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Implementation of Wireless Sensor Networks Using ZigBee

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***Abstract*— WSNs are usually composed of small, low cost devices that communicate wirelessly and have the capabilities of processing, sensing and storing. A sensor network consists of an array of numerous sensor networks of diverse types interconnected by a wireless communication network. The system extracts relevant information from the available data. Sensor data is shared between these sensor nodes and used as input to a distributed estimation system. This data is then forwarded via internet or other gateways to the user where the next course of action will be decided. The project proposes the use of sensor networks programmed on Arduino and use of ZigBee routers to wirelessly sense and transmits data respectively, from a remote inaccessible area or fields where human intervention is to be minimized. The main aim is to track or sense a particular parameter such as temperature, pressure, gas leakage etc and relay the data to a control center where necessary corrective action may be taken. ZigBee routers interfaced with LCD display can be used to continuously monitor and display the parameters sensed. The data received at the receiver end can also be logged into a computer with time stamps for future references. A GSM module can be used to broadcast a message or alert sent from the controller or the mother node to the mobile numbers of the concerned authorities and people in potential danger so necessary corrective action may be taken. The proposed model can work as an alert system, sensing a parameter and on encountering an abnormality can relay an alert via the ZigBee network. The procedure is that that the temperature and the gas sensors interfaced to the mother (transmitter side) Arduino board located at a distant place where the parameters need to be sensed, will continuously sense the surrounding temperatures and air for traces of LPG and other inflammable gases and will continuously transmit the sensed temperatures via the ZigBee module interfaced to the mother Arduino board to the other ZigBee module interfaced to a serial LCD display via Arduino. The GSM shield interfaced on the transmitting side will send alert SMS to the pre-fed phone numbers when the parameters will exceed a certain pre-defined value.**
***Keywords*— Wireless Sensor Networks, Arduino, ZigBee, GSM Module, Alerting System, Data Logging.**

I. INTRODUCTION

This topic aims at sensing parameters such as temperature and gas and notifying or alarming to a distant person through the use of Zigbee and GSM, in case the sensed parameters cross a certain pre-set value. It can be used at a variety of places from laboratories, or places where minimum human intervention is required or where manual monitoring isn't possible for detection of gas leakages or for alarming in case of all kind of fires.

Working few months on PSoC we learned a lot about programming and various other aspects. At the same time we focused on Zigbe e as well as GSM. We could successfully sense the surrounding temperature using the PSoC 3 CY8CKIT -030. We also succeeded in interfacing the Xbee module with our microcontroller; but when it came to GSM module interfacing we faced a serious setback that, we needed an intermediate microcontroller ARM which would drastically increase the cost of the project and at the same time consume a lot of time to complete and would involve tedious programming. We finally completed our project using Arduino which uses ATMEGA 328 microcontroller. Programming with the Arduino IDE being C/C++ based was relatively easier and quicker to implement. For the wireless transmission, we have used ZigBee Xbee Series 2 RF trans-receivers configured for point-to-point communication. The number of ZigBee's in the network can be increased by setting the co-coordinator in broadcast mode.

We have used the LM35 temperature sensor, which measures temperature using the thermistor method. MQ6 Gas Sensor has been used for detection of LPG and gases like propane or butane in the air over permissible levels. We have programmed the Arduino as to send an alert message if temperatures exceed above 50^{O}C or gases like LPG are detected in the air above their permissible limit. The alert is displayed on the 16x2 LCD at the transmitter side. Also the alert is sent to the concerned authorities as a text message using the SIM900AT GSM module interfaced to the Arduino board at the transmitter.

II. DETAILS OF HARDWARE USED

A. Arduino ATMEGA328

Arduino is an open source computer hardware and software company, project and user community that designs and manufactures kits for building digital devices and interactive objects that can sense and control the physical world. The project is based on a family of microcontroller board designs manufactured primarily by Smart Projects in Italy, and also by several other vendors, using various 8-bit Atmel AVR microcontrollers or 32-bit Atmel ARM processors. These systems provide sets of digital and analog I/O pins that can be interfaced to various extension boards and other circuits. The boards feature serial communications interfaces, including on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino platform provides an Integrated development environment (IDE) based on the processing project, which includes support for C and C++ programming languages.

1) Temperature Reading With Arduino

There are several ways to read temperature with an Arduino. A few of these include:
I2C or Serial Sensors – There are advanced sensor modules that often can measure barometric pressure, temperature, humidity, and other conditions all in one package. However these modules are typically much more expensive and require the use of the I2C or serial protocol to read. These might be great for a more advanced weather sensor project.
Thermal analog sensor – A three pin component that takes power, ground, and outputs a variable voltage based on the temperature by implementing a band gap core inside a single component. This class of component is useful and I'll examine this in a future tutorial.
Thermistor – A resistor that changes resistance based on the ambient temperature.

B. Temperature Sensing Using LM35

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in ^{0}C). LM35 temperature sensor is to detect the temperature level, which can sense the temperature from **-55 to** 150 °C. The detected temperature is displayed over 16X2 LCD with the help of Arduino. We can also treat this circuit as Interfacing LM35 Temperature Sensor with Arduino.
Components Required for Arduino Thermometer Project
Digital thermometer Arduino uses readily available components that everyone can obtain in any electronics retail shop.
Arduino
LM35 Temperature Sensor
16×2 LCD Display
POT 1k

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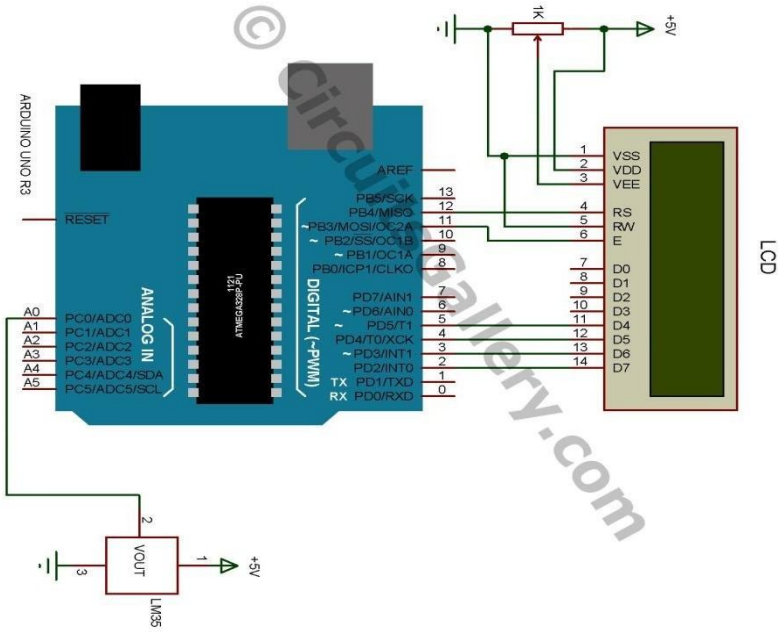

Fig 1 Arduino Temperature Sensor Circuit Schematics

1) Working Of Arduino Temperature Sensor

LM35 is a reasonable temperature sensor available in any of the electronics shops. Theoutput voltage of LM35 is linearly proportional to the Celsius (Centigrade) temperature.

The output of LM35 is of 10mV/°C scale factor that means for each 1°C increase in temperature there will be a corresponding increase in 10mV, so we can easily read temperature value. Arduino has an analog pin (A0) capable of reading analog signals from any sensor. As shown in the circuit diagram the analog pin A0 of Arduino is connected to the output pin of LM35.

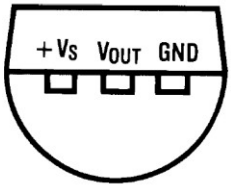

Fig 2 Connection diagram of LM35 Temperature sensor

Arduino has 10 bit inbuilt ADC, so it can read value from 0 to 1023, i.e. for zero voltage it reads 0000 and for VCC (5V) it reads 1023. Thus I have mapped 0 – 1023 to 0 – 500, because LM35 increments 10mV for each centigrade so the maximum possible increment is 500.

$$10mV \times 500 = 5000mV = 5V$$

5V is our supply Vcc, so maximum increment is 5V

Using this mapping we can take each increment in the ADC value as centigrade increment. (If the ADC value is 27, the temperature value is 27°C)

Now let's go to the program logic. First we may have to declare a long variable 'A' to store the value read from LM35, which has its range from 0 to 1023.

Then declare another integer variable, 'B'to store mapped (converted) value.

The temperature value obtained from pin A0 which is stored to variable 'A'.

Variable A is then mapped or converted to 0 to 500 range and stored on variable 'B'

The value of 'B' is directly displayed on 16×2 LCD screen.

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C. Gas Sensing Using Arduino (MQ6)

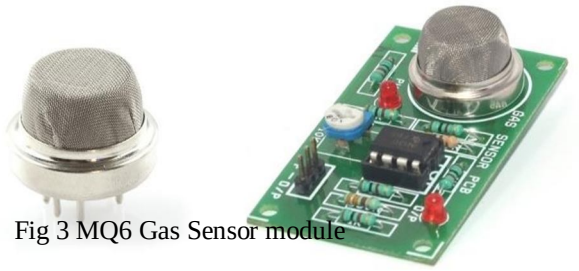

Fig 3 MQ6 Gas Sensor module

MQ6 gas sensor is a 6 pin device and it requires 5 volt DC maximum which is derived from a Zener based power supply. There is a heating element inside the sensor which becomes hot at 5 volt and remains stand by. When the sensor detects gas molecules between 100 ppm to 1000 ppm, in the atmosphere, its output turns high and triggers T1 to activate the buzzer. Red LED indicates the high output from the sensor.

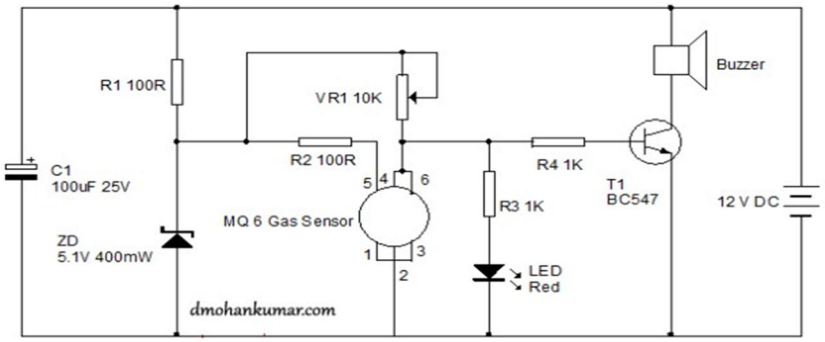

Fig 4 Circuit diagram of The MQ6 Gas Sensor Module

D. ZigBee

The ZigBee network layer natively supports both star and tree networks, and generic Mesh networking. Every network must have one coordinator device, tasked with its creation, the control of its parameters and basic maintenance. Within star networks, the coordinator must be the central node. Both trees and meshes allow the use of ZigBee routers to extend communication at the network level. ZigBee builds on the physical layer and media access control defined in IEEE standard 802.15.4 for low-rate WPANs. The specification includes four additional key components: network layer, application layer, ZigBee device objects (ZDOs) and manufacturer-defined application objects which allow for customization and favor total integration. ZDOs are responsible for a number of tasks, including keeping track of device roles, managing requests to join a network, as well as device discovery and security.

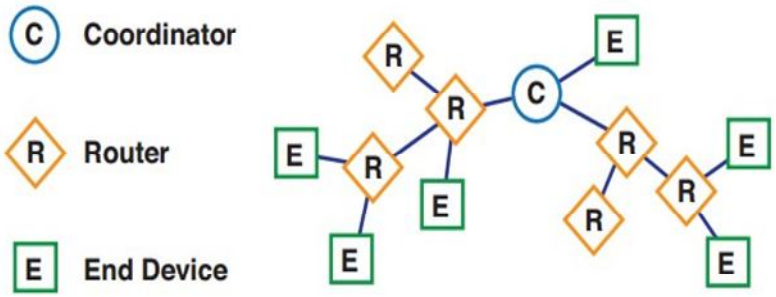

Fig 5 ZigBee network Topology

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F. GSM Module

GSM module is based on SIM900A Quad-band GSM/GPRS module. SIM900 is a complete Quad-band GSM/GPRS module in a SMT type and designed with a very powerful single-chip processor integrating AMR926EJ-S core, allowing you to benefit from small dimensions and cost-effective solutions. GSM module is a compact and reliable wireless module. This module is compatible with Arduino and other MCU's. It is configured and controlled via its UART using simple AT commands. The GPRS Shield provides you a way to use the GSM cell phone network to receive data from a remote location. The shield allows you to achieve this via any of the three methods:

Short Message Service

Audio

GPRS Service

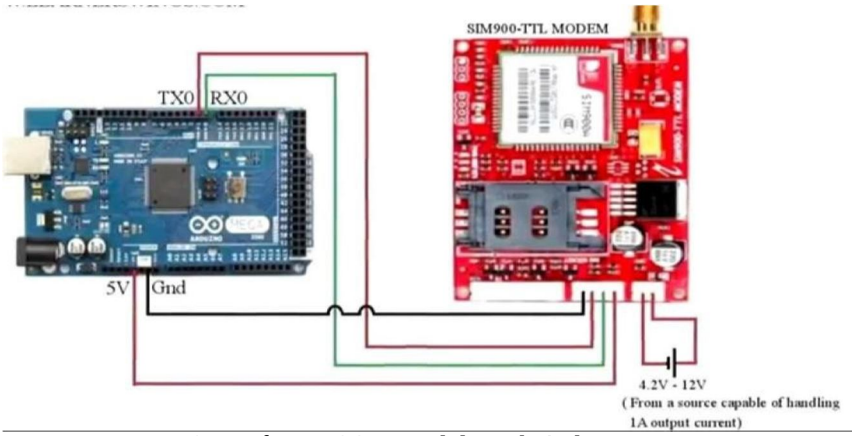

Fig 6 Interfacing GSM Module with Arduino

The GSM board connects to the Arduino board with pins 7 and 8. Now when the temperature exceeds a certain point or gas leak is detected, that particular loop starts execution.

G. PSoC

A PSoC integrated circuit is composed of a core, configurable analog and digital blocks, and programmable routing and interconnects. The configurable blocks in a PSoC are the biggest difference from other microcontrollers. PSoC has three separate memory spaces: paged SRAM for data, Flash memory for instructions and fixed data, and I/O Registers for controlling and accessing the configurable logic blocks and functions. The device is created using SONOS technology

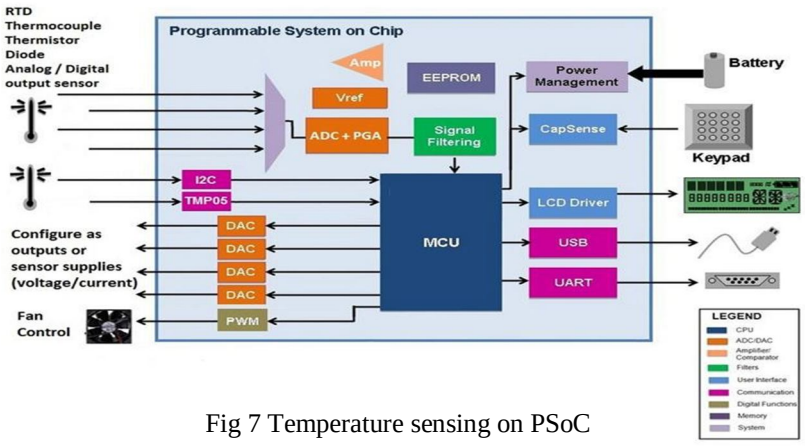

Fig 7 Temperature sensing on PSoC

III. SIMULATION RESULTS

A. Temperature Sensing with PSoC 3

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PSoC provides complete high performance temperature sensing and control solutions for RTDs, thermocouples, thermistor, temperature diodes, IC temperature sensors, other analog output temperature sensors and digital output temperature sensors. PSoC includes current and voltage sensor drive, DAC and PWM outputs for control, LCD drive, key pad or touch screen interface, power management and USB or RS-232 communication

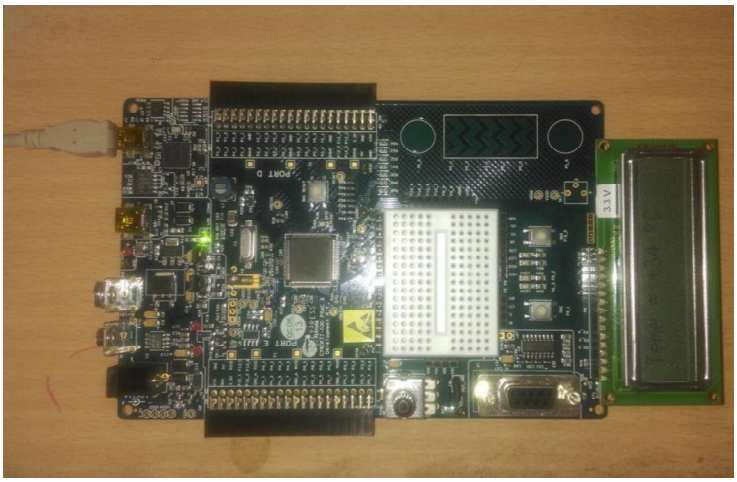

Fig 8 PSoC CY8CKIT-030 Dev Board

Fig 9 Temperature Sensed by PSOC displayed on LCD

A. Communication between Two ZigBee

Step 1: Installing drivers for USB-to-Serial Port

Download and install the Virtual COM port driver from FTDI website:

http://www.ftdichip.com/Drivers/VCP.htm

Step 2: Install XCT-U software

X-CTU is XBee Configuration and Test Utility. It is primarily used for configuring XBee Modules from Digi and also to upgrade the onboard MCU firmware. It comes with a Serial-Terminal to interact with XBee modem using AT commands. X-CTU is a Windows application.

Download X-CTU from Digi's X-CTU Page

Install X-CTU.

Open X-CTU --> PC Settings Tab.

Select USB Serial Port (which is connected to UartSBee / Grove - XBee Carrier).

Click Test / Query Button

A dialog box shows the Modem Type, Modem firmware Version and Serial Number.

In this case, XBee ZNet 2.5 modem is displayed as XB24-B. This has to be upgraded to XB24-ZB firmware as shown in figure below.

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Open Modem Configuration Tab.
Click Download New Versions button

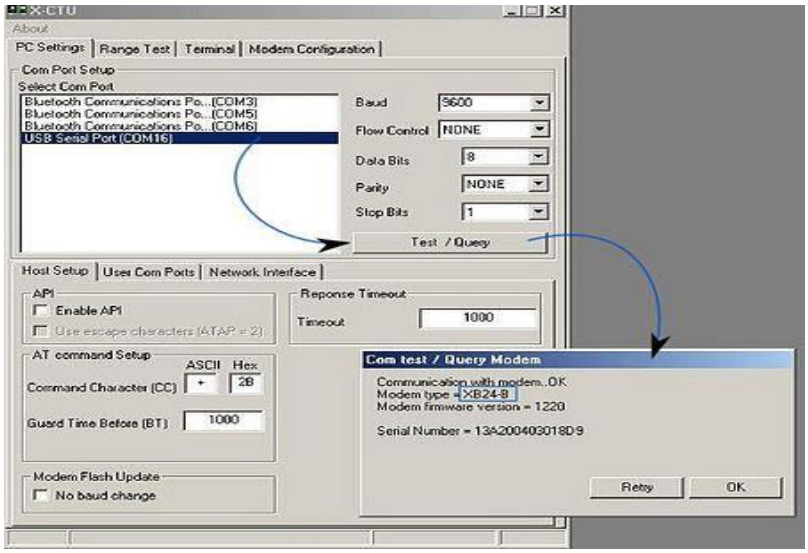

Fig 10 Testing ZigBee on X-CTU Software

Fig 11 Updating XBee Drivers

This opens the following dialog box:

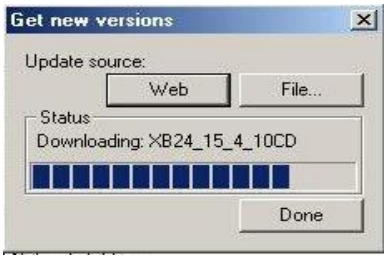

Fig 12 XBee drivers getting an update

Click Web button. This downloads all devices firmware from Digi's serverOnce, latest firmware are downloaded an update summary is displayed. This indicates that update happened without any issue. If you do not get this dialog box, repeat the above steps.

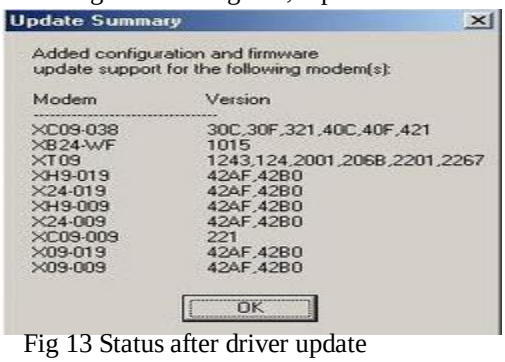

Fig 13 Status after driver update

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Open Modem Configuration Tab.
Click Modem Parameters and Firmware -->6Read button.

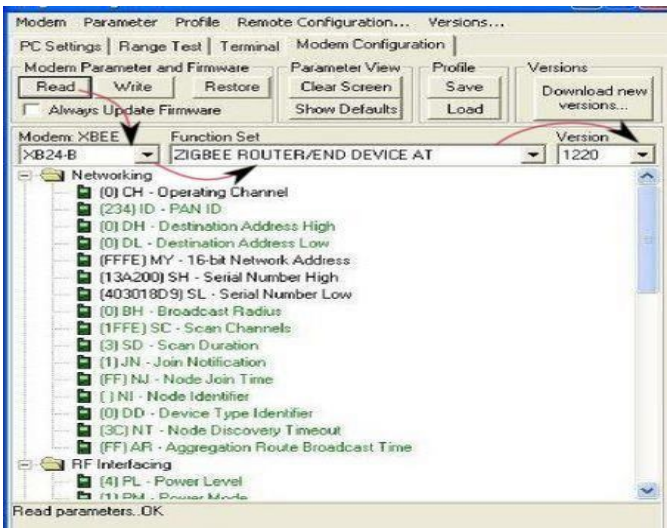

Fig 14 Reading XBee parameters

XBee ZNet 2.5 firmware XB24-B is detected and all its configured parameters are shown.
It also shows the firmware Function Set as ZIGBEE ROUTER/END DEVICE AT and version as 1220.
Function Set decides which firmware is already programmed / to be programmed to XBee Module. Series 2 devices can be used in many different modes (ZC or ZR, ZED). We have to choose the appropriate firmware function set.
Now, update the firmware to XB24-ZB. (Please note, we are not using XB24-B firmware, we are using a different firmware set compatible with XBee ZNet 2.5 Module Hardware)
Select Modem: XBEE as XB24-ZB
Select Function Set as ZIGBEE COORDINATOR AT.
Note: ZIGBEE COORDINATOR AT is one function set that we will use in the next section. You can choose any function set which is suitable for you application.

Select the latest version of firmware. At the time of writing this guide, it is 208C
Click Write button. This permanently writes the firmware to XBee module.

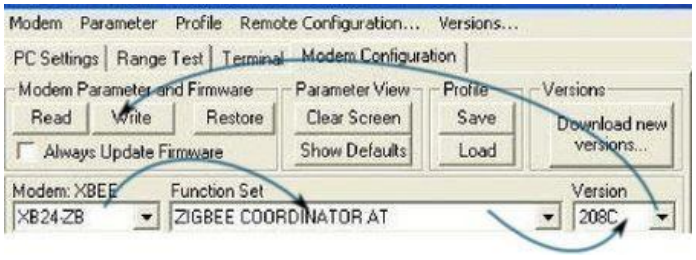

Fig 15 Writing Parameters on to ZigBee

B. Wireless UART Demo Using XBee ZB Modules and PC
This demo configures two XBee modules to connect to each other automatically upon power-up and continuously Trans-receive data. This setup can be used as a Wireless UART to connect any two PCs or two MCUs with serial ports.

Connect these modules to PCs Serial port and make sure the drivers are installed.
Open X-CTU, select the USB-Serial Ports of the device as shown below:

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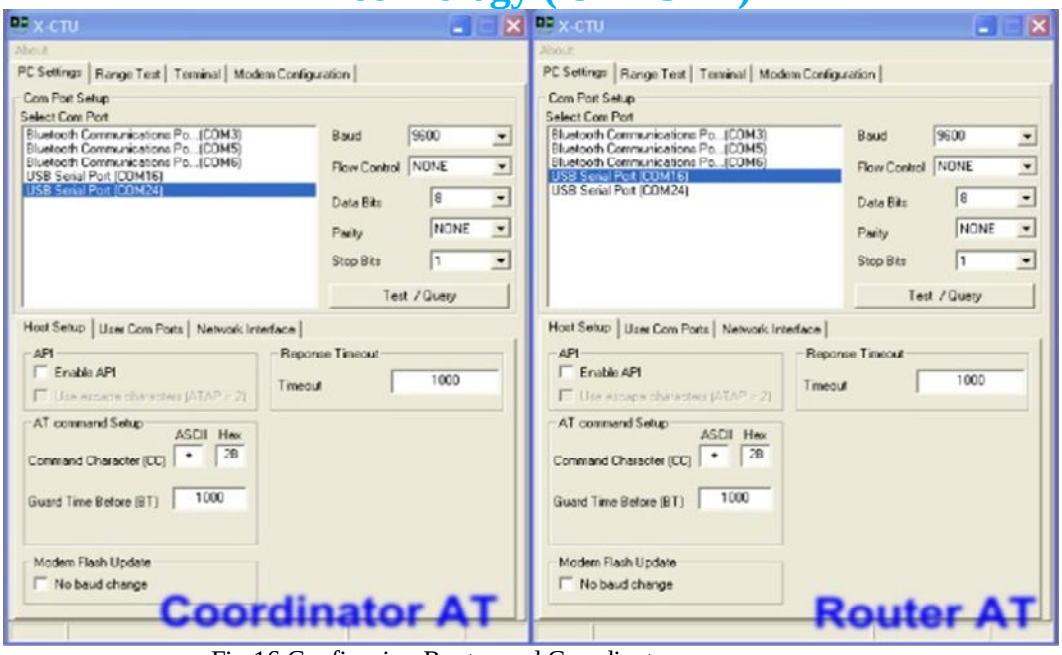

Fig 16 Configuring Router and Coordinator

Program one module with COORDINATOR AT function-set firmware and another module with ROUTER AT function-set firmware. Always use the latest version of firmware. See the above section on how-to program firmware.
Now, Open Modem Configuration Tab and configure the destination addresses of both the modules as follows:

Set the destination address high of COORDINATOR to serial number high of ROUTER.
Set the destination address low of COORDINATOR to serial number low of ROUTER.
Set the destination address high of ROUTER to serial number high of COORDINATOR.
Set the destination address low of ROUTER to serial number low of COORDINATOR.
Write these parameters to the modules.

PAN ID was not modified during parameters configuration. It was left to 0, as there is only one Zigbee network in the vicinity. You might want to change these PAN IDs (of both the modules) to a 16bit number.

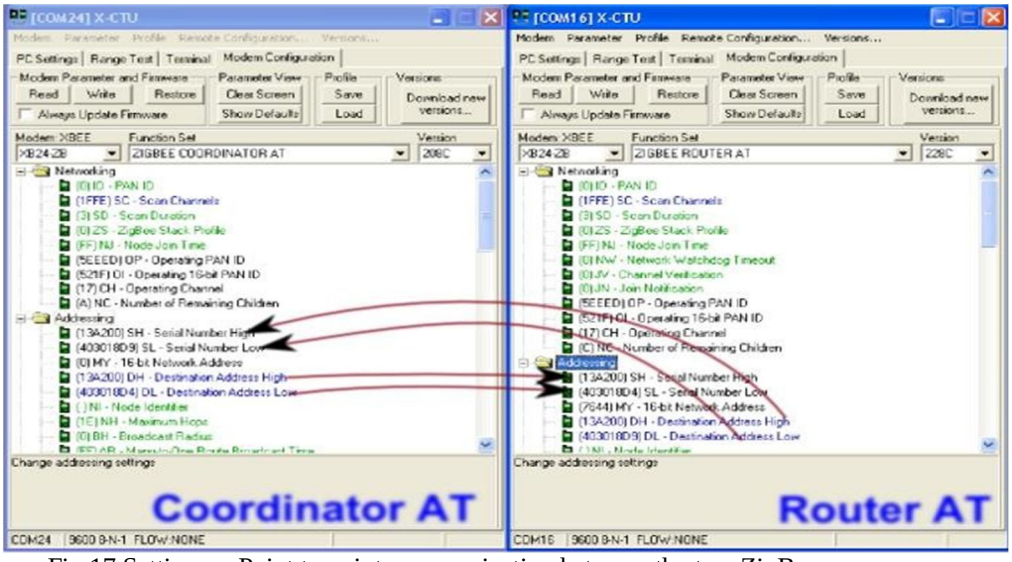

Fig 17 Setting up Point to point communication between the two ZigBees

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Open the Terminal Tabs for both the modules and click the Show Hex buttons.
Type a message in COORDINATOR terminal and it will be sent to ROUTER via wireless. Similarly, any text typed in ROUTER terminal is sent to COORDINATOR terminal.

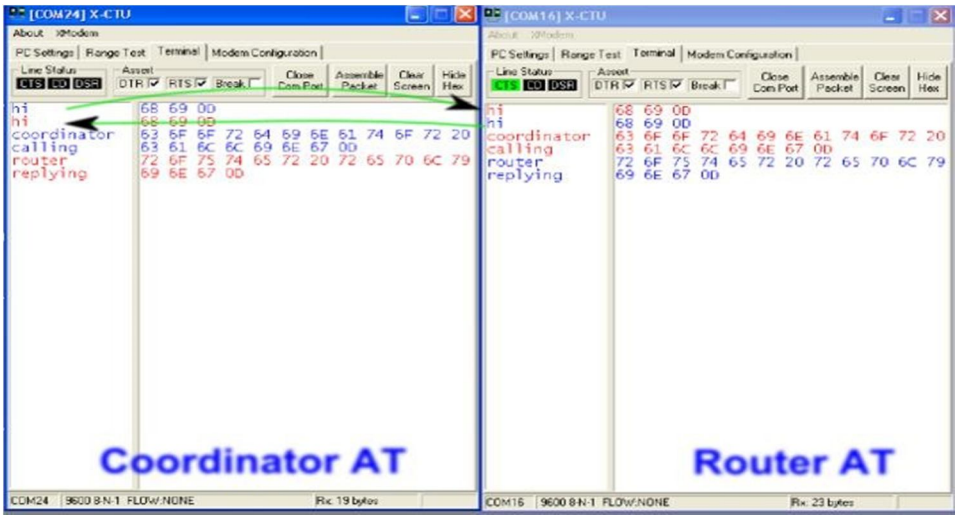

Fig 18 Data transfer between the two ZigBees

This is how two ZigBee's are configured and communicated with each other using XCTU software.

C. GSM Output
First the GSM is initialized to a particular baud rate.
Then with CMGF AT command it enters into text mode.
Next the number on which the message should be transmitted is given by CMGS.
Then the string which is to be sent is given using a print function.
Then CTRL+Z is to be pressed so that data is transmitted. The ASCII code for CTRL+Z combination is 26. Hence a character string containing 26 is sent.

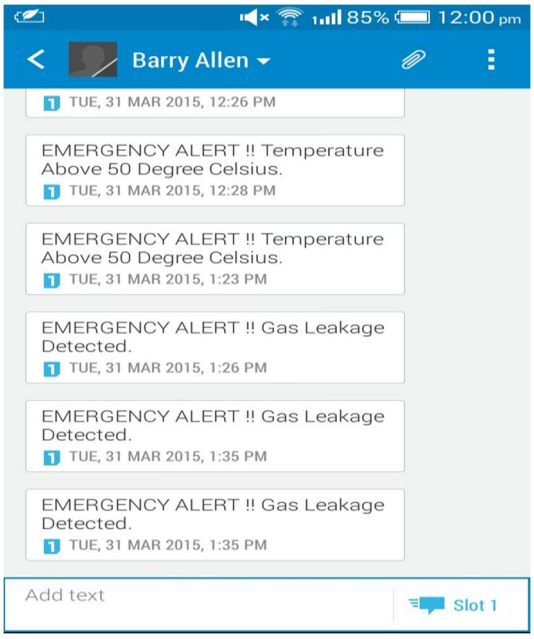

Fig 20 Screenshot of the alert message

IV. CONCLUSION AND FUTURE SCOPE

The aim of this project is to establish a wireless sensor network and send relevant data using a GSM module. The wireless transmission was carried out by ZigBee modules. The temperature was sensed by a LM35 module and gas was done by mq6 module. Through this project we got to learn about theoretical and practical aspects of various technologies like Arduino, ZigBee, GSM, and PSoC. The project was implemented in various parts. First, the ZigBee communication was established between various nodes. Next using Arduino modules, various sensor data was collected and displayed on LCD. Then the GSM part was implemented.

Currently we have implemented two sensors. In the next stage of our project, we can use various other sensors like Carbon dioxide sensor (CO2), Carbon Mono oxide sensor for environmental conditions detection.

Currently we have used only a single receiver and the two ZigBees communicate point to point. However we can increase the number of receiving ZigBees so that all can receive data by setting them in Broadcast mode. Encryption can also be added to ensure data is not tampered with in the broadcast mode.

The sensor data is currently available locally to the PC connected to the receiver. But the same data can be uploaded to a server or a remote location. By using Arduino Ethernet Shield which is available easily, the data can be uploaded to a specified remote server and then that particular data can be accessed from anywhere.

Also, we can use GPRS functionality to upload the data to a server.

A mobile application can be developed that can sync data from server and display temperature at various points.

Using higher range RF modules in place of ZigBee, better range coverage can be achieved.

The system can be further developed into an emergency alert system which can sense various parameters and in case of a potential disaster will broadcast emergency alerts to the people who may be affected

The project also finds use in home automation systems, alerting the owner in case of gas leakages or fires when he/she is away from home.

V. ACKNOWLEDGMENT

It is our pleasure to refer Microsoft Word exclusive of which the compilation of this project would have been impossible. An assemblage of this nature could never have been attempted with our reference to and inspiration from the works of others whose details are mentioned in references section. We acknowledge our indebtedness to all of them. Last but not the least my Sincere thanks to all my friends who have patiently extended all sorts of help for accomplishing this undertaking.

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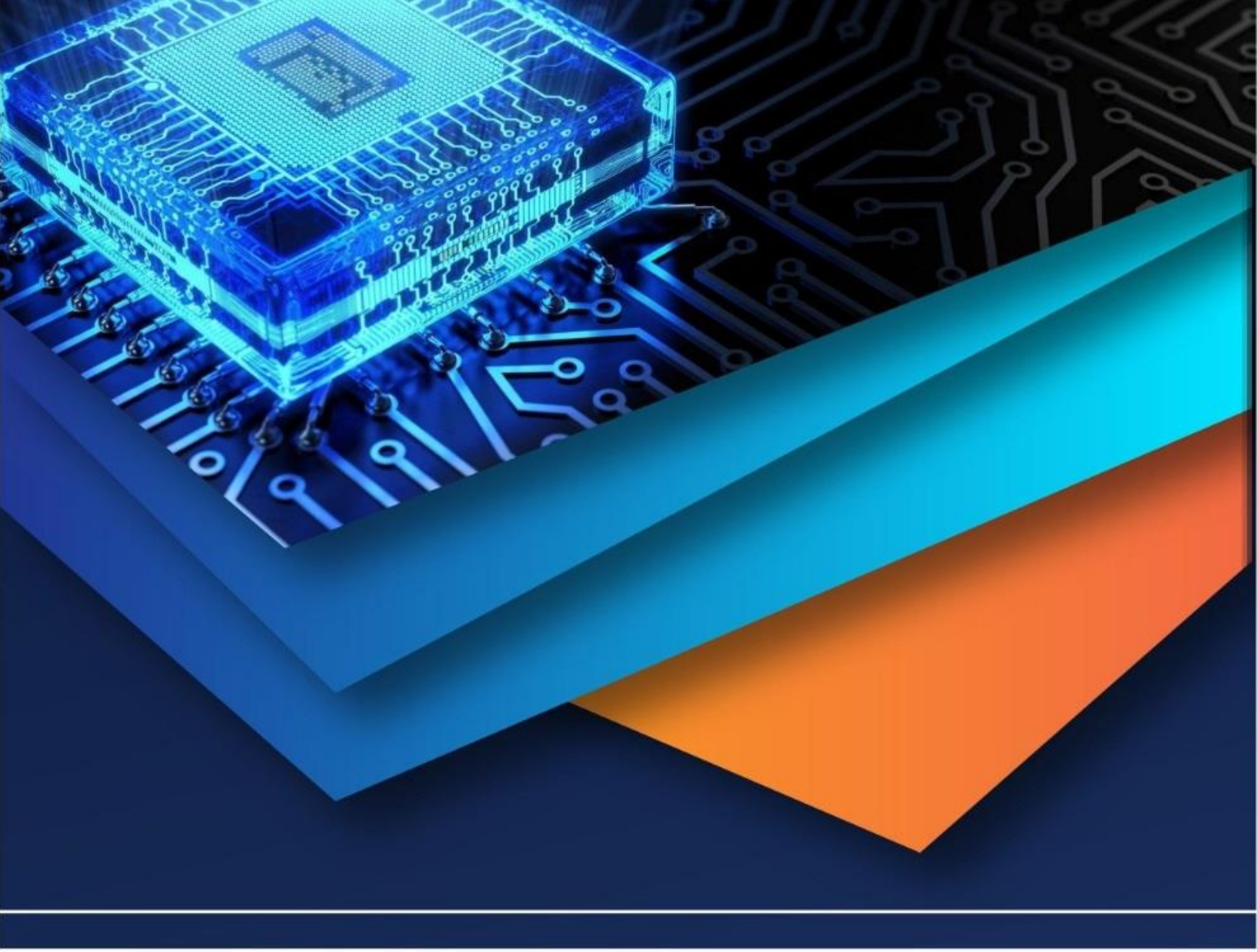

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