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# Design and Development of Wireless Sensor Network (WSN) for Water Quality Monitoring using Zigbee

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**Abstract**

This paper presents the implementation of Wireless Sensor Network for water quality tracking using Zigbee. For continuous monitoring a number of sensor nodes with networking ability can be installed using wireless sensor network for water quality monitoring. In water quality monitoring the parameters involved are pH, and turbidity. These parameters are measured in real time by the sensors that send the data to monitoring room/control station (Base station). Such monitoring system can be setup on the aspect of low cost, low power consumption, easy handling, installation and maintenance. The system consists of sensor nodes (pH Sensor, Turbidity Sensor), a microcontroller, a Zigbee radio, and a base station (Zigbee radio and microcontroller).For comparing routing results of different topologies OPNET simulator is used.

Keywords- pH measurement, Turbidity measurement, Zigbee technology, X-CTU, Water quality monitoring, PLX-DAQ, wireless sensor networks, OPNET.

## INTRODUCTION

For human survival water is necessary. Also, water is required for various purposes like Agriculture, Industry, human activity, etc. Depending on water quality we can decide its usability. For water quality criteria as per government norms there are five classes i.e. Class A, Class B, Class C, Class D and Class E. Class A of water is designated for drinking water source without conventional treatment but after disinfection. Class B is designated for outdoor bathing. Class C is designated for drinking water source after convential treatment and purification. Class D is used for generation of wild life and fisheries. Class E is for irrigation, industrial cooling, and controlled waste destruction. In this project Class C of water is used. Approximately 80% of people in developing country have not access to potable water. There are many diseases like cholera which are caused due to impotable water. After considering such critical circumstances of polluted natural water this work has been started. For water quality continuous monitoring is required to detect changes in environment either by natural resources or human intervention. Purpose of water quality monitoring is to identify pollutants and its resources, also its chemical, physical, biological characteristics needs to be included. Water is mostly used in agriculture primarily for crop irrigation. The contamination degree can be decided with water quality index (WQI). Contamination of water wells, rivers by fecal matter causes fish death. For this, it is very important to have the characteristics like low cost, reliable, flexible and low power consumption. Project focuses on water quality level like pH, Turbidity. Monitoring is planned to be carried out in distant areas having limited access of signal, Sensor data sends wirelessly to base monitoring station. In this project, currently becoming famous and mainly used technology for wireless sensor network i.e. Zigbee, as it gives low cost implementation,

flexibility, reliability, low power consumption. Zigbee based wireless sensor network technology is used in this work. For reliable communication Zigbee is a communication standard for wireless sensor network technology having specification of IEEE 802.15.4. The key component of Zigbee protocol is the ability to support mesh networks. In mesh network nodes are interconnected to form multiple paths. In is project star network is implemented. Zigbee standard uses two sub layers one is physical layer and another is MAC layer. Simulation of wireless sensor network required because of nature of hardware design, energy limitation, and vast number of nodes. Study and testing of Zigbee protocol within Opnet simulator for mesh topology and routing scheme is suggested here.

## RELATED WORK

There have been many works on implementation of WSN for observing system and prototype design such as in [1], where zigbee is used to monitor the sensor values. Survey of the current state of art in the design and monitoring WSN –based WQM systems, discussing techniques used at the stage of implementation process, also several advantages, several open issues that require extra research for further use of WSN-based WQM systems such as in [2] . For zigbee simulation there are some works on WSN i.e. routing of zigbee using OPNET simulator routing includes Number of hops simulation, End to End delay simulation such as in [3]. The performance abilities of OPNET Modeler in simulating Zigbee WSNs, OPNET has good prospective in simulating Zigbee WSNs since it can provide a variety of reports and statistics at different network layers for individual node or entire WSN, also it is easier to install and configure compared to other WSN simulators such as in[4].

## DESIGN CONCEPT

By considering area of 16 Km from water source and maximum 250 sensor nodes as end device, we have simulated wireless sensor network by using OPNET Simulator and analyzed the routing results with Zigbee routing OPNET Simulator, also designed a prototype of star topology network with Zigbee by sensing pH, Turbidity. Technological standard created for control and sensor networks named for erratic, and designed for wireless controls and sensors. Zigbee works in star, cluster tree and mesh. First study the performance, inclusive study and analysis of Zigbee with the help of Opnet simulator and then design a prototype. In prototype design the main concept is sending data (pH, turbidity) wirelessly using Xbee radio having range of 30 to 50 meters to microcontroller (Arduino Uno) and connect microcontroller to pc (Base station) using USB cable. After getting data on pc with the help of PLX-DAQ all data is fetched on Excel sheet so we can monitor. Fig.1 shows hardware architecture of prototype. Prototype is designed for testing the system conflict of data. The network consists of node system and base station. The node system consist pH and turbidity sensors data over wireless network which transmit through Zigbee protocol. The base station has Zigbee radio which is configured as coordinator in XCTU.

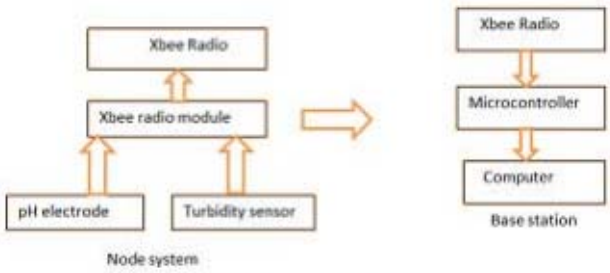

Fig.1 Hardware architecture

## PROTOTYPE DESIGN

The base station receives data and transfer to pc via USB port. While sending data through Zigbee radio with module at first both Zigbee has to configure through X-CTU software one Xbee as coordinator which further will be used in base station for receiving data from node system, other one as end device which is used in node system for sending data. The Xbee configuration in X-CTU software is as shown in fig.2. The Zigbee which is configured as end device and coordinator have same ID (PAN ID), Scan Channel, Scan duration, etc. Zigbee which is configured has coordinator enable and end device

enable respectively so the data is transferred wirelessly. The hardware implementation of prototype is shown in fig 3(a, b) .In node system i.e. fig 3(a) shows the sensors having their own circuit connected to Zigbee which is enabled as end device in X-CTU. Sensors used in this paper are pH sensor E-399 and turbidity sensor CZ15/46. pH sensor is connected to end device i.e. Zigbee through ADC circuit, also turbidity sensor is connected to Zigbee end device through its ADC circuit. The data is monitored through base station having controller i.e. arduino Uno which is linked to Zigbee that is configured as coordinator in X-CTU. Fig.3 (b) shows implementation of base station. We get the data on pc which is shown in fig.3 (b).The output of prototype gives pH value 7.25 to 8.9 and turbidity is 73.93%.The water used for this prototype is from college campus. With the help of PLX-DAQ we can monitor the data on excel sheet.

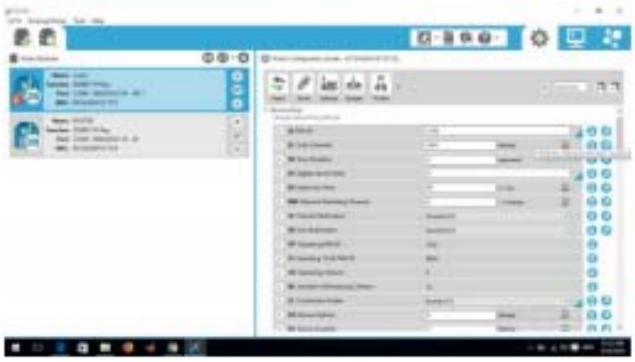

Fig.2 Xbee configuration

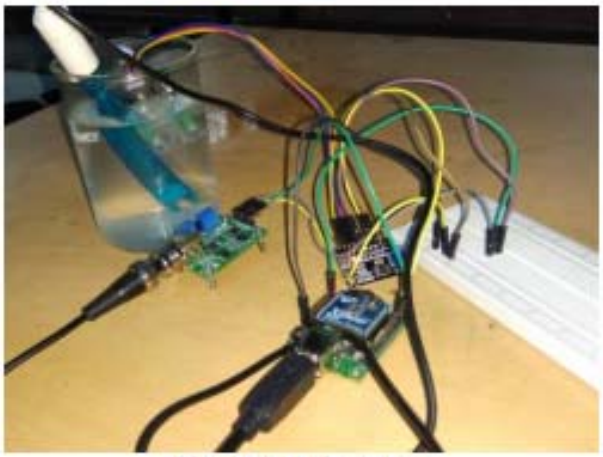

Fig. 3(a) Node system

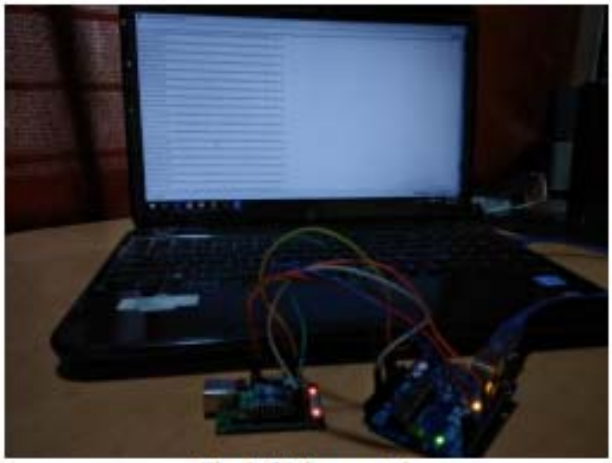

Fig.3 (b) base station

**SIMULATION USING OPNET**

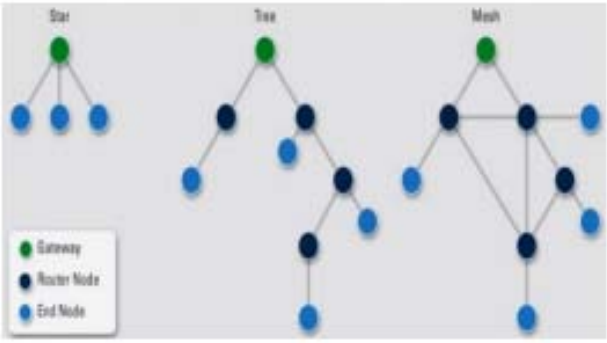


Fig.5 star, tree, mesh topology

While simulating the wireless sensor network using Zigbee we have to study the three topologies:(1) Star topology, (2) Tree topology, (3) Mesh Topology

(1)Star Topology: In this network each node connects to central network device like hub, switch, coordinator, computer.

(2)Tree Topology: In this network contain elements of both bus topology and star topology, in which the central nodes of two star networks are connected to one another.

(3)Mesh Topology: If one node can no longer operate, the others can still communicate with each other, directly or through one or more intermediate nodes. When mesh network is wired, the topology could be expensive. So, we use wireless sensor network.

Zigbee is the good communication protocol for mesh topology also network reduces cost compared to wired network. A. Introduction to OPNET Modeler The OPNET modeler environment comprises tool of simulation. OPNET Modeler gives inclusive development environment supporting the modeling of communication networks and distributed systems. Both functioning and execution of model can be examined by performing distinct event simulations. The hierarchical levels for arrangement are distinguished:

1) the network status generating the topology of network under analysis.

2) The node level describing the performance of the node and controlling the flow of data in-between different functional elements inside the node.

3)the process level, relating the underlying protocol.

Different graphical presentations for the simulation results are accessible and node portability can be easily implemented in different kinds of nodes i.e. Zigbee coordinator, end device and router nodes. Zigbee Protocol:

1) Zigbee MAC model which executes a model of the IEEE802.15.4 MAC protocol. The model executes channel scanning, joining and failure operation of the protocol.

2) Zigbee application model which gives a low fidelity version of the zigbee application layer as defined in the Zigbee specification.

3) Zigbee carrier sense Multiple Access model which executes the media access protocol of the MAC layer.

4) Zigbee network model which implements the Zigbee network layer as defined in Zigbee specification. This standard is responsible for routing traffic, network join, formation requests and generating beacons. B. Simulation Important goal of the simulation of network is to test the operation of a zigbee network in a context WSN. The Wireless Sensor Network may vary from some meters to several kilometers for example; environmental application, agricultural application, Industry application, etc have a large distance but some application have small distance like residential construction, etc. Fig.6 indicates the simulation scenario for star network. In this network one coordinator node is directly connected to seven end device nodes which are displayed in fig.6. The result of data traffic received by the network is shown in fig.7. Management Traffic: It is the amount of data going across the network at a given point of time. Network data contained in network packets ore bits, which provide a load in the network. Traffic received and the load is average traffic received or sent by higher level node. The traffic received and sent by higher level node i.e. coordinator is almost same. The management traffic is varied in between 3100 bits to 3300 bits for duration of 1 hour. In star topology if any one router node fails then we are unable to receive data from the end device nodes which is connected to that router node even if end device nodes are working properly. This limitation of star network becomes better in mesh topology. Zigbee is more reliable protocol for mesh network formation. We can extend the range only because of mesh network. Fig.8 indicates the mesh network in Opnet simulator. In this network there is one coordinator which is connected to seven router nodes and twelve end device nodes to form mesh topology. The beauty of mesh topology is if any one of the above router node fails then also we could get data from end device nodes to coordinator or we could detect which router failed. The routing results of mesh network are shown in fig.9. In this fig.9 the Zigbee 802.15.4 MAC management traffic received is around 11000 bits per second. The Zigbee application traffic sent is 1000 bits per second, the conversion in packets per second is 1packet/sec. Zigbee mesh network is more suitable even if it is complicated than other topology as we can extend the range.

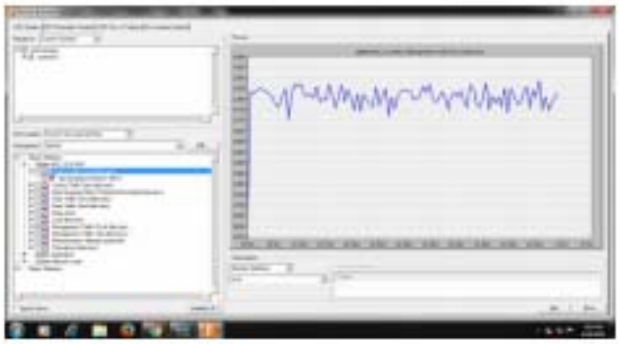

Fig.6 Star topology

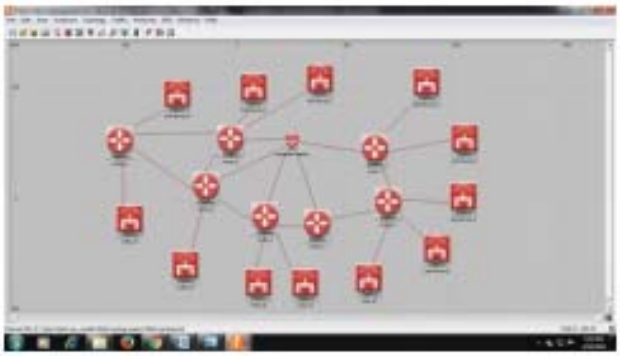

Fig.7 traffic received for star Network

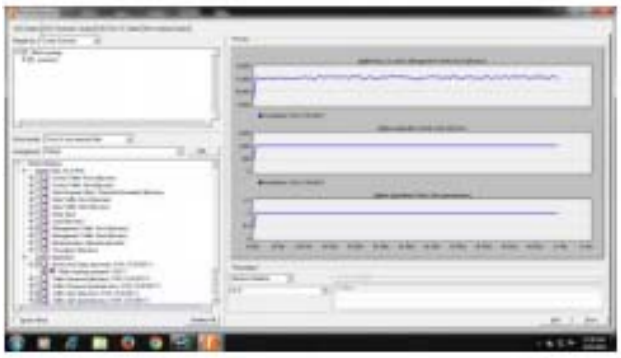

Fig.8 Mesh Network

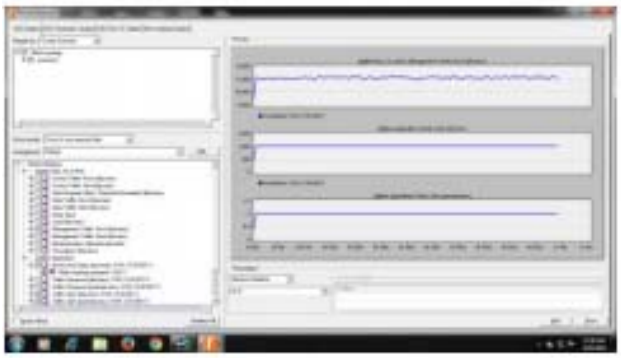

Fig.9 Mesh output

## FUTURE WORK

Once the data from node system is received to base station i.e. on pc in the prototype, we can make monitor it in Excel sheet using PLX-DAQ software which gives data from arduino to Excel sheet.

## CONCLUSION

The motivation of this paper was to explore the presentation capabilities of OPNET Modeler in simulation of zigbee wireless sensor network, also design a prototype for water quality monitoring. It can be concluded that OPNET Software has capability to form mesh network using Zigbee. The output is varied between 7 to 8.9 for pH sensor node and turbidity displayed around 73% for water which was tested in lab. The suggested prototype has low power consumption as the protocol is Zigbee.

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