WIRELESS SENSOR NETWORK TO MONITOR WATER PIPELINE LEAKAGE

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Abstract: Leakage in general, takes an international attention because it causes serious fluid shortage. Due to waste and increased cost incurred in water supply systems whenever there is leakage in the pipeline, there is a necessity for real-time monitoring of pipeline for leakage in order to ensure immediate corrective measure. Water control is very essential in every area of life in order to prevent wastage. Since the monitoring of water supply can be done locally, there is a need to also monitor water from a remote location. Assuming a number of different locations where water control is done, information is further sent to a final location where decisions are made. This decision can be either to pump water to the system (for low water level) or to turn OFF the supply. Also, during the operation of the system data are stored in the memory which is sited in a remote location. This way information can be retrieved when needed but this becomes an issue in situations where the operators prefer to see all operations in real-time hence, the necessity for this study.

Keywords: Wireless sensor network, Water, Pipeline leakage, Monitoring.

I. INTRODUCTION

Wireless sensor networks (WSNs) have gained a lot of attention from researchers both from academia and industry during the past decade. This key technology enables a wide range of potential applications and services including monitoring of physical environments, enhanced industrial control, surveillance, remote health care and logistics. Real-time monitoring of pipeline network is one such application where WSN plays significant role. The issue of water is considered to be one of the largest and most serious challenges. It is expected to aggravate over time, given the scarcity of available traditional water resources and the massive costs of providing fresh potable water from non-traditional sources such as desalination plants [1]. Therefore, a robust and reliable WSN technique is required to monitor leaks, bursts and other anomalies in the water pipeline systems. This paper presents a consolidated review on WSN for water pipeline monitoring applications.

The global consumption of water has increased considerably due to the increase in population worldwide. Since fresh potable water is a scarce commodity, it needs to be conserved. Government organization and utility companies invest considerable amount of money in the maintenance of pipeline network infrastructure. One of the major problems pipeline may encounter is the leakage. Leaks are categorized into two main types: supply (service) line leaks and valve (joint) leaks. Depending on the magnitude of the leak flow, leakage can also be categorized into main two types. The first type is referred to as slow leaks, which is usually of small size when it occurs but develops gradually over time. The second type of leak is sudden burst with a greater leak flow which occurs mostly due to pipeline or joint break. In most cases, largest portion of water is lost through leaks in supply lines. [2]The leakage is sometimes also due to the usage of old pipelines, inadequate corrosion protection, poorly maintained valves and sometimes due to mechanical damage. The temperature, velocity and pressure of water may also be a contributing factor. External conditions, such as contact with other structures, stray electric currents from other utilities (in case of buried pipelines) and freezing soil around a pipe can also contribute to leakage. In order to conserve detection and repair of leaks in the pipeline is very important. Pipeline should employ advance monitoring techniques for detection and location of leakage. Several non-WSN techniques for detecting leaks in pipelines are reported in open literature [3]. These include tracer gases and ground penetrating radars (GPR) for underground leak detection which are very efficient but costly and intrusive in nature. Other techniques such as acoustic sensors, geophones and microphones are also employed for pipeline monitoring. These techniques normally require a direct wired connection (copper wires or optical fibers) to communicate with the sensor which makes it unsuitable for monitoring long distance pipelines. Wired networks expose the water pipeline infrastructure to unauthorized person or intruder who could disable the monitoring system by cutting the wires. If the wires are damaged, the whole pipeline monitoring system is compromised.

Leakage in general takes an international attention because it causes serious fluid shortage. Due to waste and increased cost incurred in water supply systems whenever there is leakage in the pipeline, this study reports a design and implementation of wireless system to monitor such pipeline at different locations within its stretch and report same at a remote location. This study is to design and implement a wireless sensor network system that could detect or monitor leakage in water pipeline at various locations within the stretch of the pipeline. The specific objectives of the project include developing a sensor node capable of detecting a water leakage a particular section of a pipeline, developing a sink node capable of acquiring data from different sensor nodes placed at different locations and log them, developing a network that consist the two, and a user interface to take decision whenever a leakage is reported from any node. This study aims at minimizing huge economic and raw materials losses accompanying fluid pipeline leakage. It enhances real time detection and remote monitoring of the pipeline.

II. RELATED WORKS

Leakage in general takes an international attention because it causes serious fluid shortage. That doesn't only cause a revenue losses but it also affects the national reserves. For example, 25% at least of water in Nigeria is being leaked in the pipeline networks and some developed countries are facing around 50% of water leaks Countries like Spain, Britain, Australia, France and the United States are experiencing serious water shortages that are getting worse from year to year [4]. The use of water and oil is increasing significantly which lead to seeking out the best system to avoid leakages in pipeline networks. One of the most effective ways of how to detect leak is the use of Wireless Sensor Networks (WSNs).

Recent advances in wireless sensor networks have provided researchers with an easily, deployable, flexible, efficient and an inexpensive approach for real-time distributed data acquisition and monitoring. Ad-hoc wireless sensor networks are self-organized networks that have a large number of sensor nodes interacting with the environment they are in and communicate wirelessly. The main goal of the sensor nodes is to transfer the recorded and processed data to a remote station. The utilization of a WSN to be implemented underground for monitoring proved to be benefited from rapid and flexible deployment. Both decision made and management system are based on the continuous recording and processing of the received WSN signals. From the received signals, integral part of a leakage management strategy can be formed by providing either the water or oil network administrators with real time data or a useful decision-making tool Christodoulou *et al.* (2010). The WSN could be implemented everywhere including the suffering countries because it is considered to be the least expensive and effective method for leakage detection.

A wireless sensor network (WSN) is a network of small autonomous devices, called sensor nodes with on-board sensing, processing and communication capabilities which cooperate together to solve at least one application task. Typically, a wireless sensor node (or simply sensor node) consists of sensing, computing, communication, actuation, and power components [5]. A WSN consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. The tasks include some kind of perception of physical parameters [6]. The more modern networks are bi-directional, also enabling control of sensor activity. WSNs are used in many applications, such as industrial process control, precision agriculture, health monitoring, and environmental monitoring and so on [7].

III. METHODOLOGY

The system consists of hardware and software platforms being integrated together. The block diagram of the developed system is as shown in Figure 1. The system consist of two sensor nodes being located at different locations within the pipeline stretch, and one sink node which act as the network coordinator and data collector. At the heart of the system are the wireless sensor nodes (SN).

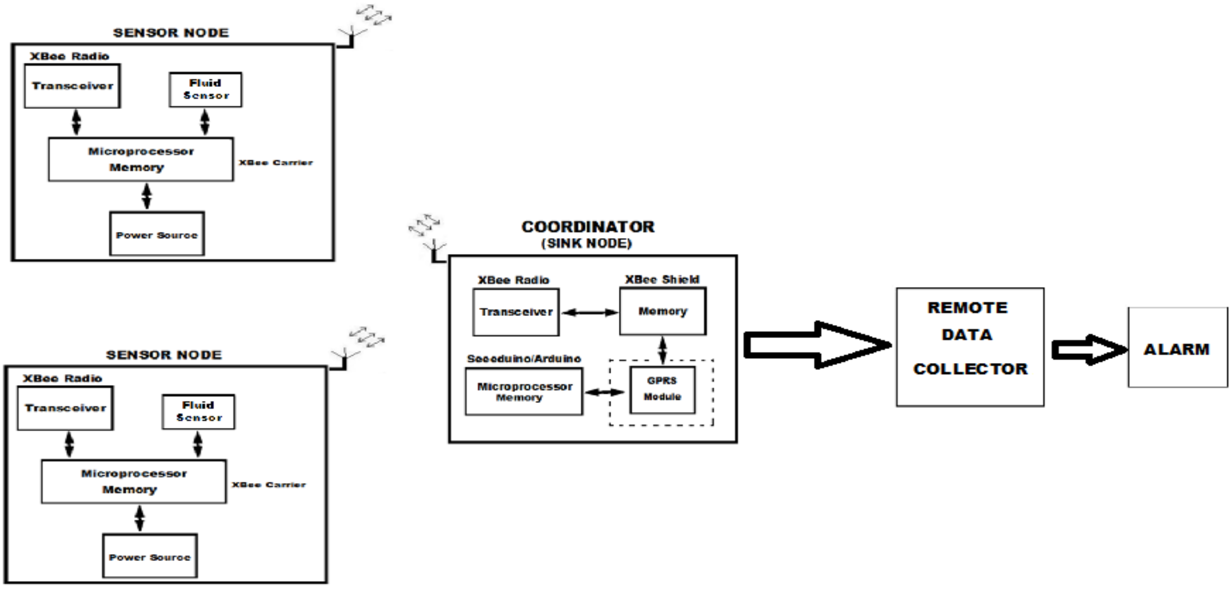


Figure 1: Block diagram of the Wireless Sensor Network

A. Design of hardware unit

The hardware unit of the system was designed for best performances by selecting appropriate components for the sensor node, and coordinator according to [8]. The block diagram of the internal hardware components of the sensor nodes is as shown in Figure 2. The pictorial view and the specifications of the selected XBee transceiver module are as shown in Figure 3.

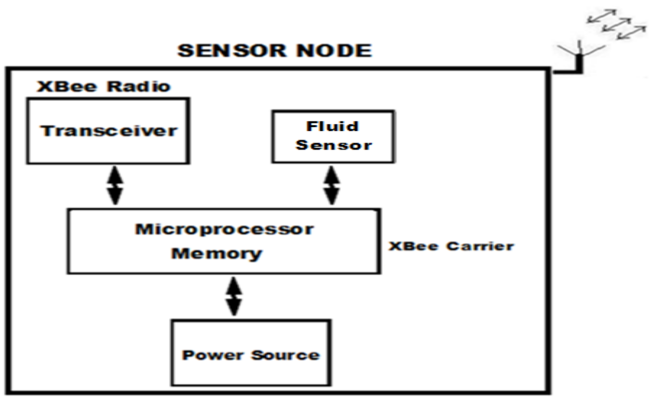


Figure 2: Block Diagram of the Hardware Components of the Sensor node

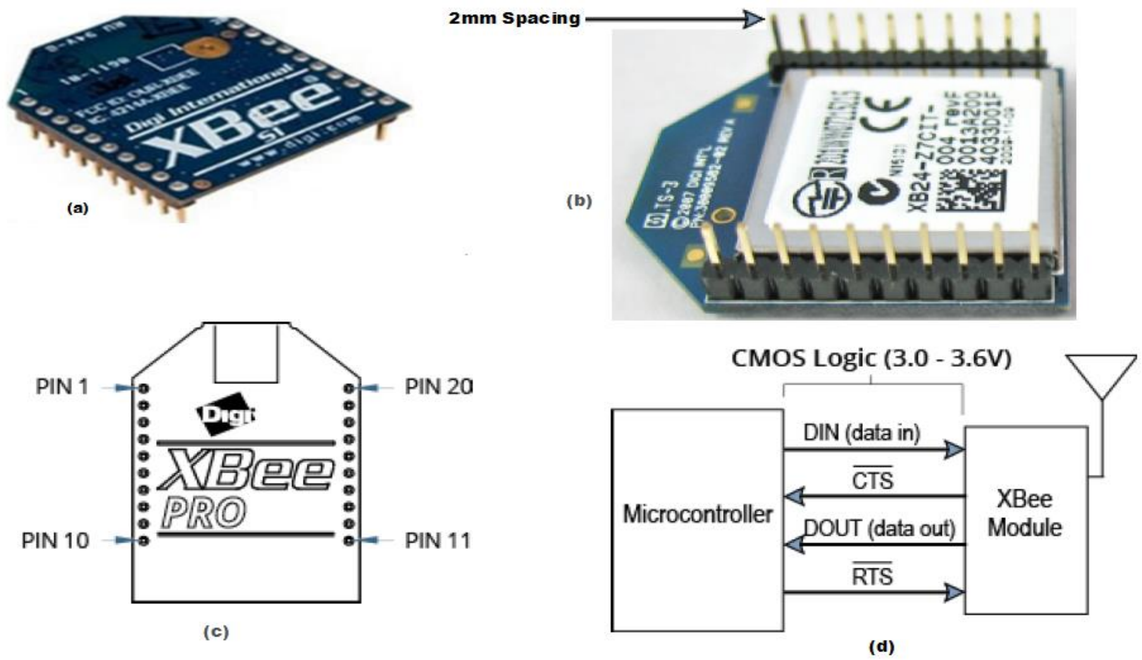


Figure 3: XBee RF module (a) Top pictorial view, (b) Reverse pictorial view showing the pins (c) Pin labels, (d) XBee – UART data flow [9]

B. Design of the software unit

This section highlights the design and implementation of the software units of the wireless sensor network system. The software unit of the system included the programming of the Seeeduino in the coordinator, the configuration of the transceiver modules, and the setting up of the network for optimal performance of the system.

i. Node Configuration

The radio module of each node was configured in order to assign identification and operational interaction with other nodes within the network. XBee modules were configured locally through serial attention commands 'AT commands' using the serial terminal software XCTU (Configuration and Test Utility Software by Digi International). The flowchart of the node configuration is as shown in Figure 4.

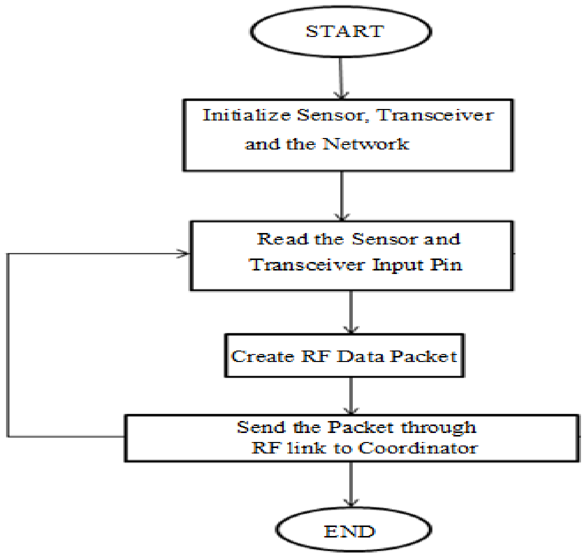


Figure 4 Flow chart of Sensor node Configuration

ii. Network configuration

The network was configured using a modified mesh topology. This configuration sets a distributed network in which all the nodes use using peer-2-peer (equal-to-equal) mode. The configuration allows networks to be strengthened having self-healing features of lattice interacting. The network cycle of the system is as shown in Figure 6, while the flowchart of the network configuration is as shown in Figure 5.

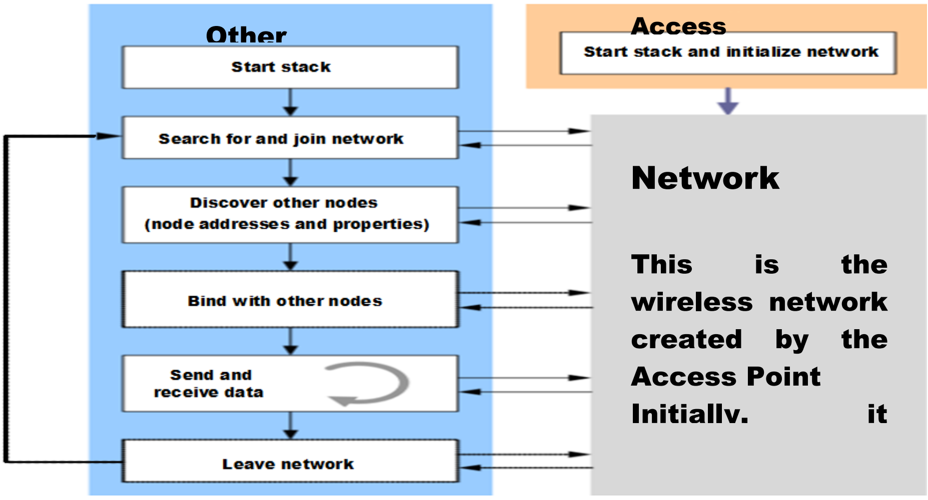


Figure5: Network Lifecycle

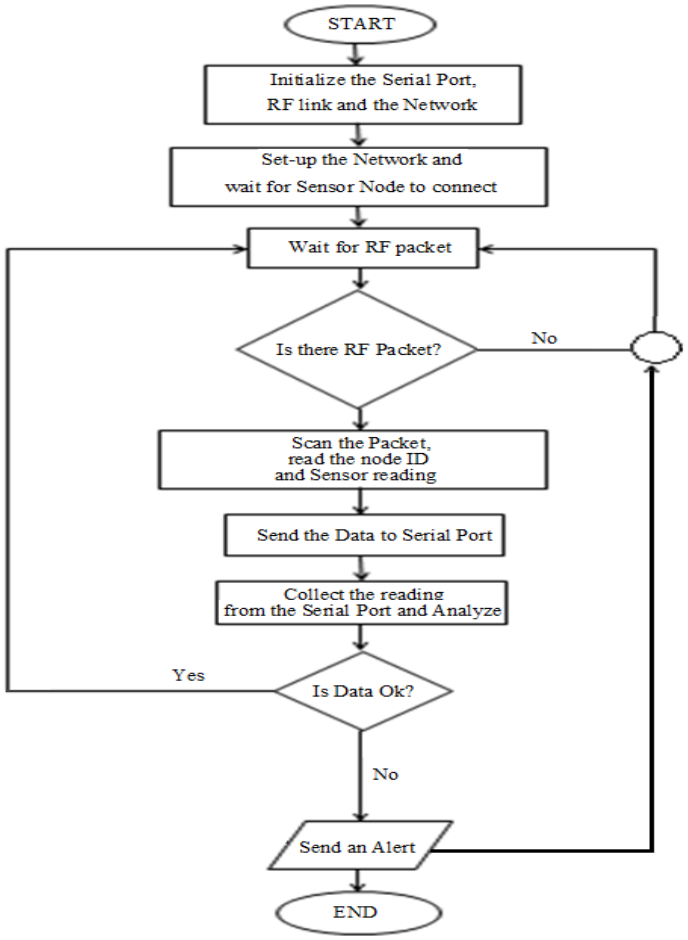


Figure 6 Flowchart of the Network Configuration

iii. User interface design

The user interface was the platform designed for human interaction, logging, analysis and interpretation of the data collected. The graphical user interface (GUI) in this study was designed using Laboratory Virtual Instrument Environment Workbench (LabVIEW). The block diagram of the GUI developed is as shown in Figure 7. The basic idea was to design how data did flow from a device port to nice looking generated displays.

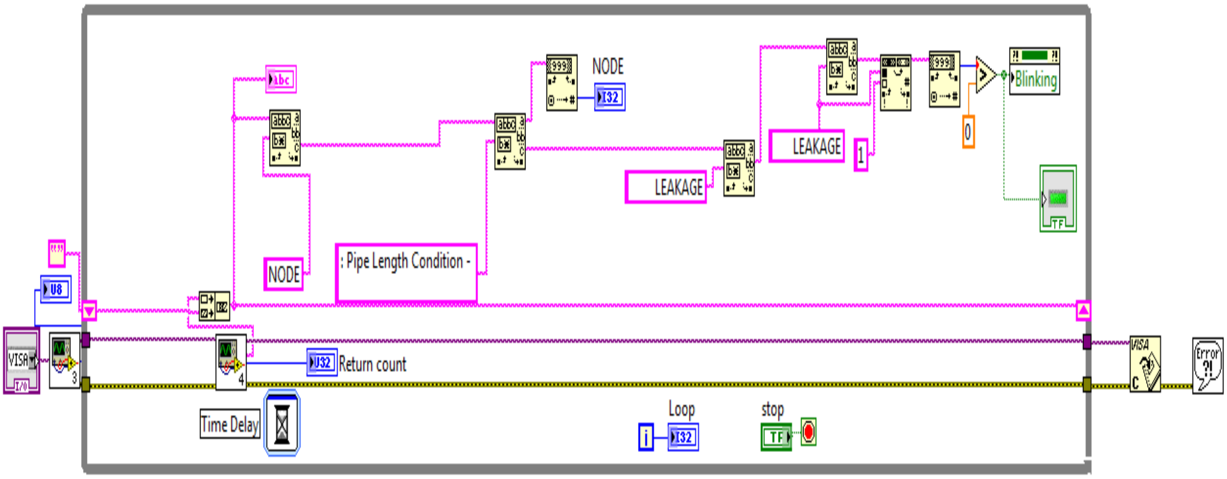


Figure 7: Block Diagram of the Graphical User Interface

IV. RESULTS AND DISCUSSION

The results of the implementation of hardware and software units of the system of wireless sensor network are presented in this section.

A. The resulting nodes

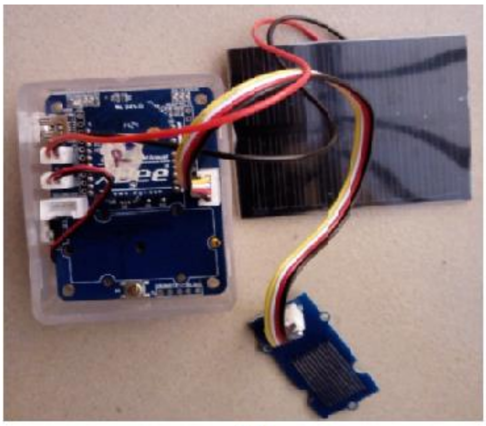
The pictorial views of the composite nodes within the monitoring system are as shown in Figure 8. The components of the sensor node included Grove – water sensor, XBee DigiMesh RF module with PCB antenna, Grove - XBee carrier, 5 Volts Lithium battery and a solar panel for battery charging. The components of the coordinator included XBee DigiMesh RF module with PCB antenna, Arduino microcontroller platform, and XBee Shield.

B. The resulting network

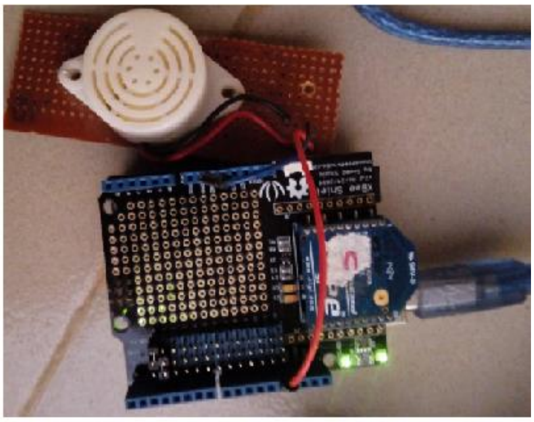
The XCTU screenshot for the resulting node configuration is as shown in Figure 9. The network was formed and managed by the coordinator and initially consisted only it, while each sensor node searched for and later joined the network sequentially.

C. Graphical User Interface

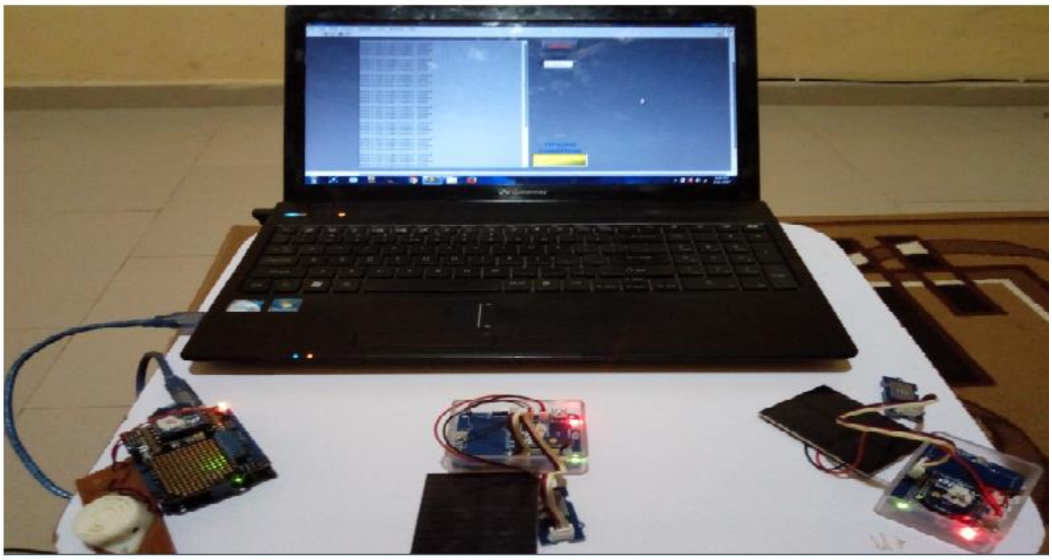
The resulting graphical user interface (GUI) designed for this project using LabVIEW is as shown in Figure 10. The output when there was no leakage in any of the node is as shown in (a), while the output when there was leakage in Node 2 is as shown in (b).



(a)



(b)



(c)

Figure 8: Pictorial View of (a) Sensor Node, (b) Sink Node, and (c) The System Nodes

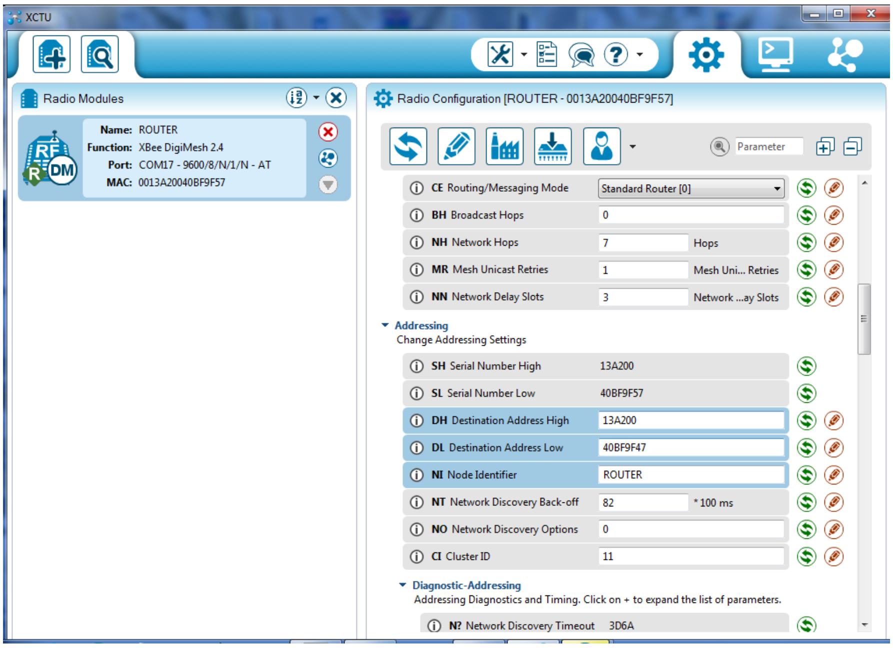
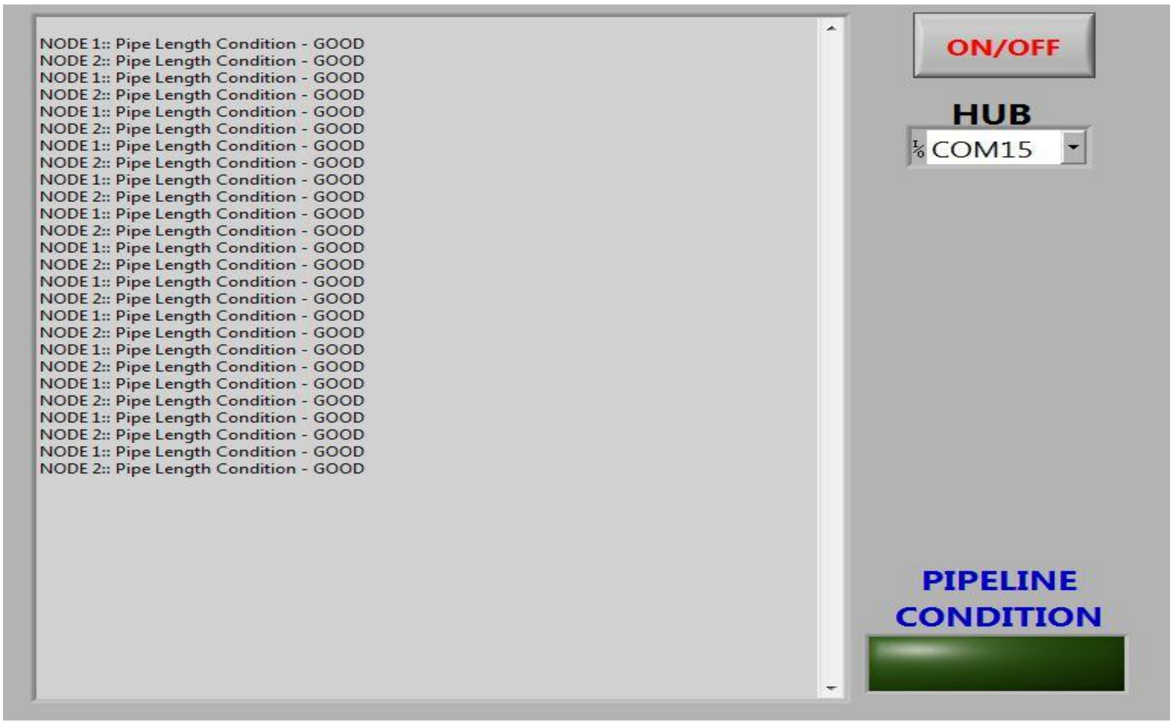
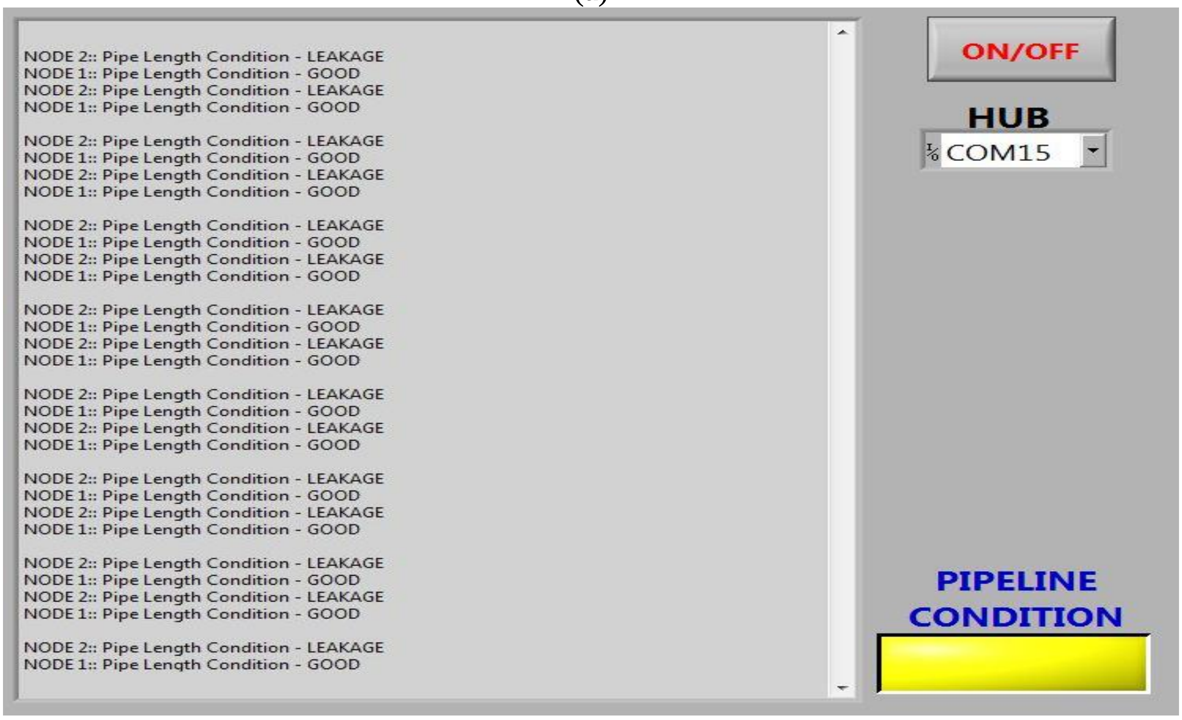


Figure 9: XCTU Screenshot for Radio Modules Configuration



(a)



(b)

Figure 10: The Graphical User Interface (GUI)

V. Conclusion

Fluid leakage is a very hassling worldwide matter that needs to be dealt with immediately; otherwise it will cause huge economic and raw materials losses. This project work has designed and implemented a wireless sensor network system that can efficiently detect leakage at various locations and report them in real-time at a remote location. This system has contributed to minimizing huge economic and raw materials losses accompanying fluid pipeline leakage. It enhances real time detection and remote monitoring of the pipeline. It is meanwhile concluded that the project work has achieved its aim and objectives. It is recommended that more sensor nodes are required for better network connectivity. Future works can concentrate on increasing the range of transmission of data by the sensor nodes.

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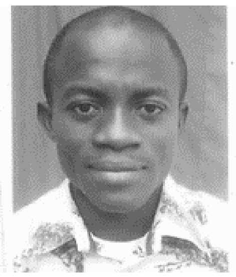

Moses O. Onibonoje was born in Ikere Ekiti, Nigeria in 1979. He received B.Sc., M.Sc. and Ph.D. in Electronic and Electrical Engineering from Obafemi Awolowo University, Ile-Ife, Nigeria in 2007, 2012 and 2016 respectively. From 2011 to 2015, he was a Research Assistant with Obafemi Awolowo University, Ile-Ife, Nigeria. Since 2015, he has been a Lecturer with the Department of Electrical/Electronics & Computer Engineering, Afe Babalola University, Ado-Ekiti, Nigeria. He is presently on a Senior Lecturer cadre, and he is the Coordinator of the Postgraduate programmes of the Department. He has authored 12 academic publications. His research interests are rooted in Wireless Instrumentation and Distributed Control Systems. The prior researches were embedded in wireless sensor network (WSN) with focus on Remote Sensing, Wireless Optimization, and Distributed Methods. He has interest in designing and building distributed control systems by optimizing WSN for possible applications which include: intelligent transportation system, vehicular ad-hoc network, robotics and precision agriculture.

Dr. Onibonoje was a recipient of the Council for the Regulation of Engineering in Nigeria certification in 2015.