# LOW-COST WIRELESS SENSOR DATA ACQUISITION AND TRANSMISSION FOR REAL-TIME MONITORING DURING DISASTERS

**Jon Alvin L. Macariola**
*College of Engineering,Samar State University,*
*Catbalogan City, Samar, Philippines*
jonalvin.macariola@ssu.edu.ph

## Abstract

*This research designed and built a portable wireless sensor network that is capable of handling data acquisition and transmission over a generic and dedicated network. The project used sensors, actuators and a real-time tracking system application in demonstrating the capability of wireless sensor network which is useful during disasters when all communication systems are down. The finished design includes a base station that controls three wireless sensor nodes which can communicate up to a maximum distance of 2 miles outdoors (line of sight) and 300-400 feet urban/indoors. Each node featured a device or module application that sends data to our base station for proper monitoring and processing. The network is self-configurable when powered on and is expandable in supporting a number of wireless sensor nodes to create a network. The use of wireless sensors in tagging and sensing data to the application in many industries and disaster mitigation provides endless possibilities that have potential to be economically viable replacement to wired networks.*

**Keywords**: wireless sensor network, real-time tracking system, data acquisition, communication system alternative

## I. INTRODUCTION

Wireless sensor network uses distributed computing in a smart environment to be able to monitor physical or environmental conditions. By using a wireless communication network topology, this will revolutionize the development steps in building utilities, industrial processing monitoring and control, home automation, and transportation system automation. The versatility of this sensor network lends them to a diverse variety of uses from providing information to distributed computing. The data that is being transmitted use a low bandwidth and handle comparatively low power consumption allowing them to function for several months using a DC battery boosted power supply.

People heavily rely on the existing network or communication infrastructure that we have today. For example, in the case of using a commercial service provider, which rely on the speed and reliability of the connection even the strength of signal are sometimes unreliable due to power interruption, system failures, and no network signal accessibility in some of the villages especially rural and far flung areas, agricultural lands, and fishery not to mention the aftermath of catastrophic event or man-made disasters that might occur in the future where the existing power and communication facility could be destroyed.

According to the project funded by the AUN/SEED-net (Asean University Network / Southeast Asia Engineering Education Development Network) under the special research program for disaster prevention and mitigation (UM SDM 1201) on their 2012 Engineering journal issue ISSN 2094-0297 research in title "A Framework of Wireless Ad-hoc Network for Disaster Mitigation" by Gin-Xian Kok and Chee-Onn Chow, in the aftermath of natural or man-made disaster the existing communication facility could be destroyed. As a result, communication is prevented. This made worse by the sudden increase/peak in the number of calls into and out of the affected area in forms of distress calls and enquiries. In these dire times, temporary wireless ad-hoc networks could be set-up with small, mobile, cheap and flexible programmable wireless sensor nodes to mitigate the effects of the disaster.

These networks could also be deployed to co-exist with traditional infrastructure networks before a disaster actually happen for and added dimension of reliability or to monitor environmental or process variables.

It was in this regard that the motivation of this research project decided to design and develop a low cost dedicated wireless sensor network that would be capable of handling and processing all of the modules and devices attach to the sensor, using a single stand-alone dedicated network with such varying distance up to 28 miles that would act as a communication framework between two system and to developed a front-end and back-end central database for all the data that has been collected. The system can be utilized for disaster mitigation in sending distress signals from the affective areas. It can be deployed and set up as a temporary communication infrastructure as a mean of communications. Due to their versatility, wireless sensor networks can be deployed to monitor conditions in the concerned areas instead of sending persons which could be costly and dangerous.

## II. METHODOLOGY

The researcher described and elaborated the method of developing a wireless sensor network in acquiring data over a specified network. It presents the process of implementing of each sensor, designing and creating the circuits, designing and implementing the backend database for proper repository of the data structuring a remote website or front-end application that would serve as an interface in displaying of the data from the database.

No matter what components that have been decided to use in these research project, the majority of the work will be writing firmware or drivers to run the devices as well as coding the backend database to integrate with the design. Most of the time will be allocated to In-system programming, testing and debugging software and hardware that has been written and implemented throughout the design process.

### *2.1 Research Design*

The paper adopted the top down design method in implementing the system as well as straight forward approach in creating a prototype and the final design. Temporary forms had been created for the input display and temporary tables for the database had been organized to test and analyze data capturing before integrating both front-end and backend software as one whole system. This was an attempt to build and alpha testing on the project before conducting the final stage or beta testing on the system both on the hardware side and on the software part.

Developing the wireless sensor nodes is one of the targets of the study, because they are the one who carry the data back to our database and also responsible of handling communication throughout the entire network.

The Design of Low-Cost Wireless Sensor Data Acquisition and Transmission was made through research and investigation on the different network topologies, electronic components and wireless system. The concept and theories have been developed from the information gathered and integrated it to the system. System Block Diagram and System Flowchart were developed to identify different components and system flow. Functionality of the system was implemented through embedded system development and designing a backend database as a mean of data repository.

Throughout the research processes, a number of design options and standards were considered in the area of wireless communication, network topologies, and software design up to the circuit design modules and to the components that are being used.

Fig. 1 below shows the system block diagram below shows the target design setup on how each of the components are being implemented and used. The circuits design for each sub module is developed or modified to suit the needs of the system. All the components, firmware, driver and software of each sub module are being tested for reliability and efficiency.

It also demonstrated the setup of a wireless sensor network were each node has a corresponding modules attach that is capable of handling data and transmitting those data over to the network. Those standalone modules and applications have been developed and designed by the researcher to support the target setup design of a wireless sensor network where each application can be integrated or hooked up to the network.

Each router node is capable of communicating to the other node. All the data that was sent to the database will pass through to the coordinator node and the database can be accessed via a web interface, desktop application or a smartphone.

*2.2 Block Diagram*

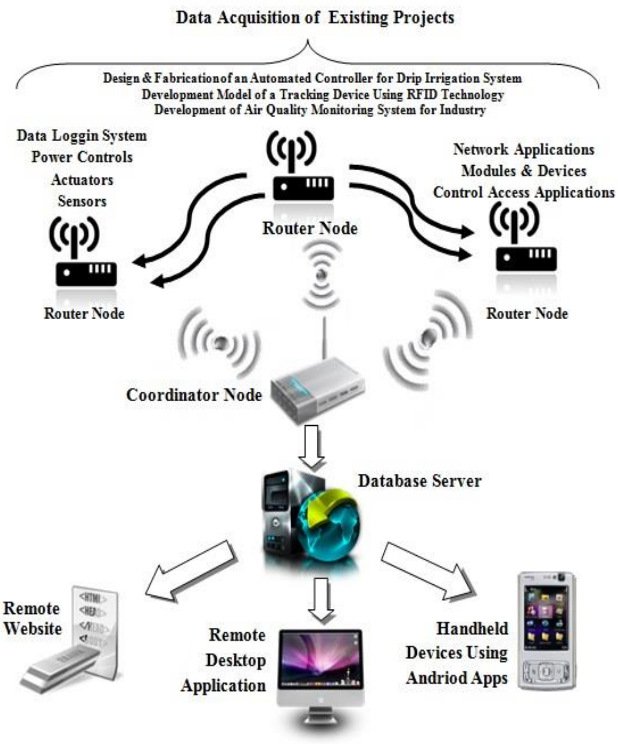


*Fig. 1. System Block Diagram*

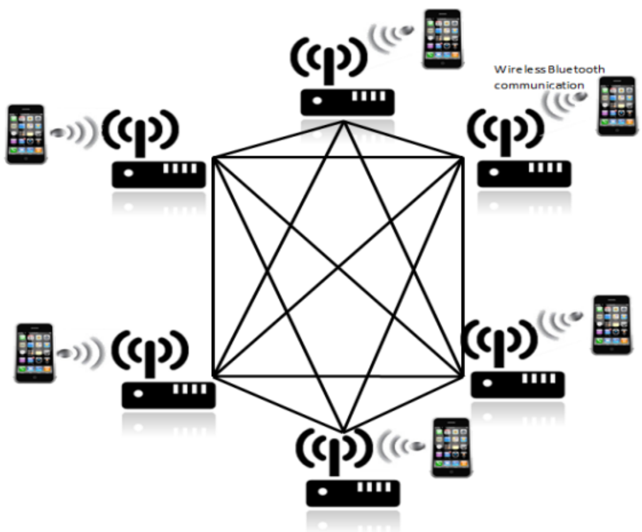


*Fig. 2. Ad-hoc network using mobile phone in sending data*


ISSN 2449-4577 (online) 2408-283X (print)

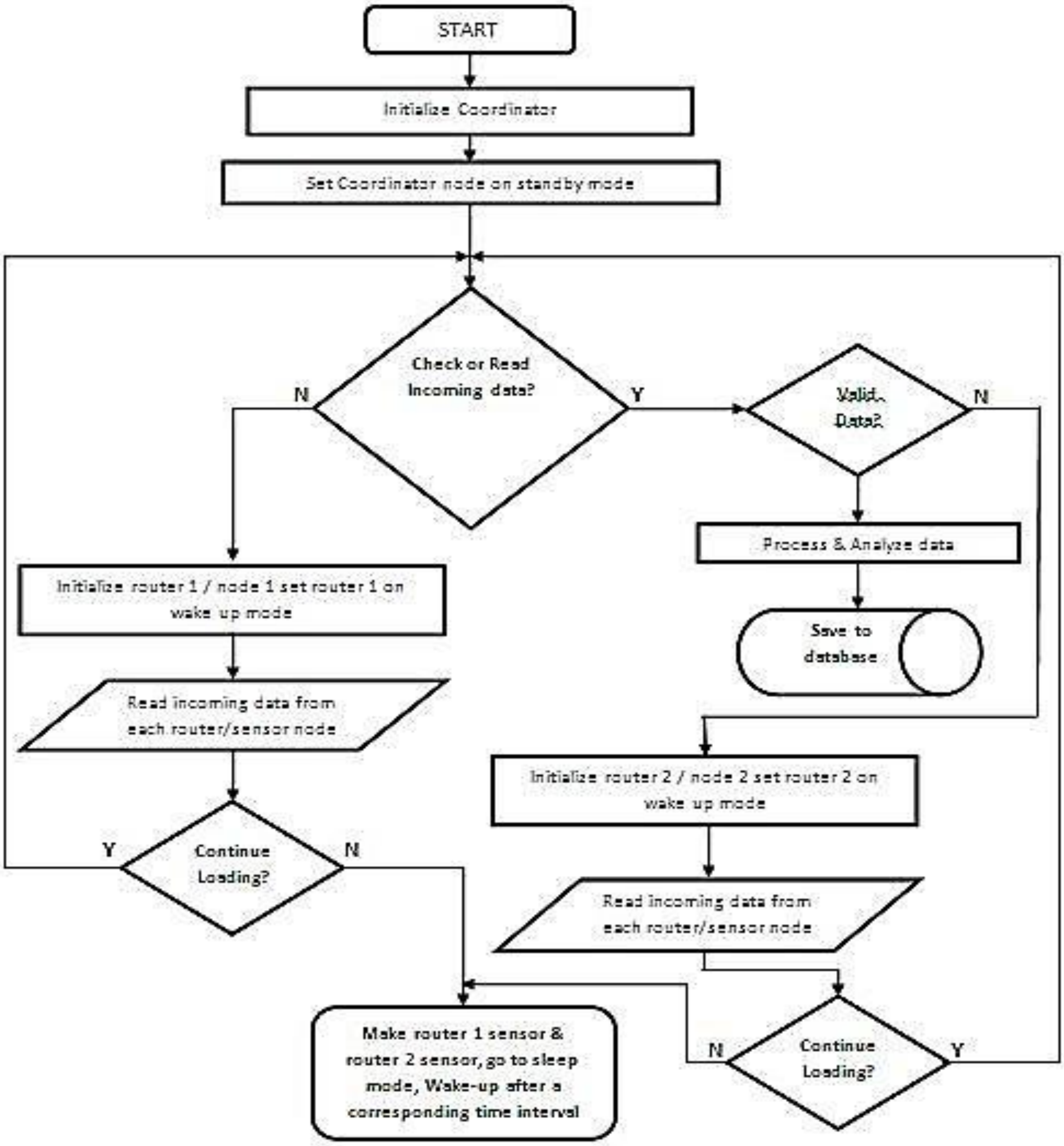


Figure 3. System Design Flow Chart

Fig. 2 illustrates the setup in deploying a network as a temporary means of communication using a handheld mobile device capable of sending data over a wireless Bluetooth communication.

Fig. 3 shows the system flow chart of the design, each node needs to be initialize before it can accept any process, ones a node sense an incoming data it will check and read the validity of the incoming data and forward the verified data to the database repository.

*2.3. Hardware Design*

Fig. 4 shows the main circuit diagram of the main controller, a 5volts boosted regulator power supply as a source of power both system and the microcontroller.

*2.4. System Flowchart*

Upon evaluation and study on the above wireless communication technology the researcher decided to use xBee modules that use Zigbee protocol that would serve as the backbone framework of wireless sensor network design setup due to its low cost, low power consumption, acceptable range of communication that can be extendable, and adoptability of the sensor in many different environment.

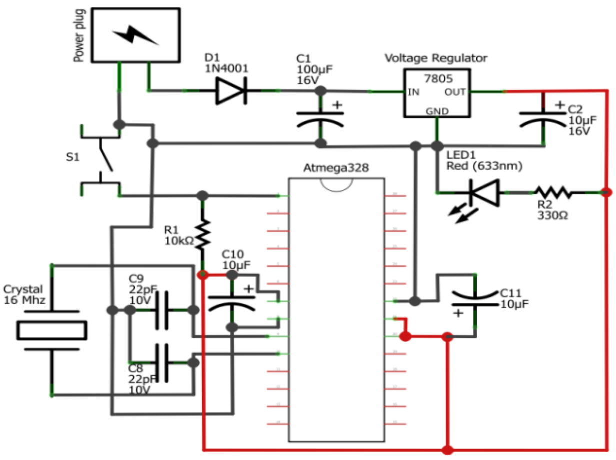


*Fig. 4. Circuit Diagram of the Main Controller*

*2.5 XBee Pro S2B RF Module*

The xBee RF Module allows to communicate wireless using Zigbee protocol, up to 2 miles (line of sight) (3200meters) and up to 300ft (90meters) indoor/urban distance transmission. According to Digi International xBee modules are embedded solutions providing wireless end-point connectivity to devices. These modules use the IEEE 802.15.4 networking protocol for past multipoint connection. They are design for high-throughput applications requiring low latency and predictable communication timing. Zigbee and alliance and a standard of cost energy efficient mesh networks. xBee uses Zigbee standard.

*2.6 Software Design*

The system uses a server to store data, process, and analyze. The design relies on the stored data and the data that was being transmitted from the wireless sensors to the main controller and to the coordinator sensor which is attach to the PC. The researcher looks for the appropriate programming language to implement to the system which will be utilized in coding the front-end and the back-end software of the system. The researcher also looks for the appropriate programming language in creating and loading firmware and drivers for the component and devices.

MySQL is an open source relational database management system that can be integrated with programming language such as PHP, Java, Visual Basic, Visual C#, C++ and others to develop rich dynamic software applications. The researcher decided to use MySql as a backend database server for a scalable, fast, and easy to use application. MySql can run comfortably on a desktop or laptop, alongside your other applications, web servers and so on, requiring little or no attention.

Subsequently, the researcher decided to use Visual C#.Net as a front end interface of the system, this will serve as a GUI (Graphical User Interface). Upon receiving the data it will be processed and analyzed by the server and interpreted by the admin user for proper clearing of the identified items, the system is capable of scanning un-enrolled data, the software is also capable of generating print out reports, accessing on the inventory list and creating settings for the front end user.

In the same manner, the researcher made use of C Programming language in creating and loading a program to the MCU/Microcontroller Unit. C language is noted for the terseness of its source code and the efficiency of its object code. C programs, if correctly written, are highly


ISSN 2449-4577 (online) 2408-283X (print)

portable. The same IDE(Integrated Development Environment) also is being utilize in bootloading the chip or what we called In-System Programming it is the ability to program any embedded devices directly to chip, rather than loading a programmed prior to installing it into the system. Before you can load a program to the MCU it needs to be bootloaded, a bootloader is a program that sits on any microcontroller and manages the uploaded program into the chip, it's like a program on top of a program. There are plenty of programmer and debugger out in the market but the researcher decided to build one for the purpose of minimizing the cost and being able to customize the design setup.

## III. RESULTS AND DISCUSSIONS

The main objective of the study is to develop a "Low-Cost Wireless Sensor Data Acquisition and Transmission" that is capable of handling data in real-time tracking over a generic and dedicated network through tagging and sensing of any attach sensor, the system utilizes RFID and Bluetooth module in transmitting and communicating to the network with a minimum distance of 3200 meters outdoors and 300 feet urban/indoors and 10 to 15 meters for the Bluetooth module. To develop a backend database for proper repository, analysis and processing of data gathered through the wireless sensor, and be able to display the output on the front-end graphical user interface.

The system is also capable of handling RFID equipped device in sending data thru real-time acquisition each item or device that was with a unique RF tags in identifying. These tags are registered to the system for proper inventory and monitoring. Each tag has a corresponding electronic product code which is being used by the RF reader in identifying items. Once the tag was identified it will be sent over to wireless sensor nodes and transmit the data to the gateway/coordinator to the database.

Findings of the study were identified based upon testing and observation to the system. The following conditions and prepositions are considered:

- The wireless sensor is capable of transmitting data in real-time with a varying distance of 300ft – 400ft outdoors. And reliably transmit data without any loss pockets. Also the number of sensors can be extended and customizable.
- The system could display any data collected on the database in evaluating, mitigating, analyzing the data also it serves as a repository for the data that is being gathered, and uses a remote website, front-end application or any handheld mobile devices for displaying information to end user.
- The system is stable and efficient in handling incoming data from the wireless sensor.
- Customizable routing protocol of each node, using mesh topology network.
- Network setup can be done without fixed infrastructure and ideal for the non-reachable places such as across the sea, mountains, rural areas or deep forests.
- The system is functional, user-friendly and easy to use.
- The aim of building a low-cost wireless sensor together with the bundle software is cost-efficient.
- Using a handheld mobile device or smartphone as an ad-hoc in sending data across devices.
- Of course to omit cables in a wired connection and portability.

### *3.1 . System Evaluation*

Figure 6 shows the coordinator node wherein all data passes thru these node it serves as the main sensor of the entire network without these node the entire system won't be able to transmit data to the server backend database.


*Figure. 6. Actual Wireless Sensor Node (Coordinator Node)*

The researcher preferred the utilization of X-CTU in configuring and loading firmware to the wireless sensor as it offers a simple Graphical User Interface (GUI) in setting up all the wireless sensors at the same time the software was utilize to test the efficiency, accuracy and precision of the system as well as built in tool to test xBees range test and reliability of pocket transmission.

Figure 7 illustrates the result of the test in acquiring data from each router and end-point node. The system accurately identifies incoming data and transmits data efficiently. It shows the data being received from the sensors were successfully identified. Figure 9 shows the string code and hex code of the data being transmitted and received.

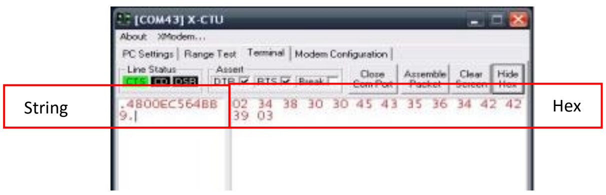


*Figure 7. X-CTU Configuration & Testing Soft*

Figure 8 shows the com port being detected by the X-CTU software. When the program is launched, the default tab selected is the PC Settings tab where you can select a com port and configure the selected com port settings when accessing the port, you can test and try to communicate to your modem/sensor by clicking the test/query button to test the selected com port. Figure 8 shows that the system was able to communicate on the modem attach to the computer.

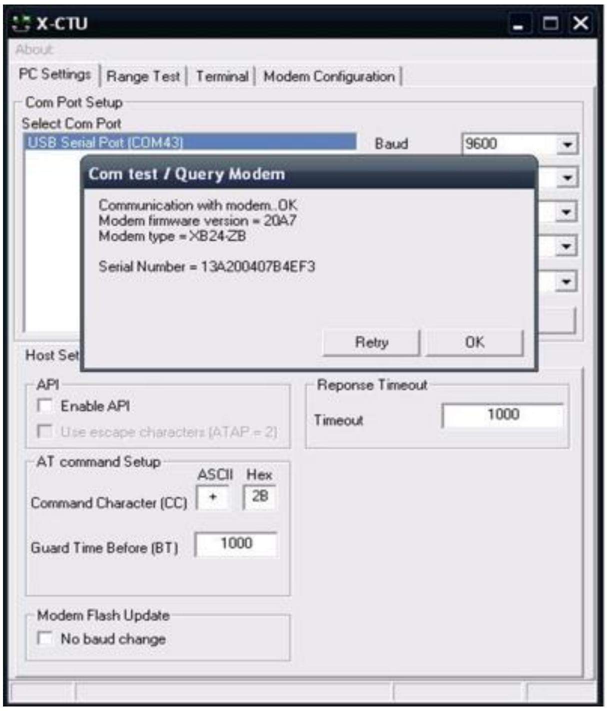


*Figure 8. X-CTU Com Port Setup Reliability check on detecting comport devices*

Figure 8 shows the com port being detected by the X-CTU software. When the program is launched, the default tab selected is the PC Settings tab where you can select a com port and configure the selected com port settings when accessing the port, you can test and try to communicate to your modem/sensor by clicking the test/query button to test the selected com port. Figure 8 shows that the system was able to communicate on the modem attach to the computer.

Figure 9 demonstrates the real-world RF range test of the xBee embedded module. This radio range test information is useful when planning for and deploying an actual network. Figure shows the actual range test of two remote router sensor nodes and the coordinator being detected by

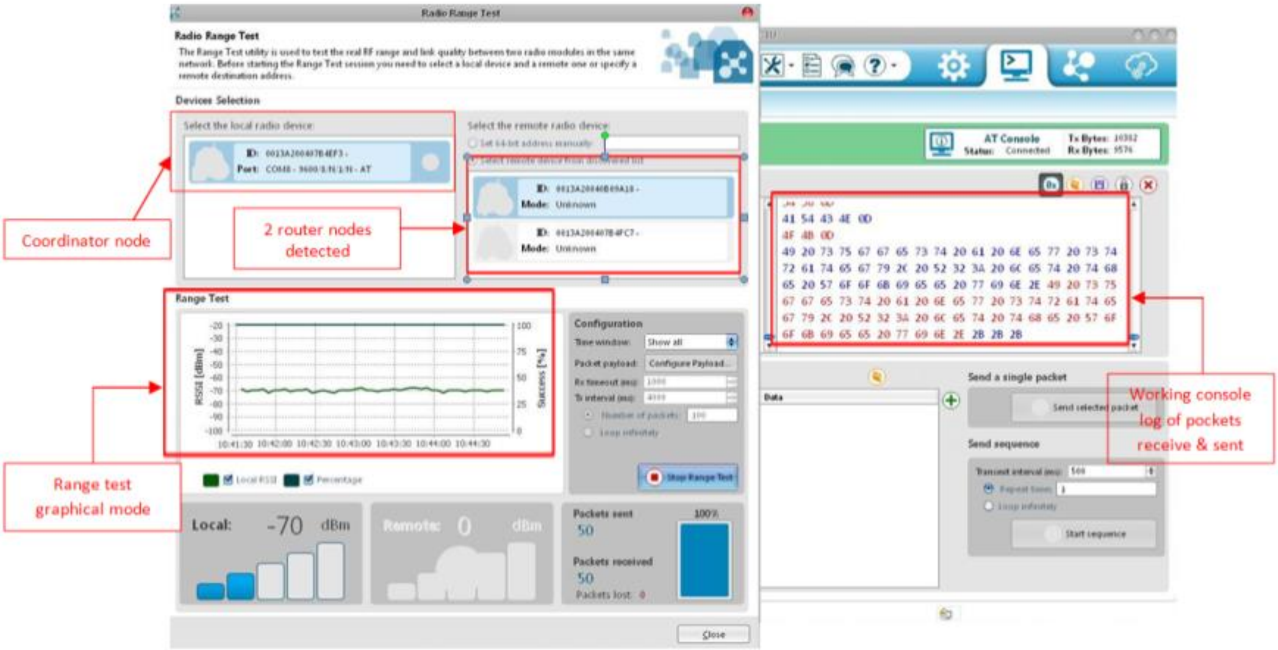


*Figure 9. X-CTU Actual Range Testing of the Sensor Nodes*

the x-ctu configuration and testing software where each pocket loopback that receives by the coordinator can be monitored on the working console log.

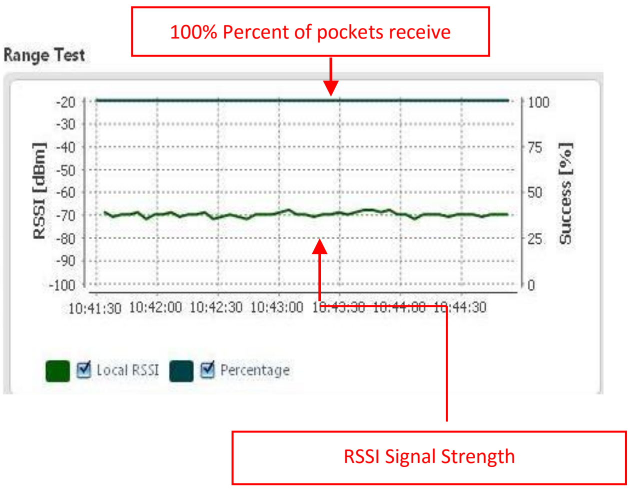


*Figure 10. Graphical Analysis of Range Test*

Shown in Figure 10 is the actual range test in graphical mode where the percent field indicates true link by showing the percentage of successful transmission. The RSSI (Received Signal Strength Indication) showed the signal strength of pockets receive by the xBee module depending on the distance of both the coordinator node and the router node.

### *3.2 Technical Specifications and Cost*

Table 1 shows the costs and specifications of different systems available commercially. The WaspMote model is superior in terms of its data rate and range but its cost is 4 times that of the developed system. Generally the new system is comparable and even exceeded some of the specifications of the commercially available systems. Tests shows that in open spaces, the system can acquire data up to 2 miles but indoors and in urban setting where line of sight are obstructed, the system is only capable of sending and receiving signal ranging 300-400 ft. This limitation can be overcome through the instllation of several sensors nodes to create network and expand the range capacity in highly obstructed line of sight.

Table 1. Cost and Specifications of Different Systems

| Features & Specs | WaspMote 802.15.4-Pro | Monnit Wireless sensor solution | NI-WSN 3212 | Low-cost Wireless Sensor Network |
|---|---|---|---|---|
| Data Rate | 14.7456Mhz | 250Kbps | 250Kbps | 250Kbps |
| Data Type | Small data pocket | Small data pocket | Small data pocket | Small data pocket |
| Range | 22,965 ft | 300-350 ft | 984 ft | 300-400 ft |
| Extendibility | Yes | Yes | Yes | Yes |
| Complexity | Simple | Simple | Simple | Simple |
| Operating Voltage | 3.3v – 4.2v | 3.3v | 3.3v | 3v – 4.2v |
| Supply Voltage | 6v | 2v – 3.6v | 3.6v – 7.5v | 6v |
| Protocol | 802.15.4 | 802.15.4 | 802.15.4 | 802.15.4 |
| Operating Frequency | 2.4GHz | 433MHz | 2.4GHz | 2.4GHz |
| Weight | 20g | 75g | 242g | 10g receiver |
| Microcontroller | ATMega1281 | T1 CC1110 | | ATMega328 |
| Price (PhP) | 10,048 w/ software | 8,841 w/ software | 24,836 w/ software | 2,507 w/ software |

## IV. CONCLUSIONS

The newly developed system is cheaper compared to commercially available systems but has comparable capacity. Signals can be transmitted up to a maximum of 2 miles in the outdoors where line of sight is clear and about 300-400 ft in urban setting or indoors. The system which is self-configurable can be installed on several stations to create a network which improves range capacity and efficient transmission of data.

The system specifications including its being lightweight, small in size and with small power requirement is best suited after disasters where all available networks are damaged or non-functional. Its self-configurable capacity makes the installation of the network system faster and more efficient providing information dissemination needs immediately.

## REFERENCES

Alexander A. Hernandez, Jonathan M. Caballer, (2010).“Introduction to MySQL”, Mindshapers Co., Inc., AT Mega 328 ATMEL Corporation (2005).retrieved from http://www.datasheetarchive.com/ATMEGA328-datasheet.html.

Cadsoft E.(2002) PCB Design Software Tutorial. Retrieved from http://www.cadsoftusa.com/training/tutorials/?language=en

Faludi,R,(2002). “Building Wireless Sensor Network” O'Reilly Media Publishing 1st Edition

Jones,A. Macdonald, M. and Rajan R. (2006). “Visual C# 2005 Recipes – A Problem Approach”, APRESS.

Luo,C. and Wu,F.(2012). “Comprehensive Data Gathering for Large-Scale


ISSN 2449-4577 (online) 2408-283X (print)

Wireless Sensor Network", Patent, October 2, 2012

Otto,C (2012). "Wireless Sensor Network Data Management System and Method", Patent.

Tocci R. and Amborsio, F(2005). "Microprocessors and Microcomputers Hardware and Software" Fifth Edition, Prentice Hall International Inc.