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Wireless Sensor Network for

Precision Agriculture

BY

Lee Ching Hong

A REPORT

SUBMITTED TO

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in partial fulfillment of the requirements

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DECLARATION OF ORIGINALITY

I declare that this report entitled **"Wireless Sensor Network for Precision Agriculture"** is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

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I would like to express my sincere thanks and appreciation to my supervisor, Mr. Goh H.G. who has given me this bright opportunity to engage in a WSN implementation design in project. It is my first step to establish a career in IT design field. A million thanks to you.

I must say thanks to my parents and my family for their love, support and continuous encouragement throughout the course.

When I asked for strength, God gave me more burdens to carry.
When I asked for love, God sent me people with problems.
When I asked for wisdom, God gave me more problems to solve.
I see that I did not get the things I asked for but I have been given all the things that I needed. Thanks God.

Abstract

This project is a Wireless Sensor Network (WSN) technology based project with the title of "Wireless Sensor Network for Precision Agriculture". Problems always encountered in the traditional agriculture for example the natural disasters, water scarcity, diseases and so on. All these are contributing to the bad effects on crops yield which is not satisfied enough. WSNs here will be used in agricultural aspect and enhance the current agricultural world standard in term of controlling and productivity. For instance, wireless sensor nodes are preferable because of its small size advantage and free from the disadvantages of the wired used in the past. In addition, the sensing accuracy of the sensor node is also one of the good factors contributing to it usage. Also, this project will provide us with the methodology, concept and design of this WSNs technology.

Besides, the history of sensor networks will be explained and some comparison will be done between existing applications on using WSNs technology as to differentiate the importance of each of the application and able to elect the best sensing characteristic and capability which will be utilized in this project. Those needs to be differentiated are the geographical terrain, network topology, the type of the sensor being used for and many other parameters being discussed. In addition, advantages and its disadvantages will as well be one of the topics here for better understanding in utilization. And finally, in the analysis section, either of the methodology models such as waterfall development, Agile Methodology, Prototyping, Rapid Application Development (RAD) (Hoffer et al., 2008) or as well Phase development will be in used.

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LIST OF ABBREVIATION

WSN	Wireless Sensor Network
FSPL	Free space path loss
MANET	Mobile Ad Hoc Network
MAC	Medium Access Control
FHSS	Frequency-Hopping Spread Spectrum
DSSS	Direct Sequence Spread Spectrum
VM	Virtual Machine
COM	Computer

1.0 Introduction

1.1 Background

Wireless Sensor Network (WSN) is a device consists of spatially distributed autonomous devices which use sensors to cooperatively monitor physical or environmental parameters such as temperature, sound, vibration, pressure, and even the electromagnetic wave strength detection and light intensity captured for others purposes. The term ‘wireless’ does mean the evolution from the conventional wired devices into the wireless devices as to overcome the constraints of using wire especially those expose to environmental hazard. For instance, the use of wires is much costly and troublesome in cabling installation.

WSNs have been broadly used nowadays in many applications such as environmental monitoring, Industrial sensing, academia, Infrastructure Security, Traffic Control and so on. The Smart Dust is either one of these which has a very small sensor node and used currently by military. Apart from this, WSNs have also played a critical role in the detection of forest fires and plant fires (Tanenbaum et al., 2006 ; Yu et al., 2005 ; Hedeeda, 2007). Needless to mention, WSN has emerged as a viable technology in the agricultural sector either, where the sensor nodes are deployed in outdoor fields to monitor soil conditions such as moisture, air temperature and ambient light intensity. Data collected from the sensors play a key role in crop management and crop productiveness (Langendoen et al., 2006 ; Mayer et al, 2004 ; Rachel et al, 2005 ; Richard et al, 2004 ; Thelen et al., 2005 ; Zhang et al., 2004). Furthermore, agriculture also refer to livestock in where the sensor equipped around the collar of the animals for example cattle as to retrieve their current health and perform some comparison in predicting the optimal health care in order to counteract the transmissible diseases (Schoenig et al., 2005).

One example of how crop management can be enhanced using WSNs is the project Accenture (Burrell et al., 2004) carried out in Northern California. Accenture Technology Labs installed a WSN at Pickberry Vineyard across a 30-acre area to continually sense air temperature, humidity and soil moisture. Since viticulture is highly sensitive to climatic conditions, therefore the sensor data combined with other data sources such as weather forecast data helped farmers in the better understanding of agriculture practices to be adopted for crop management. Another application of WSN in agriculture field is Greenhouse monitoring (Liu et al., 2007 ; Mancuso et al., 2006 ; Timmerman et al., 2003).

1.2 Problem Statement and Motivation

In traditional agriculture, some constraints do exist and generate troubles to farmers and bring them inconvenience. Labour power can be categorized as one of the problems contributing to farmers because crops fields can usually be few hectors wide and human labour will be demanded to do frequent monitoring on the crops land, predict the humidity as well for watering system. This will lead to another problem in where water scarcity is one of our major concerns since watering crops need a lot of water supply. This is even worse if inadequate watering system is applied.

For instance, most of the farmers will predict their crops, soil humidity and weather with their own limited knowledge and experiences which is not a good practice sometimes. Their prediction may lead them to a wrong fact and direction and bring them a huge lost in the worst case. In this case, optimum yield of the crops production will not be achieved and most probably weakening the crops vitality if improper care has been taken. This circumstances will lead to food shortage if prolong expose to this world nowadays with increasing growth of population.

WSNs are used mainly to achieve the impossible thought of human and aid them overcoming some problems which are unavoidable. Since flaws always occur from human prediction, sensors are good in predicting a reliable statistic which is just slightly differed from the actual value. In other word, the sensors were chosen with great care to ensure high interchangeability and high accuracy. Each sensor has less than 3% variation when interchanged with others of the same model. And also, the accuracy of each sensor is within 3% of the actual value. Through calibration, the interchangeability and accuracy can be reduced to below 1% depending on the requirements of the application. Out of the box, the nodes will be accurate for most applications (Mainwaring et al., 2002).

This is important to know that food shortage is a very serious issue that are currently discussed and one of the significant issues is the natural triggers such as drought or flood. Global warming could be blamed for this cause. Because of this, productivity of the crops yield must be sufficient enough to support the current and even the future population. Thus, WSNs are used here for several advantages. First, it allows agricultural researchers to study more details about the crops information such as their weakening point of reaching a certain temperature and humidity threshold. Secondly, this is helpful either to gain a new knowledge of the crops behaviour towards today climate changing. With these important knowledge, the 'how' and 'why' of the crops characteristics can be obtained non-physically from the crop lands and easy to do certain comparison precisely.

Moreover, small sensor nodes are used and placed on the fields mostly due to its suitability and lightweight measurement. These characteristics are required as sensors node can be placed or hung easily somewhere in between and perform its job. In addition, it would be more flexible if compare to the situation in where an average size of devices is used and end up wasting up a lot of precious space. Furthermore, small but light node can be as well easily shielded with hard cover protection as to prevent the damage triggered by either the natural disasters or wild animals attack. Besides, wireless medium is more preferable instead of wired due to several advantages such as the cost for physical wire, vulnerable to physical damage and so on.

1.3 Objectives

As to enhance the situation that traditional agriculture encountered, lot of efforts has been done and WSNs have been brought in for improvement. The objectives are:

1. To provide real-time monitoring on crops land by farmers.
2. To minimize the human labour usage in term of duty numbers per day.
3. To assist agricultural researchers' activities be done in a more convenient way, and allow them to carry out the long term measurement easily.
4. To prevent the water scarcity intrusion.
5. To implement and establish a simple interface in the user computer for sensing data scanning.
6. To set up a database for data storing and queuing.
7. Enabling the multihopping system between nodes.

Since sensors have been used in crops monitoring, the embedded sensors will be playing their roles by capturing their respective data and combine it before sending to the control centre multihoppingly. These combined data will result in real-time monitoring. Due to this easiness, it has unexpectedly reduced the usage of human labour in where human does not have to "hang around" the whole field and provide somehow an unreliable statistic of information. Besides, this has subsequently help researchers in doing their agricultural research on crops growths more thoroughly. Research activities therefore can be done periodically and long term measurement can be carried out easily. All these are done by just having a simple interface interaction in the end user computer and this will as well significantly save a lot of time in searching process with the data being stored in the database server. Agricultural researchers and farmers will have the authorization in searching the data anytime and anywhere with their mobile devices on hand. In addition, water usage is either important issue that needs to be dealt with. For example, Saudi Arabia having some difficulty in water distribution (Water use in agriculture, 2005) due to the growth of their population demands more water supplies. As a result, agriculture must significantly improve its water use efficiency and productivity.

1.4 Project Scope

Agriculture was developed quite long time ago and currently still under enhancement. This can be told based on several stages of development that the agricultural world experienced. It started with the primitive agriculture stage in where stone wares were more preferable as the tools. Meanwhile, it started changing into traditional agriculture stage and ironwood tools were in used widely. Until recently, modern agriculture stage has taken over the lead in where information and knowledge are highly recruited in, and hence the application of wireless sensor network (WSN) (Akyildiz et al., 2002) is contributing towards the realization of those agriculture concepts.

Agriculture is the production of food and goods through farming, in other way, using science knowledge in farming. It consists of 2 major categories which are the agriculture on crops and agriculture on livestock. By using WSNs technology, the WSN nodes can be placed either mobile or statically in achieving the respective data collection. In this project, it will be focusing on crops planting and static type of sensor will be chosen. Sensors will be allocated in their right field and forming an interconnect network where data can be passed through via multi-hopping transmission. Data such as temperature and humidity will be sent and reach the control center for data translation. Afterward, the result will be shown on screen of the user computer and queuing of data received will be performed and stored into a database.

From the user aspect, GUI environment will be implemented in his/her computer for a better understanding and easy to handle. Types of data received could be either using proactive or reactive network. Meanwhile, when the data obtained achieves or over the threshold for the respective sensing data, alert will be shown on screen for user attention. If connection to the internet or GPS is established, warning message can be sent to the user’s mobile phone as well only if the situation is critical. Therefore, adequate actions can be taken once any of these abnormal kinds of data received.

2.0 Literature Review

Early research on sensor networks started during the Cold War. As with many technologies, military applications have been a driver of research and development in WSN. During the Cold War, a network of seabed called Sound Surveillance System (SOSUS) was deployed at strategic locations to provide warning of Soviet Submarines approaching the continental United States. SOSUS is a system of acoustic sensors (hydrophones) that are placed at the bottom of ocean. Several years later, more sophisticated acoustic networks have been developed for submarine surveillance. SOSUS is currently being used by the National Oceanographic and Atmospheric Administration (NOAA) for monitoring events in the ocean, such as the seismic animal activities (Nishimura & Conlon, 1994). Networks of air defence radars were also developed and deployed to defend the United States and Canada during the Cold War. The system has evolved over the years to include aerostats as sensors and Airborne Warning and Control System (AWACS) planes, and is also used for drug interdiction.

Modern research on sensor networks started around 1980 with the Distributed Sensor Networks (DSN) program at the Defence Advanced Research Project Agency (DARPA). R. E. Kahn, who was co-inventor of the TCP/IP protocols and responsible for originating DARPA’s Internet Program, was interested to know how the Arpanet (predecessor of the Internet) could be extended to sensor networks. Initial testing was done on minicomputers, such as PDP-11 and VAX machines running Unix and VMS; while the modems were running at 300 to 9600 Baud.

In 1978, DSN was identified as a technology component in Distributed Sensor Nets workshop. The workshop was held in Carnegie Mellon University (CMU), Pittsburgh, Pennsylvania. Distributed acoustic tracking was chosen as the target issue for demonstration. Several researches have been carried out on this issue as follow.

Research Institute	Research Focused Area	References
Carnegie Mellon University (CMU), Pittsburgh, Pennsylvania	Provided a network operating system that allows flexible, transparent access to distributed resources needed for a fault-tolerant DSN.	Rashid & Robertson, 1981.
Massachusetts Institute of Technology (MIT), Cambridge	Implemented knowledge-based signal processing techniques for tracking helicopters using a distributed array of acoustic microphones by means of signal abstractions and matching techniques.	Myers, Oppenheim, Davis, & Dove, 1984
Advanced Decision Systems (ADS), Mountain View, CA	Developed a multiple-hypothesis tracking algorithm.	Chong, Chang, & Mori, 1986; 1990.
MIT Lincoln Laboratory	Developed a real time testbed for acoustic tracking of low flying aircraft.	Lacoss, 1987
University of Massachusetts, Amherst	Developed a testbed for distributed vehicle moniroting.	Lesser & Corkill, 1983.

Table 2-T1: Researches carried out for DSN testbed.

Although early researchers on sensor networks had an idea in mind on large numbers of small sensors to be deployed, the technology for manufacturing these small sensors was not yet ready. However, planners of military systems recognized the benefits of the sensor networks and its potential to become a crucial component of network-centric warfare. In a platform-centric warfare, sensors and weapons are mounted with and controlled by separate platforms that operate independently. Sensors and weapons collaborate with each other over a communication network. Examples of network-centric warfare are Cooperative Engagement Capability (CEC) (Hopkins, 1995) using multiple radars to collect data on air targets, Fixed Distribution System (FDS) (Pike, 1997) and Advanced Deployable System (ADS) (Pike, 1999) using acoustic sensors arrays for antisubmarine warfare, and Remote Battlefield Sensor System (REMBASS) (2000) and Tactical Remote Sensor System (TRSS) using unattended ground sensors in ground battlefield.

In the 21st century, advances in computing and communication technologies have caused a significant shift in sensor networks research and brought it closer to achieving the original vision. Small and inexpensive sensors based on MEMS technology, wireless networking, and inexpensive low-power processors allow the larger deployment of wireless sensor networks for various applications. Again, DARPA started a research program on sensors networks to leverage the latest technological advancements. DARPA contributed two ideas in research and development through Sensor Information Technology (SensIT) (Kumar & Shepherd, 2001) program. The first one is to develop new networking techniques for as hoc fashion and high dynamic environments. Another idea is to introduce networked information processing, which is how to extract useful, reliable, and timely information from the deployed sensor network. SensIT networks have new capabilities; such as it is interactive and programmable with dynamic tasking and querying. One of the examples of this system is Tactical Automated Security System (TASS) (Corella, 2003).

Today, WSN represents a new generation of real-time embedded system with significantly different communication constraints form the traditional networked systems. It can be self-organized and achieve communication through multihop fashion. It has become a realization of the Pentagon’s “smart-dust” concept (Brett et al., 2001) that was proposed by researchers at the DARPA. The idea was to sprinkle thousands of tiny wireless sensors on a battlefield to monitor enemy movements without alerting the enemy of their presence. A “smart-dust” optical mote (Kahn et al., 1999 ; Pister et al. 1999) uses MEMS to aim submillimeter-sized mirrors for communications. By self-organizing into a sensor network, smart dust would filter raw data for relevance before relaying only the important findings to central command.

WSN architecture

WSN is a wireless ad hoc network that is formed by a group of sensor/actuator devices (nodes). A WSN node is consists of at least a transceiver, a transducer, a processor, and a power unit. It is expected to be built small in size with inexpensive components as shown in Figure 2-1-F1. WSN nodes are capable to form a self-organized multi-hop network.

Figure 2-1-F1: A WSN device (MICAz platform).

In detail, there are several core components needed in WSN such as sensor, actuator, microcontroller or microprocessor, unique ID chip, external flash memory, radio chip, antenna, and batteries as shown in **Error! Reference source not found.**-1-F2. Sensor is a component used to detect a parameter in one form and present it in another form of energy like signal, while actuator is used to convert electrical signal into generally non-electrical energy. They are referred as transducer. Microcontroller is a small computer built on a single integrated circuit that executes program. It consists of a relatively simple central processing unit (CPU) combined with support functions such as a crystal oscillator, timers, interrupts, interfaces and etc. The interfaces can be GPIO, UART, USART, I2C, or SPI. Unique ID chip is used to provide a unique identification to each sensor node. Flash memory is an external storage for keeping data. Flash can be optional. Radio chip is responsible to transmit signals by modulation of electromagnetic waves with frequencies below those of visible light. Antenna is used to transmit or receive electromagnetic waves.

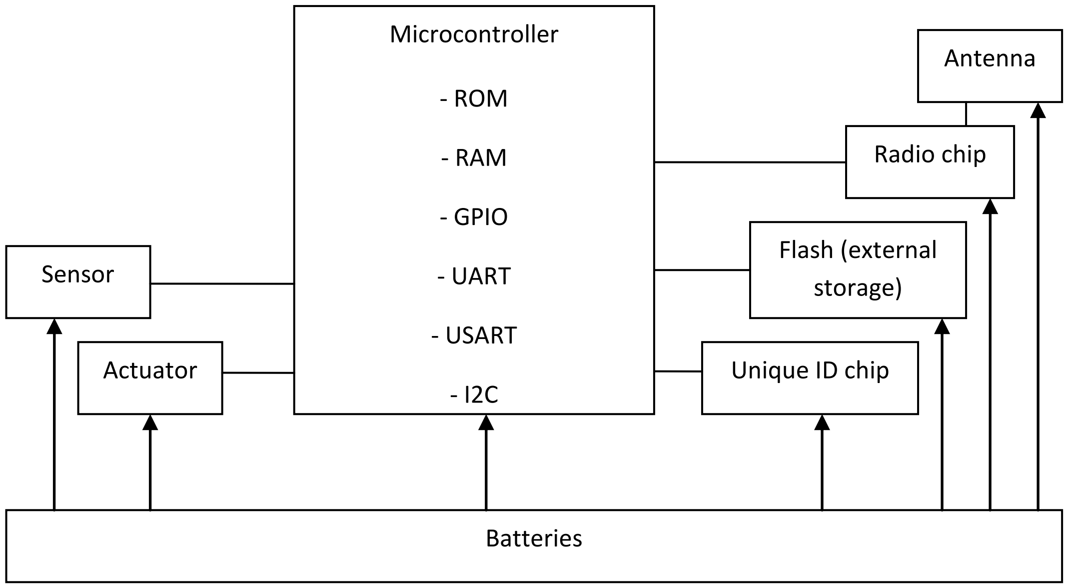


Figure 2-1-F2: General hardware diagram of a WSN device.

WSN architecture can be represented in block diagram as shown in 2-1-F3. Transducer is responsible to interact with physical world. Processor is handling the signals between the transducer and transceiver. Transceiver is in-charge of transmit or receive the radio signal. All these components are powered by power unit.

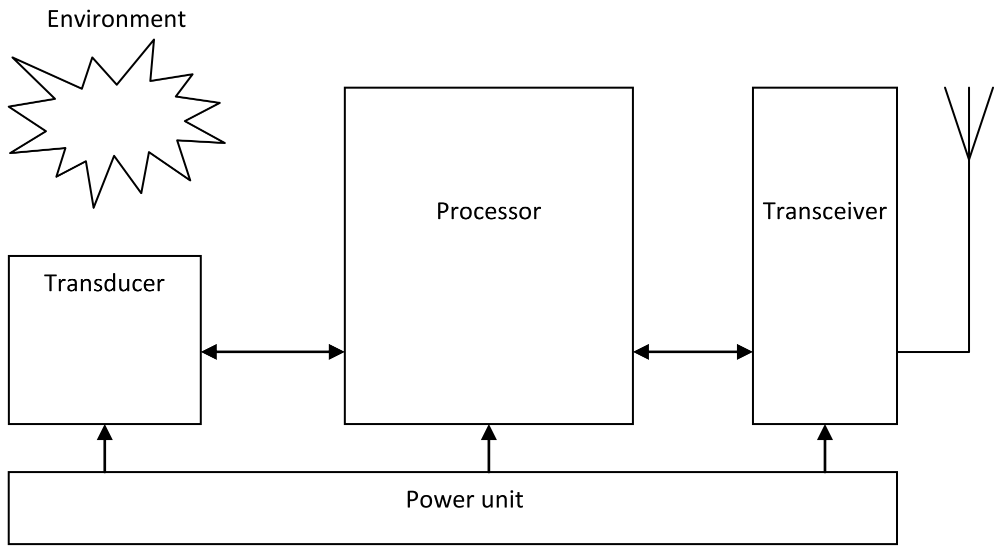


Figure 2-1-F3: A WSN architecture block diagram.

The sensor nodes are usually scattered in a sensor field as shown in 2-1-F4. Each sensor node has the capabilities to collect data and route data back to the sink node. The sink node is usually connected with existing networks, such as Internet, satellite, or cellular network. After some information processing, the information will reach the end user through personal computers or mobile devices.

WSNs activities are usually include data gathering for continuous sensing and data gathering for event-triggered sensing. Data gathering for continuous sensing is used for the application to have closely monitored of a situation or for the analysis purpose. Data gathering for event-triggered only report when a specified event is detected. In WSN, different application requires different needs.

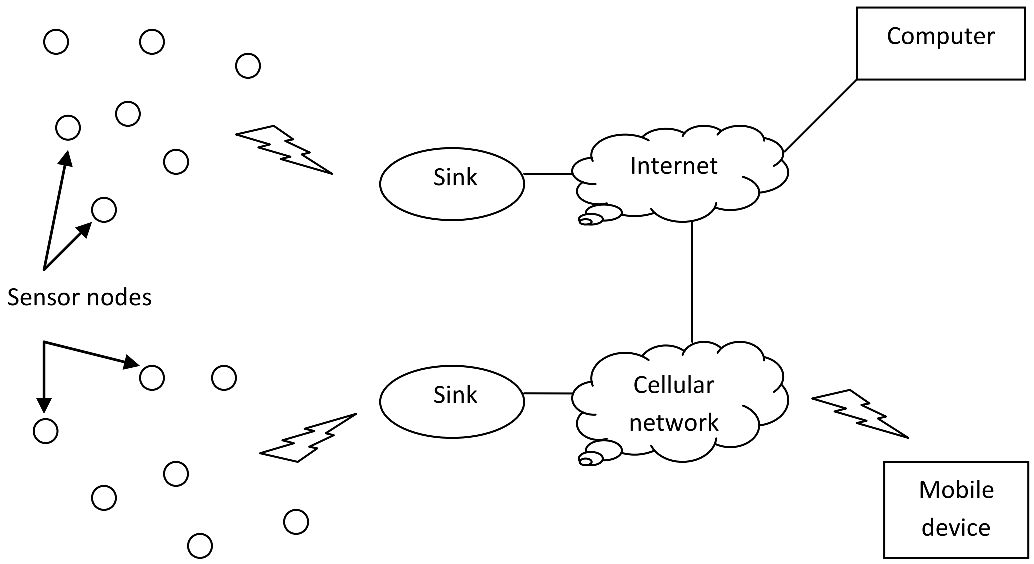


Figure 2-1-F4: An example of communication from sensor network to the end user.

Transceiver unit

Due to the cost of manufacturing and market demand, the transceiver of WSNs that built is using low data rate and low cost ISM unlicensed bands. Many of these nodes are able to form a self-organized network using multihop communications.

No doubt advanced radio chip with multiple antennas can be used for WSNs in order to achieve better data rate, energy is always a trade-off. A better power unit can be used but the size of the sensor node and the easy of deployment will be a constraint.

The basic of transceiver unit consists of a 5-layer Open System Interconnection (OSI) Reference Model as shown in Table 1-1-1-T1. Those layers are physical layer, data link layer, network layer, transport layer, and application layer.

Layer	Data unit	Function
Application	Data	Network process to application
Transport	Segment	End-to-end connections and reliability
Network	Packet	Path determination and logical addressing
Data Link	Frame	Physical addressing and access control
Physical	Bit	Media, signal and binary transmission

Table 1-1-1-T1: A 5-layer OSI Reference Model for WSN.

Physical layer

Physical layer is responsible for bit-level transmission between the network nodes. It consists of the basic hardware transmission technologies of a network. The layer defines the means of transmitting raw bits rather than logical data packets over a physical link connecting network nodes. The bit stream may be grouped into code words or symbols and converted to a physical signal that is transmitted over a transmission medium.

The performance of this layer is affected by 3 major factors, which are hardware, software, and the environment of propagation. The hardware includes the shape of antenna, antenna gain, and operating frequency. The software is referred to modulation, bit synchronization, and transmission power. The environment impact as in follows:

1. Free space path loss (FSPL): FSPL is the loss in signal strength of a radio wave that would result from a line-of-sight path through free space. The loss depends on the frequency selection and the distance between a transmitter and a receiver. The loss can be calculated using the following equation.

$$FSPL = 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right) \qquad (1)$$

$FSPL$ is in dB, d is the distance between a transmitter and a receiver in m, and f is the selected frequency in Hz. As the distance between the transmitter and the receiver increases, the path loss is also increased. For the same distance, higher frequencies suffer for higher path loss as shows in Figure 2-1-1-1-F1.

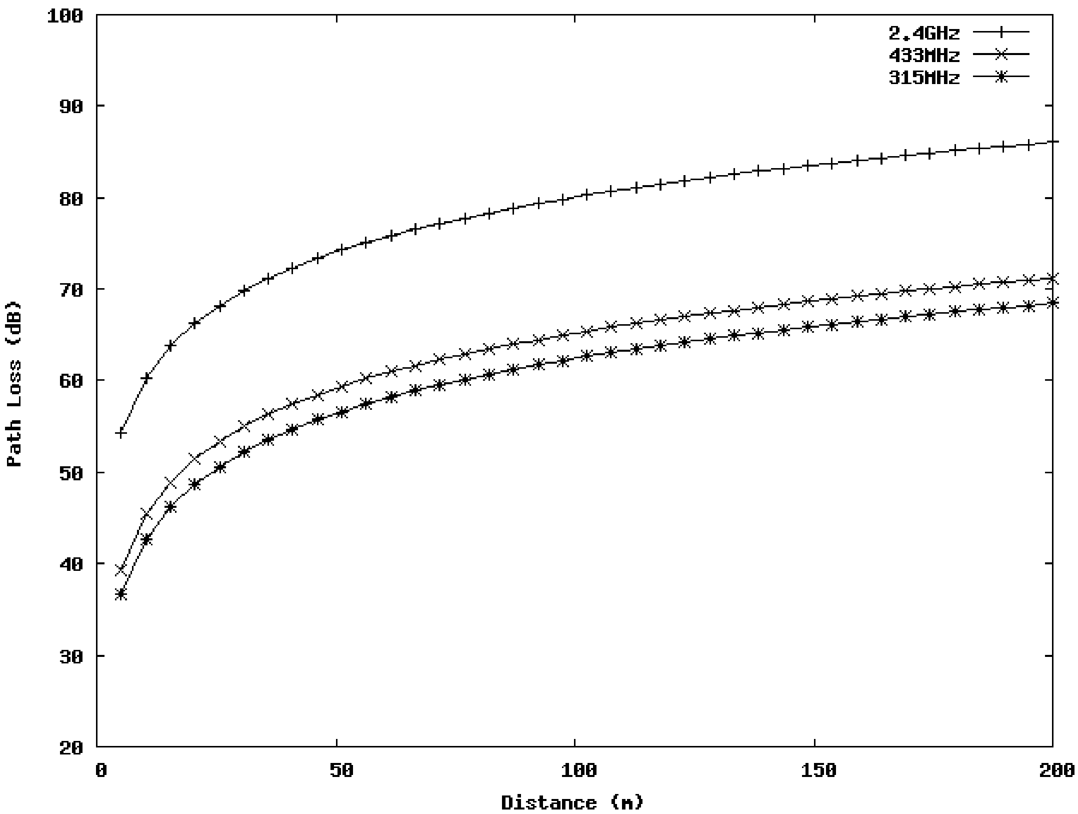


Figure 2-1-1-1-F1: Path loss comparison for 315MHz, 433MHz, and 2.4GHz.

2. Attenuation: Attenuation is any reduction in the strength of radio wave signal when the signal penetrates through solid objects. This is due to some of the signal power is absorbed. Attenuation can vary greatly depending upon the structure of the object the signal is passing through. Metal in the barrier greatly increases the attenuation. Thickness also increases the loss.

3. Scattering: Scattering is the situation where the signal is diffused when a radio wave is incident on a rough surface object. Scattering occurs when incoming signal hits an object whose size in the order of the wavelength of the signal or less.

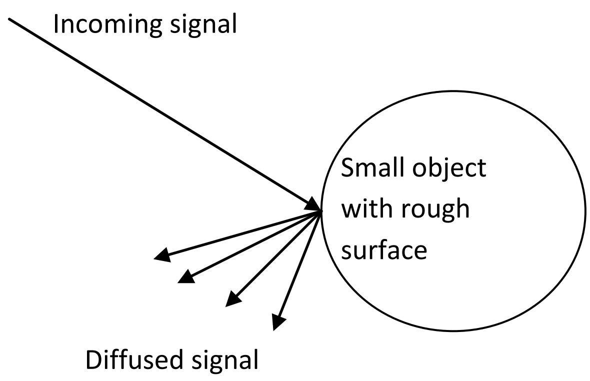


Figure 2-1-1-1-F2: Scattering causes the signal is diffused.

4. Reflection: Reflection is the change in direction of a radio wave when the signal encounters a surface that is large relative to the wavelength of the signal. Radio waves may be reflected from various substances or objects they meet during travel between the transmitting and receiving sites. The amount of reflection depends on the reflecting material. Smooth metal surfaces of good electrical conductivity are efficient reflectors of radio waves. When radio waves are reflected from flat surfaces, a phase shift in the alternations of the wave occurs. The shifting in the phase relationships of reflected radio waves is one of the major reasons for fading.

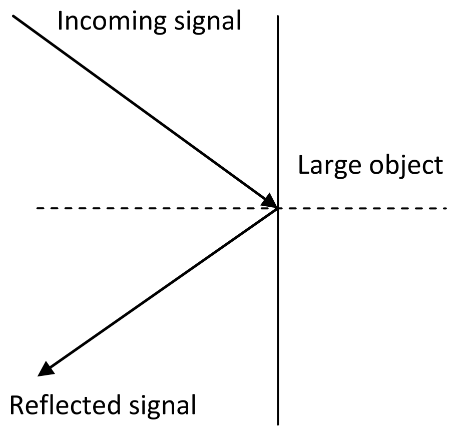


Figure 2-1-1-1-F3: Reflection.

5. Refraction: Refraction is the change in direction of a radio wave due to a change in its speed. This is happen when a wave passes from one type of medium to another type of medium.

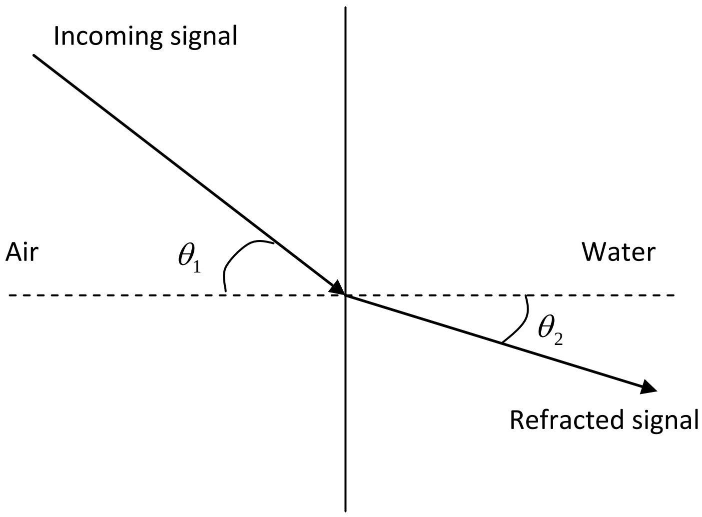


Figure 2-1-1-1-F4: Refraction.

6. Diffraction: Diffraction happens when a radio wave that meets an obstacle has a tendency to bend around the obstacle. This results in a change of direction of part of the wave energy from the normal line-of-sight path. The change makes it possible to receive energy around the edges of an obstacle.

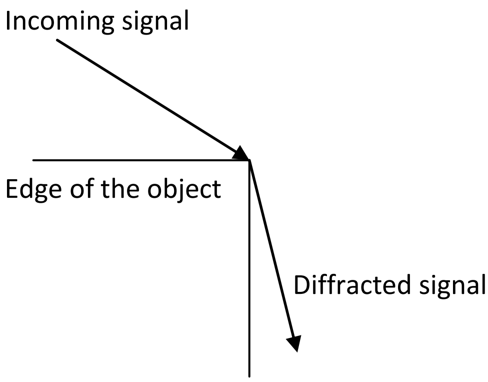


Figure 2-1-1-1-F5: Diffraction.

7. Interference: Interference refers to the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency (by same type of device from other people). Interference causes the radio waves reaching a point are in phase (constructive interference) or out of phase (destructive interference).
8. Noise: Noise is an unwanted perturbation to a wanted signal. It could be generated from different type of radio devices.

2.2 Sensor Network Communication Architecture

The sensor nodes are usually scattered in a sensor fields. Each sensor node has the capabilities to collect data and route data back to the sink node. The sink node is usually connected with existing networks, such as Internet, satellite, or cellular network. After some information processing, the information will reach the end user through personal computers or mobile devices.

Among all the existing networks, MANET (Mobile Ad Hoc Network) (Macker et al., 1997) is the closest sensor networks in term of wireless networking. MANET is commonly based on IEEE 802.11b (IEEE Standard 802.11b-1999/Cor 1-2001, 2001) and Bluetooth (Haartsen, 2000) standards. It shares many of the characteristics of WSN, such as supporting asynchronous communication and assembling into ad hoc networks, but also differed in a number of key areas. The power consumption of both IEEE 802.11b and Bluetooth has exceeded what is desirable for WSN. This is partially due to the data rates provided by these networks are being greater than what is needed for many WSN applications. IEEE 802.11b and Bluetooth networks are usually designed with some mobility capability, while WSN is designed to be operating in quasi-stationary state. Although the protocol stack of both the IEEE 802.11b and the Bluetooth are similar, the communication protocols and paradigm are different.

Initial protocol stack of sensor network consists of 5 layers as shown. In figure 2-2-F1 below, the protocols stack also combines power and routing awareness, integrates data with networking protocols, communications power efficiently through the wireless medium, and promotes cooperative efforts of sensor nodes.

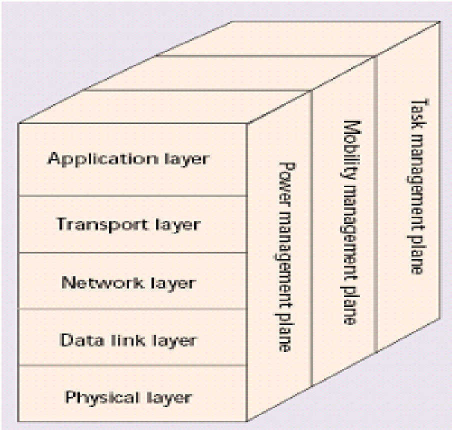


Figure 2-2-F1: The early WSN protocol stack

In the Zigbee with the IEEE 802.15.4 standard, the protocol stack for wireless sensor network can be stacked up to 7 layers: application layer, presentation layer, session layer, transport layer, network layer, data link layer, and physical layer. This will enable more functionality and sophisticated protocols (such as security protocol) to be implemented into the WSN.

2.3 Advantages and Disadvantages of WSN

There are some common pros and cons of the WSN when come to a certain constraints. Meanwhile, the advantages of it makes sensor network more productive if compare to the existing disadvantages. Figure 2-3-T1 shows the table of its pros and cons.

Advantages (pros)	**Disadvantages (cons)**
1. **Varying network size:** can be deployed in a large number (1 to 1 million nodes).	**1. Limited in energy resource, computation capacities, and memory:** compare to ad hoc network device, sensor network has much lesser. Batteries will die off quickly. (because of the smaller computational capacities and memory)
2. **Low cost:** Current sensor's price is still costly, but will be achieving USD 1 -10 once reaching the commercialization stage.	2. **Application awareness:** Due to the limitation in energy resource, computation, and memory, WSN cannot handle complicated tasks.
3. **Self-organize:** expected to operate by itself in a large nodes deployment. No longer same as traditional computer which needs human interaction.	3. **Unreliable link communication:** prompt to more frequent and various error (signal propagation is not powerful as compared to environment noises, causing limitation to be used in outdoor application because affected by weather).
4. Querying and re-tasking: WSN is designed to handle specific application. It can be designed for handling on-demand request from user and reset the operational tasks. Re-tasking take several form such as duty-cycle, sampling rates, making routing decisions, processing data, and in-network reprogramming.	
5. **Multihop data aggregation:** data passed hop-by-hop from source to destination node. Although energy limitation is one of the problems, it does not limit the data transmission.	
6. **Multi-environment deployment:** Because of small and cheap size, it can be deployed anyway regardless indoor or outdoor.	

Table 2-3-T1: Advantages and disadvantages of WSN

2.4 Wireless versus Wired

WSN can operate in a wide range of environments and provide advantages in cost, size, power, flexibility and distributed intelligence, compared to wired ones. In a network, when a node cannot directly contact the base station, the message may be forwarded over multiple hops. By auto configuration set up, the network could continue to operate as nodes are moved, add-in or removed; this is also categorized as self-organizing capability. Architectures for sensor networks have been changing greatly over the last 50 years, from the analogue 4-20 mA designs to the bus and network topology of today. Bus architectures reduce wiring and required communication bandwidth. Wireless sensors further decrease wiring needs, providing new opportunities for distributed intelligence architectures (Baronti et al., 2007 ; Akyildiz et al., 2002 ; Arampatzis et al., 2005).

For fieldbus architecture, there is a risk of cutting the bus or connection that connects all the sensors. WSN eliminates all these problems arising from wires in the system. This is the most important advantage of using such technology for monitoring. Wireless sensor technology allows Micro-Electro-Mechanical Systems Sensors (MEMS) to be integrated with signal conditioning and radio units to form "motes", all for a low cost, a small size, and with low power requirements. Available MEMS include inertial, pressure, temperature, humidity, strain-gage, and various piezo and capacitive transducers for proximity, position, velocity, acceleration and vibration measurements (Arampatzis et al., 2005), and according to several research works, connecting wires to these devices can be more problematic than doing it by means of wireless designs (Jackson et al., 2008 ; Wise et al., 2007). Motes can form networks and co-operate according to various models and architectures. They came with miniaturized sensors mounted that allow, in a small space (2.5 × 5 × 5 cm), the gathering of data not only just about temperature, but also relative humidity, acceleration, shock and light (Website of Crossbow Tech., 2010).

Another advantage for wireless sensor devices is the feasibility of installation in places where cabling is impossible, such as large concrete structures (Norris et al.,

2008) or embedded within the cargo, which brings their readings closer to the true in situ properties of perishable products (Ruiz-Carcia et al., 2008). Wired networks are very reliable and stable communication systems for instruments and controls. However, wireless technology promises lower installation costs than wired devices, because required cabling engineering is very costly (Maxwell et al., 2002). Table 2-4-T1 shows the simplest of the wireless if compare to wire.

2.5 Wireless devices and their comparison (Wi-Fi, Bluetooth, ZigBee)

2.5.1 Wi-Fi

Wi-Fi is belong to a class of wireless local area network (WLAN) devices based on the IEEE 802.11 standards, which is by far the most widespread WLAN class today. Because of the close relationship with its underlying standards, the term Wi-Fi is often used as a synonym for IEEE 802.11 technology. The earliest standard was the 802.11a version, which allowed a maximum throughput (speed) of 10 MBPS. The next Wi-Fi Standard was the 802.11b and the one after that, the 802.11g Standard. This is the de-facto version today. Since it is backwardly-compatible with 802.11a, earlier devices can co-exist with 802.11g as well. On 802.11g, the maximum possible throughput is about 5 times higher, at 54 Mbps. It is good enough for transferring larger files too and has really boosted the usage of Wi-Fi across the world. Currently, a few experimental versions of Wi-Fi standards such as 802.11n are being worked upon. These will further increase the maximum throughput and coverage area of Wi-Fi Networks.

Wi-Fi Networks are very sensitive to signal strength. To ensure good connectivity, technicians must ensure that all devices and gadgets receive adequate signal strength at all times. Besides, Wi-Fi signals are likely to be adversely affected by climatic conditions such as thunderstorms. This will be troublesome if it is placed either indoor or outdoor. Furthermore, when there is an increasing in number of devices on the Network, it must incorporate a Wi-Fi Access point and this is a must for Wi-Fi access. Also, technician will need a power socket to plug in and power the Wi-Fi Access Point and causing a lot of cumbersome situation.

Consequently, Wi-Fi doesn’t work as good device for WSN as it is affected by the climate conditions. It is hardly be used especially for agricultural monitoring purposes since this monitoring process will be all the time in open area. Besides, even though Wi-Fi has a good distance of connectivity which is about 100 meters in range, device will only communicated with the access point and hence making the perimeter restricted to the 100 meter range. This is unsuitable for crops lands especially paddy fields which need few hectors in size. For instance, adequate signal strength needs to be maintained all the time.

2.5.2 Bluetooth

Bluetooth (IEEE 802.15.1) was developed as a wireless protocol for short-range communication in wireless personal area networks (PAN) as a cable replacement for mobile devices. It uses the 868 and 915 MHz and the 2.4 GHz radio bands to communicate at 1 Mb per second between up to seven devices. Bluetooth is mainly designed to maximize ad hoc networking functionality. Some of its common functions are passing and synchronizing data, for example between a PDA (personal digital assistant) and a computer, wireless access to LANs, and connection to the internet. It uses frequency-hopping spread-spectrum (FHSS) communication, randomly hopping across 79, 1-MHz channels (in the United States) at a rate of 1600 hops per second. Bluetooth uses a master-slave-based MAC (medium access control) protocol (Dursch et al., 2004 ; IEEE standard, 2002 ; Bluetooth, 2010).

Although Bluetooth is often suggested for sensor network applications, the Bluetooth physical layer is not very suitable for wireless sensor networks. Frequency hopping spread spectrum makes network discovery and association difficult because the network and prospective member node are asynchronous and the search must be done on a packet rate time scale. This causes a power consumption problem as the prospective member searched the band for the network, which may, in fact, not be present, and is especially problematic for low duty rate systems. Furthermore, frequency hopping systems employ relatively narrowband modulation schemes (1 MHz wide in the case of Bluetooth); this means that integrated channel filtering will be difficult and expensive due to the large component (usually capacitor) values required to achieve the low-frequency filter corner. In addition, the large capacitor values associated with low-frequency circuits must be charged to a bias voltage during circuit warm-up, prior to operation; this lengthened warm-up period negatively affects node duty cycle. Further, the narrow channel separation makes the phase noise requirements of signal sources in both transmitter and receiver more difficult.

2.5.3 ZigBee

The ZigBee standard is built on top of the IEEE 802.15.4 standard. The IEEE 802.15.4 standard defines the physical and MAC (Medium Access Control) layers for low-rate wireless personal area networks (IEEE standard, 2003). The physical layer supports three frequency bands with different gross data rates: 2,450 MHz (250 kbs-1), 915 MHz (40 kbs-1) and 868 MHz (20 kbs-1). It also supports functionalities for channel selection, link quality estimation, energy measurement and clear channel assessment. ZigBee standardizes both the network and the application layer. The network layer is in charge of organizing and providing routing over a multi-hop network, specifying different network topologies: star, tree, peer-to-peer and mesh.

The application layer provides a framework for distributed application development and communication. Aside from the agriculture and food industry, it is widely used in home building control, automation, security, consumer electronics, personal computer peripherals, medical monitoring and toys. These applications require a technology that offers long battery life, reliability, automatic or semiautomatic installation, the ability to easily add or remove network nodes, signals that can pass through walls and ceilings and a low system cost (Baronti et al., 2007)

	Bluetooth	ZigBee
Standard	**IEEE 802.15.1**	**IEEE 802.15.4**
Data rate	**1 Mb s^{-1}**	**20-250kb s^{-1}**
Latency	**< 10 s**	**30 ms**
Frequencies	**2.4GHz**	**2.4GHz**
No. of nodes	**8**	**65000**
Range	**8 m (Class II, III) to 100 m (Class I)**	**1-100m**
Modulation	**FHSS**	**DSSS**
Network topology	**Ad hoc piconets**	**Ad hoc, star, mesh**
Data type	**Audio, graphics, pictures, files**	**Small data packet**
Battery life	**1 week**	**> 1 year**
Extendibility	**No**	**Yes**

Table 2-5-T1: Comparison between Bluetooth and Zigbee

Currently two there standard technologies are available for WSN that are ZigBee and Bluetooth. Both operate within the Industrial Scientific and Medical (ISM) band of 2.4 GHz, which provides license-free operations, huge spectrum allocation and worldwide compatibility. Wi-Fi is not being discussed here because of its huge disadvantages that largely limiting itself being used as the wireless medium. In Zigbee, because of the nodes size support and the batteries life are largely satisfied, Bluetooth will no longer being considered especially used in the wide area applications. Furthermore, the data latency in transmission in Zigbee is quite reasonable to be chosen. Meanwhile, although Bluetooth with data rate of 1Mbps capable in sending “big” packet such as audio and picture, it is no longer needed in this project design and hence, the smaller data rate is sufficient enough to better conserving the energy. Even if picture is needed in transmission such as camera capturing screen, the data rate would not be that high to support it.

2.6 Implementation of Wireless Sensor Network in Agriculture

In this section, 5 applications have been taken into research on their respective features study. Out of all the applications, these 5 are the agricultural applications which are the vineyard, potato, tomato, cattle and fish. Features of research have been shown in the table 2-6-T1 below and some comparison will be done to pick up the desirable features to be used in this project. Usually, WSN technology has been implemented in such agricultural applications mainly to obtain a higher productivity and prevent massive lost due to the diseases attack and extreme weather. Furthermore, a same feature in each of the application does not necessary using the same parameter value because every application with different deployment of sensor nodes and physical measurement will be having a different need and way of implementation to get the best result. So, table 2-6-T1 will show detailed parameters for each of the application.

Applications / Features	Vineyard	Potato	Tomato	Cattle	Fish
Number of node	65 nodes	150 nodes	6 nodes and one bridge node.	One node per cattle.	Limited to 30 nodes.
Wireless device	SensiNet	(not mention in text)	(not mention in text)	Bluetooth	Zigbee
Sensor types	Thermistor, moisture sensor.	Thermistor and other sensors (not mentioned in the text).	Thermistor, moisture sensor.	Accelerometer and other sensors (not mentioned in text)	pH and temperature sensor.
Pattern of nodes deployment	A topology with up to 8 hops. Grid like pattern ten to twenty meters apart covering about 2 acres.	Nodes installed at a height of 75cm, sensors installed at a height of 20, 40 , 60cm. Grid pattern.	Arranged in 2 rows, 12.5m apart. (20 by 50 meters). Grid pattern	Mobile deployment of node hung on the cattle's neck (20 by 50 meters corral)	Maximum number of hops to 6. Topology in classical tree configuration. (Trunk and leaves similar)
Parameters	1. Temperature of the fields 2. Humidity of environment.	1. luminosity 2. Air pressure 3. Precipitation 4.Wind strength and direction 5. Soil humidity 6. High of the ground water	1. Air temperature 2. Soil temperature 3. Humidity	Core body temperature Heart rate Respiratory rate Movement Ambient temperature, Humidity and wind Behaviour Electronic identification	PH of the water. Temperature of the water.
Operation life time	(not mention in text)	(not mention in text)	(not mention in text)	(not mention in text)	(not mention in text)
Battery solving /saving method	After synchronization, the motes go to sleep and reawaken at the appropriate time to take the next measurement.	Using delta encoding when data sent over the wireless links	(not mention in text)	(not mention in text)	Energy management layer – reduce the power consumption.
Data sampling rate	Every 5 minutes	Once per ten minutes.	Every single minute.	< 0.5 seconds for accelerometer.	Every 5 minutes.
Data collection method	Multi-hopping	Multihop routing protocol MintRoute available within TinyOS	(not mention in text)	Direct sent to nearby Bluetooth access point.	(not mention in text)
Frequency used	916MHz	(not mention in text)	2.4GHz.	2.4GHz	2.4GHz

Table 2-6-T1: Comparison of 5 Applications that use WSN

Reference: (Beckwith et al., 2004) (Baggio,2005) (Mancuso,2006) (Schoenig et al., 2004) (Lopez et al., 2010)

2.7 Comparison of the agricultural applications

Based on the table 1 above, vineyard, potato, tomato, cattle and fish have been taken into references. It seems like majority of the applications use the frequency range of 2.4GHz as the data transmission frequency. This is mostly because the 2.4GHz is the license-free frequency and hence it is cost saving. It is permissible to use 2.4 GHz frequency range and they are not subject to special regulations. However, the higher the spread spectrum centre frequency (at the same power level), the shorter the transmission ranges. This is especially the case for the vineyard plantation in USA in where the crop lands are too much bigger and longer ranger of transmission is required. More sensor nodes will be needed and hence making it costly. As a result, 916MHz as the one of the license-free frequency range has been utilized to achieve a longer range in data transmission. A 916 MHz will achieve reliable line-of-sight (LOS) range up to 1/2 mile, and the long range system can reach 6-7 miles LOS. Compare that to the 2.4 GHz system ranges of 1/4 mile LOS (standard) and 3.5 miles LOS (long range). Of course, disadvantage does exist for example, interference will happen when 2.4GHz is used in where Wi-Fi for internet connection is using the same range of frequency either. Moreover, even though 916MHz can provide a longer range due to its lower spread spectrum centre frequency, it is susceptible to environment interference such as noise and distortion.

Besides, the data sampling rate for each of the application is different due to the way and which parameters are being sensed. For example the cattle, its accelerometer takes less than 0.5 seconds for the data collection. This is done because accelerometer in movement monitoring is very crucial in detecting cattle’s behaviour on the spot. Delay of this might result in a slightly non-satisfied condition. This could be even better if the data rate collection for cattle’s movement be lesser than 0.1 seconds as to increase the sharpness in accuracy. On the other hand, vineyard, potato and tomato do not have a very frequent data sampling rate and ranging from 5 minutes to 10 minutes. This is because, majority of the parameters sensed are based on temperature and humidity in air or grounds which are not an instance changes in value but takes time. Hence, it purposely be adjusted into minutes as it can be further saving the power of the batteries used and able to prolong the usage of the batteries’ energy sufficiently in a completed one cycle activity. Cattle's accelerometer data sample might put in the high energy consumption rate category, however, accuracy of the data is far important than the batteries' durability.

Furthermore, in power saving method, sensors used in vineyard monitoring have an additional better approach. During the data transfer, sensor nodes will synchronize themselves before sending data, and these nodes have been configured so that the nodes will go to the sleep mode right after the active period in data transfer. These sleeping nodes will be reawakening at the appropriate time as to take the next measurement. By using this method, further energy can be saved and hence possible either to preserve the so call extra energy in other sensing use for example on-live camera monitoring. However, the conversion from the active mode into sleep and reawaken mode will consume high power consumption in the case. So if the planning is not adequate enough, such as reawakening the node every single minutes or lesser, the power in restarting the nodes will definitely over the unexpected value and therefore not an efficient design. In other case like the delta encoding used in the potato farm, it is another good idea to save the average energy consumption. Delta encoding is eventually reducing the size of the data transfer and hence lesser power can be used to perform.

From the topologies taken by those applications, majority such as vineyard, potato and tomato are using grid pattern topology in deploying the sensor nodes. Fish farm will have some difference in where using classical tree configuration while cattle's are respectively installed on each cattle's neck in mobile state. Based on these differences, grid topology would perform the best result as the each micro-area can be evenly monitored. Besides, the data transmission is done evenly between the nodes and consume approximate the same energy level. Instead of random deployment would result in some nodes getting died off first due to uneven longer range of data transmission than others. This is same either if the sensor nodes are deployed in mobile state. Mobile nodes will usually be used in moving object such as cattle, sheep and so on for their health monitoring and seldom be seen using in crops lands. Since it nodes is freely moving, hence the probability for some of the nodes to be further way from either the neighbour or base-station (for direct data sending to base) will be very high. This is very power-wasting and better energy saving method shall be implemented. Meanwhile, classical tree topology might not cover the whole or specific area in overall, instead it only able to monitored certain part of the area where sensors being deployed. For this case, the so call micro-area changes will not be accurately measured in overall average.

2.8 Summary

Wireless sensor network term can be separated into wireless and sensor network. From the analysis did, the use of the wireless is because of the simplicity if compared to wire. Hence, wireless is much cost effective and no longer has messy cabling installation. Thus, risk in bus connection inside sensor node can be eliminated if wireless is in used. Flexibility of the wireless network is much encouraging especially the data multihopping style which is much suitable for wirelessly transmission. Meanwhile, Zigbee is significantly being chosen as the wireless device because of its fascinating features especially the number of node size and the batteries life duration. In the sensor network, features of it such as frequency used, data sampling rate and so on are very crucial in determining the accuracy of the data being receive. For example, higher frequency tends to transmit shorter in range, but it is not as susceptible to environment noise as lower frequency transmission. Furthermore, energy saving method has been discussed either on batteries power saving. In future or even current researches have been designing some wonderful of power usage method for example using solar panel to overtake the batteries usage so that the power will no longer die off but better care need to be consider such as the operational time especially in night where solar power is not applied.

3.0 Research Method and Development Tools

3.1 Research Methodology

This project is related to study, design, develop and utilize the WSN through implementing the sensor network devices and its software. A lot of studies and researches need to be done on how to make the sensor network to perform better through several of methods. Hardware components dominance in this project is from different categories, so further understanding on several of available hardware components can help to strengthen the research and studies. As for software part, a deeper review of the particular programming language is needed in order to build an efficient communicable programming.

3.1.1 Development tools

Several hardware has been taken into consideration such as:

- Computer with specific or least requirements as shown:
  - Processor: 1.6GHz in Windows XP or 2.4GHz in Window 7 machine
  - Disk Space: At least 15GB of free disk space
  - RAM: 1.0GB of available physical RAM
- Minumum of 9 MICAz
  - Microcontroller – radio platform, able to do self-organizing, data sent in multi-hop fashion. Using 2.4GHz frequency band.
- 1 sink node which consist of 1 MICAz and 1 MIB520.
- 1 USB cable with approximate 2 meters long for computer and sink node connection.
- Minimum of 18 AA batteries.
- Minimum of 9 sensor boards (sense temperature, humidity, etc.)

Several software that will be running on this project development are:

- Windows XP/ Window 7 Operating System
- MySQL Server 2008 as Database System software
- Java Development toolkit to implement simple interfaces on user computer
- TinyOS as the Operating System for Sensor Node

3.1.2 Project design:

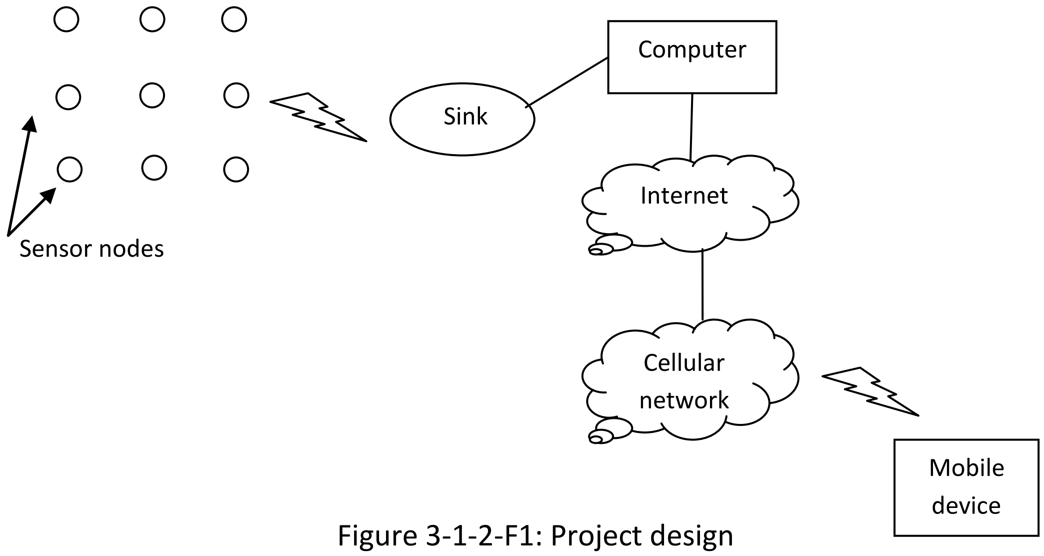


Figure 3-1-2-F1: Project design

In this project design, only implementation of the wireless sensor network is the main purpose here. Simple interfacing in the computer and the database system is not much of the concern.

Based on the comparison done in previous chapter, sensor node will be choosing ZigBee as the wireless device. The main idea in this project is to monitor crops growth and hence static form of sensor is needed. Since it is static, Grid topology with 9 sensors would be the best pattern just enough for this project. Grid pattern topology is in used so that the durability of batteries on each can be maintained equally. Meanwhile, 2.4GHz frequency range will be chosen here since it is license-free, for instance, shorter distance in data transmission would be the best as the area in land size is not few acres wide, thus enable it reduces the environment interference. Interference with Wi-Fi is not much the problem because Wi-Fi usage in Malaysia has not reached national wide yet. But, this is still the existing problem that needs to be overcome.

Moreover, humidity and temperature will be the main parameters that need to be sensed, therefore, its data sampling rate can be adjusted not less than 3 minutes and allows it to go into sleep mode and reawaken mode in time, and still able to preserve energy in average.

3.2 System Development Life Cycle

The systems development life cycle (SDLC) is a conceptual model used in project management that describes the stages involved in an information system development project, from an initial feasibility study through maintenance of the completed application. Various SDLC methodologies have been developed to guide the processes involved, including the waterfall model (which was the original SDLC method); rapid application development (RAD); prototyping; phased development; the fountain model; the spiral model; build and fix; and so on (Systems Development Life Cycle, 2010).

Often, several models are combined into some sort of hybrid methodology. Some methods work better for specific types of projects, but in the final analysis, the most important factor for the success of a project may be how closely the particular plan was followed.

Commonly known development phases in SDLC are:

- **Planning**. It is the process of understanding why the system should be built and defining its requirements. It also includes feasibility study from several different perspectives, technical, economic, and organization feasibility aspects.
- **Analysis**. This phase includes activities such as problems identifying and analysis, and even predicting potential problems that may arise in the future regarding the system. The deliverables / products of this phase will drive how the system will be built and guide the developers' works.
- **Design**. System analysis leads to design decision, which exactly determines how the system operates in terms of process, data, hardware, network infrastructures, user interface, and other important factors in the system environment.
- **Implementation**. This is probably the most resource, cost, and time-consuming phase of all. This is when the system is actually built, tested, and finally installed. It also includes activities such as user training and system maintenance. Some experts like to separate them into different phases **Deployment** and **Maintenance**. However the four phases are the most

commonly known and accepted steps (System Development Life Cycle (SDLC) Methodologies, 2008).

3.2.1 Systems Development Life Cycle Models

In this section, 3 models of Waterfall development, Prototyping model and V-model will be discussed and a better selection from them will be chosen to be used in this project planning and implementation.

3.2.1.1 Waterfall Model

The Waterfall Model is the oldest and most well-known SDLC model. The distinctive feature of the Waterfall model is its sequential step-by-step process from requirements analysis to maintenance. Figure 3-2-1-1-F1 below will show the diagram of the traditional waterfall design steps.

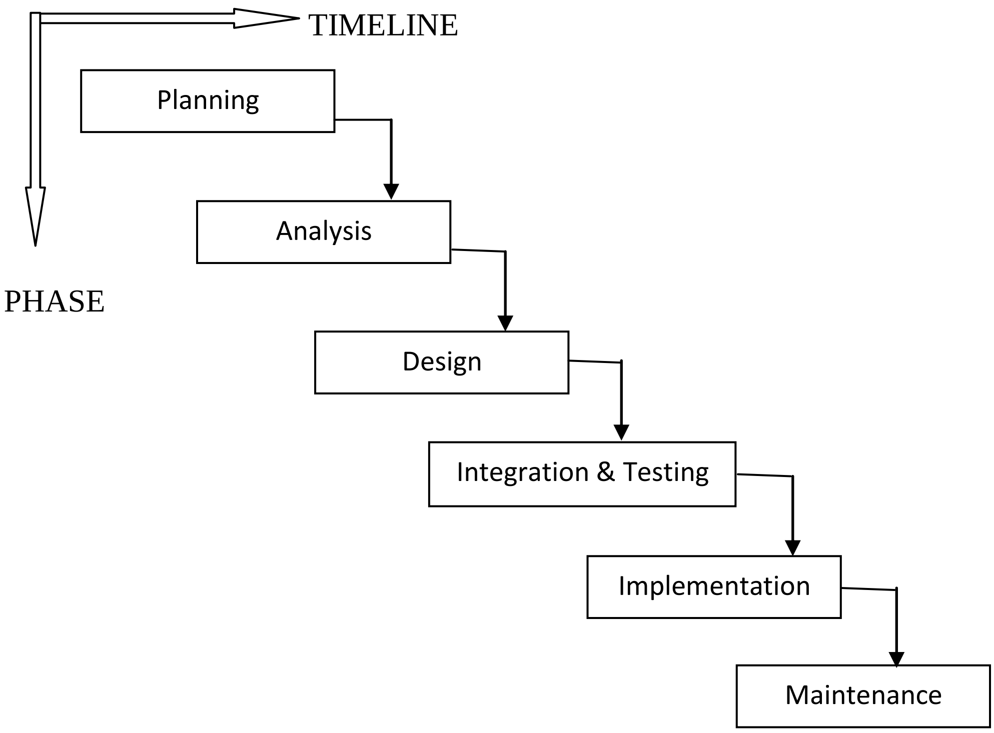


Figure3-2-1-1-F1: Waterfall model

Meanwhile, advantages and disadvantages do exist in this model, and these will be illustrated in the table 3-2-1-1-T1 below.

Advantages	Disadvantages
It allows users to compartmentalize the life cycle into various phases, which allows users to plan the resources and effort required through the development process.	Users do not see a working version of the software until late in the life cycle. For this reason, Users can fail to detect problems until the system testing phase. Problems may be more costly to fix in this phase than they would have been earlier in the life cycle.
It enforces testing in every stage in the form of reviews and unit testing. User conducts design reviews, code reviews, unit testing, and integration testing during the stages of the life cycle.	The lack of ability to go backwards of the development phases makes this methodology unaccommodateable.
It allows users to set expectations for deliverables after each phase.	

Table 3-2-1-1-T1: Advantage and disadvantage of Waterfall model.

3.2.1.2 Prototyping Model

This methodology used usually when the process is likely to be changed as the project proceeds or when the project sponsor has little idea of what system to be built. The Analysis, Design, and Implementation phases performed concurrently and on each cycle resulting in a “system prototype” that will be reviewed by the project sponsor. The cycle repeated continually based on the sponsor comments until the prototype successfully meets the requirements. The last prototype will then be called the product. Prototyping development needs only initial basic analysis and design, but as the result important system functions may not be recognized until somewhere in the middle of project timeline. Thus there is a possibility to alter the initial design decision and start all over again from the beginning. It can delivers system quickly to users, though it not exactly meets the requirements. Table 3-2-1-2-T1 will show the advantage and disadvantage of this model in short.

Advantages	Disadvantages
It allows users to start with requirements that are not clearly defined.	It can lead to poorly designed systems. The prototypes are usually built without regard to how they might be used later, so attempts to reuse them may result in inefficient systems.

Table 3-2-1-2-T1: Advantage and disadvantage of Prototyping model.

3.2.1.3 V-model

The Verification and Validation model commonly known as V Model is considered to be an extension of the Waterfall model. This is because just like the waterfall model, it's a well-structured method in which the different phases progress in a sequential or linear way. That means each phase begins only after the completion of the previous phase. Figure 3-2-1-3-F1 shows the diagram of it model and table 3-2-1-3-T1 shows the advantage and disadvantage of this model.

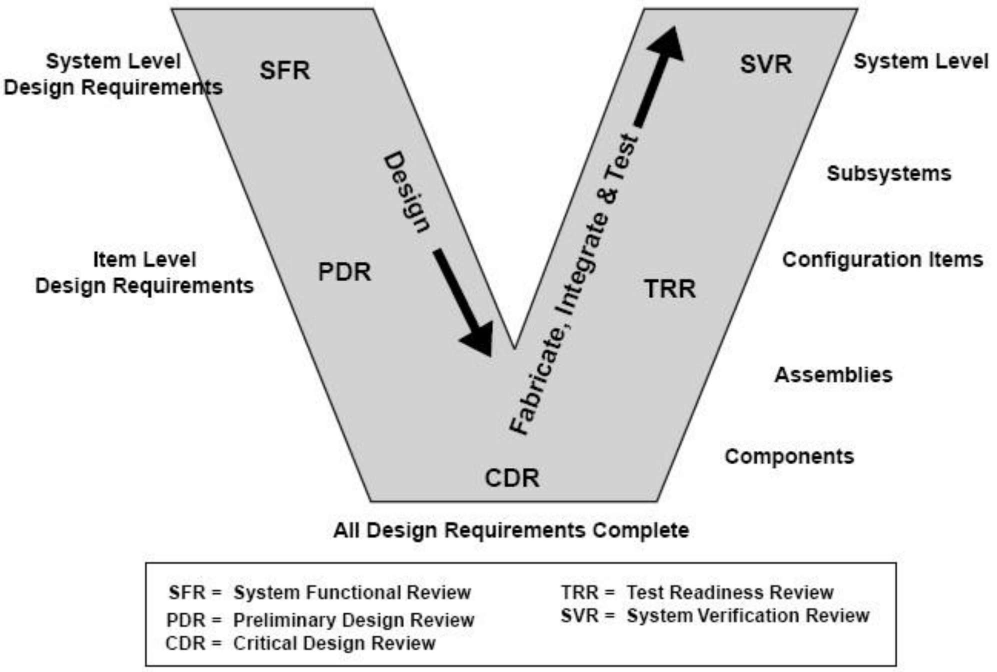


Figure 3-2-1-3-F1: V-model

Advantage	Disadvantage
it saves ample amount of time and since the testing team is involved early on, they develop a very good understanding of the project at the very beginning.	It is very rigid and the least flexible. If any changes happen mid-way, not only the requirements documents but also the test documentation needs to be updated

Table 3-2-1-3-T1: Advantage and disadvantage of V-model.

3.2.2 The project design of the relevant SDLC model

Throughout the models shown in the previous sub chapter, it has been found that the hybrid of the waterfall model and the prototyping is eventually a better model solution. This is because the disadvantage in prototyping model which lead to a poorly designed systems has been eliminated by the advantages of the waterfall model. Waterfall model allows users to compartmentalize the life cycle into various phases, which allows users to plan the resources and effort required through the development process, has successfully worked with the weakness of prototyping. Its own drawbacks as well being eliminated by the advantage of prototyping. Figure 3-2-2-F1 below shows the diagram of the hybrid waterfall-prototyping model.

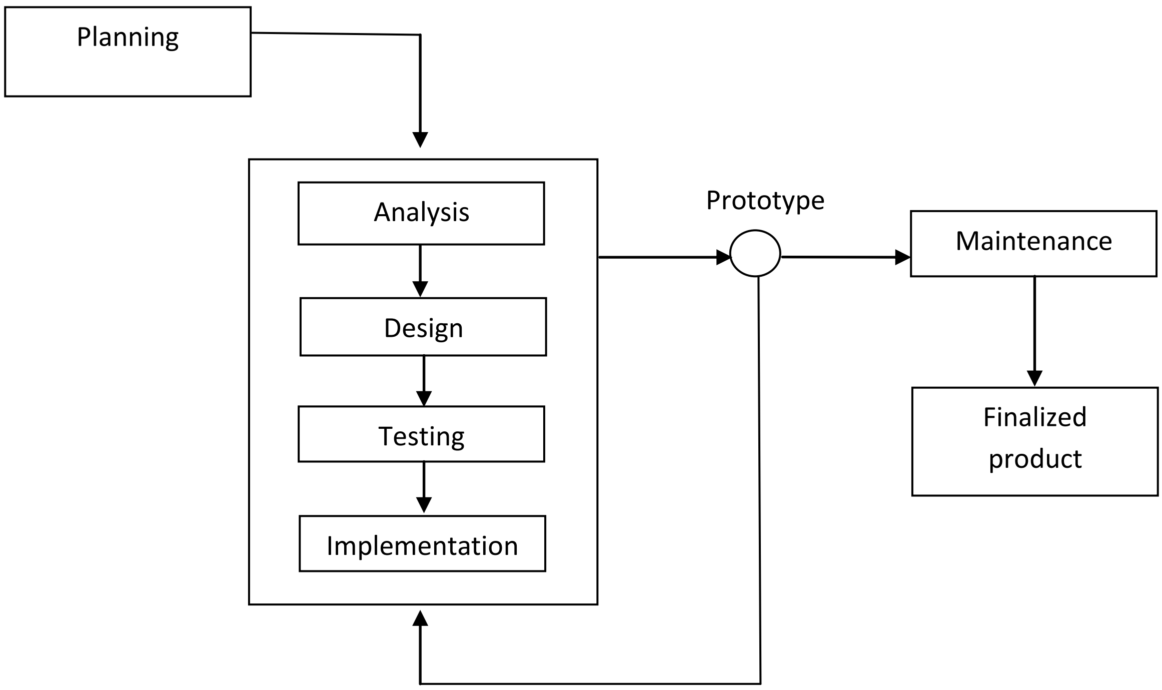


Figure 3-2-2-F1: Hybrid waterfall-prototyping model

3.3 Development Phases

3.3.1 Planning:

First and foremost, related projects and articles are reviewed. Identifying problem statements which will give a better understanding on the existing problems faced by the world. For instance, identify the objectives which lead to this project main purpose and to achieve it at the end. Collecting the sufficient information such as journals and articles wrote by experts from the entire world is very crucial to the start of this project. Meanwhile, time frames and budget planning would be either important as it can allow user or sponsor to have clear idea on what the project designer needs. Besides, a good planning of work will provide a better punctuality and confident and able to prevent from having a “feature creep” situation. Feature creep is the overwhelming project which includes unnecessary fancy features that will only burden up the implementation load and subsequently delaying the actual due date.

3.3.2 Analysis:

This phase is about the beginning of the project prototyping analysis. And hence, many thorough researches need to be performed to get known of the existing applications, or even some ideas from experts. This is just to prevent some unnecessary and full with disadvantages systems or technologies being implemented. Therefore, this phase is very crucial to assist project designer himself in choosing a right and useful “gadget” to perform the desirable project. So, pros and cons of each existing applications will be defined as to make sure the pre-design steps is worth to be done. Furthermore, a good development model in developing and act as guideline to this project is evenly useful to enhance the feasibility of the accuracy in the analysis phase. For example, hybrid of waterfall-prototyping has given user a perfect and adequate model planning and able to perform try and error process either due to the minor mistake did in the planning part or some unpredictable changes such as system failure.

3.3.3 Design:

In this phase, every single detail from analysis phase will be accommodated in and actual and worthy project design will be done. By eliminating the disadvantages in the existing applications, benefits from each are likely to be selected and hence being utilized in this design. The design must be useful and full filled the good requirements that are stated such as correct, verifiable, consistent, modifiable, and traceable and so on. The design of this project as illustrated in chapter 2 utilizes the benefits of each of the features hence considerate on the every aspect without blindly and inadequately follows the others.

3.3.4 Testing and implementation:

Testing and implementation, or debug on the project is highly encouraging because a system will only be done if the designed functions are perfectly worked. If any problem encountered, refer to back to the hybrid model in where backward checking start from the analysis will be taken action to find out the actual “bug”.

3.3.5 Maintaining the system functionality

Enhancement is one of the main topics here after it is error free and works properly. The hardware and software will be adjusted or able to be upgrading according to the current constraint. After that, a final test is carried out to examine on the overall project and debugging will be performed repeatedly to ensure the entire system is working in the desirable manner and free from error.

3.4 Project activities and milestones

Project Activities	**Jun,2010**				**Jul,2010**				**Aug,2010**				**Sept,2010**				**Oct,2010**			
Gather research & Literature Review	■	■ DONE	■	■	■															
Identify development tools and report writing				■	■	■ DONE	■	■	■	■										
Familiarize with the hardware														■	■	■	■	■		
Familiarize with the development software														■	■	■	■	■	■	■
Implementing and testing the WSN																				
Validation and Verification																				

Project Activities	**Nov,2010**				**Dec,2011**				**Jan,2011**				**Feb,2011**				**Mar,2011**			
Gather research & Literature Review																				
Identify development tools and report writing																				
Familiarize with the hardware																				
Familiarize with the development software	■	■	■	■	■															
Implementing and testing the WSN	■	■	■	■	■	■	■	■	■	■	■	■	■							
Validation and Verification														■	■	■	■	■	■	■

Table 3-4-T1: Gantt chart of work progress

- The marked column with black indicates the work to be done.

The schedule is very important in order to do a project because it defines a time limit for project designer to achieve his goal. A specific timeline should be clearly defined in order to precede the work efficiently. The deliveries of each phase should be done whenever there is a check point. It able to minimize the risks only if the progress is in planned.

As shown in the Gantt chart, the work of gathering and literature review should be done in the corresponding time frames as to achieve the effectiveness in the current progress. Project designer should follow the phases and the predicted time to complete up the planned project. For example here, 10 months has been in plan by having the first 3 months in doing the researches, analysis and design starting from June 2010. The remaining months as in September and October are mainly due with the familiarizing of the hardware and software needed and able to do some practises of it before starting the actual implementation. Meanwhile, the actual implementation will be started around the November and predicted to be finished in 3 months. And last, validation and verification of the project shall be started around February 2011. Debugging process will be done from November 2010 until the validation has been made.

3.5 Cost and Budget

Tools	Cost (Quantity)
MICAz nodes	-
Sensor board	-
AA Battery	-
USB cable (2m)	-

All the hardware needed is eventually provided. This will be much easier for this project to be started without any hindrance from the very first. Besides hardware, software support can be obtained freely either.

3.6 Conclusion

The only major risk of this project is the time constraint, so a proper timetable if possible with extra slots for each progress is strongly encouraging. Appropriate time buffers must be defined in the planning process to over uncertain and accidental issues such as sudden break down of the machine. SDLC model is especially good in producing a better idea of the process flow as both the designer and company could able to understand the time limit taken as well as the over requirement needed.

4.0 System Design

4.1 Network Architecture

Once the MicaZ units have been configured with software and external sensors (the sensor board), it will need to build an infrastructure to support them. Without a human interface, there is no way for the data collected by the sensors to be used. The purpose of this infrastructure is to provide a method for transporting event data from the sensor network to a human-readable form. To accomplish this, a design has been proposed in the following.

4.1.1 System Overview

To aid in the explanation of the infrastructure, it has included an overall system diagram, shown in Figure 4-1-1-F1.

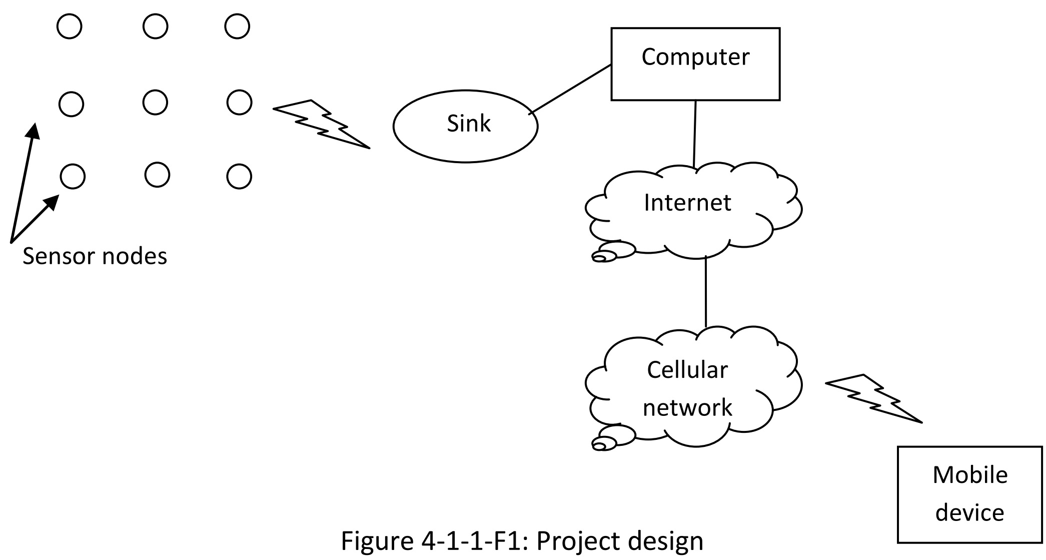


Figure 4-1-1-F1: Project design

This diagram shows the interactions between each major component in the system. Beginning with the network of sensors, information travels to the base station through the sink node. Once the data has been parsed by the base station, it is sent to the database. Finally, users are able to view the status of the sensor network by using an application that queries event information from the data storage.

4.1.2 Base Station

By necessity, the base station will be a computer connected to the network sink node, the node to which all other nodes will be programmed to send their packets. This base node will need to parse sensor data, and format the data for transmission into an appropriate storage medium.

4.1.3 Data Storage

For effective implementation of the sensor network, it requires a centralized storage mechanism allowing for multiple concurrent clients reading and modifying the system at a given time. This storage mechanism must be able to hold the readings of an arbitrarily large number of sensor nodes, effectively organizing it for efficient read and write access. However, too complicated way of doing will not be discussed here.

4.1.4 User Interface

Given that at this point, all of the information will be housed in a central medium, it requires an appropriate user interface (GUI) to parse and display this data in a user-friendly manner. At the minimum, this interface needs to display the current status of each node, along with a description of past node readings.

4.1.5 Overall Requirements

The wireless sensor network must sense and detect the temperature and others of the surrounding environment. To this end, the nodes have to collect pertinent data from the available sensors, which include temperature and light intensity sensing, in order to not just only ensure that temperature will be sensed, but also to verify the current light intensity since certain plants are sensitive to the radiation of the strong light density. Of course, if to make it even better, camera or other sensors such as humidity sensor can be considered applied into, but it will not be discussed here. This cohesive application will show that wireless sensor networks are not only a viable new technology, but also that they can form a good, cohesive solution for today's real-world problems.

4.2 Flow chart of Wireless Sensors Network

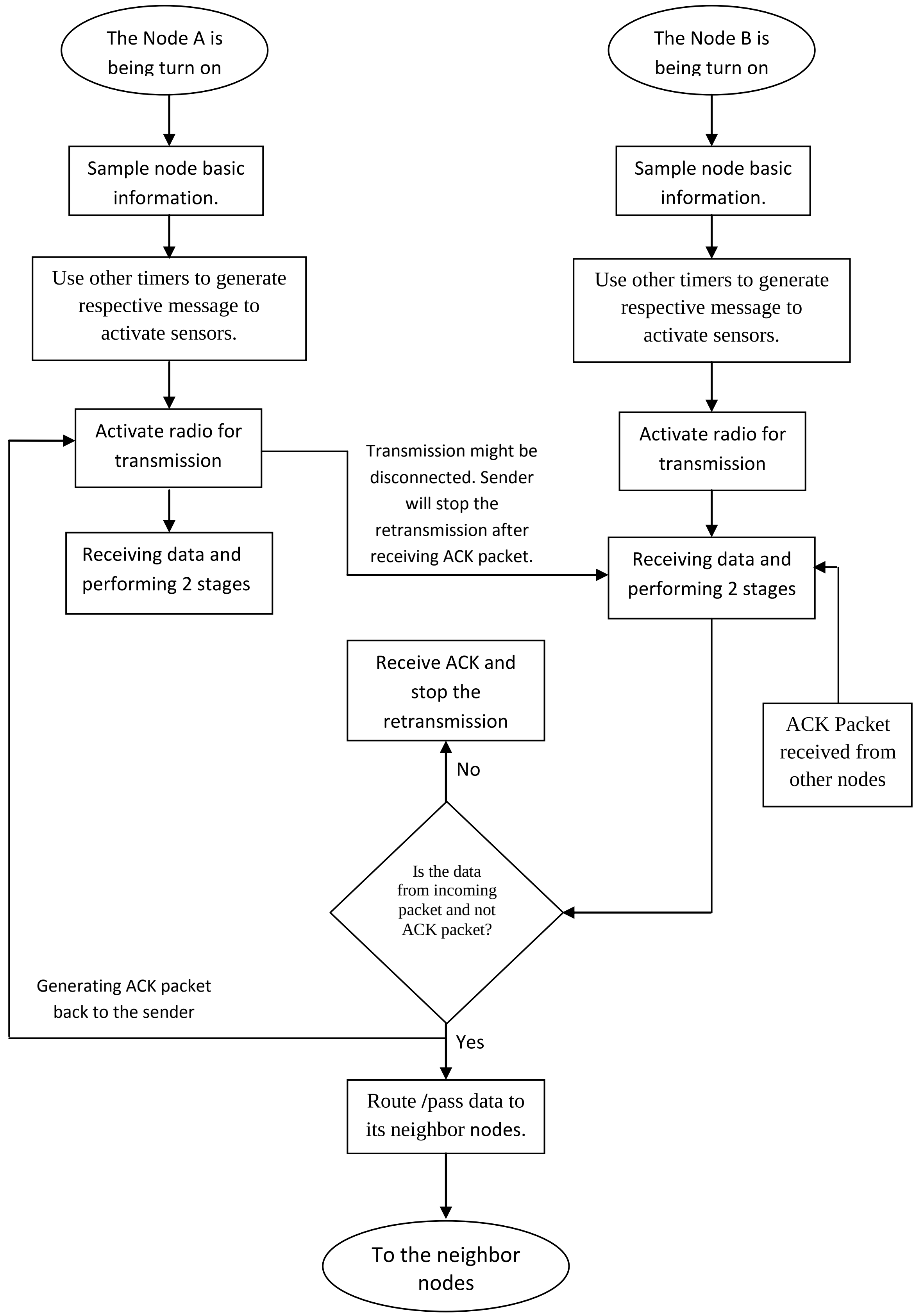


Figure 4-2-F1: Flow chart of node

From the figure above, it shows the very brief explanation of the system flow in the sensor nodes themselves, meanwhile there will be even more detailed checking which is not clearly defined in the chart but will be explained in the following including another add-on of flow diagram of the respective fragment. Also, the above idea is based on the absolute transmission in where no packet lost is determined. Whereas in the actual decision, packet lost will definitely happen once awhile or in long duration even in an absolute perfect system. However, ACK checking is the advanced configuration that will not be implemented here, but will be discussed.

From the beginning, every node (device) will be powered on by supplying two 1.5volt batteries. After that, nodes will respectively collecting their own information (after the nodes have been programmed). One task can be performed in a process and if another task need to be activated, interrupt is impossible to be done here as it will straight away stop the first process and continue the second. Here, "atomic" has been used to create a non-interruptible process which will definitely complete its process without having any halt except processor failure or power down. The first task will handle the basic information such as the node ID, node packet ID, the RSSI value (transmission power figure), current battery power level, and as well the current time and date to be captured. After that, it will handle the sensor value from its sensors. Over here, ADC circuit will be implemented and 6 available sensors type can be performed concurrently. After the task finish collecting their respective information, data will be sent to the neighbors' nodes for data passing (this forwarding technique also called routing).

Besides, second task has been assigned specially to encounter the packet lost issue. So, the 'task' mentioned is actually the call function in this tinyOS program using NesC programming language. So, it uses call Timer.startPeriodic() or Timer.startOneShot() which will be used in the program to activate the timer and Timer.fired() will be activated to launch the task after certain of period. So, the second task as mentioned is very important to check the packet condition and able to resend once lost. However, if the packets loss too long, there is no packet recovery can be done here. The fragmented flow chart below will explain how it works when packet is lost and what will happen once timeout after several resend.

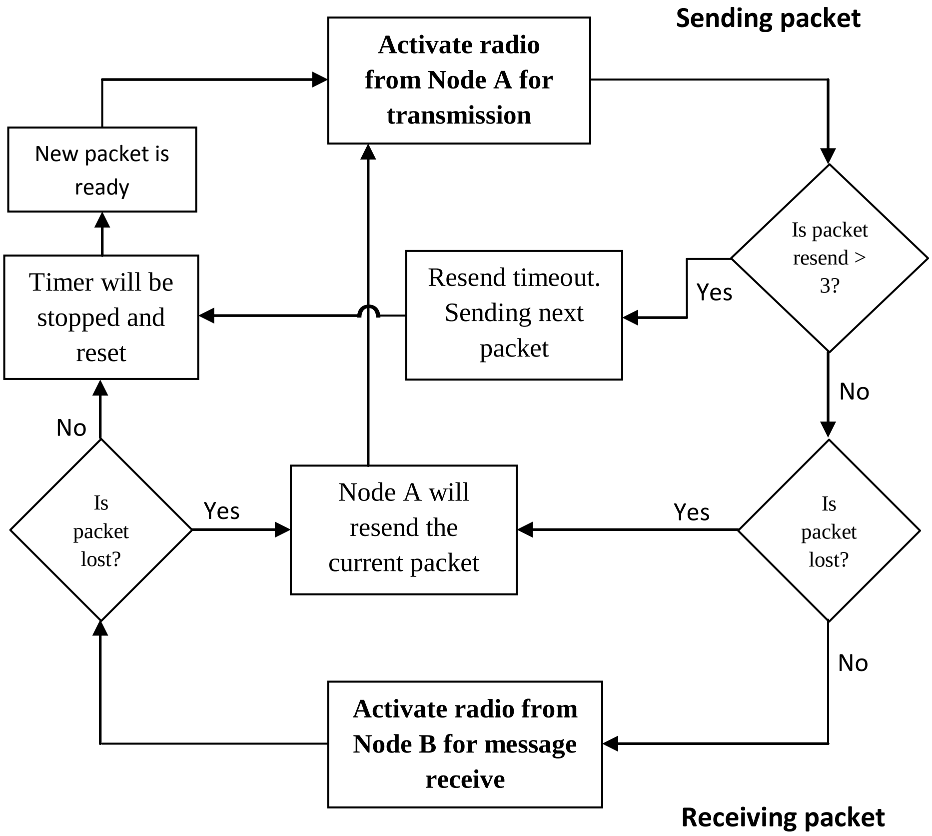


Figure 4-2-F2: Fragment of part where packet sent and received.

At first, one or multiple node will actively send their packets once being activated. So, the receiving node(s) will be trying to receive the sent packet. In the Figure 4-2-F2, two situations would happen when packet is resent; the first one is, when Node A sends the packet and the packet lost in the middle. So, no ACK returned for sure. Secondly, Node B received the packet and generate the ACK message but lost in the way transmitting to Node A. This is another way the ACK cannot be received by Node A. These both cases will result in Node A to resend the packet in a giving condition limit. In the figure above, it will only resend for 3 times and afterwards it will timeout and next packet will be sent now instead of pending on a packet for so long. Also, the retransmitting time must be smaller than the interval of 2 continuous transmission times depend on how many resend packets are involved. However, the retransmission time is better not more than 250 milliseconds because it should not take much time as the receiver might urgently need the corresponding data. If for testing purpose, it is encouraged to enlarge the time to seconds as developer can see the significant changes of the result.

Once the data has been sent, the sender will eventually wait for the ACK packet reply and sender can perform particularly with what it should do either resend it or stop the timer. Timer in the sender side will be stopped and reset whenever after the 3 times retries. Besides, when the sender successfully receives the ACK message, it will reset and stop the timer too. Reset is rather important here or else it will affect the counting.

By default, for the ADC circuit, if 2 sensors that are using the same pin for sensor activation (such as temperature and light intensity sensors), it cannot be on concurrently. One pin must be shutting down before turning on another one. So, 2 of the sensors must be activated differently as to capture both of the sensing data. The table of the Pin connection will be shown in the Figure 4-2-F3 and Figure 4-2-F4 shows the example of the sensor board and its pin condition. But in this project, only one sensor is used which is the ADC1 for temperature capturing.

	A	B	C	D	E	F
1	GND	GND	GND	VCC	VCC	VCC
2	OPEN	OPEN	USART1_CK	INT3	ADC2	PW0
3	OPEN	OPEN	UART0_RX	INT2^{+}	ADC1^{+}	PW1^{+}
4	OPEN	OPEN	UART0_TX	INT1	ADC0^{+}	PW2
5	OPEN	OPEN	SPI_SCK	INT0	THERM_PWR	PW3
6	OPEN	OPEN	USART1_RX	BAT_MON	THRU1	PW4
7	OPEN	OPEN	USART1_TX	LED3	THRU2	PW5
8	OPEN	OPEN	I2C_CLK	LED2	THRU3	PW6
9	OPEN	OPEN	I2C_DATA	LED1	RSTN	ADC7
10	OPEN	OPEN	PWM0	RD	PWM1B	ADC6
11	OPEN	OPEN	PWM1A	WR	OPEN	ADC5
12	OPEN	OPEN	AC+	ALE	OPEN	ADC4
13	OPEN	OPEN	AC-	PW7	OPEN	ADC3
14	GND	GND	GND	VCC	VCC	VCC
15	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN
16	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN
17	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN

Figure 4-2-F3: Connection Table for MDA100.

Figure 4-2-F4: MDA 100CB sensor board

For sure, packet sent is eventually being routed to the next neighbors. Neighbors can be a lot as long as the sender node's transmission power is reaching the nodes around. Thus, packet will passed to the next and the next node will pass to the next and so on. However, because of same data re-routing will be happened amongst the nodes in every transmission period, it must be solved so data would not be looping amongst again. The fragmented flows below will show how the packet loops when no checking and with checking.

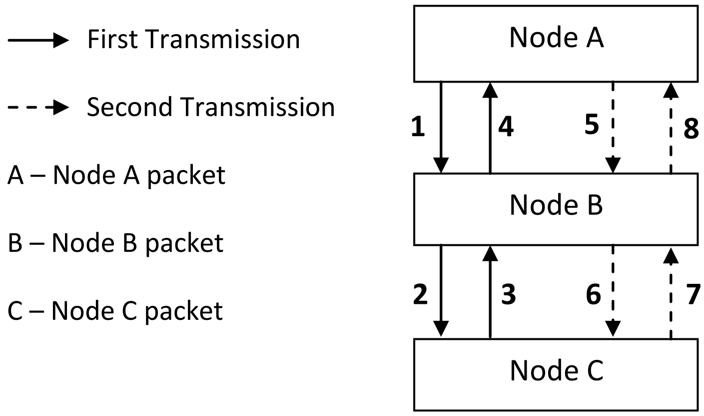


Figure 4-2-F5: The looping case when re-routing

Base on the figure above, it shows 2 transmission periods. 1, 2, 3, 4 are for the first transmission, while 5, 6, 7, 8 are the second transmission. In the first transmission, node A will send the packet to node B, so 1=A. And in Node B, it sends to Node C. 2=A, B. When node C send back to Node B, 3=A, B, C. And when node B broadcast again, 4=A, B, C, B. From this case, it is already redundant in certain packet. Therefore, it is not much efficient here. After first transmission ended, second transmission will eventually do the same thing as the previous mistake. As a result, packet loop does occur and quite serious if the one transmission period is very long. To overcome this, some checking need to be done correctly as shown.

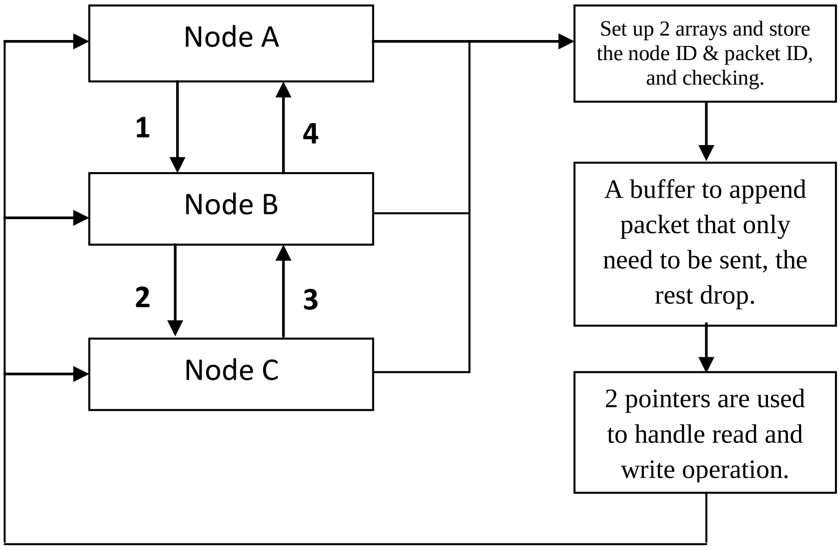


Figure 4-2-F6: The re-routing case with eliminated looping

From the figure above, it shows when either of the nodes receives the packet, it will go through the checking instead of just routing the packet to the neighbors. Hence, packet sent after received will no longer be redundant as it will keep comparing about the parameter until the second transmission happen. In the checking, it uses 2 arrays which to store node ID and packet ID. Whenever packet comes in, it will check the arrays for comparing. If node ID is differed, its node ID and packet ID will be written into. If node ID is same but differed in packet ID, only packet ID will be overwritten. If both the same, no action will be taken. When the node ID is able to be written into the arrays, the whole data structure of the packet contain will be stored into a buffer of certain size. The buffer will be treated as a circular buffer as it would save space of the RAM. After that, the packet stored will be one by one forwarding out to the next nodes by kept tracking of a read pointer. While a write pointer will be used to indicate whether the current buffer slot pointed is empty. If not, packet will be dropped either.

4.3 Flow chart of computer as sink's base station and link to database

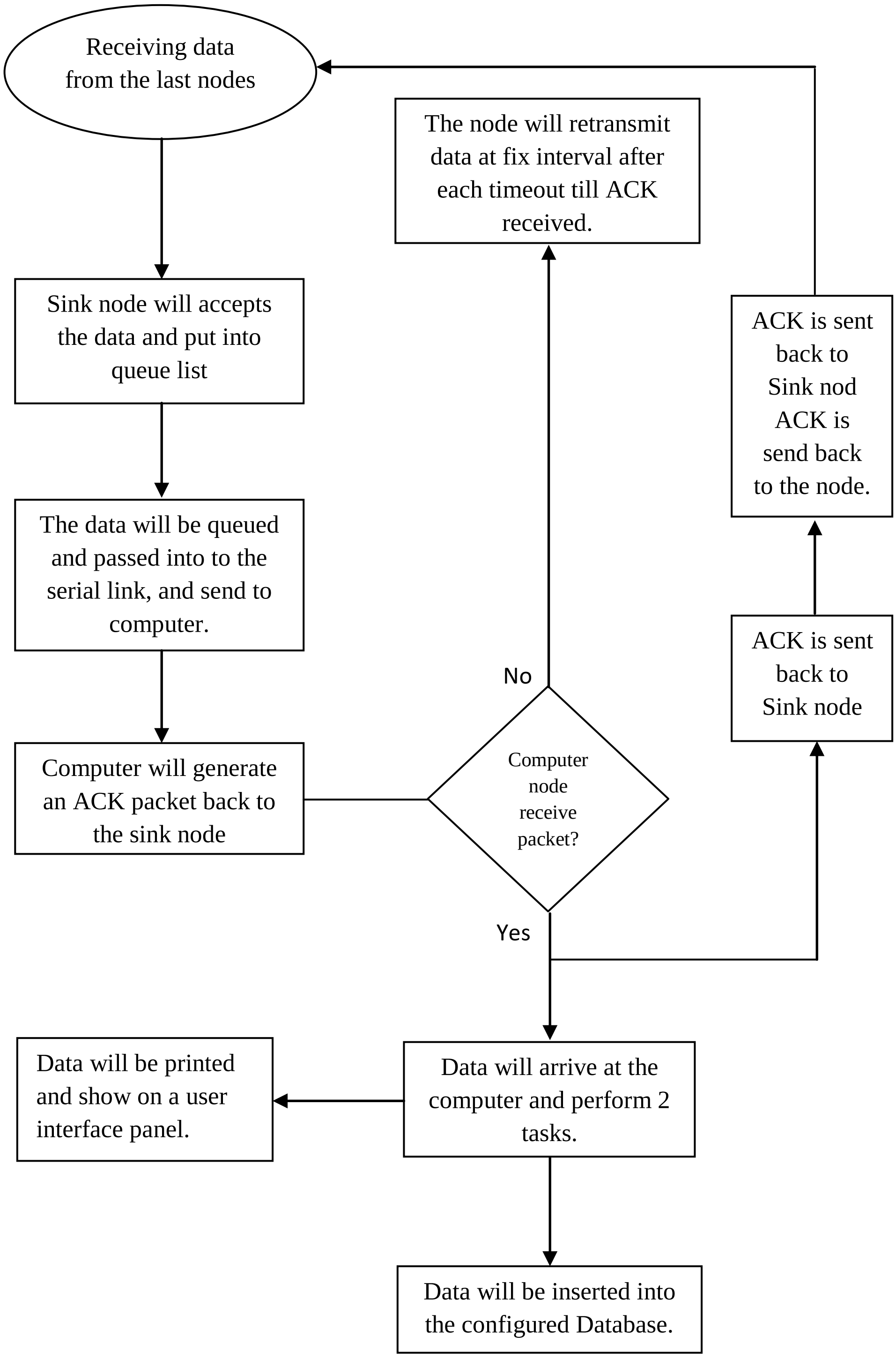
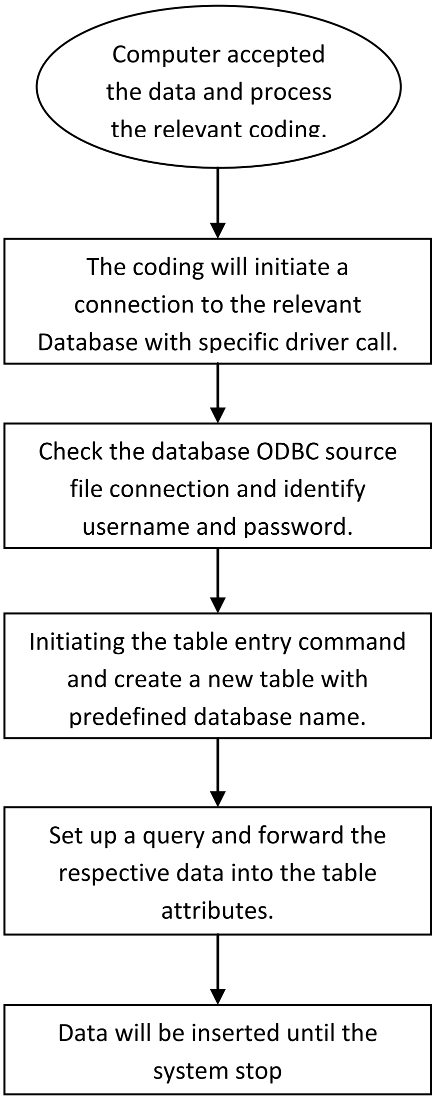


Figure 4-3-F1: Flow chart of base station and database

The packets will be sent, stamped and forwarded and at last will reach the base station, or named as sink node. Over the sink node, it will put those data into a queue and afterward forwarding to the computer for host checking. The computer will have a piece of programming that will receive the packets and send an ACK back to the sink node. Very brief, the computer will use a program named "Java" and perform 2 tasks. The first task is, able to print out the particular nodes information to the screen. Over, 2 platforms have been tried on which are Linux and Window, with both utilizing Java as Java is a platform independent program. For the second task, it only be done in window platform because it is dealing with database storage feature. Once data arrive and ready, data will be push into the simple database and can be seen in the database client terminal. If a special GUI for mysql is used, user can as well view the database in GUI form instead of browsing through sql command prompt.

As for the database part, a flow chart will be described at the section 4.4. It is basically a part of the program code inside the Java Program. So, for more information on how to implement the mysql code in java, please take a view on section 5.2.4.

4.4 Flow chart of simple database setup and storage



5.0 Implementation and Testing

5.1 Basic introduction on software selection

In this project, several of software has been taking into consideration and only some of them have been selected. For example, Virtual Machine has been used and must be worked with the virtual operating system (OS) that consists of TinyOS embedded software. Over here, XubuntOS is one of the choices as it is an OS of ubuntu (Linux), which is programmed with TinyOS necessary software. TinyOS is eventually the OS for the MICAZ standard node and using nesC programming which needs Linux environment to compile the respective code, thus that is why XubuntOS is used. For instance, a dual OS can be installed too as one of it is assigned to Linux OS. In this case, more memory will be consumed and therefore is not a good choice unless a permanent usage of the Linux is needed.

Besides, there is software that can work in window platform and providing Linux environment, which is the Cygwin program. It is eventually a simple and easy command-prompts that allow user to code and compile it just like performing action exactly in Linux's Terminal. However, since Cygwin is not support so far in Window Vista and above, so only Virtual Machine is the most suitable selection. Meanwhile, some OS version would have supported different software and some might not work well in some window OS. Therefore, Virtual Machine Workstation has been installed in this project. However, Cygwin will be installed as well in other computer that supports window XP mainly for the use of GUI as it needs Cygwin certain library to execute.

Besides, Java and C sharp can be both used to produce a simple GUI, and Java is much preferred here since its syntax is more familiar with. So, Java will be used to produce a GUI and print out the respective value as to show the output. At the same time, a part of the Java code will perform the action by accessing into the database driver and enable it to be connected yet passing the data into the database. MySQL as the database will be chosen.

5.2 Basic introduction on software and hardware implementation

5.2.1 Virtual Machine and serial port implementation

At first, virtual machine is an important tool that needs to be installed before the configuration can be done. So, it is a necessity in this project. For instance, version of the Virtual machine need to be determined as some version is impossible to be supported in window vista and above. Over here, Virtual Machine Workstation 6.0 and above has been preferred as it work well in window vista. The icon shown will be the shortcut key right after the virtual machine has been successfully installed.

Figure 5-2-1-F1 Icon of the Virtual Machine WorkStation

Meanwhile, xubuntos as the operating system will be used inside the virtual machine. Whenever the xubuntos image was placed, click the "File->Open" then select the directory of the image located then activate it.

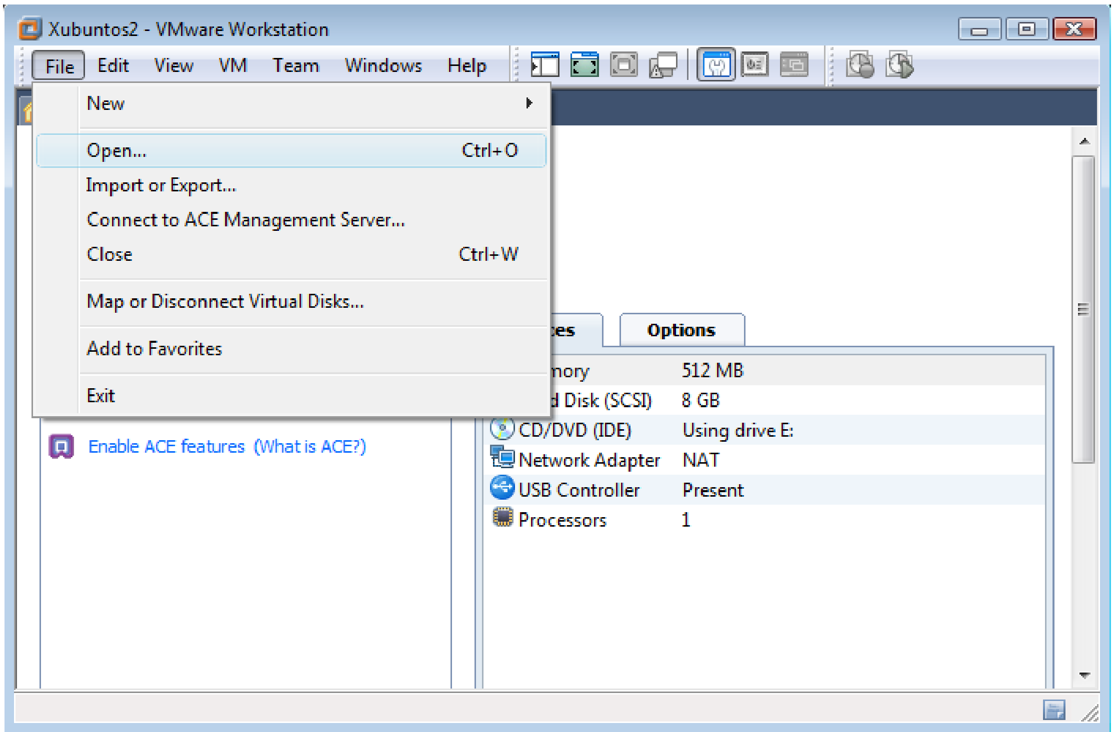


Figure 5-2-1-F2: Screen shot of location to include new image

After the image ready, it will be able to run the virtual OS. However, error opening might be happened and this case mostly because of the incompatible version or the directory path is wrong. If it is successful, it will be able to boot into the OS. Get it login and it is time to start working. Before that, let show an interface of the xubuntos.

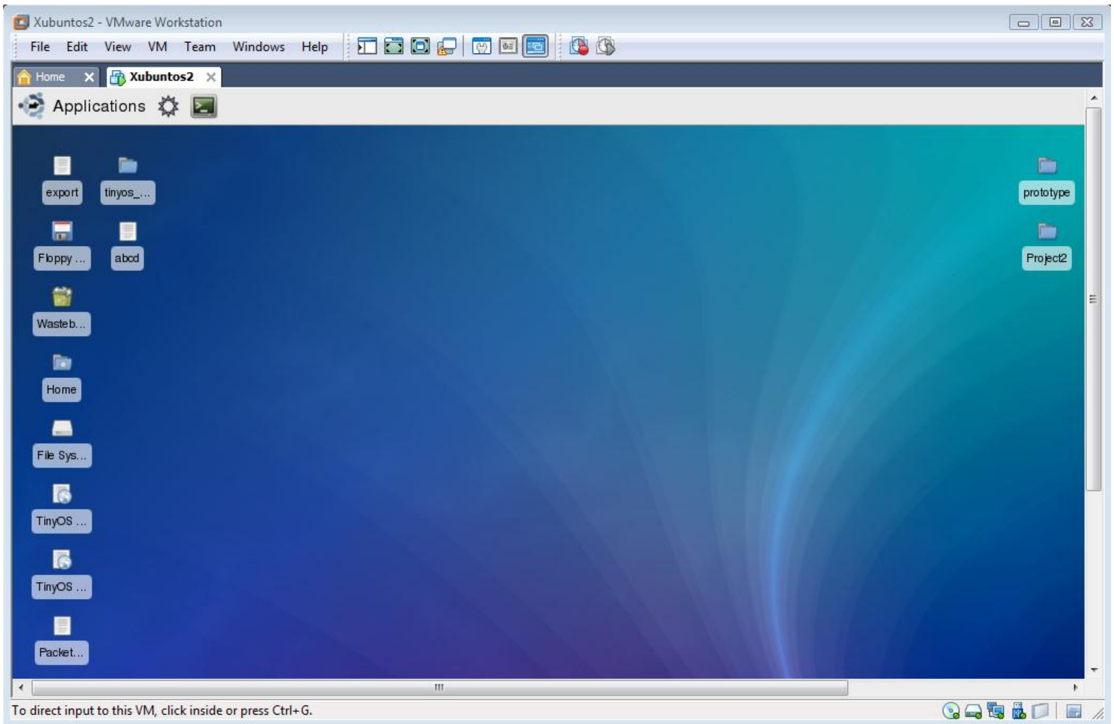


Figure 5-2-1-F3: The first page of the xubuntos

On the left corner upper part, that is an icon right beside an icon which beside the "Applications" tab. The icon is named as "Terminal" which is same meaning as command prompt in window. However, Linux Terminal is much powerful and supporting more commands. So, let click on the command and begin the work. Inside the terminal, a lot of commands can be executed such as "make", "make install", "cat" and so on. Even though, this will not be discussed here as it is the basic understanding of Linux command. For more information, please view http://www.ee.surrey.ac.uk/Teaching/Unix/. Since then, micaz nodes and the programming board will be in used. So, programming board will be connected to the computer through a USB cable. Of course, installation will be needed for the new device driver and the driver name is "MIB520 USB Driver". If the driver is unsuccessfully being installed, there will be no connection at all to the computer and hence nothing can be achieved.

The fully completed installation will show the following screen shots.

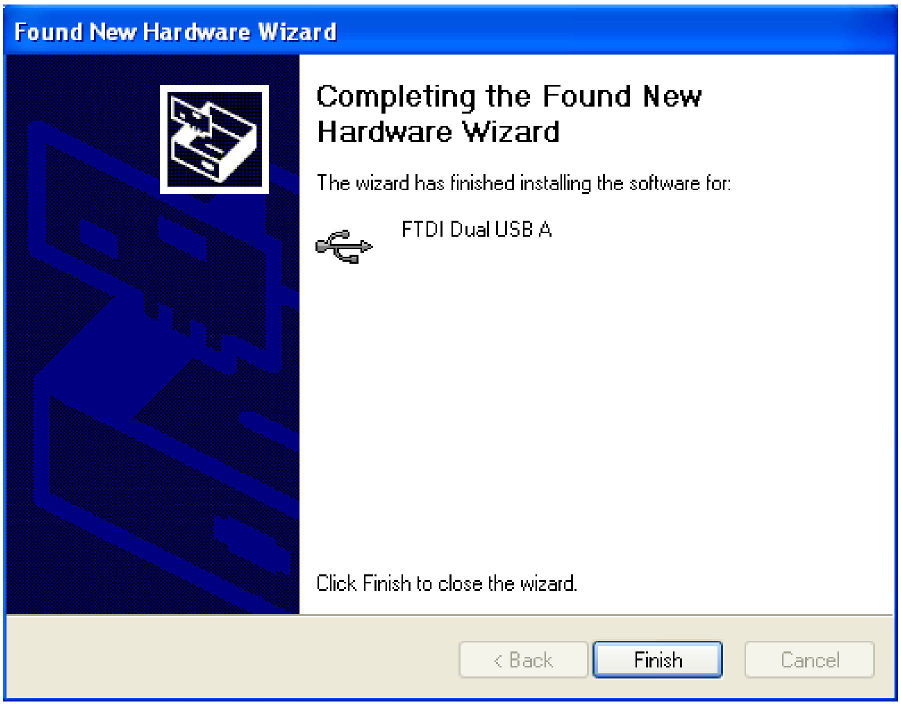


Figure 5-2-1-F4: The successful installation of first stage

Figure 5-2-1-F5: The successful installation of second stage

It must have 3 stages to be installed successfully as there are 2 communication ports in which the first port is for control base while the second port is for data transfer.

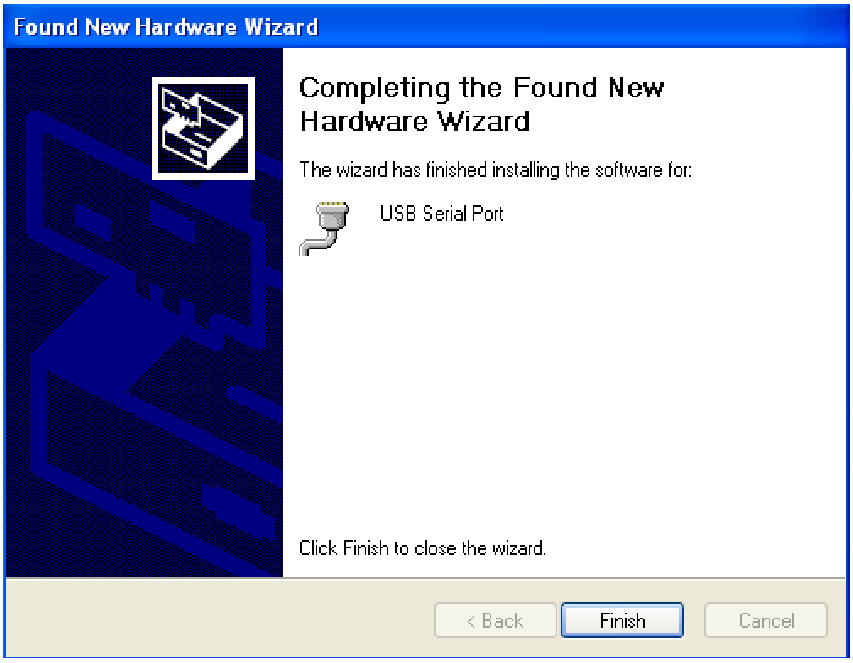


Figure 5-2-1-F6: The successful installation of third stage

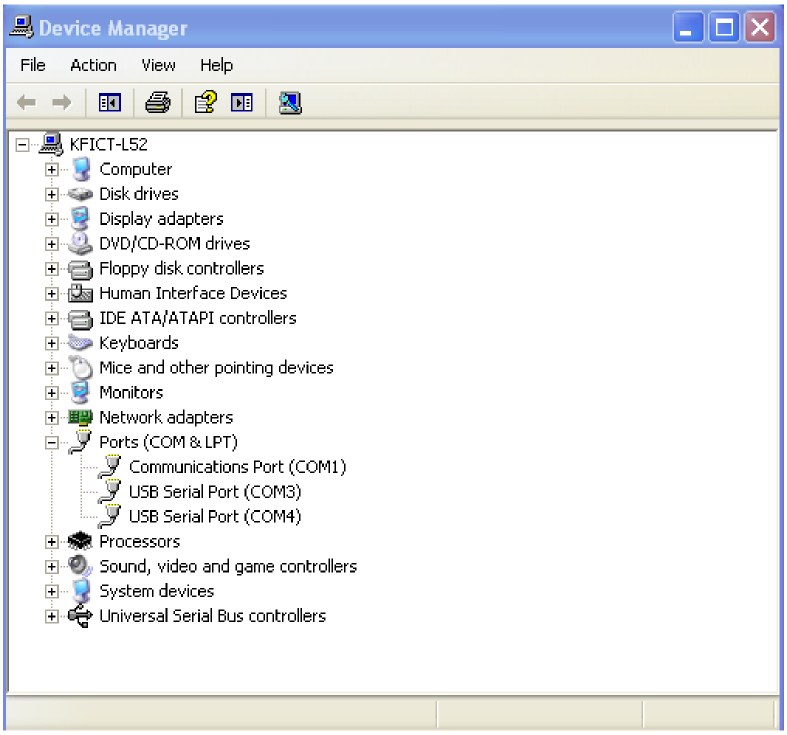


Figure 5-2-1-F7: 2 serial of the new COM ports

5.2.2 Configuration of micaz nodes and process

In general, creating a file to write can be done in 2 ways. First open up any word editor just to write or second execute the command in terminal. Once created, it is time to start building up the program as intended. In here, there are certain files which are a must for this project. They are the header file, node files, base station files and the last, the Java files. With these files exist, it will allow the most basic WSN project to be done. After the entire program has been configured, save the files and compile them respectively. Base station files are being compiled on base station node, while node file is configured on nodes which are just used to send and receive data. For instance, the header files are built because it is needed to be compiled with the java files as to show out the output stream. So, java file is used to execute print stream to the user output. To associate with java with the header file, a command “mig java –java-classname=PacketMsg PacketMsg.h PacketMsg –o PacketMsg.java” will be executed to compile a PacketMsg.java file. This is like a parent class which consists of “get” and “set” function inside. In this mig command above, PacketMsg.h will be the header file name.

When compiling a node, the command needed will be “make micaz install,1 mib510,/dev/ttyUSB0”. In this case, the 1 the node identification and the 1 is usually being assigned to base station node for better standardize configuration idea just like network id will usually get the very first IP while router will always use the IP from behind’s. “USB0” here simply meant the control line while USB1 means data line. During this compilation error might have occur in some unexpected way such as the figure shown below.

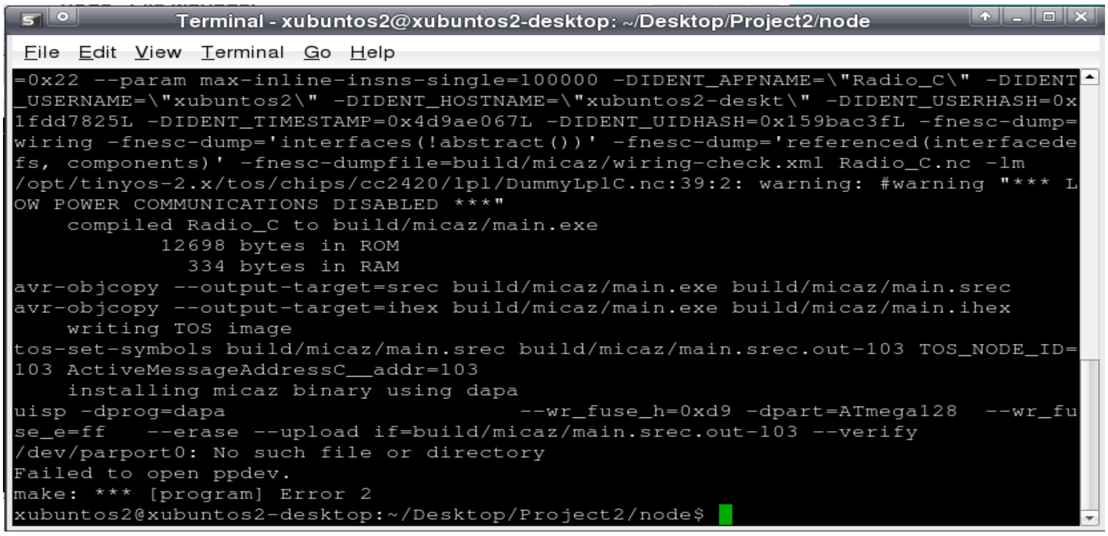


Figure 5-2-2-F1: Error in Compilation

From the figure above, it shows Error 2. This error basically is not the program or code error, but can due to 2 possibilities, which are command string error in way the command is typed incorrectly, or connectivity issue in where the programming board does not well fit with the node. These errors are easily to be traced and should not show any further corruption. This can be solved by recompiling again. Sometime, it is really troublesome when encounter the connectivity problem in such its error 2 still exist after several of retries. However, if error 1 is encountered, it is due to the code error.

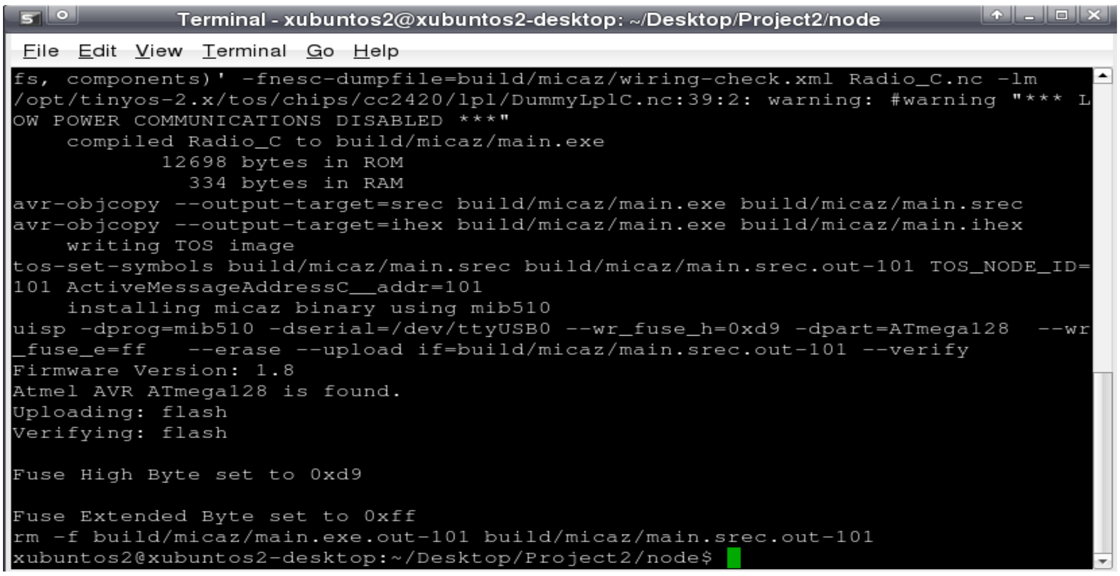


Figure 5-2-2-F2: The successful compilation

After both the node and sink (base station) node have been compiled, java application will be executed as to show out the data information. Before starting, it must be set with the respective environment path so it is possible to be activated.

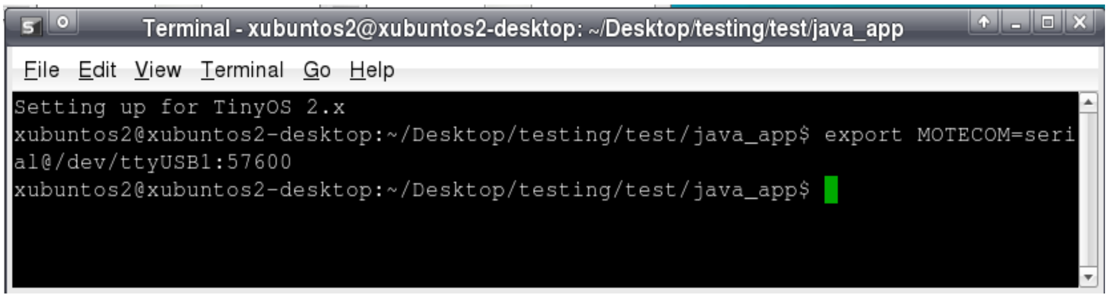


Figure 5-2-2-F3: The environment to activate the COM port

If no environment is set, the figure below will show the example of error occurred.

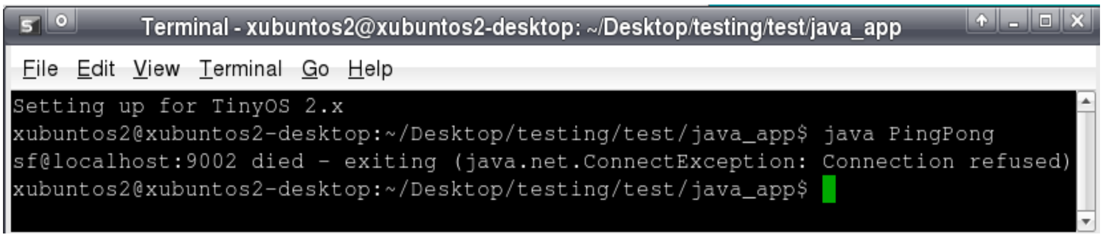


Figure 5-2-2-F4: Error in opening port

Sometimes even when the environment path is activated, it is still died in connection. In this case, the only way that can be done is restarting the host.

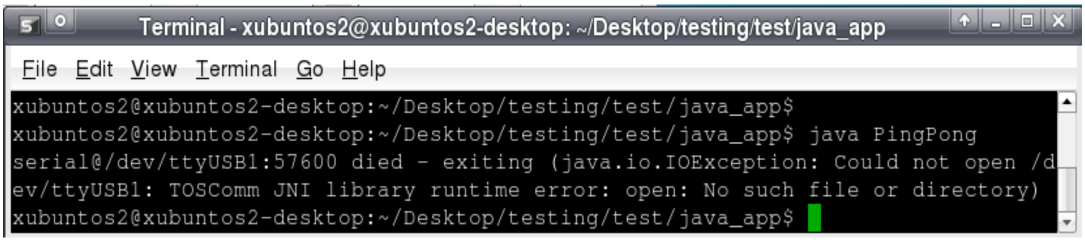


Figure 5-2-2-F5: Unexpected error

Once the COM port is successfully connected, the output of the code can be seen in the terminal output. Before the node is start sending packet, the below screen will be hold until the first packet arrives.

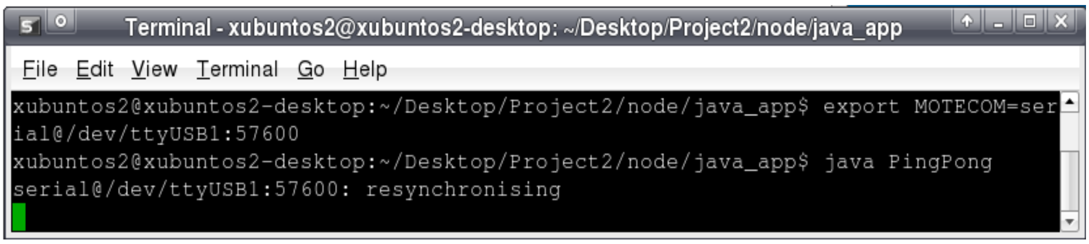


Figure 5-2-2-F6: Executing java program

5.2.3 Testing on the output in VM

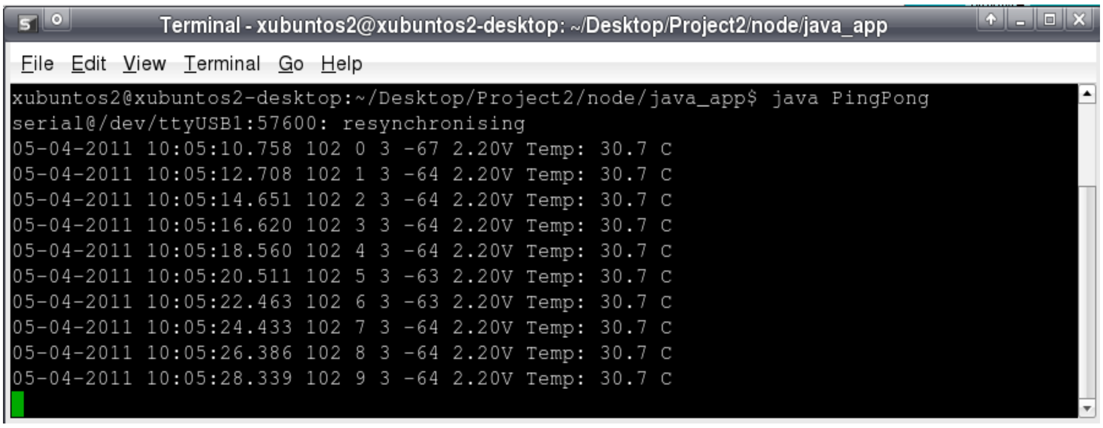


Figure 5-2-3-F1: Data output on VM

Once the packet is successfully sent and received by sink node, the output will be shown as the figure above. The first element is the date, second element is the time, third element is the node id, forth element is the packet id, fifth element is the power transmission, sixth element is the RSSI value, seventh element is the battery value, and the last will be the temperature value. Please take a look at the temperature value, it is not in accurate form because the existing sensor embedded on the micaz node is not functioning well. To enhance it, a sensor board (MDA 100CB) can be plugged in to increase the accuracy.

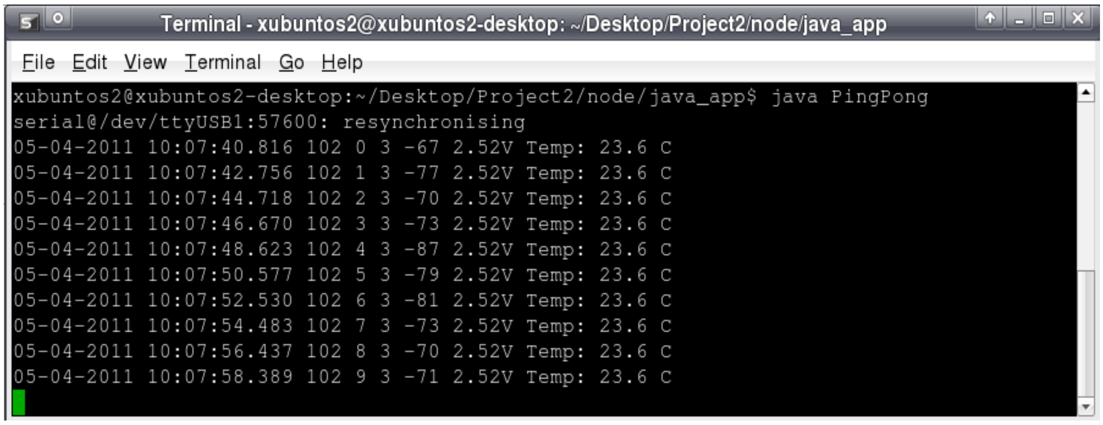


Figure 5-2-3-F2: Accuracy of the temperature.

The figure above shows the significant changes of the temperature after using the sensor board.

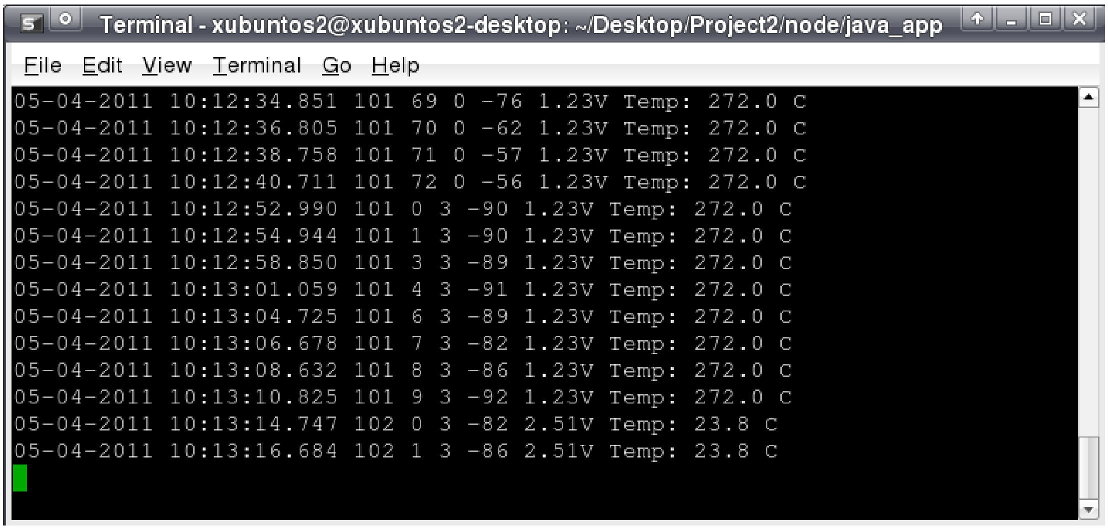


Figure 5-2-3-F3: Battery power affecting value

In other case, battery value would significantly affect any of the sensing value. The figure above shows when the battery value is around 1.23V which is absolutely low, the temperature value collected is totally out of the range. While take a note on the last 2 lines, when using a better battery power, it shows a much accurate data. Therefore, battery value must be in the range of not more than 2.6Volt will produce an accurate result.

As discussed, it shows data is able to send and receive and show out the output stream. Meanwhile, let take an example of using 2 nodes to perform multihopping data transfer and received in sink node.

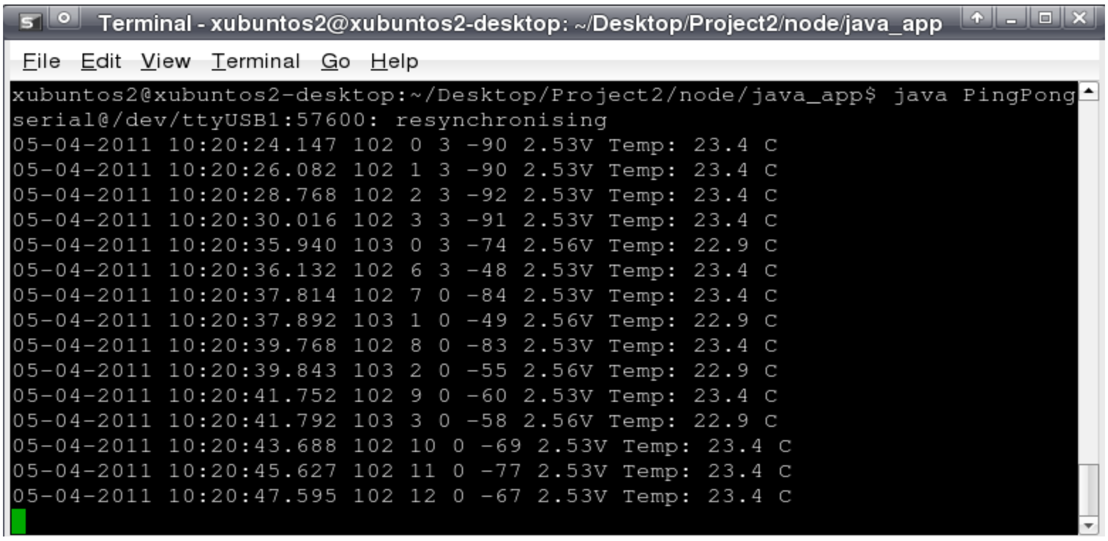


Figure 5-2-3-F4: Multihopping data captured

From the figure above, it is basically showing the multihopping of data transfer to the sink node which receiving it and able to show on the output stream. At first, node with id 102 is switched on and it starts sending packet. It goes well until packet id reaches 3, it stops because it has been dragged to a far range where the sink node no longer able to receive the packet. Next, a node with id 103 will be placed in between node 102 and sink node and start activating. The first packet sent from node 103 is showing its packet id 0. When the next round of node 102 being received, it shows the packet id 6. Obviously it means 2 packets have lost before the node 103 is starting working. This example shows micaz node is capable in multihopping the packet.

5.2.4 Testing on MySQL and GUI

In this section, java software and mysql database software will have to be installed as mysql work as data storage place and java be used to create a GUI in window platform for data output showing. In fact, the mysql command line will be inserted in the java programming so that when the java programming is executed and run, mysql will be perform throughout the java GUI. At first, after the mysql has been installed, there are several important setups that must be achieved before the GUI is working perfectly with mysql. The figure below will show how is the mysql client command line interface looks like before starting the actual design.

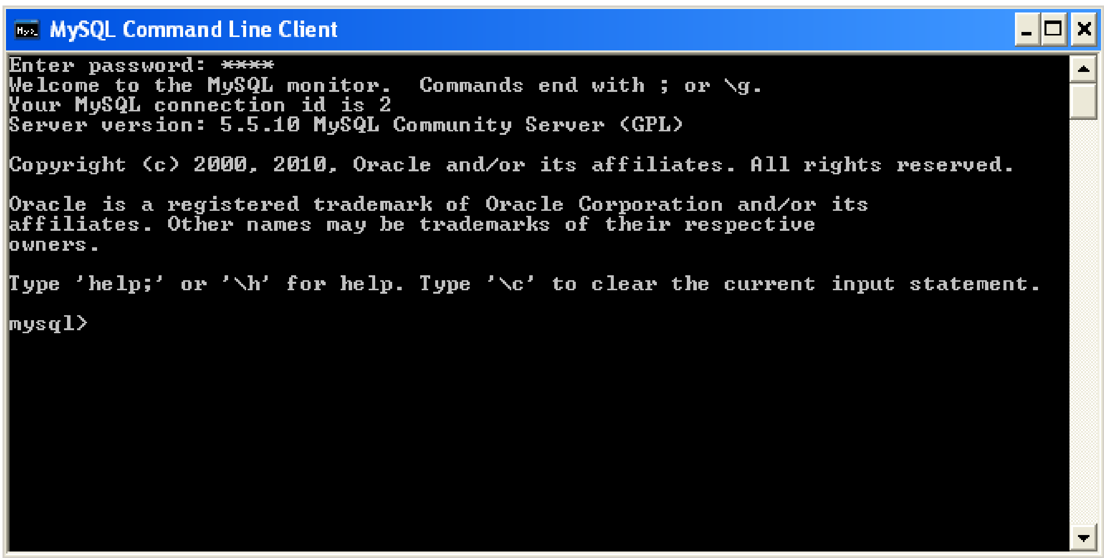


Figure 5-2-4-F1: First page of the mysql client command line.

In the java program, there is a line to execute command to the mysql and enable it to be login. The code will be like the statement as going to mentioned, “DriverManager.getConnection("jdbc:mysql://localhost:3306/wsn_project", "root", "abcd");” For different database might have different way of method calling. So, for mysql, this will be the called method. “jdbc:mysql” is the must to indicate this is the mysql database. The “localhost:3306” means the database is located in the local host, instead, 127.0.0.1 can be used either. Meanwhile, “wsn_project” will be the predefined statement for the database name. Because of this, a database named “wsn_project” will have to be created beforehand in mysql client command itself. For instance, “root” will be the predefined administrator username and “abcd” is the administrator password which is configured manually during the setup. In the following figure, it shows the databases names in the very first before any add-on. After that, a command “create database wsn_project” has been executed and a new database has emerged.

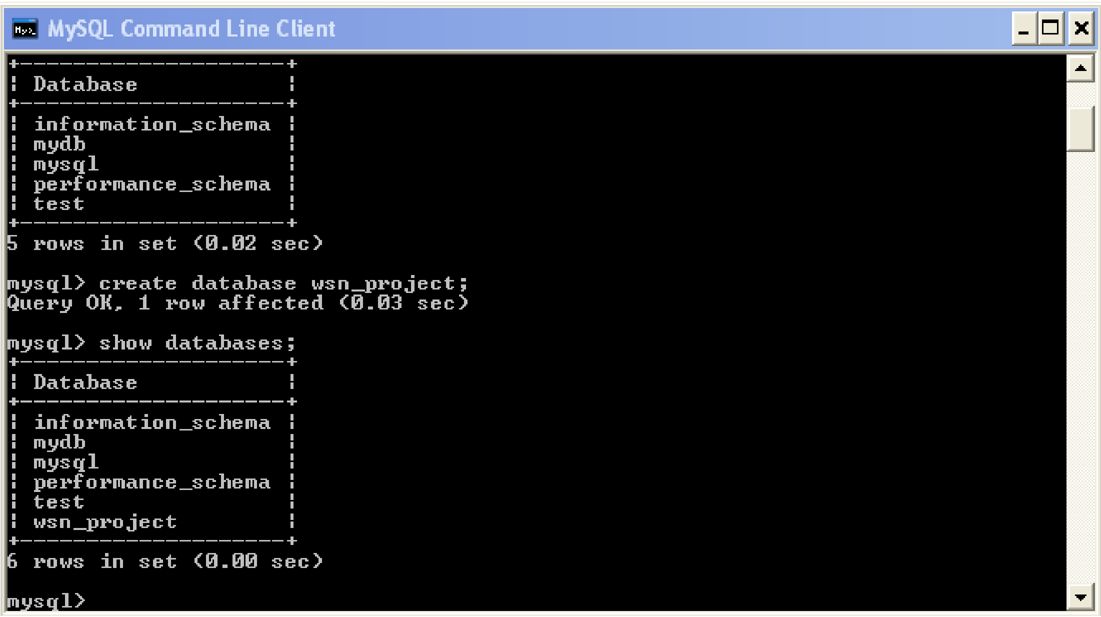


Figure 5-2-4-F2: Creating a database named “wsn_project”

This mysql client command interface can be simply exited by typing “quit” with no case sensitive issue.

Until now, even though the mysql client command line interface is accessible and able to do any add-on, however, there is still no source of ODBC that the java program can locate to. For example, 2 lines of code will be shown below as it is the most important part as to allow java programming to automatically connecting to the mysql source file. First, the code will be "com.mysql.jdbc.Driver", which is the driver connector execute command to locate the driver. Because of this, the driver needs to be download and installed it in the computer's particular path. There are 2 ways of providing the driver. The first one will be the "mysql-connector-odbc-5.1.8-win32.msi" which will create a driver after setup. It needs several steps to make it done before completing. Go to the "Control Panel->Administrative tools->Data Source (ODBC)". Over there, click the "Add" button to perform additional add-on.

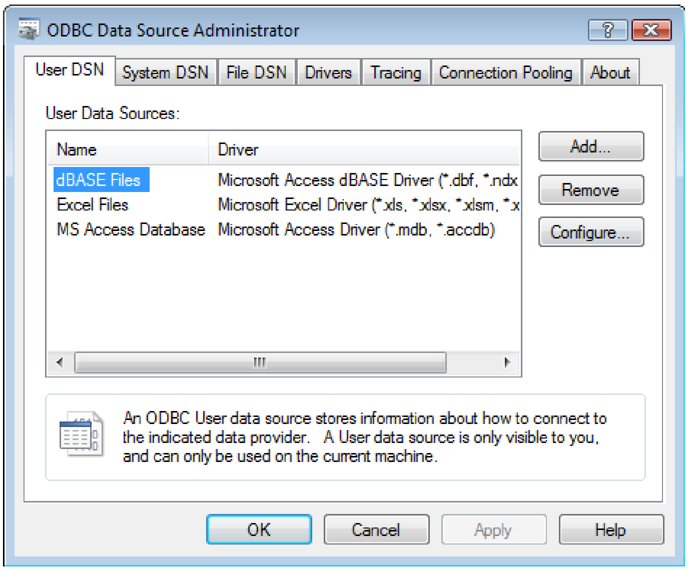


Figure 5-2-4-F3: First page in ODBC Data Source.

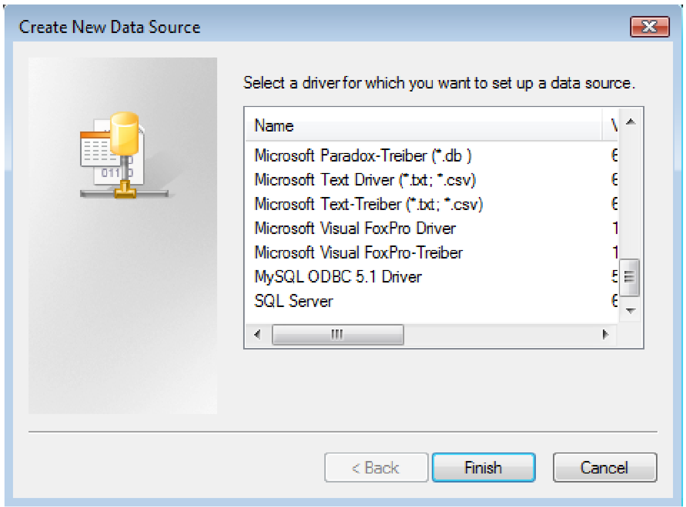
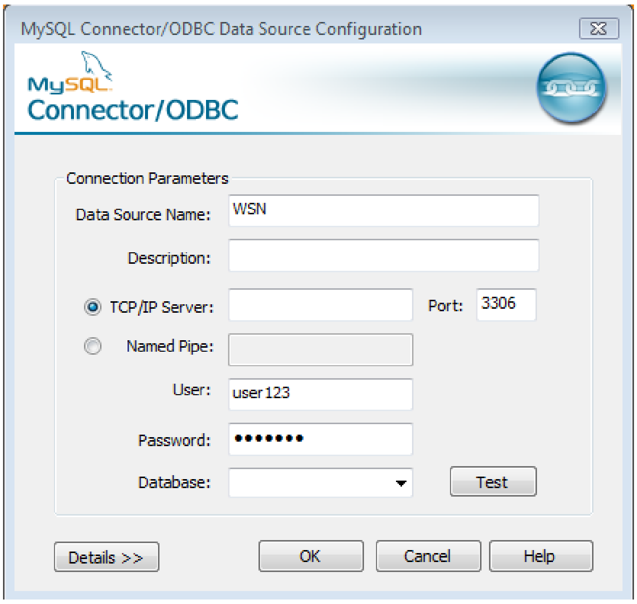


Figure 5-2-4-F4: The page after "Add"

Notice that there is a "MySQL ODBC 5.1 Driver". That is the driver as mentioned. Click on it and "finish" the step. Afterward, next page will show a basic source description and testing on the connectivity path. Just put in the relevant information especially the user and password word and test on it. If it is successfully connected, it will show



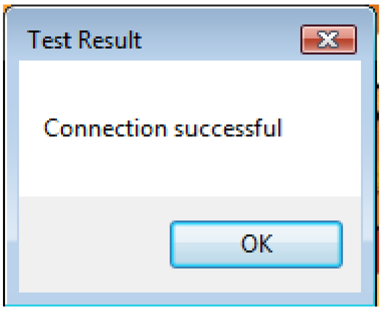


Figure 5-2-4-F5: Authenticate the driver OBDC with database.

After it is done, the driver is now connected. For second method to deal with the driver, this method will be much simpler and fast enough. First, download a "mysql-connector-java-5.0.5.jar" and paste it into the directory of where the java folder is installed. For example, place it in "C:\Program Files\Java\jdk1.5.0_22\jre\lib\ext". Beside the driver, there is another .jar file which needs to be paste on the same directory. The file is tinyos.jar which consists of the libraries that is needed for certain headers compilation used in the code.

With all these preparation and setup, it is for sure the GUI will work perfectly. Meanwhile, as mentioned in the part 5.1, Cygwin indeed is a must since the GUI needs certain libraries that are inside.

Once the driver is successfully connected, try it on the window command prompt and make sure it is working. If it is not working, then it will be impossible for the GUI to access into database, and troubleshooting will have to be done. The figure below show the command typed in window command prompt “mysql –u root –p -> <password>”.

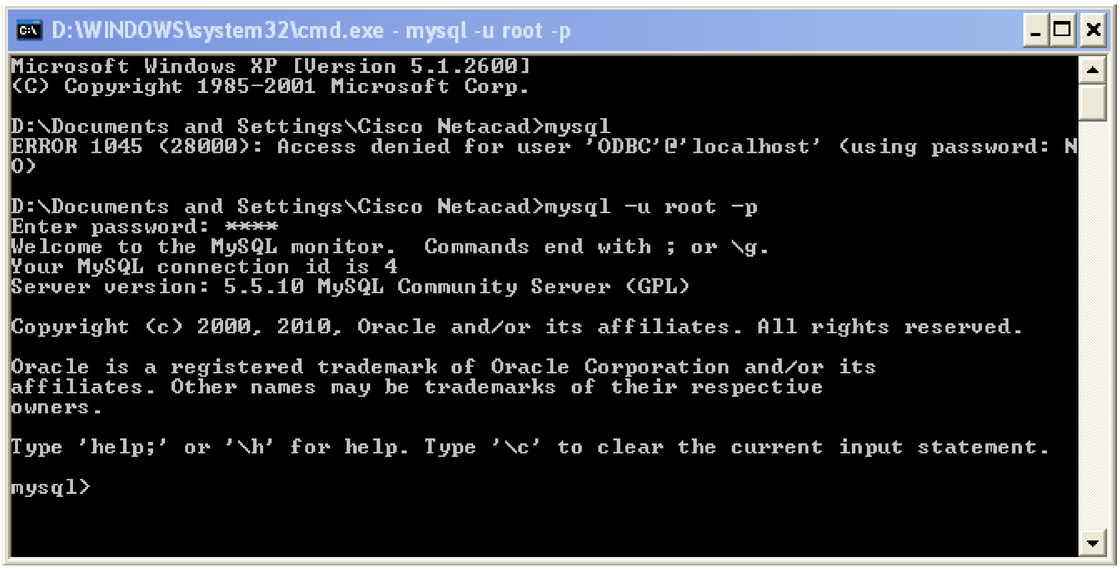


Figure 5-2-4-F6: Accessing mysql in window command prompt.

Once everything that is mentioned in this section above have been achieved, it should be work fine in the GUI execution. Use the command prompt and locate it to the right directory in where the GUI’s .java files reside. Afterward, execute “javac *.java” to compile every single java files and generate .class files. If it is successfully compiled, run “java <java filename>” to run the GUI. In this project, the name of the main GUI file is CommsApp.java. So, as to run it, type “java CommsApp” and a GUI will be shown up.

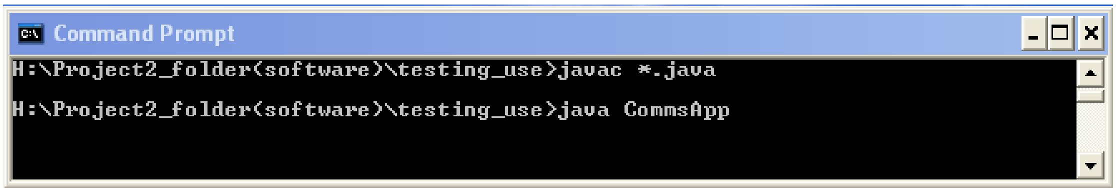


Figure 5-2-4-F7: Running the GUI execution command

Below will show the GUI pop up and how it works.

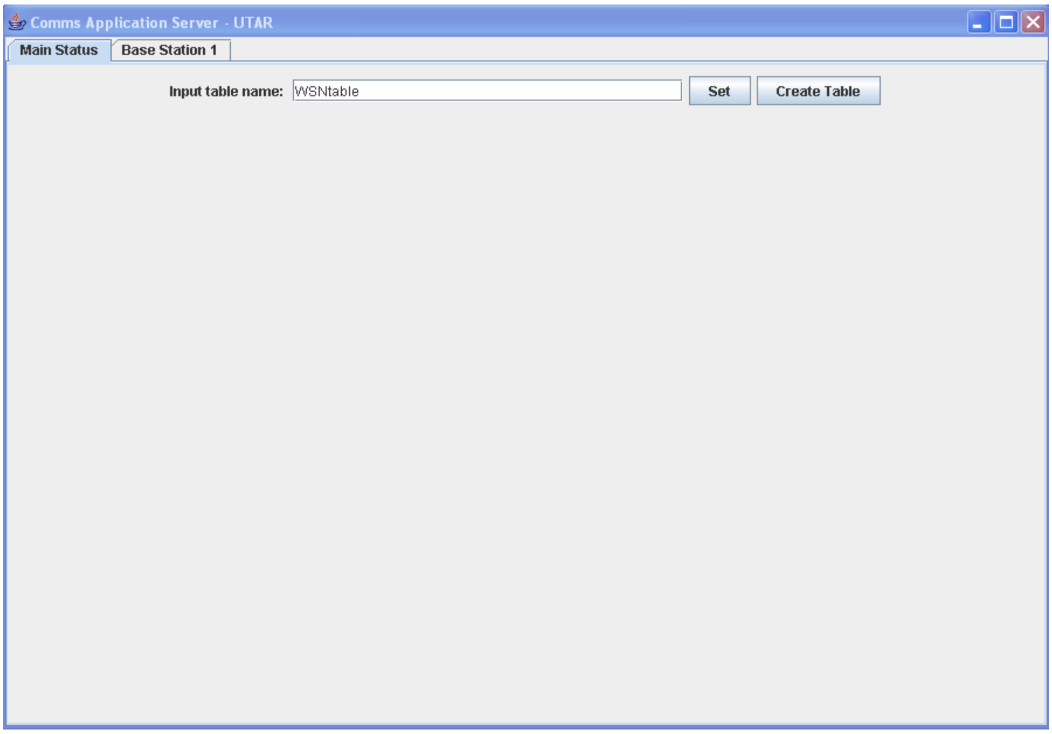


Figure 5-2-4-F8: First tab in GUI

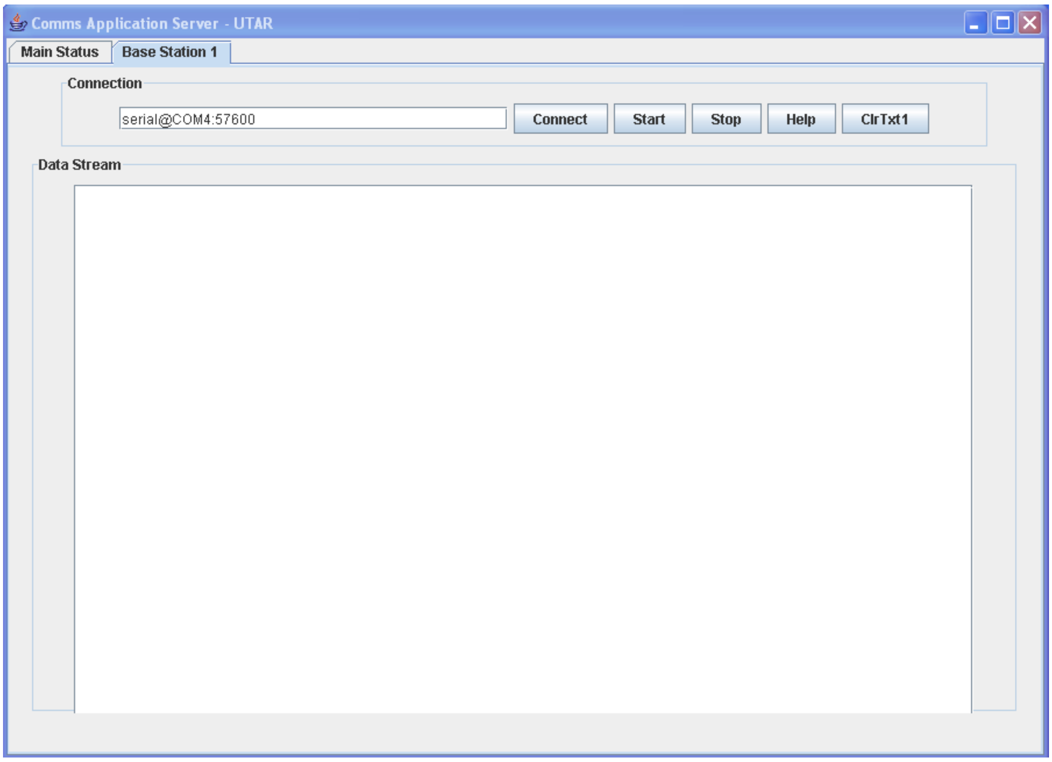


Figure 5-2-4-F9: Second tab in GUI

From the both figure above, when the first enter into the GUI, it will show the first tab screen, which is the “Main Status”. Its function here is just to create a NEW database. After type in any table name as user like, click on the “Set” as to copy the string into the variable which will be used when click on the “Create Table” for the next step. Afterwards, a table name in the wsn_project database will be created. For example, the figure below will show how this works by showing there is no table inside at first.

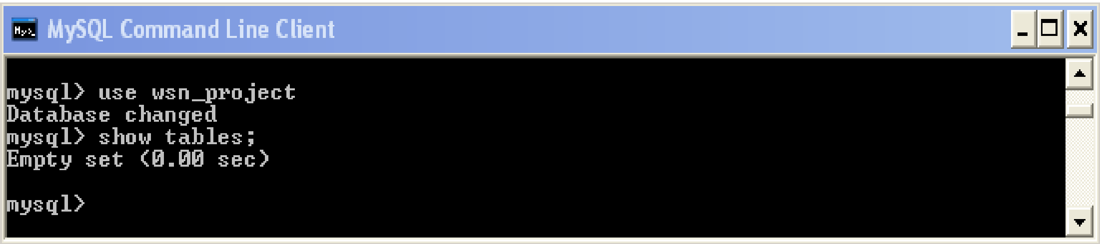


Figure 5-2-4-F10: Showing database content

“use wsn_project” is just to access into the particular database and “show tables” is showing all the tables inside the particular database. In this case, no table has been created yet. Right then,

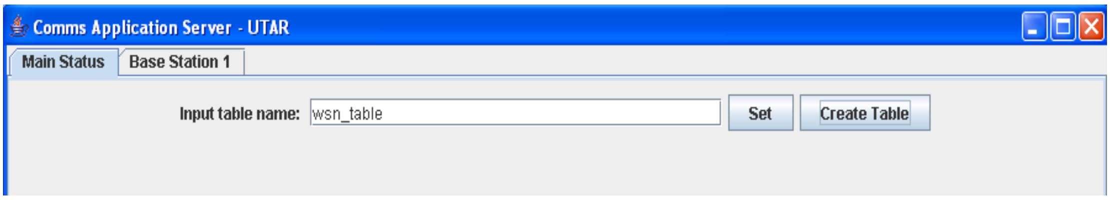


Figure 5-2-4-F11: Entering string of table name

After the “Set” and “Create Table”, the table has been created.

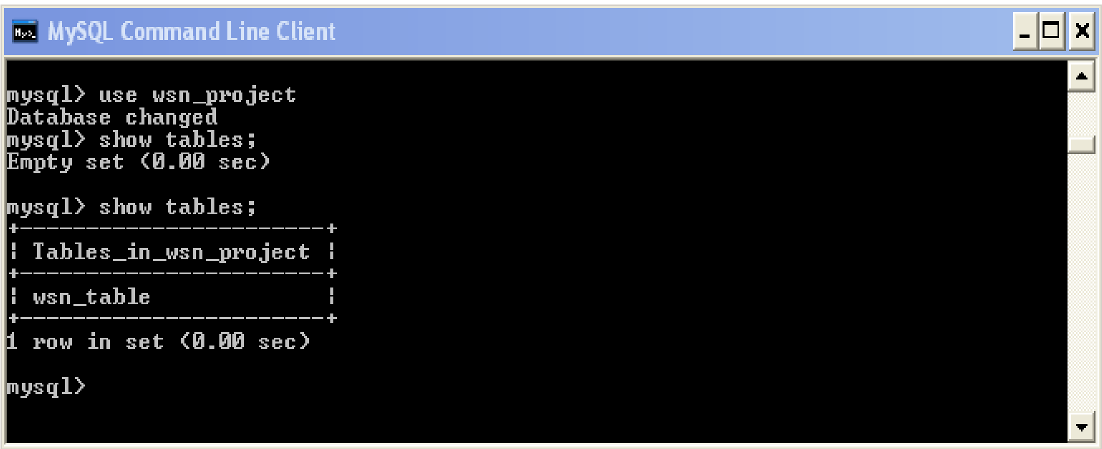


Figure 5-2-4-F12: New table created in database

The second tab will be the Base Station area in where it will show the data output stream once received. The text is the serial connection for the computer port. In this case, which port of the programming board uses for data control will be place into as a string.

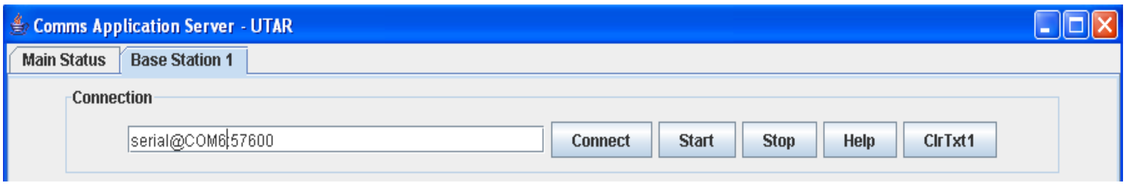


Figure 5-2-4-F13: Entering serial com port line

Right after placing a right computer port, click "connect" as to establish the connection between this GUI and computer serial port. A pop up of the preset serial forwarder port will be shown and if it is showing "listening to client connection" with no "died" or "restarting" connection appear, it is a success.

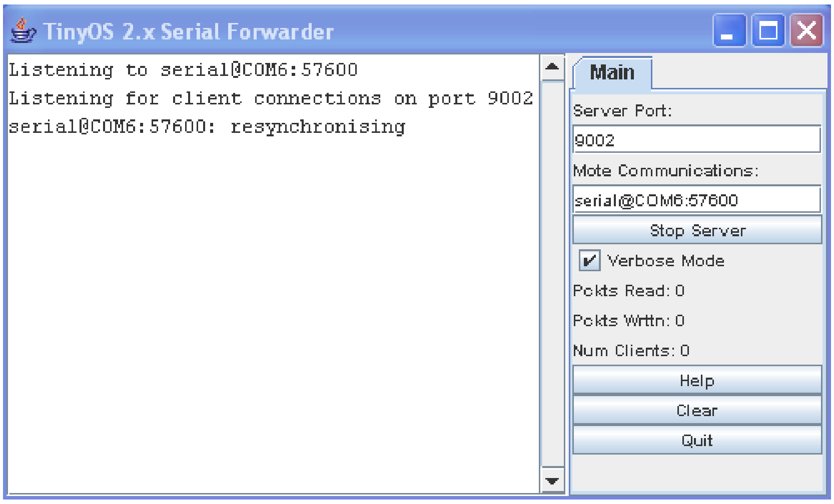


Figure 5-2-4-F14: Serial Forwarder preset com port connection.

After this has been establish, it is just waiting for the user to click on the "Start" button. Once button "Start is clicked", it will show the following output stream print out.

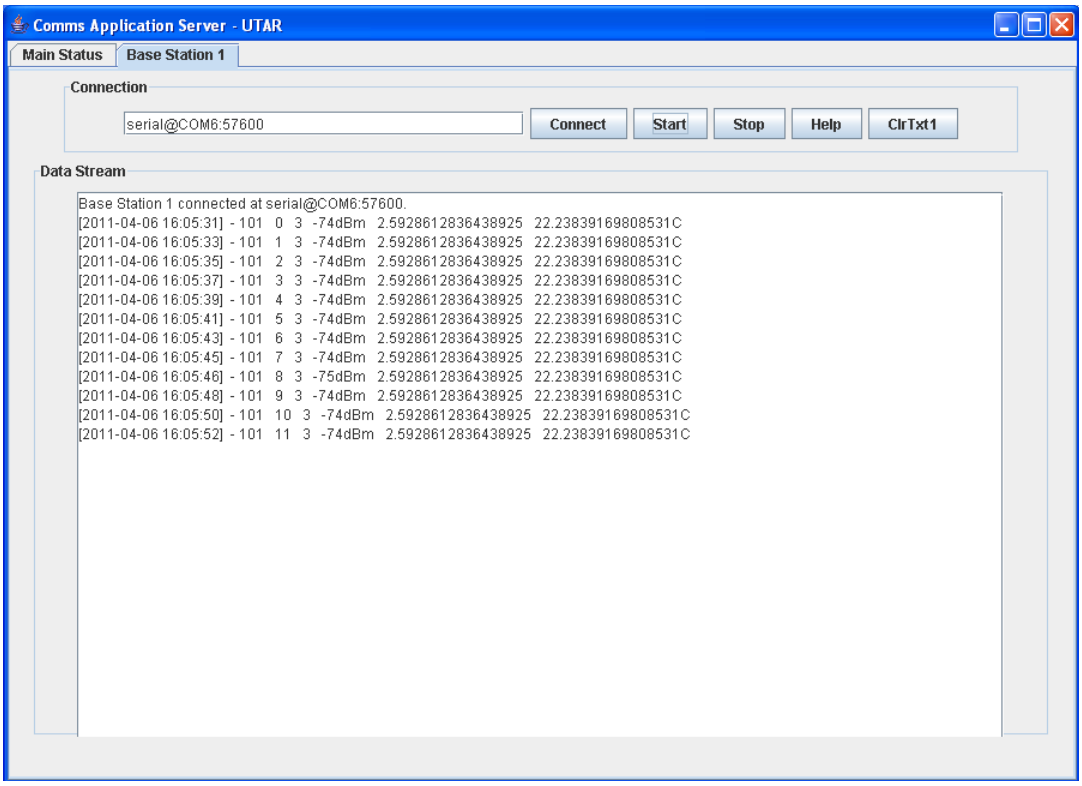


Figure 5-2-4-F15: Data print out in GUI

The “Stop” button is just to stop the data stream from received. While the “Help” is just mentioning the example on how to set the serial com. The “ClrTxt1” is meant clear text, it does to clear the current output in the data stream.

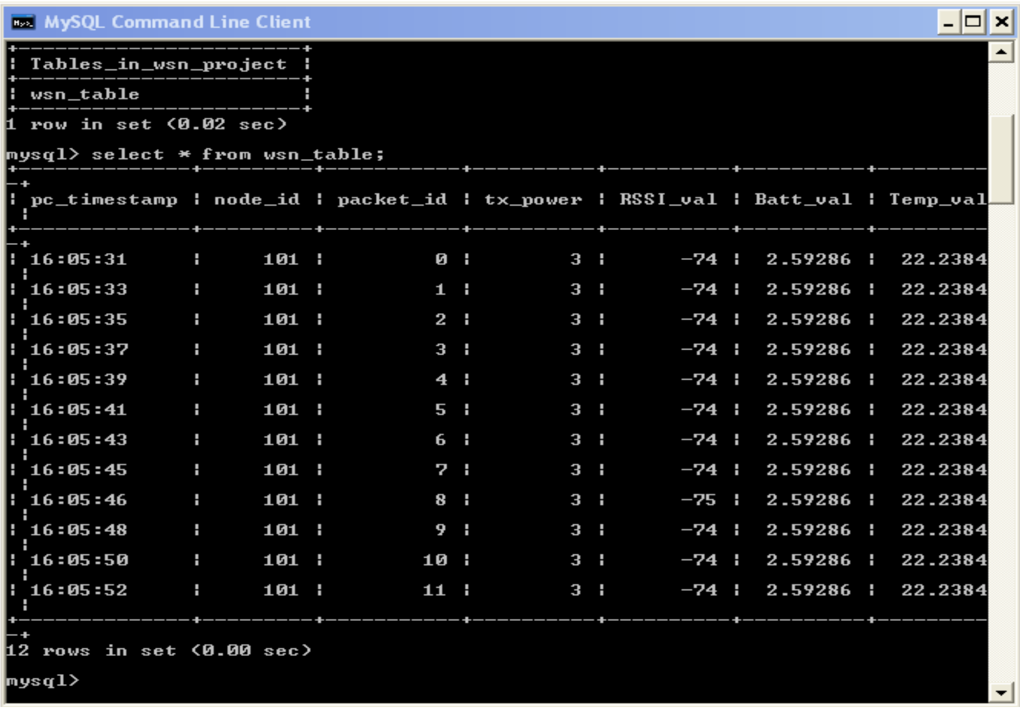


Figure 5-2-4-F16: Data has been stored in mysql database

5-3 Summary

The project guideline indeed shown as the print screens above. Every possible error and problem encounter should have listed clearly unless new error has not been reached. Therefore, with the help of this guideline, it is possible for a newbie to follow on their own as to achieve what the writer has achieved throughout the days. Meanwhile, more enhancements shall be encouraged to add on for the future developing of this project. There will be a detailed discussion on enhancement method in the section 7.2.

6.0 Discussion

6.1 What has been Achieved.

In this design, nodes have been configured and able to send packet in multihopping fashion. Packets will be sent to their neighbors and continuously until packet reaches the sink node. Packets consist of the particular node identification will be parsed to the sink node and sink node will perform its internal preset queue system and allowing packets to be dumped onto the user computer. User computer will therefore able to show out the result on the screen. For instance, once data received, user can as well performing by running a GUI on window platform to have a better viewing since not much of users know how to use Linux OS. From the GUI based, a mysql table can be created and allowing the data received to be stored into the mysql simultaneously. Thus, data received will show onto the screen while storing the data into the database with respective table at the same time with given username and password.

6.2 What has not been Achieved

Based on implementation, the task that still is pending would be the testing ACK sending and received as previously discussed. By default, it is not considered as a part this project, but it is a very accurate yet useful checking for the traffic control and design. Even though it is good to be included, it is just the idea to build is very complicated and time consuming. To deal with this before hand, it needs a very strong concept of the nesC program and able to utilize it with no error. Therefore, it is not being implemented here.

6.3 System Contribution

The contribution that achieve here is basically the advancement of using sensor network. Since this is a prototype of WSN, it will eventually has a very great contribution on monitoring, in wide range of communication and capable to show user the desirable result. As this project is dealing with precision agriculture, so as long as it can be deployed on a wide range of the field and retrieved particular sensing value such as temperature, it is indeed a very useful benefit for user as it is user friendly.

6.4 System Weakness

The currently drawback of using this device is due to the high cost of the gadget and limitation of using large number of nodes. Therefore, it is very hard to be deployed in very large area, and if so, lesser node will be purchased and therefore producing a not so accurate reading of data. (Because of lesser nodes, its power transmission will have to be set to a certain high range by using low frequency radio transmission.)

7.0 Conclusion and Enhancement

7.1 Overall Conclusion

In the nut shell, wireless sensor network is indeed a very flexible device. It flexibility is defined by its usage on various fields. I could be used in plantations, used in nature and as well used in human activities. Basically, after this project, the writer understands the sensor network's most important element is the multihopping function. With a prototype of the wireless sensor network in which can hop for several distances away, it is indeed a very successive technology. Because of this nature, any add on can be done and able to deploy in any relevant field hence making it to have multi-environment capability. Soldering on any additional sensors on the sensor board (MDA 100CB) such as camera, accelerator and so on would enable the sensor node to perform multiply tasking. Hence, creating a very powerful future gadget.

7.2 Future Enhancement

From the sensor point of view, it is in fact a very smart gadget which can perform the task for example multi-hopping capability which is undeniably cannot be done by some type of other devices. However, as mentioned in the system design, it could have flaws if just only setting the filtering at the host side. If the problem occurs, nodes will eventually pushing and forwarding packets amongst themselves at the same time will forward to the sink node. Thus, this unstable process will wasting much of the processing power and therefore not fulfills the main priority of the wireless sensor network (WSN) mission which is energy reservation in the optimum mode. For instance, it is really inefficiency when a large number of sensors are being deployed. This will much burden up the “middle” sensors as they need to keep tracking on a lot of traffics. Eventually, it will cause the traffic output significantly reduced due to the traffic redundancy. As a smart developer, it is encouraged to sketch out a blueprint on how the problem shall be done gracefully. As the stepping stone, developer shall need certain of storage mechanisms to handle the flaw because multiple packets can simultaneously sent and received by nodes. So, the storage mechanism can be simply an array of suitable size depending on the nodes required, and able to associate with large number of packets. Whenever the receiving node receives packets, packets will be stored in the respective array index and thus for the checking purpose in the later stage.

Meanwhile, ACK packet as mentioned is a very particular process in where packet will no longer be resend once timeout occurred at the sender site. This is a very critical issue if the data need to be transmitted is utterly important for a certain process or development. This will subsequently affect the complete system as a part of the information has lost. Packet lost can be due to several of consequences and yet it is a very crucial part if it can be enhanced and prevented. And again, WSN is having optimum energy usage idea, and therefore, it is not really encouraging to have high power transmission for each node. Besides, perhaps using lesser nodes with higher power transmission is much better than deploying more nodes, but it is render questionable when the WSN is deploying on cow farm. Thousand of nodes will be needed and hence the suggestion is being violated. In fact, the best idea to overcome this would be setting the transmission power to an adequate level in which possible to penetrate any tiny or average obstacles and strong enough to curve along any object until reaching the next node or the sink node. If a better power transmission is implemented, it will use up more energy, therefore, it needs a good trade-off in between the power conservation and the power transmission by reducing the energy used to the minimum. Consequently, ACK is meant to provide reliable transmission, but here, packets will still losing after the timeout. So, in its reliability point of view, it still needs "best afford" for data transmission.

As discussed in the Chapter 4 about how it toggles start and stop in a certain amount of time, it is eventually the so call sleep-and-wake design, and just it is done in the very simplest way. For the actual sleep-and-wake design, it needs a complicated algorithm to be built out and capable to work in synchronize between sender and receiver nodes. The logic is to enable a sender node to wake up from sleeping mode and transmit the data, then it will go to sleep mode again. While the receiver has to be intelligently enough to be woken up in the time when the packet is going to arrive. Instead of having all nodes wake up and sleep simultaneously, it is here designed to preserve more energy from being wasted. And therefore, it is a really good yet advanced implementation to allow sensors to send packet in a right period and receive packet in a good timing. Once packets received, nodes will perform its programmed task and join into the sleep mode right after that. For instance, as being discussed in the Chapter 2, the sleep-and-wake time period is better being set according to the optimum energy conservation.

For example, if sensors are deployed in cow farm, it would have various timers to be implemented because the deployment of the sensors here will need multiple sensors for data mining and do comparison to produce a piece of informative output. Basic sensors such as thermistor and accelerometer will use a different time period, because accelerometer as used to detect motion need to be sampled in a more frequent time internal and thus around lesser than 500miliseconds and required while themistors will be activated roughly few seconds per sample for better analyzing. So, both sensors "awaking" time will be different and this idea can conserve more energy usage. Even though thermistor can be activated along with accelerometer, but sampling temperature will not be too frequent as the changes in degree Celsius would not take any effect in short period.

Whenever mentioning about the energy conservation, it is sometime very hard to deduce how long the batteries can last for the entire life period. It could be 3 years or even as long as 6 years. Though it is considered as a very good range of life span for deploying sensors in field, but it will be getting harder if the nodes are deployed in deserted area, dangerous area, and human unreachable area and so on. Sensors node will therefore being deployed forever until itself broke down and replacement of the units will do. In the near future technique, solar energy power for sensors is a very new yet possible to overcome the drawback of the limited life span of batteries. For instance, each node's energy storage will have self-replenish capability and afford to go even longer perhaps 10 years and above until the node itself spoiled. Basically, a platform of solar energy absorption panel will be attached to the node and of course wiring will be done and interconnectivity between the solar panel and node will be achieved with activating standard protocol coding. Thus, the node will be capable in prolonging its workable period and constant of data sending can be done even frequent. Meanwhile, even though there is a so call unlimited power consumption, nodes is discouraged to increase the power transmission to the maximum as it will indeed spoil the node itself cause of the sudden high power generation.

Finally, data retrieved or received by the sink node will be kept in some else such as a database. In fact, these data will be passed into the database for better management and easy handling when data size is growing. As mentioned in chapter 4 and 5, the database used is just the minor usage since that is just a prototype to show it is possible to work with database. So, in the next enhancement, database is a must as it can store the data in a well managed arrangement and easily to be retrieved by mobile users using mobile devices. In this case, database must able to be worked with any web programming such as PHP as users can access to it through internet. Therefore, internet enable and connection must be visible in the database itself. Besides, the sink node used here is just a single node. In general, it must be able to support 2 or more sink nodes and allow the packets to be passed and stored into either the single storage (centralized) or multiple storages (distributed).

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Appendix: Biweekly Report

Trimester, Year: Year 3 Sem 2	**Study week no:** 2
Student Name & ID: LEE CHING HONG 0803131	
Supervisor: Mr. Goh Hock Guan	
Project Title: Wireless Sensor Network for Precision Agriculture	

1. WORK DONE

In the first 2 weeks, hardware of micaz node has been adequately research through and knowing it components to send and receive data from other nodes. Some brief programming has been done on how to make its LED blink when data is received.

2. WORK TO BE DONE

Understanding how the hardware works and able to programming it to work in the most simpler version of method – Try to use 2 nodes and testing the connectivity of LED blinking.

3. PROBLEMS ENCOUNTERED

No problem is encountered in this starting stage.

4. SELF EVALUATION OF THE PROGRESS

Quite impressive in the basic data sending knowledge and how to make LED blink accordingly.

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Supervisor’s signature Student’s signature

Trimester, Year: Year 3 Sem 2	**Study week no:** 4
Student Name & ID: LEE CHING HONG 0803131	
Supervisor: Mr. Goh Hock Guan	
Project Title: Wireless Sensor Network for Precision Agriculture	

1. WORK DONE

Able to do data multihopping and able to call out those certain values in well arrangment.

2. WORK TO BE DONE

Set the nodes as they can be sending their packet multihoppingly and forwarding till the sink node. Meanwhile, passing some important value such as node ID, packet ID, power transmission, RSSI value, Battery value, and Temperature value. Of course time and date is included too.

3. PROBLEMS ENCOUNTERED

Time is getting insufficient as workload of the FYP is getting larger while other subjects tests, assignments are flooding the time schedule. The milestone might be affected somehow. (higher possibility)

4. SELF EVALUATION OF THE PROGRESS

So far still able to handle "multi-tasking", just afraid of the next coming progress will be much slower.

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Supervisor's signature Student's signature

Trimester, Year: Year 3 Sem 2	**Study week no:** 6
Student Name & ID: LEE CHING HONG 0803131	
Supervisor: Mr. Goh Hock Guan	
Project Title: Wireless Sensor Network for Precision Agriculture	

1. WORK DONE

Able to handle the GUI thingy and able to find the source driver for the mysql database connector. GUI is working well with the database.

2. WORK TO BE DONE

Handling the GUI stuff and mysql connectivity from the java program.

3. PROBLEMS ENCOUNTERED

However, it is just working with the database, but sometime it is still unidentifying the username and password and hence more troubleshoot need to be done in the following weeks. Besides, the serial com port is still remain mystery as it is not working no matter how to change.

4. SELF EVALUATION OF THE PROGRESS

Just average afford can be put on this current task and doesn't have much time on troubleshooting.

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Supervisor's signature Student's signature

Trimester, Year: Year 3 Sem 2	**Study week no:** 8
Student Name & ID: LEE CHING HONG 0803131	
Supervisor: Mr. Goh Hock Guan	
Project Title: Wireless Sensor Network for Precision Agriculture	

1. WORK DONE

Still trying on the serial com port problem while testing on new task, which is the ACK checking. This checking is totally out of the expectation and fail to perform it in time.

2. WORK TO BE DONE

To perform ACK sending amongst the nodes and the base station. This action is to enhance the traffic utility and never over congested it.

3. PROBLEMS ENCOUNTERED

The problem encountered in the previous report since remain unsolved. Furthermore, the ACK checking isn't much working as the idea of using nesC programming is differed from the other languages such as C, C++ and java. So, another pending task.

4. SELF EVALUATION OF THE PROGRESS

Not feeling good in handling something that has not enough time to do reseaches on and not enough knowledge to perform it.

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Supervisor's signature Student's signature

Trimester, Year: Year 3 Sem 2	**Study week no:** 10
Student Name & ID: LEE CHING HONG 0803131	
Supervisor: Mr. Goh Hock Guan	
Project Title: Wireless Sensor Network for Precision Agriculture	

1. WORK DONE

The working on the data to be multihopped and reaching the sink node is fine. Data can as well be showing out either in the terminal (VM) or in the GUI output. As well data can be stored inside the mysql after creating the respective table name.

2. WORK TO BE DONE

In these weeks, a prototype of the project must be achieved including everything.

3. PROBLEMS ENCOUNTERED

Time is really insuffient and doesn't have much time to stay in the lab. Because of the gadgets needed are all campus utilities, thus borrowing it home will need a lot of troublesome procedure and the gadgets are cost over thousands. So, it makes a very high contraint for me since week 2 as I cannot even do it at home.

4. SELF EVALUATION OF THE PROGRESS

It is hard to maintain a good standard for this current task and a recommendation of having an extra semester only for FYP is a very good idea. Time insufficient not only applied to burden workloads, but as well as lot of considered "irrelevant" speech and talk wasting up a lot of the lesson hours.

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Supervisor's signature Student's signature

Trimester, Year: Year 3 Sem 2	**Study week no:** 12
Student Name & ID: LEE CHING HONG 0803131	
Supervisor: Mr. Goh Hock Guan	
Project Title: Wireless Sensor Network for Precision Agriculture	

1. WORK DONE

Every possible task has been accomplished, just left the ACK checking only. ACK checking so far is working between the just one node and the base station, but not working in multihopping fashion.

2. WORK TO BE DONE

Until this stage, no more additional work can be done, just perform any enhancement as like to make the system work well.

3. PROBLEMS ENCOUNTERED

Still encounter the ACK in multihopping fashion and it is really hard to achieve as more researches and testing need to be done. Timing is really an obstacle to proceed the current task.

4. SELF EVALUATION OF THE PROGRESS

Able to do what can be achieved, the remaining one task is too advanced in my current knowledge have to be given up. Saving more time for others load.

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