Design and simulation of Smart Water Quality Monitoring System in IoT Environment

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Abstract

In this paper, the effective and efficient system of water quality monitoring (WQM) are critical implementation for the issue of polluted water globally, with increasing in the development of Wireless Sensor Network (WSN) technology in the Internet of Things (IoT) environment, real time water quality monitoring is remotely monitored by means of real-time data acquisition, transmission and processing. This paper presents a reconfigurable smart sensor interface device for water quality monitoring system in an IoT environment. The smart WQM system consists of Field Programmable Gate Array (FPGA) design board, sensors, Zigbee based wireless communication module and personal computer (PC). The FPGA board is the core component of the proposed system and it is programmed in very high speed integrated circuit hardware description language (VHDL) and C programming language using Quartus II software and Qsys tool. The proposed WQM system collects the five parameters of water data such as water pH, water level, turbidity, carbon dioxide (CO2) on the surface of water and water temperature in parallel and in real time basis with high speed from multiple different sensor nodes.

***Keywords*— Internet of Things (IoT), smart, Wireless Sensor Network (WSN), Water Parameters, Zigbee, Water Quality Monitoring (WQM), Field Programmable Gate Array (FPGA).**

I. INTRODUCTION:

Wireless sensor networks (WSNs) have become a hot research topic in recent years clustering is considered as an effective approach to reduce network overhead and improve scalability. Wireless sensor network is one of the pervasive networks which sense our environment through various parameters like heat, temperature, pressure, etc. Since sensor networks are based on the dense deployment of disposable and low-cost sensor nodes, destruction of some nodes by hostile action does not affect a military operation as much as the destruction of a traditional sensor, which makes the sensor network concept a better approach for battlefields. The transmission between the two nodes will minimize the other nodes to show the improve throughput and greater than spatial reuse than wireless networks to lack the power controls. Adaptive Transmission Power technique to improve the Network Life Time in Wireless Sensor Networks using graph theory we have distance comparison between the neighbor nodes and also local level connected from the nearest edges in wireless sensor networks.

A sensor is a device that detects events or changes in quantities and provides a corresponding output, generally as an electrical or optical signal; for example, a thermocouple converts temperature to an output voltage. But mercury in glass thermometer is also a sensor; it converts the measured temperature into expansion and contraction of a liquid which can be read on a calibrated glass tube. Internet of Things (IOT) is the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure. Typically, IOT is expected to offer advanced connectivity of devices, systems and services that goes beyond machine - to- machine communications (M2M) and covers a variety of protocols, domains, and applications. The inter connection of these embedded devices (including smart objects), is expected to usher in automation in nearly all fields, while also enabling advanced applications like a Smart Grid.

A. Wireless Sensor Network

Wireless sensor network (WSN), which integrates sensor technology, wireless communication technology, embedded computing technology and distributed information management technology, has been under rapid development during recent years. A wireless sensor network is a collection of nodes organized into an interactive network. Each node consists of processing capability (one or more microcontroller's chips) and contains types of memory, with a Zigbee transceiver module and also, each node have a stable power source and the last part of a node, it is accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc method. Such systems can revolutionize the way we live and work therefore in this project we want to use WSN technology to control and manage energy in building. On the other hand, FPGA has unique hardware logic control, real-time performance, and synchronicity, which enable it to achieve parallel acquisition of multi-sensor data and greatly improve real-time performance of the system. FPGA has currently becomes more popular than MCU in multi-sensor data acquisition in IoT environment. However, in IoT environment, different industrial WSNs involve a lot of complex and diverse sensors. At the same time, each sensor has its own requirements for readout and different users have their own applications that require different types of sensors. It leads to the necessity of writing complex and cumbersome sensor driver code and data collection procedures for every sensor newly connected to interface device, which brings many challenges to the researches. Sensor data acquisition surface device is the key part of study on industrial WSN application. In order to standardize a wide range of intelligent sensor interfaces in the market and solve the compatibility problem of intelligent sensor, the IEEE Electronic Engineering Association has also launched IEEE1451 smart transducer (STIM) interface standard protocol suite for the future development of sensors. The protocol stipulates a series of specifications from sensor interface definition to the data acquisition. The STIM interface standard IEEE1451 enables sensors to automatically search network, and the STIM promotes the improvement of industrial WSN. But, the sensors with the protocol standard have a high cost and still lack popularity in industrial WSN in IoT environment. Nevertheless, at present, examples of intelligent sensors available on the market and compliant with this standard are still limited.

Wireless sensor networks have seen extensive proliferation of applications and interest in research and industry. Such networks can be densely deployed over a diverse geographic area ranging from 10s of meters to several hundreds of kilometers through deploying small, low cost devices that can observe and influence the physical world around them by gathering status information and then transforming this into radio signals. Such signals are then transmitted to a local sink which may be connected to a gateway to send the data to external network such as internet. The data thus received may be analyzed and appropriate decision/action taken depending on the type of application. Unfortunately, these sensors suffer from resources constraint and power limitation as these sensors are usually deployed in remote places that are not easy to reach. Inevitably, there is a finite life time duration for such devices and new sensors have to be deployed to replace the old ones. The main emphasis is on maximizing the life time of sensors and to use the limited resources efficiently by adopting mechanisms, algorithms and protocols that consider these limited resources as main priorities and challenges to produce efficient and reliable networks. Wireless sensor networks utilize an efficient form of technology that has no structures or rules or adhering to a specific standard. This makes it an interesting area for research and thus significant resources are being placed on its study by research scholars and manufacturer's alike. There are a number of applications for such devices and networks such as; military, health monitoring, indoor and outdoor firefighting applications, security applications, environmental, agricultural, climate changes and studying animal behavior.

A WSN can be defined as: 'a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links. The data is forwarded, possibly via multiple hops, to a sink (sometimes denoted as controller or monitor) that can use it locally or is connected to other networks (e.g., the Internet) through a gateway. Sensor networks are a distributed small sensing devices provided with short-range wireless communications, memory and processors. This kind of network differs from conventional ad-hoc networks in the following way:

- number of nodes deployed in WSN is higher
- sensor nodes are densely deployed and usually in harsh environment
- sensor nodes have finite and limited life span
- topology of the network may change frequently
- WSN work in a broadcast fashion, while ad-hoc is point to point
- WSN has limited power and range resources • may not have a global ID

II. INTERNET OF THINGS (IoT)

With the advancements in Internet technologies and WSNs, a new trend is forming in the era of ubiquity. "IoT" is all about physical items talking to each other, where machine to- machine (M2M) communications and person-to-computer communications will be extended to "things". Key technologies that drive the future of IoT are related to smart sensor technologies including WSN nanotechnology, and miniaturization. Since IoT is associated with a large number of wireless sensor devices, it generates a huge number of data. Sensor data acquisition interface equipment is one of the key parts in IoT applications. Data collection is the essential application of WSN and more importantly it is the foundation of other advanced applications in IoT environment. IoT is a major drive to support service composition with various applications. The architecture of IoT is illustrated as in Fig.2. The data acquisition interface is responsible for the integration and collaboration of various environments and collection of sensor data. Examples of such a workflow include a environment monitoring system that adopts sensors to temperature and light. Environment monitoring is one of the IoT application fields, where complex water quality information, is used to determine the environmental quality at the same time. However, currently, there are few data collection device that are dedicated to quality monitoring on the market. Such devices can ensure high speed of data acquisition for multiple sensors and adapt to complex and various sensor types well. Thus, we design and implement a WSN data acquisition interface that can be used for environmental monitoring.

Figure: 1 Architecture of IoT

III. LITERATURE REVIEW

In this, we present the theory on Design and simulation of Smart Water Quality Monitoring System in IoT Environment. The overall block diagram of the proposed method is explained. Each and every block of the system is explained in detail

In the proposed smart WQM system, a reconfigurable smart sensor interface device that integrates data collection, data processing, and wireless transmission is designed. The hardware experimental set-up of smart WQM system is shown in Fig.2. The hardware of wireless water quality monitoring system comprises the following components:

- Ultrasonic Sensor
- pH Sensor
- Digital Thermometer Sensor
- Turbidity Sensor
- CO2 Sensor
- Radio Frequency (RF) Module
- FPGA Board

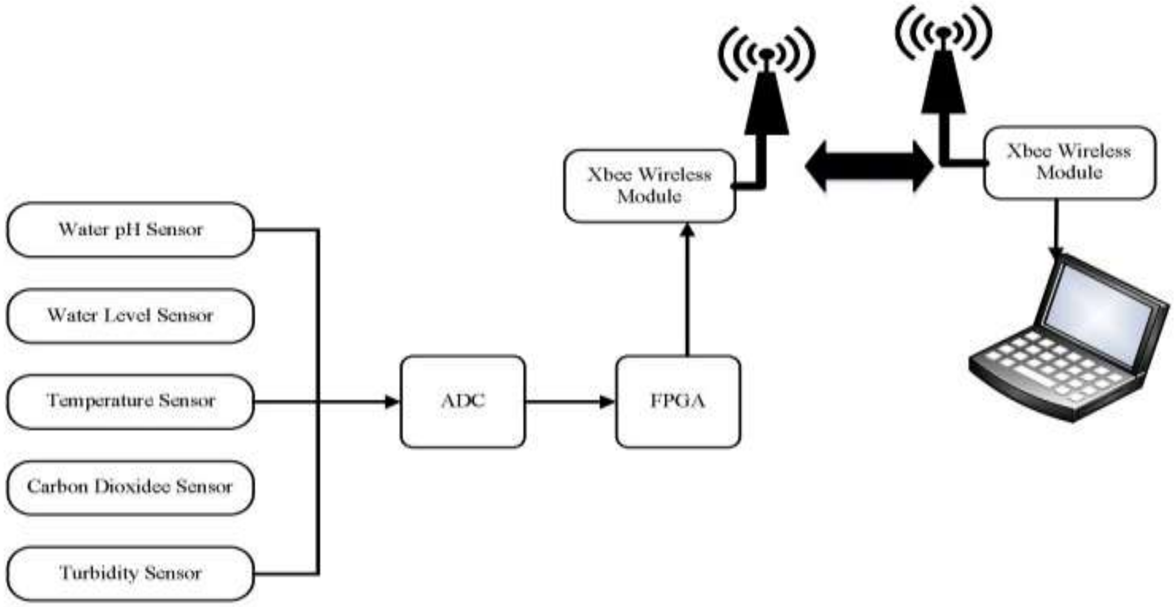

Figure: 2 The block diagram of smart water quality monitoring system

A. Ultrasonic Sensor :- An **Ultrasonic sensor** is a device that can measure the distance to an object by using sound waves. It measures distance by sending out a sound wave at a specific frequency and listening for that sound wave to bounce back. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is possible to calculate the distance between the sonar sensor and the object.

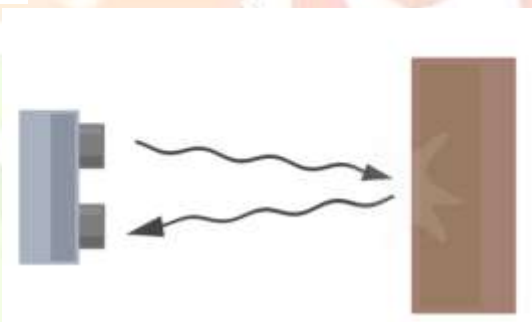

Figure: 3 Ultrasonic Sensor

The accuracy of Ultrasonic sensor can be affected by the temperature and humidity of the air it is being used in. However, for these tutorials and almost any project you will be using these sensors in, this change in accuracy will be negligible.

B. pH Sensor :- A **pH meter** is a scientific instrument that measures the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity expressed as pH. The pH meter measures the difference in electrical potential between a pH electrode and a reference electrode, and so the pH meter is sometimes referred to as a "potentiometric pH meter". The difference in electrical potential relates to the acidity or pH of the solution. The pH meter is used in many applications ranging from laboratory experimentation to quality control.

Figure: 4 pH Sensor

C. Digital Thermometer Sensor: - This sealed digital temperature probe lets you precisely measure temperatures in wet environments with a simple 1-Wire interface. The DS18B20 provides 9 to 12-bit (configurable) temperature readings over a 1-Wire interface, so that only one wire (and ground) needs to be connected from a central microprocessor. Water Temperature indicates how water is hot or cold.

Figure: 5 Thermometer Sensors

D.Turbidity Sensor:-Turbidity is the quantitative measure of suspended particles in a fluid. It can be soil in water or chocolate flakes in your favorite milk shake. While chocolate is something we *soo want* in our drinks, soil particles are totally undesired. Keeping aside the potable purposes, there are several industrial and household solutions that make use of water in some or other manner - for instance, a car uses water to clean the windshield, a power plant needs it to cool the reactors, washing machines and dish washers depend on water like fish. Turbidity Sensor, which along with a micro controller unit, takes care of turbidity measurements. Crafted with plastic and some metal-alloy traces, turbidity sensor uses light to convey information about turbidity in water.

Figure: 6 Turbidity Sensor

E. CO_2 sensor :-

A **carbon dioxide sensor** or **CO_2 sensor** is an instrument for the measurement of carbon dioxide gas. The most common principles for CO_2 sensors are infrared gas sensors (NDIR) and chemical gas sensors. Measuring carbon dioxide is important in monitoring indoor air quality, the function of the lungs in the form of a capno graph device, and many industrial processes.

Figure: 7 CO_2 Sensor

F. RF Module:-

In the proposed system, protocol based two XBee 802.15.4 RF modules are used to transmit and receive the data between the monitoring device and FPGA board. XBee modules are wireless communication modules which are built based on Zigbee standard. It utilizes the IEEE 802.15.4 protocol. Zigbee standards are standards with range between Bluetooth and WIFI. They are basically RF modules. Wireless technology can be challenging without the right combination of expertise and resources. The XBee is an arrangement of modular products that make deploying wireless technology easy and cost-effective. The module can communicate up to 100 feet indoors or 300 feet outdoors. It can be used as a serial replacement or you can put it into a command mode and configure it for a variety of broadcast and mesh networking options. The XBee modules provide wireless connectivity to devices.

XBee and XBee-PRO RF modules are embedded solutions furnishing wireless end-point connectivity to systems. XBee modules are for extended range applications and they are intended for high-throughput applications requiring low latency and predictable communication timing. And they are ideal for low power and low cost applications.

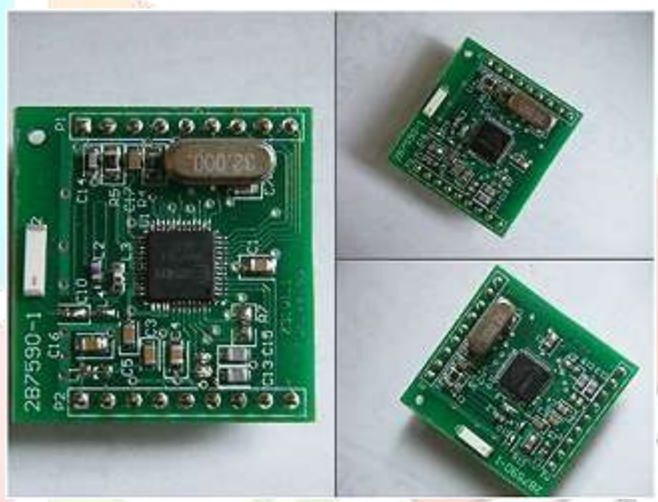

Figure: 8 XBee

The very popular XBee module is 2.4GHz from Digi. These modules allow a very reliable and basic communication between microcontrollers, PCs, systems and support point to point and multi-point networks.

Features of XBee Module:

- Complete RF transceiver
- Onboard data encryption
- Automatic collision avoidance
- Low current consumption
- Wide operating voltage 1.8-3.6 Volts
- Operating frequency: 2.4-2.483 GHz
- Programmable output power and high sensitivity
- Data rate 1.2-500 kbps

G. FPGA Board:-

The Altera DE1-SoC board is utilised to control the entire system of the proposed smart WQM system. The DE1-SoC development board includes 85K programmable logic elements, 4,450Kbits embedded memory, 6 fractional phase locked loop (PLLs) and 2 hard memory controllers. For communication, two port USB 2.0 Host, UART to USB (USB Mini-B connector), 10/100/1000 Ethernet, PS/2 mouse/keyboard, IR emitter/receiver, and I2Cmultiplexer are provided. The display of the DE1-SoC board is 24-bit video graphics array (VGA) digital-to-analogue converter (DAC). The power supply of 12V direct current (DC) is needed to power the board.

IV. RESULTS AND DISCUSSION

In the smart WQM system, when the sensor board is switched on, the sensors are activated to detect the individual water parameter data. Then, the collected water parameters are transmitted wirelessly to monitoring device which is PC using Nios II software program in the Altera Quartus II software. The data of water level, pH, turbidity, carbon dioxide and temperature are displayed on the Grafana dashboard on the PC using Python codes.

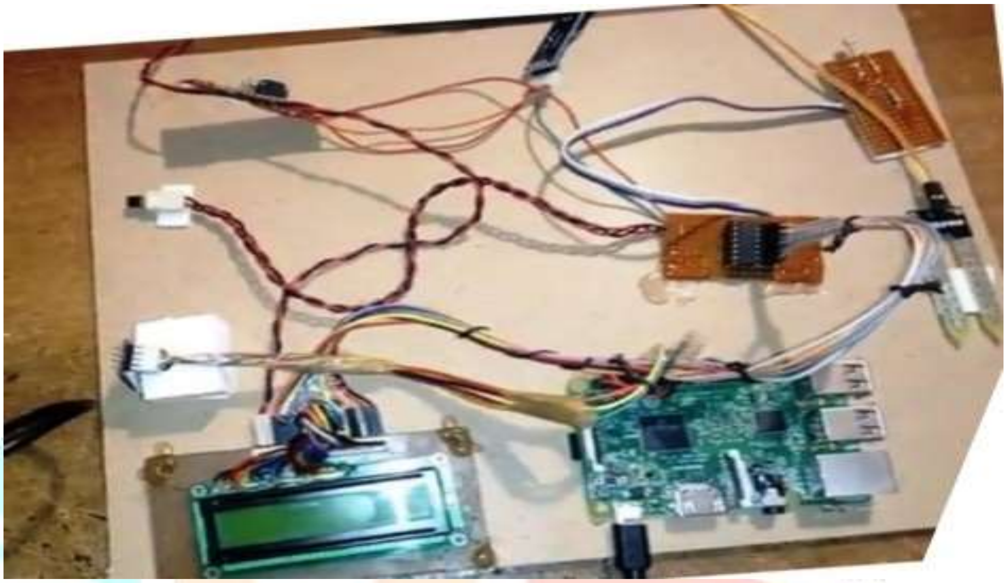

Figure: 9 Hardware Experimental Kit

V. CONCLUSION

This paper describes Design and simulation of smart WQM system of single chip solution to interface transducers to sensor network using FPGA is presented with wireless method by using a wireless XBee module. The results of the five parameters of water quality are verified that the system achieved the reliability and feasibility of using it for the actual monitoring purposes. The water temperature may vary from 0 to 0.4 Degree Celsius depending on the speed of the ambient air temperature cycles. The time interval of monitoring can be changed depending on the need. By introducing the FPGA board, the proposed system inherits high execution speed and reusable Intellectual Property (IP) design. The proposed system will assist in protecting the ecological environment of water resources. The smart WQM system minimizes the time and costs in detecting water quality of a reservoir as part of the environmental management. The WSN network will be developed in the future comprising of more number of nodes to extend the coverage range.

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