery is a type of battery composed of Lithium, the lightest metal and the metal that has the highest electrochemical potential. Lithium, however, is an unstable metal, so Lithium-Ion batteries are made from Lithium ions from chemicals. In medical purposes, it is best ideal for portable devices due to its lightness and high energy density. In addition, Lithium-Ion batteries do not use poisonous metals, such

as lead, mercury or cadmium. The only disadvantage to Lithium-Ion batteries is that they are currently more expensive than mercury battery packs. (Webopedia.com, 2011)

For the current state, Mercury is mostly used in medical equipments. Thus, there is a minority of **28%** respondent opted for it. It is comparably cheaper than Lithium-Ion battery. However, they do not last longer and they were toxic and thus required careful waste disposal. Thus for BAN usage, it is suggested that such mercury battery is replaced with lithium disposable battery.

For indoor environments (such as within the hospital), rechargeable batteries may be the solution. However, recharging the batteries may become burdensome especially for the nurses. There is only a minority of **24%** respondents opted for such option, thus it is not preferably suggested to be incorporated into BAN architecture.

4.2.11 The BAN design

The design idea is from current telemetry system. It aims to revolutionalise the way patient can be measured wirelessly, continuously and comfortably. It includes built-in vital signs processing capabilities. A newly designed wireless BAN can read spO_2, heart rate/ECG and blood pressure at the same time. The current telemetry device available in most of the hospital in Malaysia can only record the heart rate of patient.

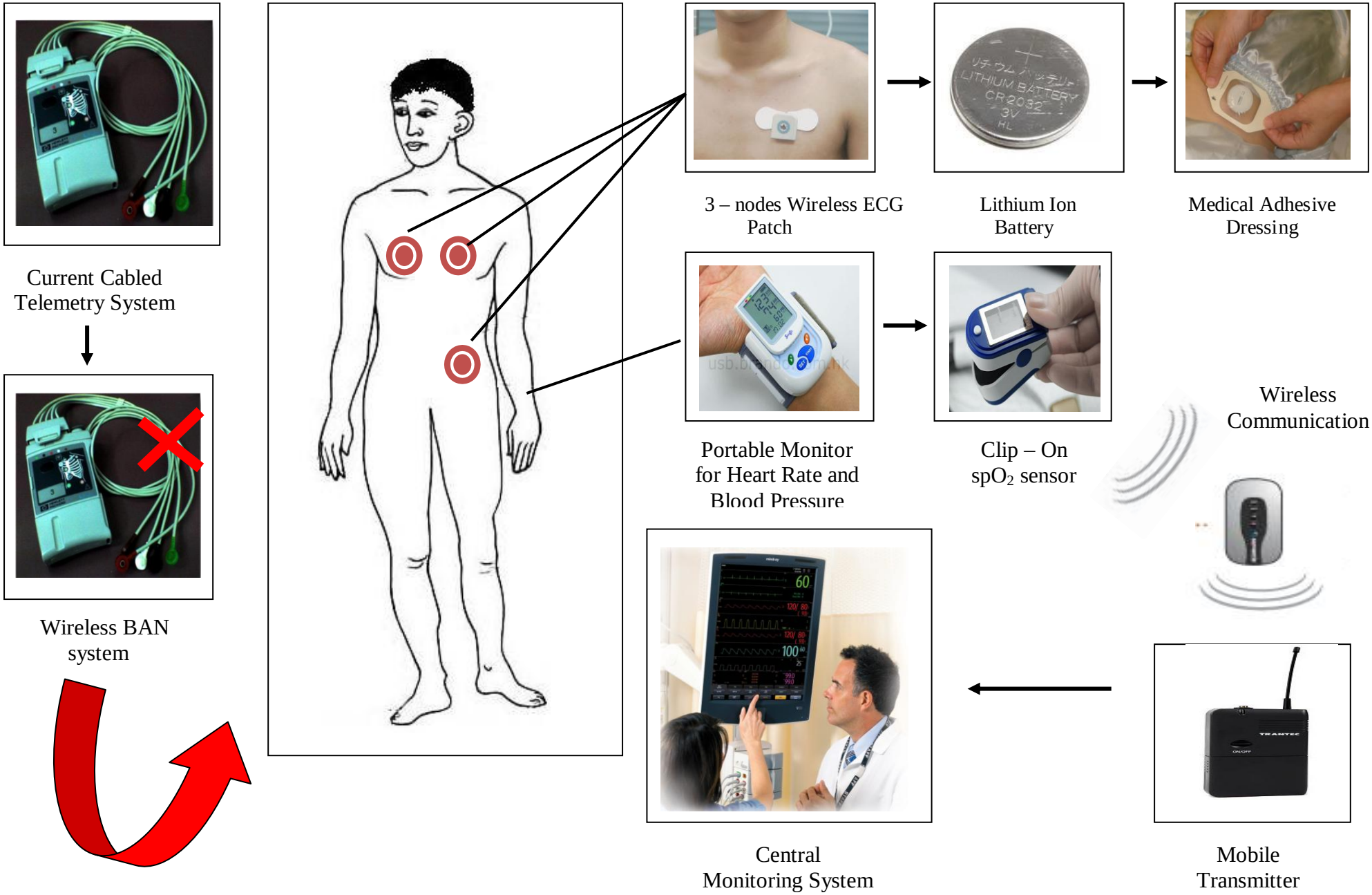
Firstly, wireless sensor is used for automated and periodic measurement of a patient's vital sign. It is attached to the patient's body with the use of medical adhesive dressing. In such a case, an adhesive patch is secured to the skin-contacting portion of the sensor. By simply pasting the disc-like sensor on the body, patient's vital signs such as heart rate and oxygen saturation (spO_2) can be sent wirelessly to the central server for storage, automatic charting and real-time alert for timely treatment. Physicians can have access to real-time continuous trend for better data analysis while patients can have better uninterrupted rest. At the same time, nurses can focus on improving patient care quality and hospitals will be able to see tangible results on improved operational efficiency and manpower savings.

Secondly, cables are no longer in need. The sensor can pick up and transmit the biological data from patient body to a patient worn transmitter. In such a case, BAN is to enable removable of restrictive wiring, enhanced ease-of-use and portable as well. The data can be stored on a SD card or read in real-time basis by caregivers or doctors on duty. Any value above the threshold level will induce alarming signal so that immediate action can be taken to avoid any late or lack of medical attention.

Thirdly, the transmitter unit is compact in design, and light weight. The transmitter is picking up vital signs from sensors. It is a mobile transmitter in which it can be either carried by patients, or put at the side of patient bed. Waterproofing and durability help to prevent accidental damage in day-to day routine conditions. It can be used with a wireless local area network (WLAN) to transmit the vitals signs of patients. After transmitter picks up the data, it will be then transmitted to PC based Central Station on real-time or non real-time basis.

It is battery-operated by using energy scavenging techniques. In such a case, a disposable lithium ion battery is recommended. In medical purposes, it is best ideal for portable devices due to its lightness and high energy density.

Figure 14: Wireless Body Area Network System as designed (for in-patients):



Part 2: Application to Out-Patients

4.3 Findings of Data Analysis (Part 2: Out – patients)

4.3.1 BAN Target for Home Monitoring Purposes

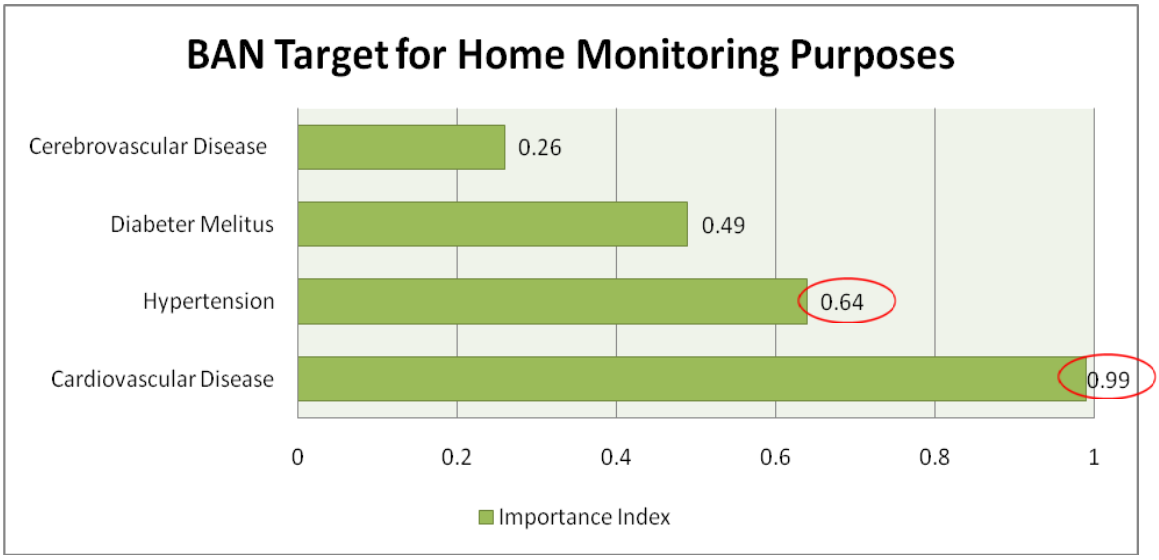


Figure 15: BAN Target for Home Monitoring Purposes

This analysis is carried out to examine BAN target for home monitoring purpose if BAN is to be marketed on out – patient basis. There is a possibility to reduce hospital or Medical Officer's office visiting frequency provided that the BAN sends patients' data regularly from home via telecommunication network.

Figure 15 above depicts that cardiovascular disease is ranked the most important with a total of **0.99** importance index on out – patient basis. In United States, heart disease is the number one killer of both men and women. The causes and cure for heart disease are now known and although many cardiovauscular diseases can be treated or prevented, an estimated 17 million people die of it each year. (National Heart Association of Malaysia, 2008) In Malaysia context, heart disease are on the rise despite improvement in health services and facilities. The number of cardiovasclar disease cases in Malaysia has increased to 14 percent in five yeears fom 96,000 in 1995 to 110,000 in 2000. It is the leading cause of death in the country claiming a third of all its patients. In fact, it is estimated that 40,000 new stroke cases are recorded annually in Malaysia.

Secondly, hypertension is rated at **0.64** importance index 96 on out – patient basis. In such a case, high blood pressure usually causes no symptoms and high blood

pressure often is labelled "the silent killer." According to Medilexicon's medical dictionary, hypertension means "High blood pressure; transitory or sustained elevation of systemic arterial blood pressure to a level likely to induce cardiovascular damage or other adverse consequences". (Monografias.com, 2010) Hypertension can be diagnosed by measuring blood pressure. If the pressure is greater than 140/90, the patients will be considered to have hypertension. If hypertension seems reasonable, tests such as electrocardiograms (ECG) will be used in order to measure electrical activity of the heart and to assess the physical structure of the heart.

Others such as diabetes melitus and cerebrovascular diseases are seen not as significant in terms of BAN context. They are both ranked at importance index of **0.49** and **0.24** respectively.

4.3.2 BAN Requirement for Patients with Cardiovascular Disease (Home Monitoring)

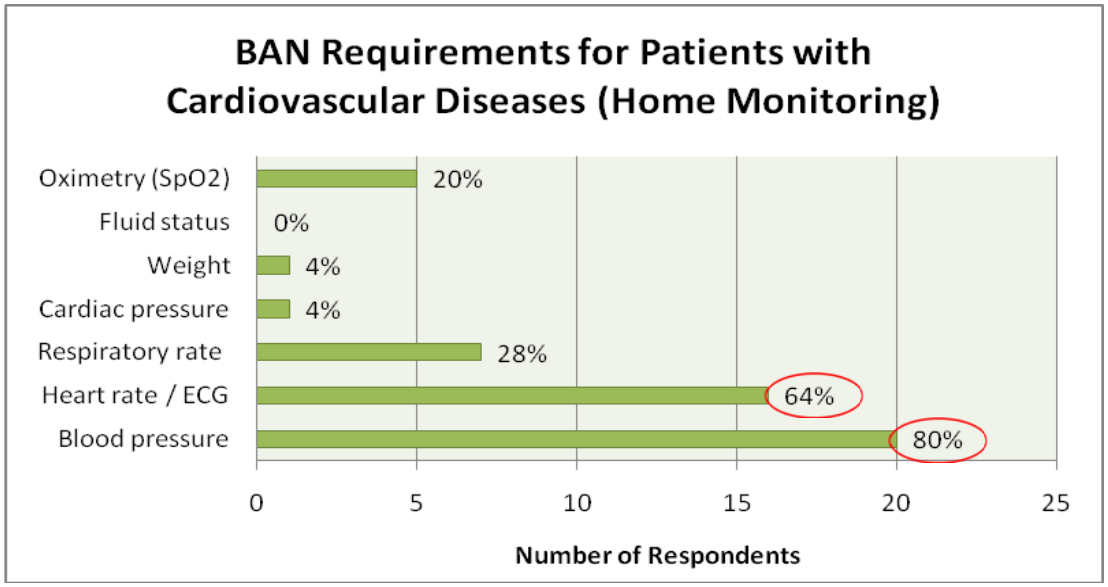


Figure 16: BAN Requirement for Patients with Cardiovascular Diseases (Home Monitoring)

Figure 16 above depicts BAN requirement for patients with cardiovascular diseases on home monitoring basis. The data collected from survey questionnaire shows that if BAN is applied on patients with cardiovascular diseases, certain requirements are needed. Firstly, the main requirement would be blood pressure measurement which is ranked mostly at **80%** (20 out of 25 respondents). It was then followed by the measurement of heart rate / ECG at **64%** (16 out of 25 respondents). There are **20%** of respondents choose oximetry (SpO_2) as optional measurement. Other measurements such as fluid status, weight, cardiac pressure and respiratory rate are seen as not significant as BAN requirements on patients with cardiovascular diseases.

For blood pressure measurement, systolic blood pressure is a readily vital sign that has been found to be a key factor in predicting mortality risk and revealing characteristics for heart failure patients, according to a team of academic researchers. Published in the Nov. 8 issue of the Journal of the American Medical Association, the new study found that the level of systolic blood pressure taken offers insight into different stages of heart failure, prognosis and disease development. (Champeau, 2006) In such a case, heart rate increases as one of the compensatory ways of maintaining

adequate cardiac output. A decrease in the resting heart rate with medical therapy can be used as a marker for treatment efficacy. For example, systolic blood pressure demonstrates the maximum arterial pressure during contraction of the left ventricle of the heart, typically the first number in a blood pressure reading. Heart failure occurs when the heart is not working effectively, including when the heart's left ventricle cannot pump sufficient blood to the body's other organs.

Secondly, electrocardiogram (ECG) can be helpful as well. An ECG cannot diagnose heart failure, however, it is simple and painless to perform and can indicate heart problems by detecting the enlargement of the heart muscle, which may help to determine long – term outlook. (Edward.com, 2006) In such a case, clinical care and medical health evaluations often involve the use of ECG. An ECG is a highly useful tool in the evaluation of a patient's a cardiac activity, including heart rate and rhythms. It is a method of recording the electrical activity of the heart. Each heartbeat is caused by a section of the heart generating an electrical signal, which then conducts through special pathways to all parts of the heart. These electrical signals, in an attenuated form, can be detected at the skin of the patient and recorded. Also, measurement of the QRS duration on an ECG has significant advantages as a tool in the clinical setting. It is relatively inexpensive, simple to perform, and yields an instant result. The measurement is objective and does not require specialized training to interpret. Perhaps most important, a prolonged QRS duration becomes a potential target for intervention with existing therapy, which may improve post – discharge mortality and morbidity. (Edward.com, 2006)

4.3.3 BAN Requirement for Hypertension Patients

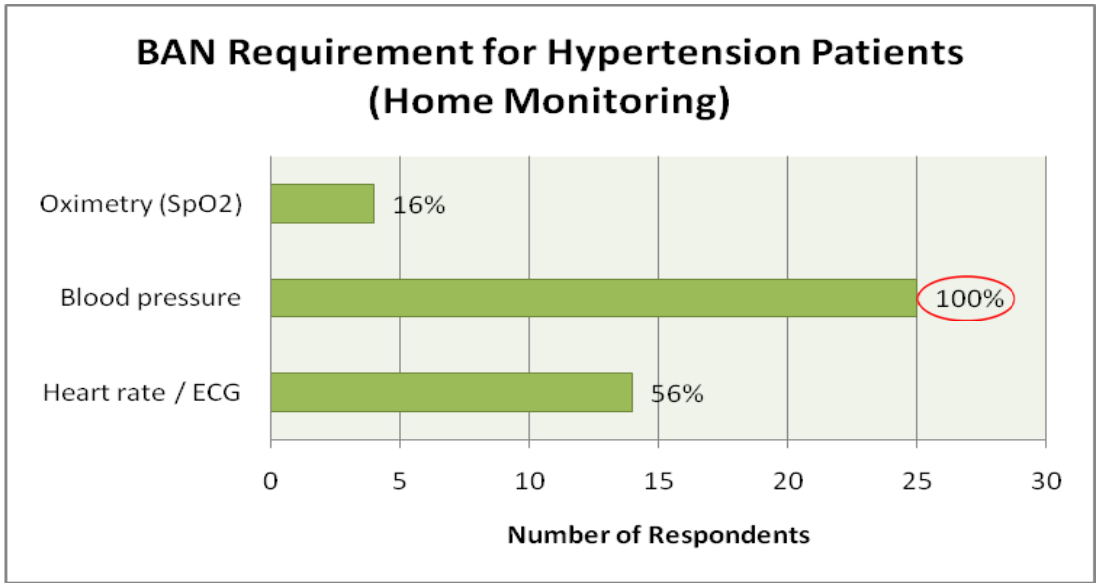


Figure 17: BAN Requirement for Hypertension Patients (Home Monitoring)

Figure 17 depicts BAN requirements for hypertension patients on home monitoring basis. The data collected from questionnaires show that if BAN were to be used by hypertension patients, certain requirements are needed. Firstly, the main requirement would be blood pressure measurement which is ranked mostly at **100%** (25 out of 25 respondents). It was then followed by the measurement of heart rate / ECG at **80%** (14 out of 25 respondents). Other measurements such as oximetry (spO_2) were seen as not significant in BAN context.

In such a case, hypertension is a cardiac chronic medical condition in which the systemic arterial blood pressure is elevated. It is generally diagnosed on the basis of a persistently high blood pressure. Thus, blood pressure measurement is significant for initial diagnosis of hypertension. Exceptionally, if the elevation is extreme, or if the symptoms of organ damage are diagnosed, immediate treatment and close monitoring is necessary. (Wikipedia.com, 2011)

4.3.4 Response of Respondents towards Idea of Wireless Cardiac Event Monitor

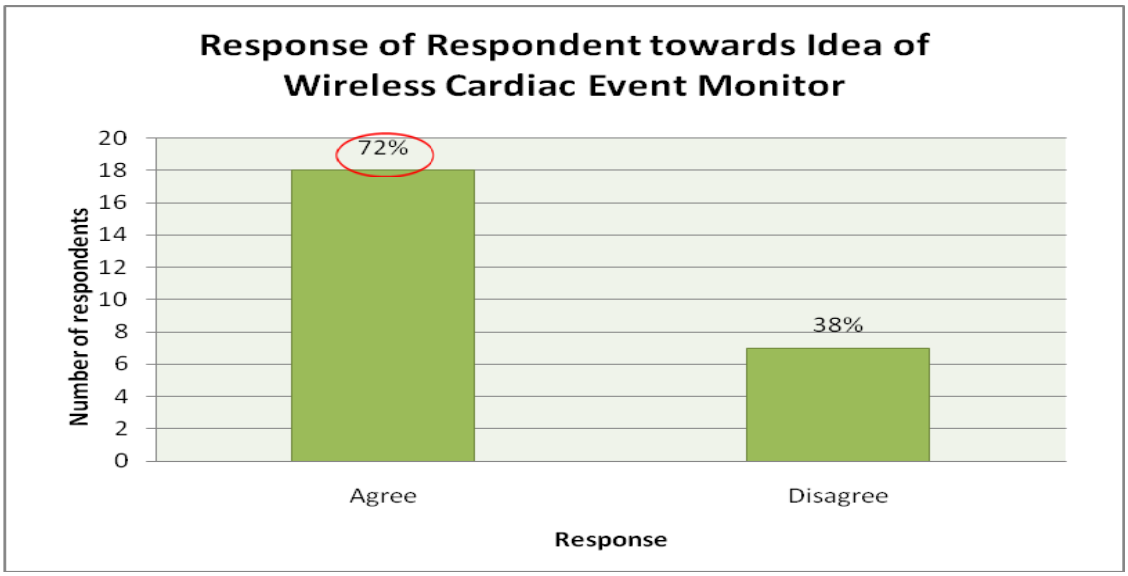


Figure 18: Response of Respondents towards Idea of Wireless Cardiac Event Monitor

Based on collected response, **38%** (7 out of 25 respondents) disagree on the idea of wireless cardiac event monitor implementation on out-patient basis. They mostly satisfy with the performance of current cabled ECG Holter system in their hospital. Because through such cabled system, there is no risk of data lost. Besides, cabled system has been adapted quite some time and they feel get used of such system.

However, most respondents agree on the idea of wireless cardiac event monitor on out – patient basis. However, most respondents agreed on the idea of BAN implementation into wireless cardiac event monitor. They consisted mostly **72%** of the surveys. According to the statistics, they would agree and support the idea of implementing wireless cardiac event monitor. This is due to the idea that current ECG Holter system is used to monitor those patients with suspected arrhythmias on 24 or 48 hour basis. At this moment, conventional Holter monitor is a recording device with a strap that patients wear over their shoulder or around their waist. During the monitoring period, patients have to bear with those cables around their body while the recorder and transmitter are working to pick up signals from their heart activities. In such a case, patients definitely feel uncomfortable with the cables.

For those patients with more transient symptoms, cardiac event monitor is recommended where it can be used on a weekly or monthly basis. If the monitoring

period is prolonged, there is a perception that wireless devices is most valued where patients are free from the burden of cables and having more quality time at home while vital signs are captured from their bodies. In such a case, it records heart rate and rhythm when patient feels chest pain or symptoms of an irregular heartbeat. (Wikipedia.com, 2011) Cardiac physicians can diagnose the nature of patient's heart problem and look at the time when patient noticed the symptoms, by referring to the reading of printouts.

4.3.5 Main Concern about BAN System (from Respondents)

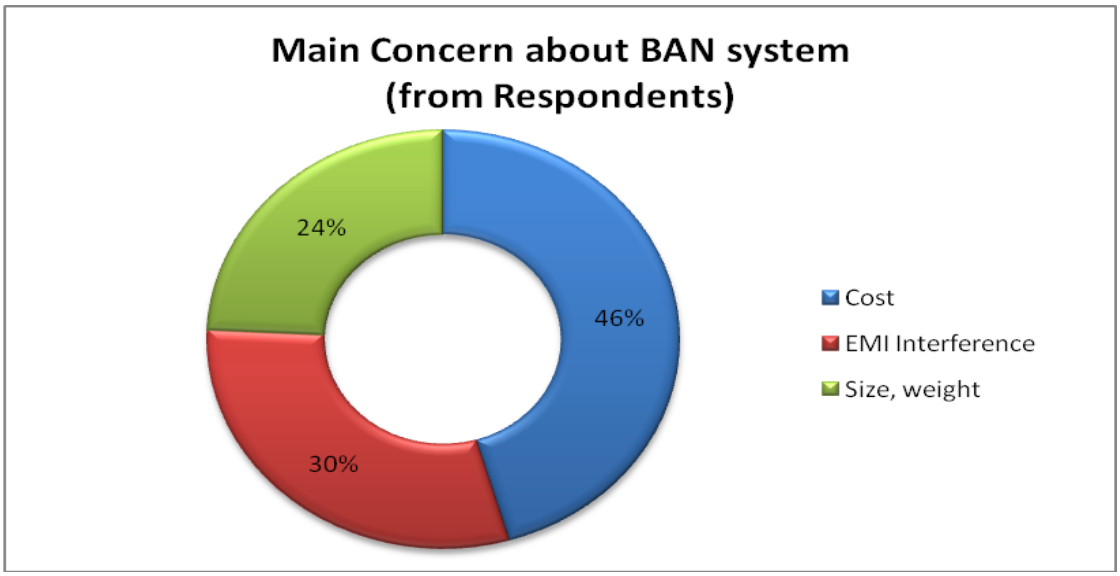


Figure 19: Main Concern about BAN System (from Respondents)

There are several major problems to be considered in order to implement such BAN system in Malaysia context. One is low cost to consumers (patients). From the questionnaires, **46%** of the respondents feel that cost is the major issue if wireless BAN is to be marketed on home monitoring basis. Others **30%** feel that Electron Magnetic Interference (EMI) will be another problem and lastly, **24%** is due to size and weight of the devices.

In order for demand to take off for home monitoring equipment, consumers (patients) must be able to afford and buy the equipment, with little or no complications from insurance reimbursement processes. As a conclusion, bulk production will help in reducing the production cost.

Secondly, a specific frequency transmission band is chosen. As users of medical devices, the radio signals transmitted from the patient to the monitoring station are vulnerable to electromagnetic interference (EMI). In such a case, it can pose a real risk to patients. If these signals are interfered while the patient is suffering a significant adverse health event, the medical response could be delayed and serious patient consequences are likely to develop.

Because of the importance of these signals and the likelihood of EMI with these vital transmissions, the Food and Drug Administration, the Federal Communications Commission (FCC), medical device manufacturers, and the health care community banded together to examine the EMI issue with wireless medical telemetry and developed solutions to minimize the risks to patients posed by EMI. These efforts in creation of the new Wireless Medical Telemetry Service, with its separate frequency spectrum and coordination, which is designed to reduce the risk of EMI to the vital patient telemetry signals from other frequency transmission operating in the same frequency bands. (Witters & Campbell, 2004)

Last but not least, the unit must be compact in design. The size and weight should be in lightweight and comfortable harness, freeing the patient from equipment burden while the sensor and transmitter are capturing the vital signs.

4.3.6 Other Findings

4.3.6.1 Suitability of BAN for Obstructive Sleep Apnea Patients

The practical purpose of diagnostic assessment in most cases of Obstrusive Sleep Apnea (OSA) is to predict which patients have symptoms that will improve on treatment. Polysomnography is widely accepted as diagnosis standard of OSA. However, it is relatively time consuming and expensive. Therefore, diagnosis of the diseases have been evaluated and resorted to several alternative and simpler devices. In such a case, home oximetry has been proposed as a valuable screening tool. For the past few years, it aims to shorten the delay in recognizing and treating clinically significant OSA in patients. (Golpe, R., Jimenez, A., Carpizo, R., Cifrian, J.M., 1999) The accuracy is measured with which clinicians make this prediction using polysomnography compared with oximeter- based home monitoring. As a result from the study, ability of physicians to predict the outcome of continuous positive airway treatment in individual patients is not significantly better with polysomnography than with home oximeter-based monitoring. (Whitelaw, W.A, Brant, R.F., Flemons, W.W., 2005)

Thus, there is a proposed idea in which wireless pulse oximeter (spO_2) is utilized as a simpler home monitoring device. Patients can wear the wireless pulse oximeter on a weekly, or monthly monitoring basis. In such a case, the level of oxygen saturation can be detected, sent to transmitter on wireless basis, and finally to a wireless enabled device such as smart phone. The smart phone is programmed with integrated automatic analysis process in each software which automatically determines fluctuating levels of oxygen saturation. Physicians can also get access to such monitoring data by retrieving data from data which stored in Flash Drive (or SD card) within the smart phone. They can retrieve the data of oxygen saturation and figure out the abnormal oxygen saturation readings based on the printouts.

4.3.6.2 Preferable Types of Battery Maintenance in BAN Architecture

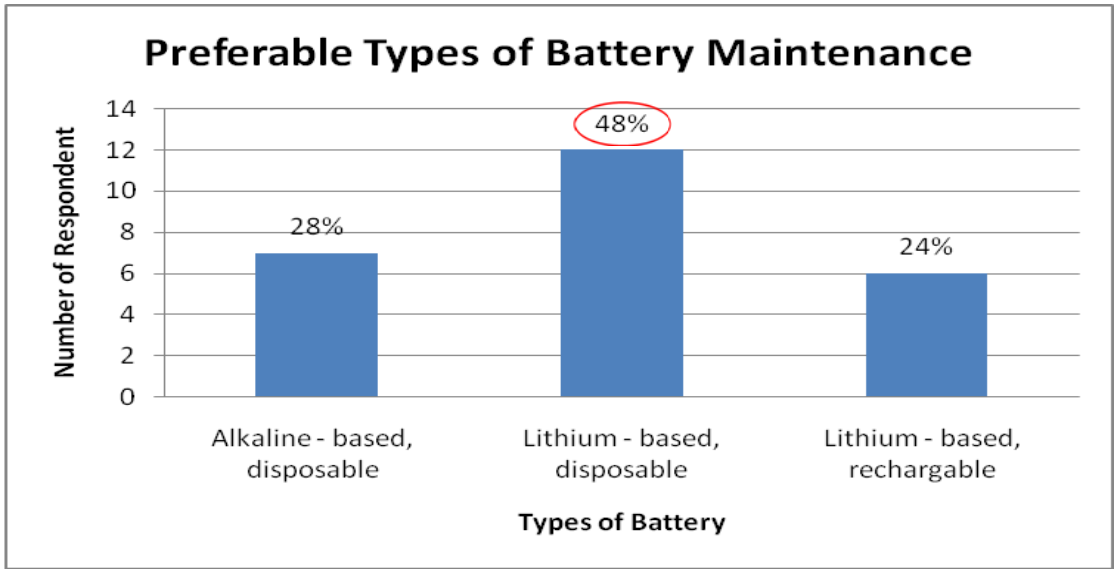


Figure 20: Preferable Types of Battery Maintenance in BAN Architecture

Figure 20 depicts preferable types of battery maintenance among respondents. There are 3 types of battery maintenance listed, which is in alkaline disposable form, lithium disposable form and lithium rechargeable form. The data collected shows that for BAN architecture in terms of medical purpose usage, lithium based-disposable form is most rated at **48%** (12 out of 25 respondents), follows by alkaline-based disposable form at **28%** (7 out of 25 respondents) and lastly, lithium-based rechargeable form at **24%** (6 out of 25 respondents).

Although batteries in the last decade have become smaller and less expensive, battery energy density does not scale exponentially as other technologies. Nevertheless, batteries are still a reasonable solution. Among **48%** of the respondents, they felt that lithium disposable form of battery is most suitable for medical equipment purposes such as to be integrated into BAN architecture. In such a case, Lithium-Ion battery is a type of battery composed of Lithium, the lightest metal and the metal that has the highest electrochemical potential. Lithium, however, is an unstable metal, so Lithium-Ion batteries are made from Lithium ions from chemicals. In medical purposes, it is best ideal for portable devices due to its lightness and high energy density. In addition, Lithium-Ion batteries do not use poisonous metals, such

as lead, mercury or cadmium. The only disadvantage to Lithium-Ion batteries is that they are currently more expensive than mercury battery packs. (Webopedia.com, 2011)

For the current state, Mercury is mostly used in medical equipments. Thus, there is a minority of **28%** respondent opted for it. It is comparably cheaper than Lithium-Ion battery. However, they do not last longer and they were toxic and thus required careful waste disposal. Thus for BAN usage, it is suggested that such mercury battery is replaced with lithium disposable battery.

For indoor environments (such as within the hospital), rechargeable batteries may be the solution. However, recharging the batteries may become burdensome especially for the users especially to elders since they might tend to be forgetful at most of the time. Thus, disposable lithium based batteries are recommended in BAN architecture in home monitoring basis.

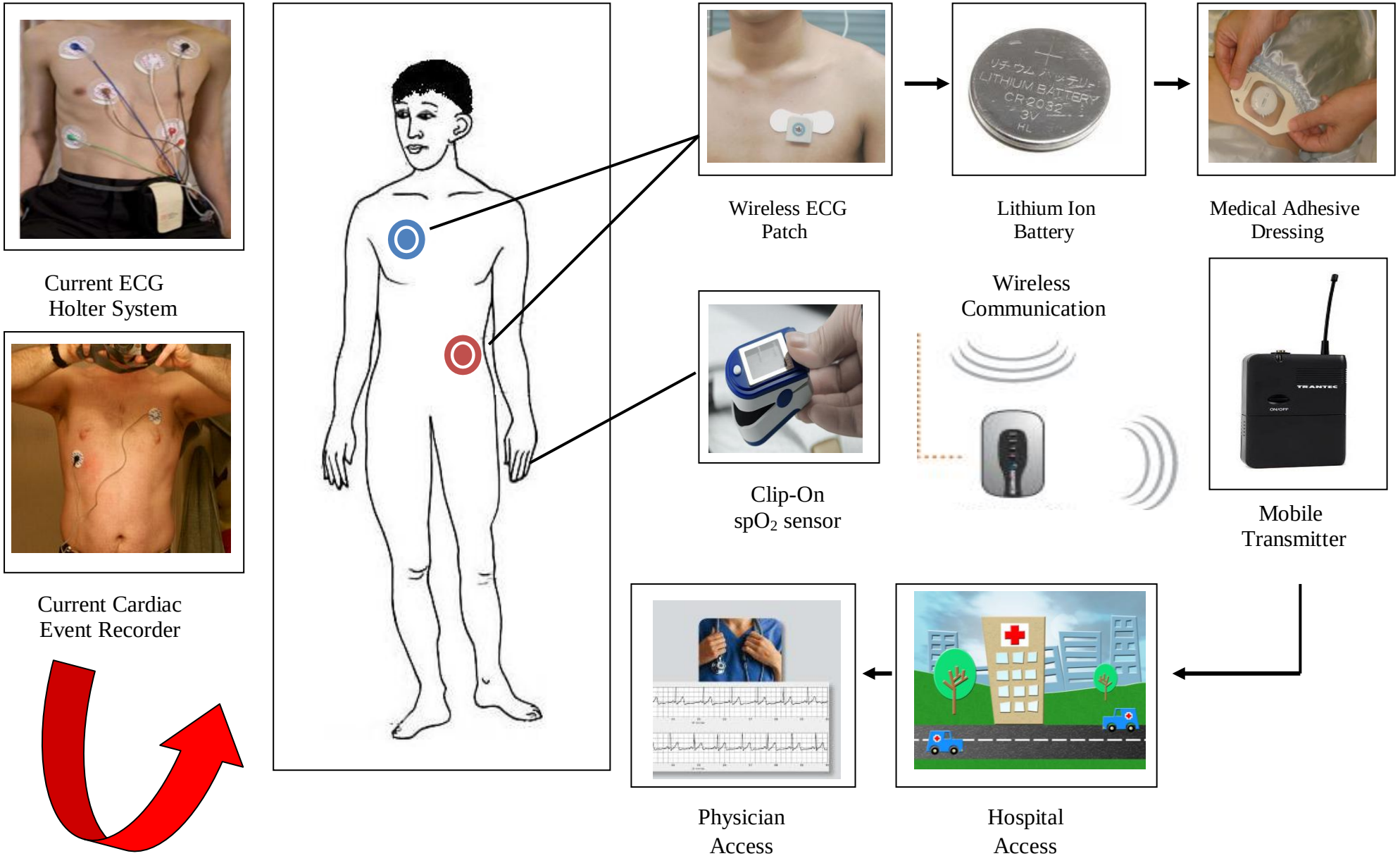
4.9 The design

The design idea is from the cabled ECG Holter system. It aims to revolutionalise the way patient can be measured wirelessly, continuously and comfortably. It includes built in vital signs processing capabilities. The current ECG Holter system is only used for patients with suspected arrhythmias on 24 or 48 hours basis. For those patients who having more transient symptom, wireless cardiac event monitor is most valued since the monitoring period can be prolonged on a weekly or monthly basis. Furthermore, patients will feel more freely without the constraints of cable. Thus, BAN concept is recommended to replace such cabled system.

Firstly, wireless sensor is used for automated and periodic measurement of a patient's vital sign. In such a case, an adhesive patch is secured to the skin-contacting portion of the sensor. By simply pasting the disc-like sensor on the body, patient's vital signs can now be sent wirelessly to a mobile transmitter. Cables are no longer in need. The sensor can pick up and transmit the biological data from patient body to a patient worn transmitter. In such a case, BAN is to enable removable of restrictive and unreliable wiring, enhanced ease-of-use and portable as well.

Thirdly, the transmitter unit is compact in design, and light weight. The transmitter is picking up vital signs from sensors. It is a mobile transmitter in which patients do not have to carry around with the transmitter. They can put the transmitter just at somewhere near with them. For example, at the side of bed. There is no more concern where patients tend to drop the transmitter at some time. Waterproofing and durability help to prevent accidental damage in day – to day routine conditions. It can be used with a wireless network (for example, WLAN) to transmit the vitals signs of patients. Physicians can also get access to such monitoring data by retrieving data from data which stored in Flash Drive (or SD card) within the transmitter. They can retrieve the data and figure out the abnormal vital sign readings.

Figure 21: Wireless Body Area Network System as designed (for out – patients):



Part 3: Application to Personal Healthcare for Health Conscious People

4.4.1 Application of BAN to Health Conscious People

Apart from the medical side, the daily healthcare is more important not to be affected by diseases. Application of BAN to daily personal healthcare or management has a significant meaning. In accordance to Malay Mail, a memorandum would be prepared by the Health Ministry in order to seek help from the relevant government ministries, agencies and departments to ensure that Malaysians become more health conscious and switch to a healthier lifestyle. (Malay Mail, 2009) There is a belief that next generation will concern more on health and well being, and the positive trend in consumer spending on more health conscious medical products across is heartening.

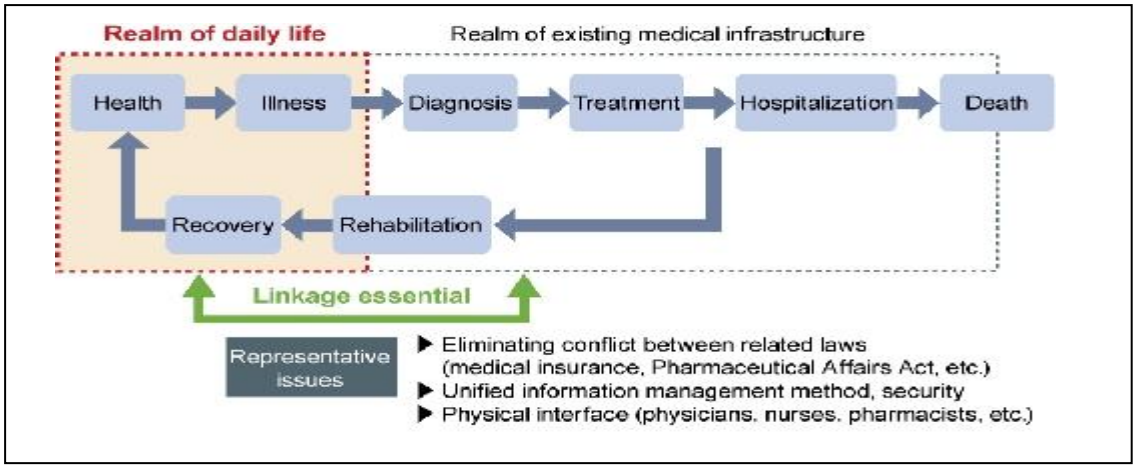


Figure 22: Daily personal health care and medical care are the demands for BAN

In such a case, disease prevention is a better management practice than disease control. There is a linkage essential between the realm of daily life and the realm of existing medical infrastructure. There is a perception that early detection is always better than cure. Being health conscious is something people all should be aware of, each and every day. By utilizing BAN system in daily life, it has a significant meaning in getting less likely to certain diseases.

4.4.2 BAN Target Diseases for Health Conscious People

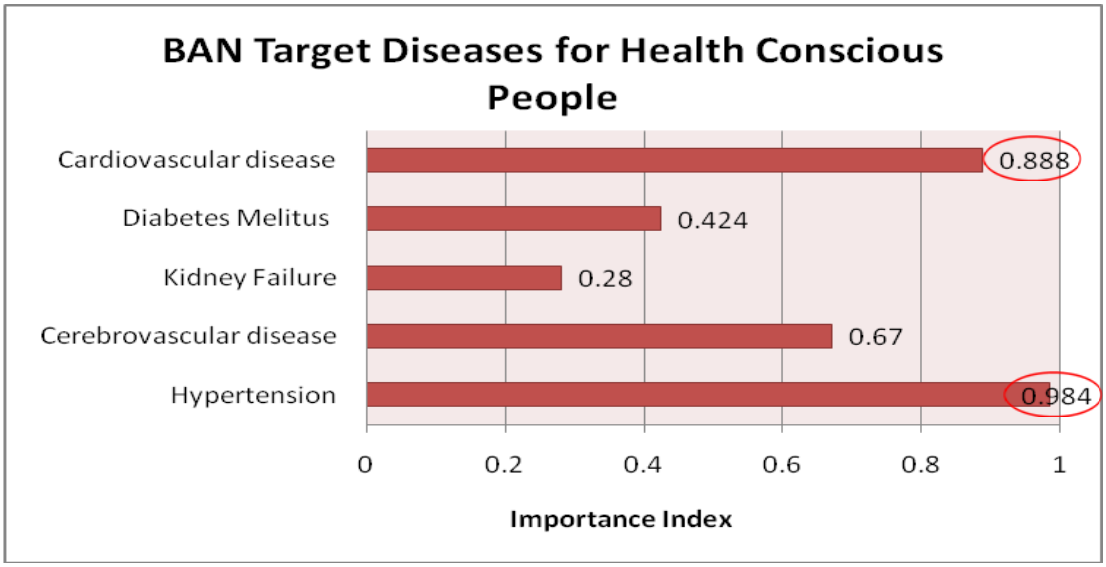


Figure 22: BAN Target Diseases for Health Conscious People

Figure 22 depicts target disease of BAN system for health conscious people. From the questionnaires, the data collected shows that hypertension is ranked at first place with its total importance index at **0.984**. It is followed by heart disease with importance index at **0.888**. Other diseases such as dcerebrovascular disease and diabeter melitues are ranked at **0.67** and **0.424** respectively. Kidney failure is ranked as the least important in BAN context, with its importance index only at **0.5**.

Hypertension is ranked at its importance index at **0.984**. In such a case, hypertension is a cardiac chronic medical condition in which the systemic arterial blood pressure is elevated. In Malaysia, hypertension has been on the rise in Malaysia over the past 10 years and now affects an estimated 4.8 million Malaysians. (The Star, 2010) In BAN context, wireless BAN is used for determining transient symptoms of pre-hypertension. In such a case, pre-hypertension may be considered if systolic blood pressure is between 120 and 139, and diastolic blood pressure is between 80 and 89, at most of the time. In such a case, the patients are more likely to develop high blood pressure (or hypertension) if they have developed pre-hypertension symptoms. Further treatment can be resorted to so that to reduce blood pressure and to lower the risk of complications as well. (Zieve D., Eltz, D.R., 2010) Thus, blood pressure measurement is significant for initial diagnosis of hypertension. (Wikipedia.com, 2011)

Secondly, cardiovascular disease is ranked with a total of **0.888** importance index. In United States, heart disease is the number one killer of both me. n and women. The causes and cure for heart disease are now known and although many cardiovauscular diseases can be treated or prevented, an estimated 17 million people die of it each year. (National Heart Association of Malaysia, 2008) In Malaysia context, heart disease are on the rise despite improvement in health services and facilities. They were the second leading cause of death in 2006, accounting for 15.5 per cent of those who died in government hospital. By 2010, they are projected to be the leading cause of death in Malaysia and other developing countries.

With BAN context, systolic blood pressure is a readily vital sign that has been found to be a key factor in predicting mortality risk and revealing characteristics for patients with cardiovascular disease. Published in the Nov. 8 issue of the Journal of the American Medical Association, the new study found that the level of systolic blood pressure taken offers insight into different stages of heart failure, prognosis and disease development. (Champeau, 2006) In such a case, the heart rate increases as one of the compensatory ways of maintaining adequate cardiac output. A decrease in the resting heart rate with medical therapy can be used as a marker for treatment efficacy.

4.4.3 BAN Measurements for Health Conscious People

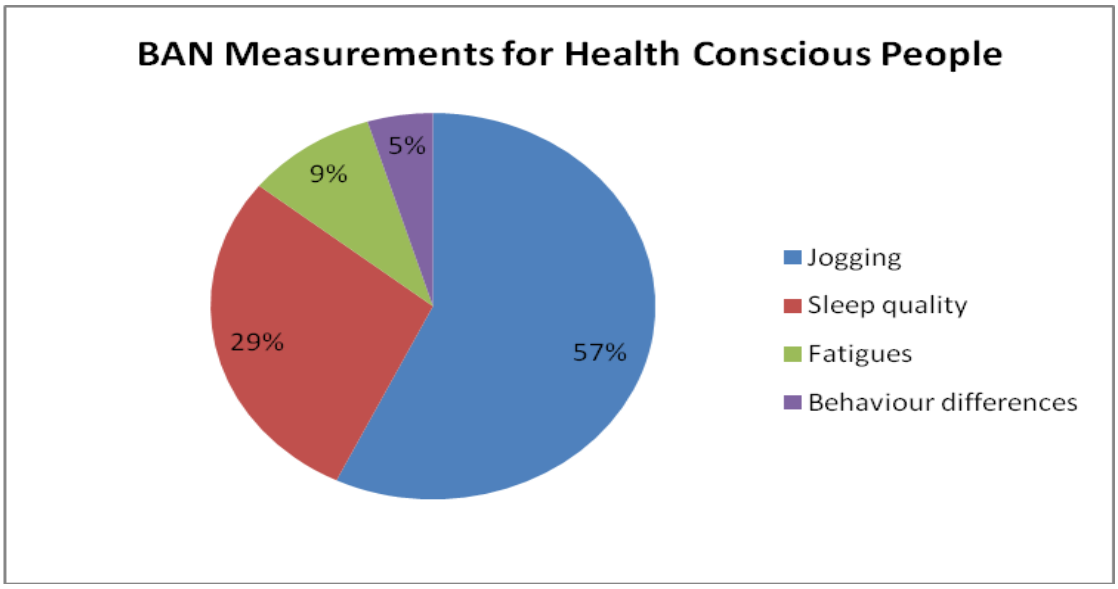


Figure 23: BAN Measurements for Health Conscious People

Application of BAN to daily personal healthcare or management has significant meaning. In such a case, several vital signs and behaviours are necessary to be monitored and measured in daily life. Figure 23 above depicts several possible measurements to be taken in daily life, such as jogging, sleep quality, fatigues and behaviour differences. From respondents, jogging is most rated at a total percentage of **57%**. It is followed by sleep quality measurement at a percentage of **29%**. Others such as fatigues and behavioural differences are least rated, which is at **9%** and **5%** respectively.

During jogging, people develop several physiological changes. In such a case, vital signs such as ECG and heart rate can be measured and monitored on a non – real time basis. An ECG cannot diagnose heart failure, however, it is simple and painless to perform and can indicate heart problems by detecting the enlargement of the heart muscle, which may help to determine long – term outlook. (Edward.com, 2006) In such a case, clinical care and medical health evaluations often involve the use of ECG in the evaluation of a patient's a cardiac activity, such as heart rate. It is a method of recording the electrical activity of the heart. These electrical signals, in an attenuated form, can be detected at the skin of the patient and recorded.

For **29%** of the respondents, they felt that sleep quality is another criteria measurement in daily life. For sleep quality measurement, vital signs which can be measured are such as heart rate, respiration and motion in bed. Recently, Japanese company *Tanita* has just announced the Sleep Scan mat technology which able to monitor and record user's body motion, breathing patterns and heart rate throughout the night. By noting the sleeper's range of motion, the type and depth of sleep can be determined. (Tanita.com, 2010)

Others such as fatigues and behavioural differences are least rated, which is at **9%** and **5%** respectively. They are rated as least importance in BAN context.

4.4.4 Preferable BAN Design for Health Conscious People

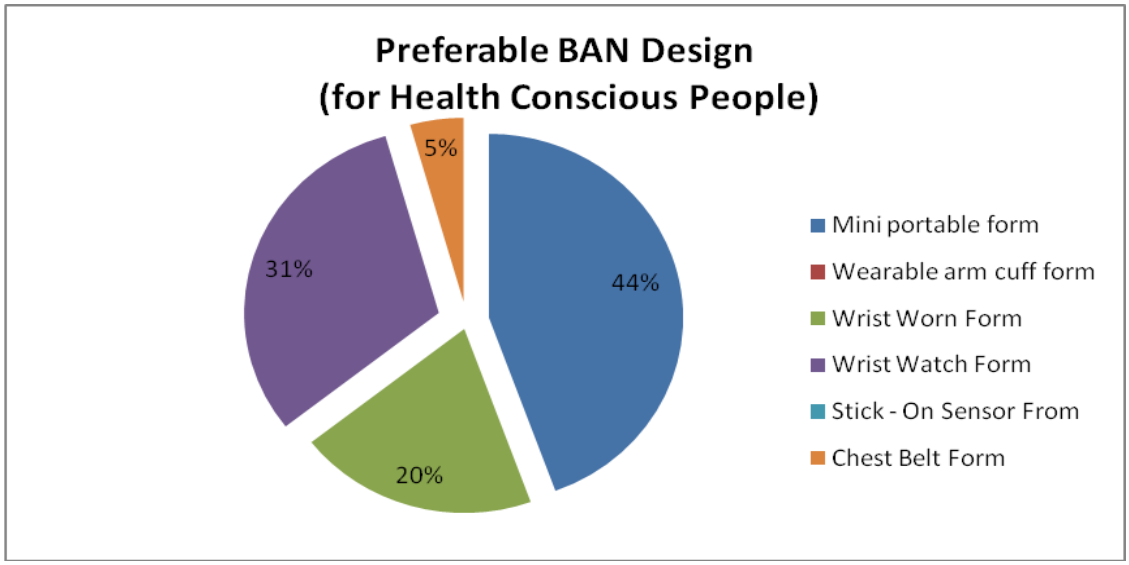


Figure 24: Preferable BAN Design for Health Conscious People

Figure 24 above depicts the opinion of medical public towards the most preferable BAN design if it were to be implemented on the basis of health conscious people. There are few basic types of design involved, which is mini portable monitor form, wearable arm cuff form, wrist worn form, wrist watch form, stick – on sensor form and lastly, chest belt form. As a result from data findings, the most rated design would be in the form of mini portable monitor form, which is rated at percentage of **44%**. It is followed by the wrist watch form design at a percentage of **33%** and wrist worn form at a percentage of **20%** respectively. Chest belt form is rated at a mere

percentage of **5%**. Lastly, wearable arm cuff form and chest belt form are seemed not practical in BAN context.

Mini portable monitor is mostly chosen at **44%** by the respondents since it is portable and the display unit is easy to be functioned. Yet, it has an adjustable wrist cuff which is tailored to different wrist size among users. Comparably, wrist worn form is attractive in design but it is not user friendly since it does not have a display unit. With a display unit, there would be a battery level indicator which allow user to notice about the battery depletion level. Also, a display unit will allow user to manipulate simple built in function as “start”, “stop” or “reset”.

Lastly, stick-on sensor is not practicality and functionality wise since the sweating effect (for example, during jogging) may cause the user to feel uncomfortable. On the other hand, chest belt from around the chest area will definitely cause constraints on users especially when conducting normal daily activities while the vital signs are being captured. If the product is to be used on a monthly monitoring basis, there is a perception that user will definitely do not opt for such device with constrictive effect.

There are a few designs for BAN in order to be marketed on the basis of health conscious people. The designs are shown as below:

A) Mini Portable Monitor form

(for Heart Rate / Blood Pressure)

B) Wearable Arm Cuff form

(for Heart Rate / Blood Pressure)

C) Wristwatch form

(for Heart Rate / Blood Pressure)

A) Wrist-worn form

(for Heart Rate / Blood Pressure)

E) Stick-on Sensor form

(for Heart Rate)

F) Chest-Belt form

(for Heart Rate)

4.4.5 Major Concern about BAN System

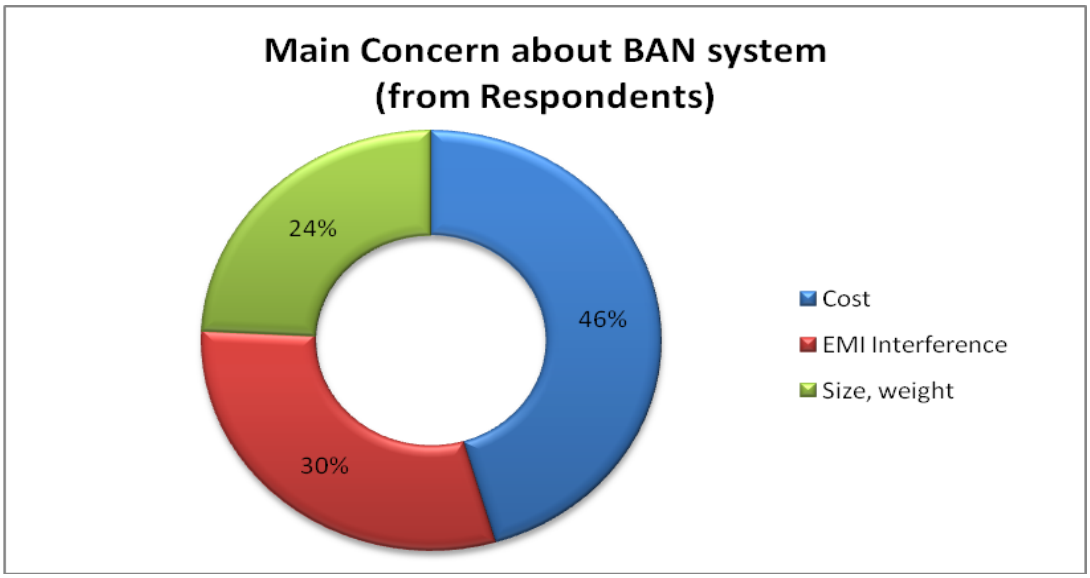


Figure 25: Main Concern about BAN System (from Respondents)

There are several major problems to be considered in order to implement such BAN system in Malaysia context. One is low cost to consumers (patients). From the questionnaires, **46%** of the respondents feel that cost is the major issue if wireless BAN is to be marketed on home monitoring basis. Others **30%** feel that Electron Magnetic Interference (EMI) will be another problem and lastly, 24% is due to size and weight of the devices.

The first concern to be considered is regarding cost issue. In order for demand to take off for hospital usage or home telemetry equipment, consumers (patients) must be able to afford and buy the equipment, with little or no complications from insurance reimbursement processes. As a conclusion, bulk production will help in reducing the production cost.

Secondly, a specific frequency transmission band is chosen. As users of medical devices, the radio signals transmitted from the patient to the monitoring station are vulnerable to electromagnetic interference (EMI), which can present a real risk to patients. The interferences may be due to sources such as hand phone and home user televisions. If these signals are interfered while the patient is suffering a significant adverse health event, the

medical response could be delayed and serious patient consequences are likely to result.

Because of the importance of these signals and the likelihood of EMI with these vital transmissions, the Food and Drug Administration, the Federal Communications Commission (FCC), medical device manufacturers, and the health care community banded together to examine the EMI issue with wireless medical telemetry and developed solutions to minimize the risks to patients posed by EMI. These efforts in creation of the new Wireless Medical Telemetry Service, with its separate frequency spectrum and coordination, which is designed to reduce the risk of EMI to the vital patient telemetry signals from other frequency transmission operating in the same frequency bands. (Witters & Campbell, 2004)

Last but not least, the unit must be compact in design. The size and weight should be in lightweight and comfortable harness, freeing the patient from equipment burden while the sensor and transmitter are capturing the vital signs.

4.4.6 The Design

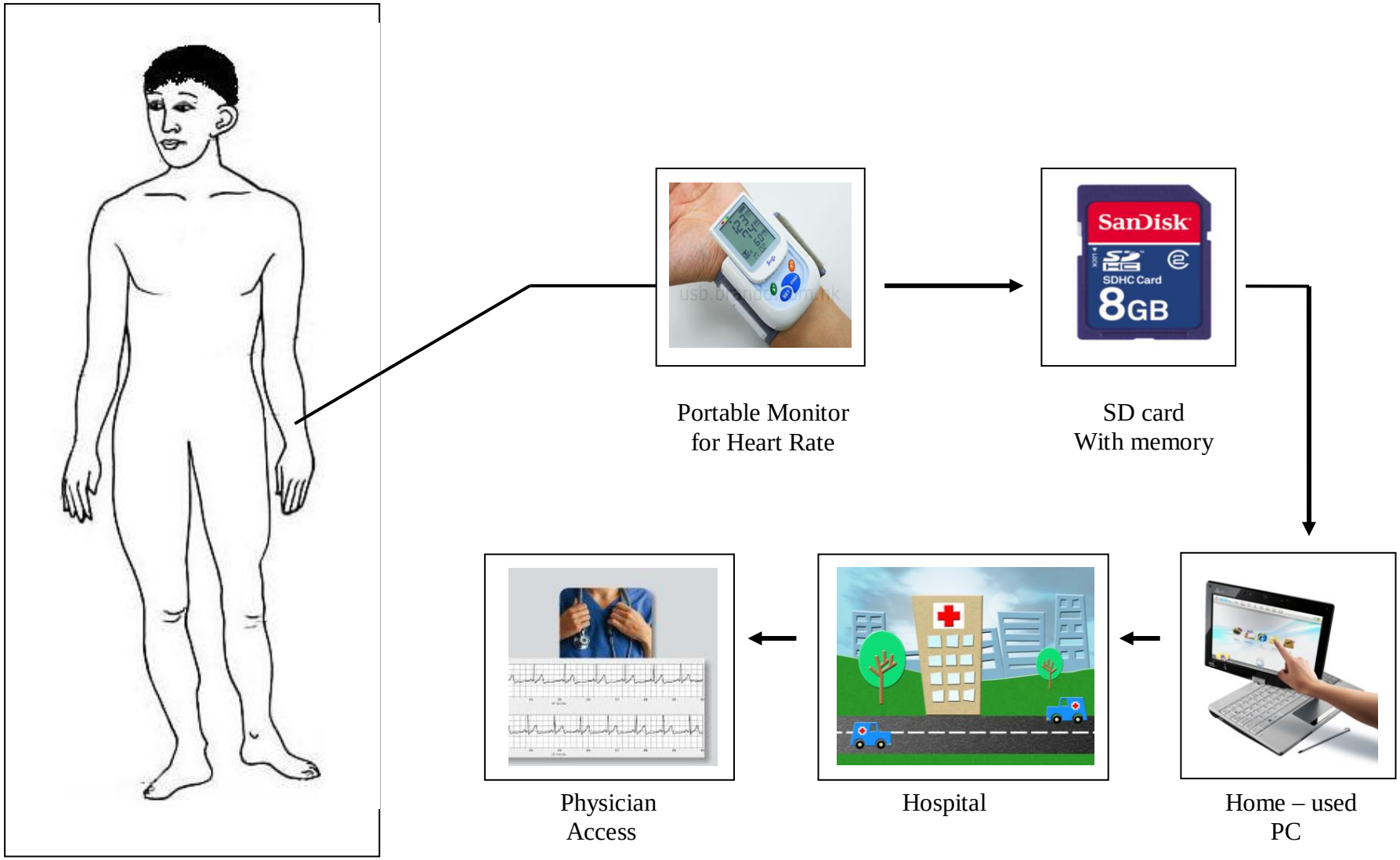
The design idea is simple. At current state, there is digital portable blood pressure monitor in arm cuff form.

Comparably, the main difference between the conventional devices with the wireless BAN portable monitor is with the existence of wireless transmission. Wireless transmission is between the monitor and the wireless enabled device such as smart phone.

In such a case, there is a wireless enabled button on the monitor. At the end of monitoring, the wireless-enabled button is switched on by user in which the data is transmitted on non real-time basis to a wireless enabled smart phone. The smart phone is programmed with integrated automatic analysis process in each software which automatically determines fluctuating levels of vital signs. Physicians can also get access to such monitoring data by retrieving data from data which stored in Flash Drive (or SD card) within the smart phone. They can retrieve the data and figure out the abnormal vital sign readings.

It has an adjustable wrist cuff which is tailored to different wrist size among users. With a display unit, there would be a battery level indicator which allow user to notice about the battery depletion level. Also, a display unit will allow user to manipulate simple built in function as “start”, “stop” or “reset”.

Wireless Body Area Network System as designed (for Health Conscious People):



CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 General Conclusion from Project

The aim in this research is to clarify the design requirement which is needed for BAN. The scope of the research is to identify the use cases of BAN and clarify specific vital sign sensors to be mounted on patients. In such a case, the functional specifications and design requirements may differ to suit different medical procedures. Thus, all these matters have to be discussed face – to face with medical doctors and biomedical engineering personnel from Malaysia's private and government hospitals. Based on the ascertained design requirements, the researcher is able to have a clear concept in developing a BAN-based, human friendly, connected health system.

Thus, at the end of this research, the objective of this research is mostly achieved where the application of connected health system in patient health monitoring is well understood. In such a case, BAN as a connected health system can be applied on in-patients, out-patients and health conscious people basis. It can be applied either as for health monitoring purpose and home diagnostic purpose.

Secondly, by studying the literature review in the second chapter of project, one way of attaining information is through the current mass media and publications. These reviews are important in such a way that they provide the latest development

especially from the biomedical field. Thus, the BAN architecture and its functionality are well understood.

The third chapter is about the methodology to define the methods to conduct this research. The methods included here such as questionnaire survey and also data analysis. During the whole year of conducting questionnaire – based surveys, interpersonal skills are important and yet to be developed and applied when conducting surveys with medical doctors and specialists during interview session. In such a case, presentable soft skills are highly required as to let them understand the concept of such system and to collect their medical point of view. Since this is a qualitative based surveys, their medical point of view are important in contributing to the accountability and reliability of data obtained.

Besides, as in conducting data analysis at the chapter fourth of the project, researcher learnt to be able developing data analysis technique in analyzing raw data from respondents. For example, qualitative data such as likert scale is measured by using a 5 points measurement scales. In this research, the 5 points likert scale is being used. At the end of computing the data, importance index is used in order to get ascertained design requirements, BAN target diseases, and so on.

In general, most respondents give feedback in such a case that the most hindrance that would cause to the BAN implementation in Malaysia context would be mainly cost issue and Electromagnetic Interference (EMI).

In such a case, in order for demand to take off for either usage within the hospital or even for home monitoring purpose, the equipment must be at reasonable range. Especially for demand to take off for health conscious people, consumers must be able to afford and buy the equipment. Bulk production will help in reducing the production cost.

Also, as users of medical devices, the respondents felt that they get used to the current cabled telemetry system and ECG Holter system since there is no risk of data lost. In order for BAN to be implemented, the EMI issue with wireless medical devices must be examined carefully and so to develop solutions to minimize the risks

to patients posed by EMI. In such a case, the radio signals transmitted from the patient to the monitoring station are vulnerable to EMI. It can pose a real risk to patients. If these signals are interfered while the patient is suffering a significant adverse health event, the medical response could be delayed and serious patient consequences are likely to develop.

Lastly, the unit must be compact in design, especially if BAN is to be marketed on out – patient and health conscious people basis. In such a case, the size and weight should be in lightweight and comfortable harness, freeing the patient from equipment burden while the sensor and transmitter are capturing the vital signs.

5.1.1 In-patients

For in-patients within the hospital usage, wireless BAN is to be implemented in certain departments such as post surgical/rehabilitation department and especially in Emergency department. Through the results based on the questionnaire surveys, the idea of incorporating BAN design into Emergency department is a useful finding. In such a case, current cabled system is where wires would be tangled around the department and it would make the emergency department look more messy and doctors would be sometimes get frustrated over this situation. Thus, wireless BAN in emergency department here is indicated for patients where it is to avoid late or lack of attention, and also to alleviate nurses' shortage as well.

Wireless Body Area Network (BAN) enhances patient safety by providing noncritical patient care areas with rapid cardiac data interpretation, improves communication through use of real-time data, and reduces liability. In such a case, its wireless monitoring assists in the early identification of physiological changes and directs appropriate assessment and treatment. It is believed to result in better clinical outcomes and enhanced operating efficiency.

As findings from questionnaires (on in-patient's basis), there are a few conclusions as below:

- BAN is recommended for post surgical / rehabilitation department and Emergency department.
- It is to avoid late or lack of attention, and also to alleviate nurses' shortage.
- There would be 3 wireless devices: 3-nodes wireless ECG patches, portable monitor for heart rate and blood pressure readings, and lastly, clip-on spO_2 sensor. They do not have to be utilized at the same time. Their usage is based on the patient's needs and measurement needed to be monitored at a particular period.
- The wireless BAN must be able to pick up 3 vital signs, which are heart rate/ECG, spO_2 and blood pressure. In comparison, the current telemetry system is able to pick the heart beat of patients.

5.1.2 Out-patients

For out-patients basis, wireless BAN is to be focused on patients with cardiovascular disease. In Malaysia context, cardiovascular disease and hypertension are ranked mostly for their importance. However at initial stage for BAN, we would firstly focus on patients with cardiovascular disease by implementing 2-nodes wireless cardiac event monitor, especially on those patients with suspected arrhythmias but with more transient symptoms. There is another suggested usage of BAN on out-patient basis, which is to be used as an alternative to monitor patients with Obstructive Sleep Apnea (OSA). In such a case, wireless BAN is most valued where patients can be constantly monitored with simple wireless oximetry devices.

Thus, wireless BAN in out-patient context is aimed to improve quality of patient's health at home monitoring basis. In such a case, there is a possibility to reduce hospital or Medical Officer's office visiting frequency provided that BAN is applied to those stabilized chronic disease patients at home. Also, wireless BAN is to allow patients to be freed from the burden of cables. Patients are free to conduct their normal daily activities while their vital body signs are being captured by the wireless sensor. The data can be read in which the smart phone is programmed with integrated automatic analysis process in each software which automatically determines different sorts of vital sign levels. For example, oxygen saturation levels or ECG waveforms.

After a weekly or monthly monitoring basis, physicians can also get access to such monitoring data by retrieving data from data which stored in Flash Drive (or SD card) within the smart phone. They can retrieve the data and figure out the abnormal vital sign readings.

As findings from questionnaires (on out-patient's basis), there are a few conclusions as below:

- BAN is recommended for patients with cardiovascular diseases and Obstructive Sleep Apnea (OSA). In such a case, BAN is used for monitoring purposes for weekly or monthly basis for those patients with transient symptoms.
- It is to reduce hospital or Medical Officer's office visiting frequency. Also, it aims to allow patients to be freed from the burden of cables. Patients are free to conduct their normal daily activities while their vital body signs are being captured by the wireless sensor.
- The wireless BAN is aimed to pick up heart rate / ECG and spO_2.
- The size and weight of wireless BAN device should be in lightweight and comfortable harness, freeing the patient from equipment burden while the sensor and transmitter are capturing the vital signs.

5.1.3 Health Conscious People

For health conscious people basis, wireless BAN has significant meaning in which it can be applied to daily personal healthcare or management. Apart from the medical side, the daily healthcare is more important not to be affected by diseases.

Thus, wireless BAN in health conscious people context is aimed to improve quality of public's health at daily basis. In such a case, wireless BAN is to allow patients to be freed from the burden of cables. Patients are free to conduct their normal daily activities while their vital body signs are being captured by the wireless sensor. The data can be read in which the smart phone is programmed with integrated automatic analysis process in each software which automatically determines different sorts of vital sign levels. For example, blood pressure and heart rate level. After a weekly or monthly monitoring basis, physicians can also get access to such

monitoring data by retrieving data from data which stored in Flash Drive (or SD card) within the smart phone. They can retrieve the data and figure out the abnormal vital sign readings.

As findings from questionnaires (on health conscious people basis), there are a few conclusions as below:

- BAN is recommended for health conscious people with the aim to reduce the possibility or early prevention of diseases such as hypertension and cardiovascular disease. It is mainly aimed to improve health status among health conscious people.
- It also aims to allow patients to be freed from the burden of cables. Patients are free to conduct their normal daily activities while their vital body signs are being captured by the wireless sensor.
- The wireless BAN is aimed to pick up heart rate and blood pressure readings.
- The size and weight of wireless BAN device should be in lightweight and comfortable harness, freeing the patient from equipment burden while the sensor and transmitter are capturing the vital signs.

5.2 Recommendation

As a recommendation, in order to improve the outcome of such questionnaire – based surveys in future, maybe to say, the sample size of the respondents should be increased. More medical officers and biomedical engineers can be involved in order to get their medical point of views. In such a case, the functional specifications and design requirements may differ to suit different medical procedures. Thus, all these matters have to be discussed face – to face with medical doctors and biomedical engineering personnel from Malaysia's private and government hospitals. Based on the ascertained design requirements, the researcher able to have a clear concept in developing a BAN based, human friendly, connected health system.

Also, this survey is only limited in Penang and Kuala Lumpur area due to the limitation of transportation and allowance allocated. The reason behind is that, most of the time, researcher are faced with financial constraints and could not afford with transport cost to conduct more surveys sites in other states. Thus as a

recommendation in future, transportation allowance can be considered and allocated to those researchers in order to get more response from hospitals in other sites. This will make the output of research more objective and more reliable in Malaysia context.

Table 6: Comparison of BAN Implementation Design between Basis of In-Patients, Out-Patient and Health Conscious People

	In-Patients	Out-Patients	Health – conscious People
Wireless ECG patches	✓	✓	
spO_2 sensor	✓	✓	
Blood pressure / heart rate sensor	✓		✓
Mobile transmitter	✓	✓	
Home used PC			✓
Central Monitoring System	✓		
Alarm Triggering System	✓		
Real – time / Non – real time basis	✓		
Aims	• To alleviate nurses' shortage. • To avoid lack or late of attention.	• To reduce patient's visit to hospital. • To allow patient's free from cables.	• To improve health status among health conscious people.

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Appendix :

Questionnaire design