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# Automatic ZigBee-Based Wireless Sensor Network for Real Time Temperature Control

**Dr. Anas Ali Hussien[1], Muntaha Jameel Eidan[2]**
[1] Lecturer, Department of Computer Engineering, Alnahrain University, Baghdad, Iraq, anasali78@yahoo.com
[2] MSc Research Student, Department of Computer Engineering, Alnahrain University, Baghdad, Iraq, muntahajameel90@yahoo.com

## ABSTRACT

With the incremental developments that the technology offers, many very promising technologies have been developed to make our lives easier, allowing us to do things more quickly and efficiently and it becomes crucial to understand and explore its methodologies. Among these technologies, the use of home automation technologies become crucial for effective research. Wireless sensor network (WSN) for temperature controlling through the use of ZigBee technology has been used in this study while temperature controlling is very important. The purpose of this work is to illustrate the design and implementation of a wireless sensor network based on ZigBee technology to monitor temperature information in remote locations, these temperature data is saved in database server save, and to control the environmental temperature by turn ON/OFF fan or heater. The implemented system constitutes with gateway (coordinator), end nodes, and a PC server. ZigBee technology has been chosen to provide a reliable wireless communication channel between the end nodes and the gateway (coordinator), and between end nodes themselves. This system has been tested by connecting the coordinator of the master station with the PC. The three end- nodes and the coordinator have been distributed inside the home. In this system the function of the main ZigBee interface is to receive temperature data collected from terminals, saving that data in a database, making a decision and then sending the feedback control signal.

**Key words :** Wireless Sensor Network, IEEE 802.15.4 ZigBee, PIC Microcontrollers, Temperature Monitoring and Controlling.

## 1. INTRODUCTION

WSN is an emerging technology that has a great potential for being effectively employed in critical situations [1], characterized by its small size and its ability to sense environmental phenomena through a set of transducers and the use of a radio transceiver driven by an autonomous power supply [2]. WSN consists of inexpensive sensor nodes distributed in the network, has the capability of collecting, processing, storing and transferring information to the main location [3].

ZigBee is an open specification that enables low power consumption, low cost and low data rate (250 KB/s) for short-range wireless that links between various electronic devices, focuses on automation and remote control applications as shown in Figure 1 [4]. The ZigBee Alliance is an affiliation of companies which produces standards and products for reliable, cost-effective, low power wireless networking. Major participants in the electronics industry are members of the ZigBee Alliance (ZigBee Alliance, 2005) [5].

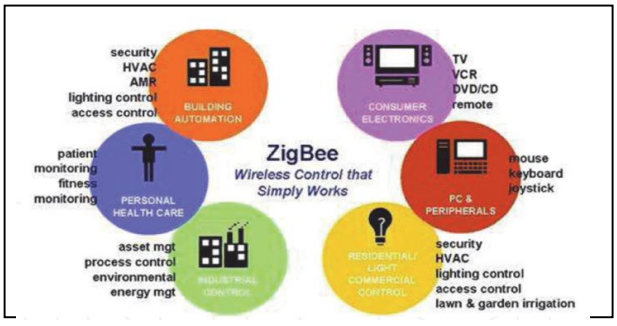


**Figure 1:** Zigbee Application [5]

ZigBee devices can be classified according to their functionalities, as shown in Figure 2. Full Function Devices (FFD) which are coordinator and routers that implement the full IEEE 802.15.4 protocol stack, and Reduced Function Devices (RFD) which are the end devices that implement a subset of the protocol stack [6].

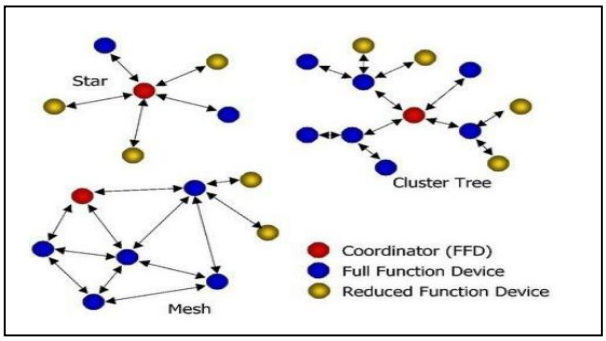


**Figure 2:** ZigBee Network Devices [5]

## 2. DESIGN OF REAL-TIME MONITORING AND CONTROLING SYSTEM

This section deals with the design of the monitoring and controlling systems. To design a system, we considered a home automation network. The system architecture is presented in Figure 3.

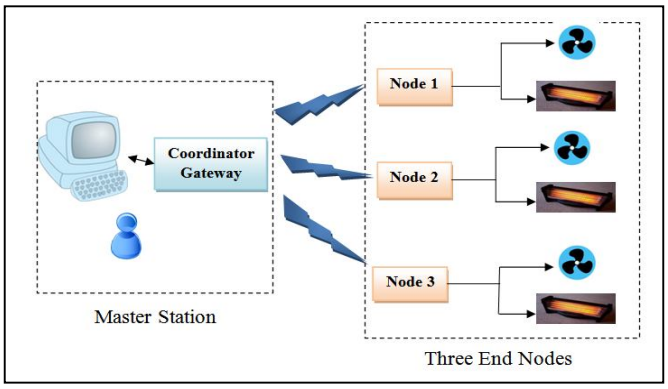


**Figure 3:** The Proposed System

The proposed system consists of three end nodes communicate with the master station, which is comprised of a ZigBee coordinator (Gateway) and PC. The user interface of the system is provided by Microsoft visual studio C#, closely coupled with a a MySQL database to maintain current state and history information. C# 2010 is installed in the PC of the master station to design The main ZigBee panel connects the PC with the coordinator (Gateway) in order to have the received temperature sensor data visible from the three end devices.

A client can access the control center through the maim Zigbee interface. The client can monitor home status through a real-time monitoring sub-system and by set a setpoint for temperature automatic control.

### 2.1 Master Station Subsystem

The master station sub-system is composed of ZigBee module as coordinator (Gateway) and PC for monitoring and controlling the temperature of the three end node environment. The block diagram of the master station is shown in Figure 4.

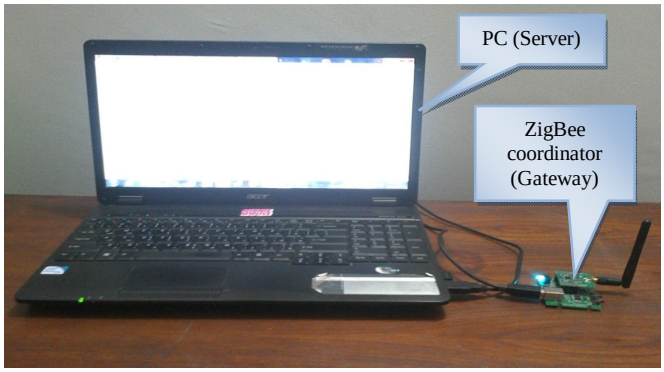


**Figure 4:** Implementation of the Master Station

Figure 5 shows the operation process of the master station sub-system. When the master station is turned ON, the Zigbee coordinator sends ID and is broadcasted to all ZigBee modules in the network of PAN ID 0x1234. All End nodes have received the request and compared the ID to its specified ID. Then the operation is started when any node matches this ID.

After receiving the temperature reading through ZigBee coordinator of the master station, these reading and the receiving time will be displayed in the main ZigBee interface, then followed by the processing step that includes: Inserting the node_id and temperature values into DB, checking the fan status while displaying it as a green label if it's ON and red if it's OFF, checking the heater status and displaying it as a green label if it's ON and red if it's OFF, and comparing the temperature reading with the set point that the user set it to send the feedback control signal as shown in Table 1 below.

**Table 1:** Feedback control signal

| Fan / Heater | ON / OFF | OFF / ON | OFF / OFF |
|---|---|---|---|
| Node1 | "a" | "b" | "j" |
| Node2 | "c" | "d" | "k" |
| Node3 | "m" | "n" | "l" |

The flow chart of the master station operation is shown below in Figure 5.

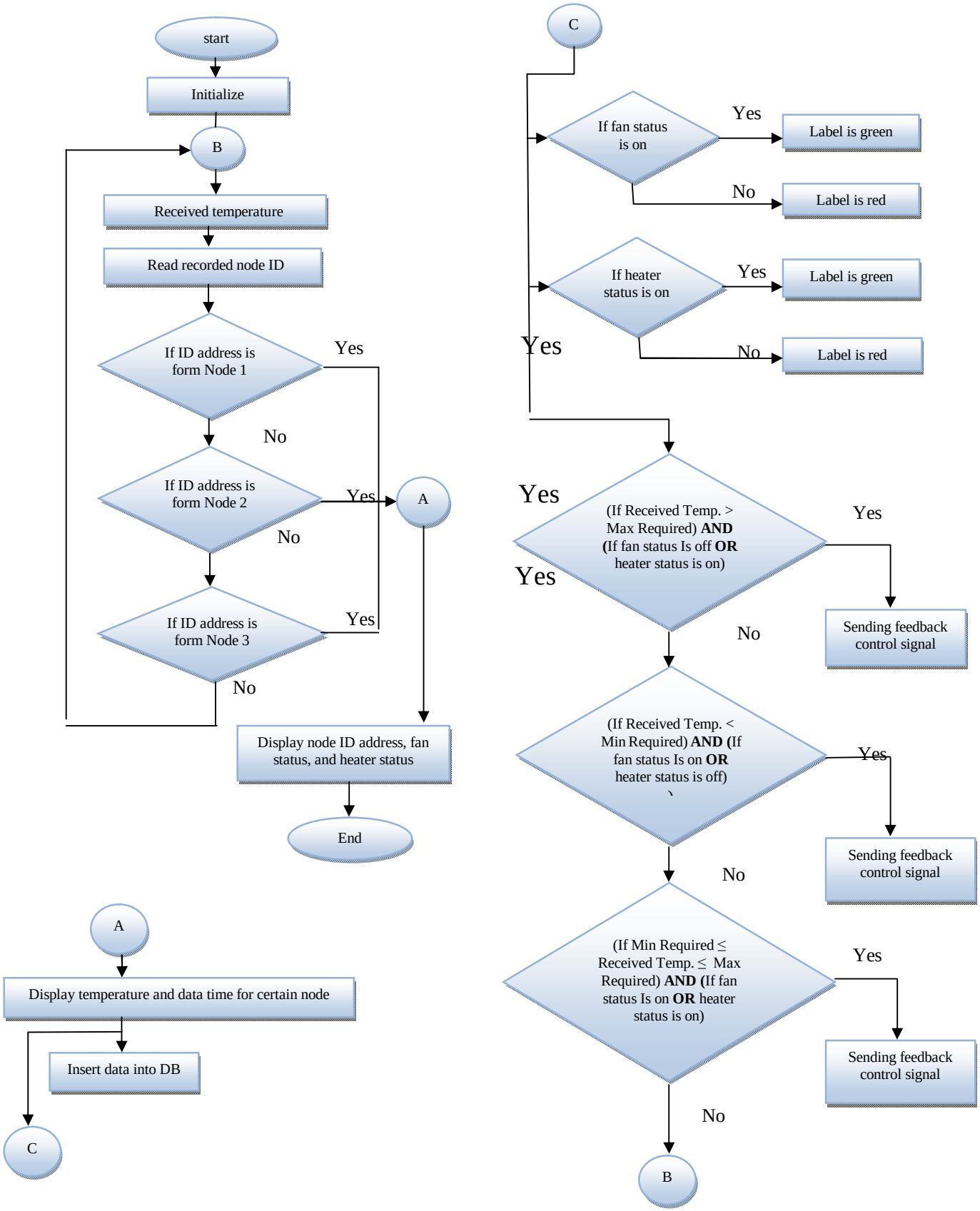


**Figure 5:** Flowchart of the Master Station Operation

### 2.2 End Node Subsystem

End node sub-system is composed of a ZigBee module as a router, temperature sensor, microcontroller, and the controlled devices (fan / thermal resistor as simple heater). As shows in Figure 6.

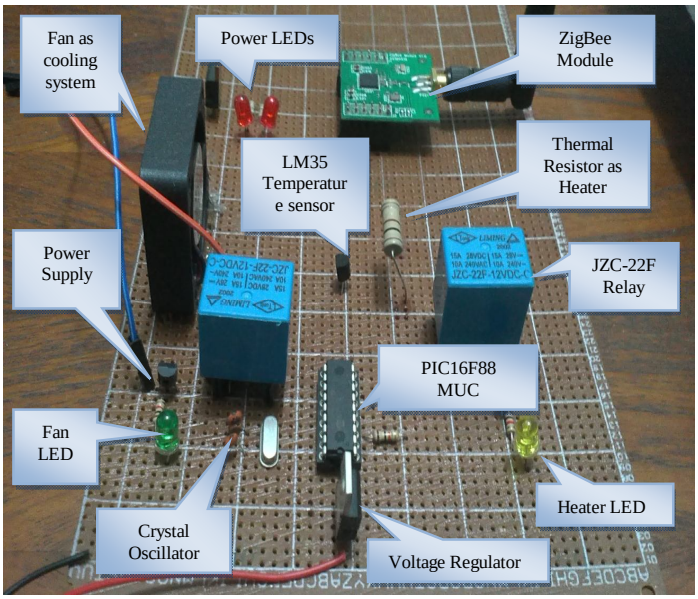


**Figure 6:** End Node Interface Board

End node has the sensors that collect the environmental information and send this information to the coordinator through a ZigBee wireless network. Then the processed information is sent to the ZigBee module. The ZigBee module sends the information to the coordinator. The ZigBee is connected to PIC16F88 through UART interface. End node also has a cooling and heating system. ZigBee module receives feedback control signal from the master station to control devices (fan/ heater) in the three end nodes.

The operation of the sub-system is as follows:

- A client program maintains a main Zigbee interface which contains three buttons Initialize, Disconnect and Connect to Server DB. In the initialize button, the ZigBee module is connected to the comm. Port. While the disconnect button when it is pressed, this button will close the connection with the serial port. Finally the Connect to Server DB, when it is pressed, will be connected to the local server XAMMP to save the sensor reading in My SQL database.
- A database server; in this database there is a data_pool table that has the records of temperature information for all end nodes. The data structure of this table consists of four columns: id (record ID), node_id (Node ID), temperature (temperature readings in centigrade), and time (current time for each reading).
- The coordinator of the master station receives the temperature data reading from the end node and the status of the fan and the thermal resistor if it ON or OFF through the ZigBee wireless network.
- The end device receives the command from the coordinator of a master station and controls the port of the switch node.
- The switch node controls the switch on the fan and the thermal resistor.

ZigBee based automatic controlling can be applied in several ways. In this paper, we considered a simple temperature control and adopted it for an automatic control sub-system.

## 4. IMLEMENTATION RESULTS

In this section we discuss implementation results of a real-time automatic monitoring and controlling system. The monitoring and controlling programs are implemented using Microsoft Visual Studio C#.

On the ZigBee networks, we use two ZigBee Chip CC2530 from Texas Instrument [7] integrated into DRF1605 board. One is configured as a coordinator and the other is configured as a router.

When the coordinator starts, it initializes all internal ports and waits for control commands from the master station. If the master station sends a control command to the coordinator through the serial communication, the coordinator receives the command and sends it directly to the end-device through the ZigBee wireless network. The end device receives the control command from the coordinator and controls the switch node.

In this paper, we work with many scenarios in order to test system performance and reliability, these scenarios as follow: **Scenario # 1:** Real time control was applied to stabilize the temperature within the range of (20-27) for the purpose of testing the behavior of the system under this controlled temperature. Also 12 readings were taken, each for one minute, as shown in Figure 7.

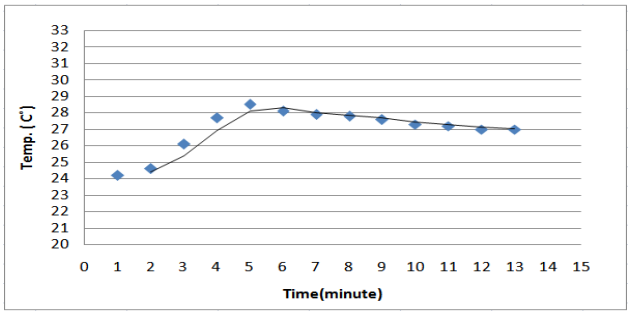


**Figure 7:** System Performance When Contorlling

**Scenario # 2:** An air cooling system was used to reduce the temperature to a very low degree for the purpose of testing the behavior of the system. The system was used to change and stabilize the temperature in the desirable range. 12 readings were taken, each for one minute, as shown in Figure 8.

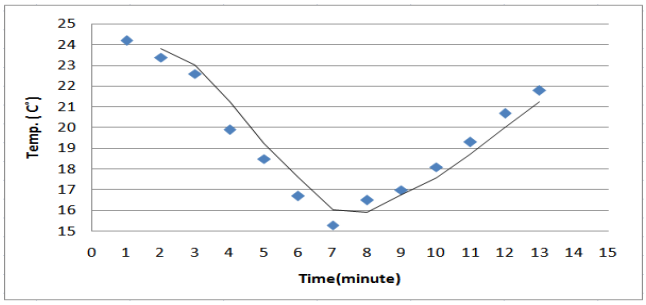


**Figure 8:** System Performance Under Control Condition

## 5. CONCLUSIONS

The project of wireless sensor network has been built based on PIC microcontrollers, ZigBee modules, and the database server. Monitoring and controlling the environmental temperature has been considered in this project in order to demonstrate the ability of the application of this system.

Remote environmental monitoring and controlling system used in the building of homes has been applied with particular emphasis on minimizing both the cost and complexity. Since PIC microcontrollers are popular and cheap in comparison with other family of microcontrollers, this will meet the main objective of the project of being inexpensive and efficient. The ZigBee protocol has been applied by using few steps of negotiation messages between the coordinator (gateway) of the master station and the three end nodes to receive and transmit information.

The ZigBee technology has provided a reliable wireless networking for the embedded devices in this work. The low power consumption of ZigBee enabled end nodes to operate efficiently and effectively.

Using DRF1605 ZigBee module has provided a reliable serial communication and data delivery to the microcontrollers. UART interface is now available in most of microcontrollers, thus this module is useful with low cost in comparison with other ZigBee modules that have been found like XBEE which is more expensive than that used in this work.

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