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ENVIRONMENT MONITORING SYSTEM IN CHEMISTRY LABORATORY

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Abstract:-The impact of air quality has to be taken into consideration especially when dealing with different chemical gases in an enclosed Chemistry Laboratory. Thus the monitoring of the environment or the air quality in the Chemistry Laboratory is essential to detect the amount of concentration of gases in the air so as to develop appropriate strategies to reduce the adverse effect of air quality on the health of people working in the laboratory. The Environment Monitoring System is designed using the Wireless Sensor Network technology. Wireless Sensor Network along with Internet of Things allows the use of various sensors to detect the environmental condition and to collect the sensor data thus permitting data integration. The system designed to monitor the environmental conditions in the Chemistry Laboratory is divided into three parts:1] Sensor node: That collects and transmits the sensor data to the central repository or the Sink node 2] Sink node: It is the core node in the network performing important functions like data storage, data collaboration, computing and data integration 3] Web Interface: Development of a Web application so as to provide access to the remote user to the sensor data and also for visualization of data in a systematic manner for further analysis. The system consists of sensor nodes designed using the Atmega328 microcontroller along with a nRF24l01 module for wireless communication and various analog sensors. The base station is designed by using the open source hardware Raspberry Pi, nRF24l01 module and analog sensors. A Web Server Interface is created to access the sensor data for the user.

Keywords-WSN, IoT, Environment Monitoring, Atmega328, nRF24l01 Raspberry Pi, Web Server Interface, Sensor node, Base Station

I. INTRODUCTION

Monitoring of the air quality indoors is important as people spend more time indoors . Especially monitoring the air quality in the Chemistry Laboratory is essential due to the concentration of fumes of gases in the environment while performing experiments. These gases can cause adverse effects on health of the people spending time in the Chemistry Laboratory. Concentration of gases like Ammonia, Hydrogen, Natural gas, Benzene and smoke when increased beyond a certain limit can cause adverse effect on health. Wireless Sensor Technology is used to design as system to monitor air quality indoors. The Wireless Sensor Network application is increased due to the low cost devices, low power consumption, the availability of reliable sensors, open source hardware and software platforms. Due to its various advantages the Wireless Sensor Networks are used in various applications like medical monitoring, agriculture monitoring, environment monitoring, Health care monitoring, Industrial monitoring, etc.. Wireless Sensor Networks are basically similar to the Wireless ad-hoc networks. The Operating System for the Wireless Sensor Network is less complex. The different Operating System for the Wireless Sensor Networks are TinyOS, Contiki, LiteOS, PreonVM OS. The Wireless Sensor Network can be structured into various topologies like mesh topology, ring topology, star topology. In the star topology all the sensor nodes send the data to the base station. The transmission of data from one sensor node to the other sensor node is not permitted; this type os structure controls and keep the power consumption of the sensor nodes to minimum. In the tree topology all the sensor nodes send the data to a sensor node that is placed higher to the tree and then it is forwared to the sink node. The tree topology is also called as cascaded topology. The tree topology has benefits where the expansion of network is needed. In mesh topology the sensor nodes forward the data to the sink node through another sensor node. The mesh topology structure has advantages like detection of fault in the network. The sensor networks are similar to the embedded systems as the sensor networks too are build for a certain application in mind rather than for overall general purpose. The Wireless Sensor Network consists of a large number of densely located Sensor nodes. These Sensor nodes are also called as Sensor mote. The Sensor Mote are small devices and are low powered. The Sensor Nodes have application in effective real-time monitoring. The reduced cost of sensors along with increase in the effectiveness, performance, accuracy, sensing, and processing have made Wireless Sensor Network even more efficient technology for real-time monitoring. Wireless Sensor Network is comprised of large number of Sensor nodes and a single Sink node. The Sensor node consists of devices like Sensors, transceiver module, embedded microcontroller, energy source. The sensor node performs the functions like collection of data and transmission of the data to the central repository. The sensors collect all the raw and real time physical data from the Environment. The sensors collect all the physical environment conditions like temperature, humidity, wind, gasses, smoke, sound, pollution levels, etc.. The sensor nodes collect and record all the physical data from the environment and send it to the centralized location called as base station or sink node. The Sink node is the core node of the Wireless Sensor Network performing important functions like data collection, data storage, data processing, decision making and transmission of data to the client terminal using different communication technologies like WiFi, Ethernet, cable etc.. The sink node organizes all the data received from the different sensor nodes. The Wireless Sensor Network can have a large number of sensor nodes with at

least one sensor connected to each sensor node but it has only one sink node. The sink node acts as the gateway in the network. The Wireless Senor Network; typically comprises of devices like the radio transceiver for wireless communication, microcontroller to interface the sensors and power supply through either batteries or some energy source. Considering the vast usage of Internet and to allow effective web interfacing also to increase the functionality of the system a Web Application Interface is developed. The Web server Interface makes it easy to the users to access the data whenever required. The Environment Monitoring System is designed to implement the client-server nature of the system.
MySQL, PHP, HTML are the languages used to develop a web application. The users can login to the web page to access the data. IoT can be incorporated for Environment Monitoring to collect, store the sensor data and provide access to the user using Internet.

II LITERATURE SURVEY

After studying the following paper the proposed system has been developed using Wireless Sensor Networks.

Gorge Mois[1]**et al**. Have presented their work in IEEE Transactions on Instrumentation and Measurement in 2017 on" Analysis of three IOT based Wireless Sensors for Environmental Monitoring". They have proposed a system using three IOT based Wireless Sensors for Environmental Monitoring one by employing User datagram protocol and WiFi communication second by using a WiFi Communication and a Hyper Text Transfer Protocol and third by using Bluetooth Smart. Their proposed work includes all the three system and its analysis based on their ease of use, energy anatomy, Internet connectivity facility; thus all these factors were analyzed and revealed that all the system are the valid or reliable candidates for the IOT based solutions. The paper proposed the most widely used protocols in applications those consists of ZigBee (IEEE 802.15.4), WiFi(IEEE 802.11) and Bluetooth(IEEE 802.15.1) .

James Gray, Thomas M. Banhazi and Alexander A. Kist[2] have proposed their work in Journal Paper on Elsevier in "Wireless data management system for Environmental monitoring in livestock buildings" . The paper deals with creating a prototype for environmental monitoring. They considered the airbourne pollutants in the enclosed buildings like Ammonia, Carbon Dioxide and dust particles. According to the writers the network technology is compromised of two sections that is sensor networking implementation and data collaboration and storage. The paper talks about the wireless technologies like WiFi, UWB, ZigBee, Bluetooth. Wireless Sensor Network is basically a adhoc network that is used for monitoring a large number of sensor network.

Min-Sheng Liao, Shih-Fang Chen[3] have proposed their work in Journal paper on Elsevier on " On precisely relating the growth of Phalaenopsis leaves to greenhouse environmental factors by using IOT- based monitoring system". The paper deals with IOT-based environmental monitoring system that consists of 12 sensor nodes and a gateway. All these 12 wireless sensor nodes are responsible for measuring environmental parameters following a fixed schedule. And all the sensor readings from the sensor nodes are reported to the gateway using a ZigBee protocol. ZigBee is a low-power and short transmission range communication protocols. The gateway is used to organize the sensor readings sent by the wireless sensor nodes and sent to the server using WiFi. To increase the data delivery rate, a request mechanism of data transmission is designed. The gateway requested the data transmission to the WSN for three times.

Hao Wang,Siyu Chen[4] have proposed their work in Journal paper in Elsevier on " Wireless environmental monitoring based on MCU C8051F020". It describes the hardware and the software implementation of the environmental monitoring system. The paper describes the design tasks and requirements that includes the implementation of two detection node with two sensors to measure temperature and illumination. The paper shows the actual parameters and the measured parameters and the error identified between them.

Oluleke Bamodu, Liang Xia, Llewellyn Tang [5] have proposed their work in Elsevier on " An Indoor Monitoring system using low-cost sensor network ". The paper represents a system developed using sensor network technology to monitor the indoor air quality. The parameters of interest are humidity and temperature. A ZigBee module is used for wireless communication along with Arduino microcontroller Mega 2560. The ZigBee XBee S2B module is used for wireless communication. DS18B20, LM35 temperature sensor and DHT11 humidity and temperature sensors are used. The paper also discusses the testing of sensor and graphical representation of data regarding the temperature and humidity in the room at various intervals and scenarios.

Sheikh Ferdoush, Xinrong[6] have proposed their work in Elsevier on "WSN System design using Raspberry Pi and Arduino for Environment Monitoring Application ". The paper represents the work on the WSN system for Environment Monitoring application using open-source hardware platforms. The open- source hardware platforms used are Raspberry Pi and Arduino. The sensor network hardware platforms like Arduino, Raspberry Pi are basically microcontroller embedded systems that are low-powered and has some onboard sensors connection via analog I/O ports. They have used the ZigBee moduke XBee S2B which is a low-cost and low-power built upon IEEE 802.15.4 standard. The paper describes the design of sensor node, base station and web interface. The sensors they used are humidity and temperature sensor RHT03. The authors say that the ZigBee module can be used for three of devices. These are coordinator, end device and router. The XBee module has Application Programming Interface mode. With this API mode the authors have designed a simple frame based communication scheme to implement function in mesh network. The authors have

designed the Base station using Raspberry Pi which can be connected to a local area network through Ethernet cable or USB WiFi adapter. The gateway application is programmed in Python that comes built in with Raspbian.

Sean Dieter Tebje Kelly, Nagender Kumar Suryadevara and Subhas Chandra Mukhopadhyay[7] have proposed their system in IEEE Journal on "Towards the implementation of IoT for Environmental Condition Monitoring in Homes". The paper represents a system used for domestic condition monitoring by IoT implementation. The system architecture consists of Sensing units, WRT54GL Gateway. The wireless communication is done using a ZigBee protocol. According to the authors the data transmission done over the internet with ZigBee can be done by integrating an internet gateway with ZigBee network. As per the authors the transmission takes place by the ZigBee protocol data frame format. The coordinator node then transmits the data further to the Internet server. Here the coordinator node translates the ZigBee protocol data format to the Internet protocol IPv6 format by Gateway. ZigBee Wireless Sensor Network comprises of XBee-S2 module which are configured as sensor nodes and these sensor nodes communicate to the coordinator node in the form of mesh topology. If the end device is within the range of the coordinator node the system runs like a star topology. If the end device is not within the range then hoping will take place from one node to the other to reach the destination thus running like a mesh topology.

III SYSTEM ARCHITECTURE

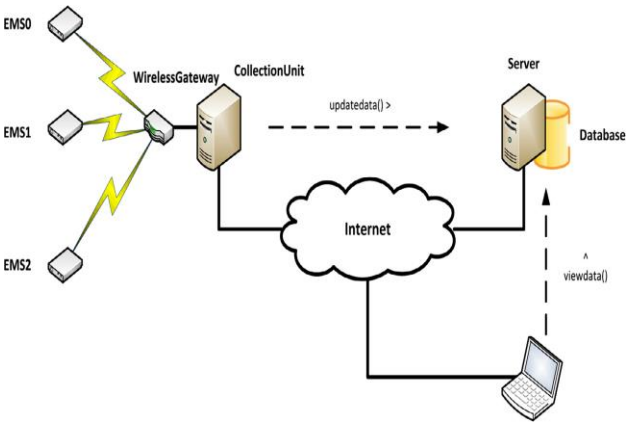

Fig 1. Overall system architecture

Fig 1 shows the overall system architecture of the proposed Environment Monitoring System. Designing a system for Environment Monitoring using Wireless Sensor Network requires the combination of both hardware and software components. The Environment Monitoring system includes a Sensor node and Sink node. The Sensor nodes are densely placed at different locations. There can be a number of Sensor nodes. But the Wireless Sensor Network consists of only one Sink node. The Sink node can also be called as the Base station. Each Sensor node is equipped with devices like Sensors, microcontroller and nRF24l0l module. The nRF24l0l module on the Sensor node transmits or exchange the Sensor data to the Sink node. Here these modules act as a router to exchange the data to the Sink node. Whereas the nRF24l0l module on the Sink node accepts the data from the Sensor node; thus acting as a coordinator. The nRF24l0l modules work together to form a star topology using the RF networking protocol. The Sensor nodes are created using the Atmega328 micro controller. Parameters of interest to monitor the Environment in the Chemistry Laboratory are gases like Ammonia, Natural gas, Methane, Hydrogen and Smoke along with temperature and humidity. Analog Sensors used for monitoring the environmental conditions are DHT11, MQ-135, MQ-4, MQ-8, MQ-9. The Sink node is designed using Raspberry-Pi zero v1.3 board which is an open source hardware platform. To access the data collected from the Sensor node a Web application is developed on the Sink node. The system architecture thus consists of low cost open source hardware platform along with the low-cost sensors making the system cost effective. Due to the vast use of Internet in the today's society the development of a web-interface makes it easy for the users to access the data and also provides a systematic representation of data for further analysis.

A.SENSOR NODE DESIGN:

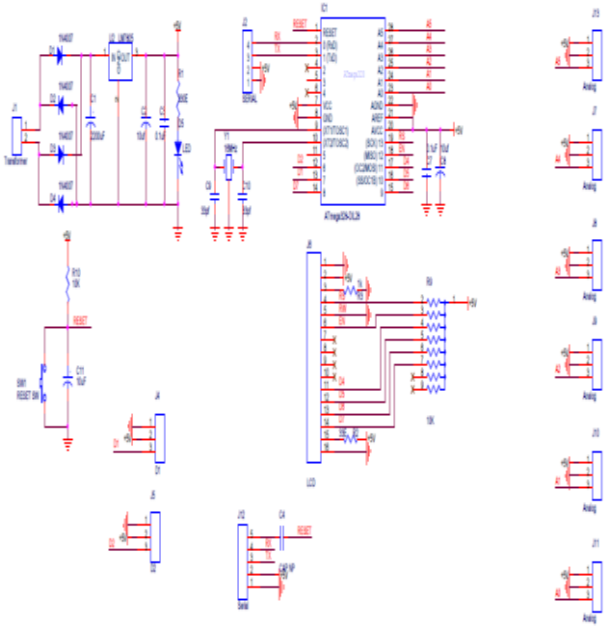

Fig 2.. Schematic diagram of Sensor Node

Fig 2. shows the Schematic diagram of the sensor node. The Sensor nodes are developed using the Atmega328 microcontroller, nRF24l01 module, Sensors and a16*2 LCD display. The Atmega328 is used as it is simple, low-powered and low-cost. It is a high performance, low power AVR 8-bit microcontroller with a clock speed of 16MHz. It has a 32Kb of Flash memory, 1Kb of EPROM, 2Kb of SRAM. It has 6 analog channels and 23 I/O lines. The device achieves a throughput approaching 1MIPS/1MHz. The sensors used are analog sensors like MQ-135, MQ-4, MQ-9, MQ-8 and DHT11. The sensors are devices that collect and record the environmental parameters like temperature,

humidity, gasses, wind, smoke , etc.. The MQ-315 is an air quality sensor that detects environmental parameters like alcohol, Benzene, smoke, carbon dioxide, ammonia, etc.. The MQ- 4 sensor detects gases like natural gas, Methane and has a small sensitivity to smoke and alcohol. The MQ-8 sensor has high sensitivity for hydrogen. The MQ-9 sensor has a high sensitivity for combustible gas and carbon dioxide. The MQ gas sensors are used at room temperature and are highly sensitive to certain range of gasses. The DHT11 sensor senses the temperature and humidity parameters. The nRF24l01 module is used for wireless communication between the sensor nodes and the base station. The nRF24l01 module supports 24GHz frequency with 2Mbps data rate low energy consumption. It operates at 1.9-3.3V. The nRF24L01 module along with the open source libraries are easier to setup into star network. The protocol of nRF24l01 is much simpler for sending small amount of data hence they consume very little current while transmitting data. Fast prototyping becomes easier for the Wireless Sensor Network application. The nRF24l01 is a highly integrated, low power RF transceiver IC. It integrates a complete RF synthesizer, RF transceiver and baseband logic. It is possible to build a network of 125 independent working nRF24l01 modem in one place as the nRF24l01 module uses 125 different channels. Each channel has 6 different addresses. The power consumption of the nRF24l01 module is very low around 12mA during transmission. The nRF24l01 module consists of 7 pins. VCC,GND, CSN, CE, SCK, MOSI, MISO, IRQ. Its operating voltage is 3.3V. The CSN and CE pins are used for setting the device into standby or active mode. The CSN pin that is the chip select pin is an active-low pin and is normally kept high. Whenever the CSN pin is low the nRF24l01 module listens for the data on the SPI port and the data gets processed. The CE pin is used for data transmission and data reception control. The SCK, MOSI, MISO pins are for the Serial Peripheral Interface Communication. The last Interrupt pin IRQ is active low and is not used here. Fig 3. shows the Block diagram of the sensor node.

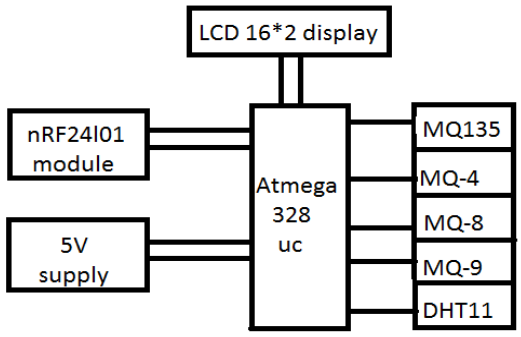

Fig 3. Block Diagram of Sensor Node

DATA PACKET FORMAT:

The data packet format is the information about what goes in the air between the nRF24l01 modules. The data packet format consists of a Preamble, address 3-5 bytes, Payload 1-32bytes and CRC 0/1/2 bytes for the Shockburst data packet. The enhanced Shockburst data packet consists of a addition of a flag field which is 9 bit long. The Preamble is send first which is 1byte long and consists of alternating 0 and 1 bits. The next byte sent are the address bytes those are 3-5bytes long. The user sets this address field. The next field send is the payload of 32 byte in the Shockburst data packet. While the enhanced Shochburst data packet sends a flag field of 9 bit long. The flag field consists of a retransmission message status. The final part is the CRC field which is 1-2 bytes long which is set to 0.

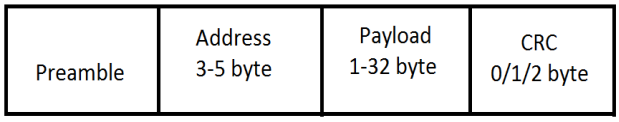

Fig 4.1. Data Packet Framne for Shockburst

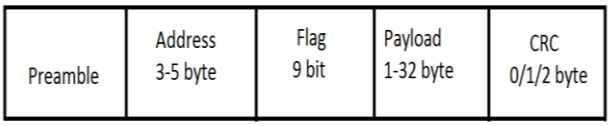

Fig 4.2. Data Packet Frame for Enhanced Shockburst

B. BASE STATION DESIGN:

The base station also called as coordinator node is designed by using Raspberry Pi zero v1.3 board and nRF24l01 module. The coordinator node is the core of the Wireless sensor network. The function of the coordinator node is to collect the data from all the sensor nodes, data integration, data storage and then transmission of data to the server over the internet. The Raspberry Pi board is a small credit card size computer. The Raspberry Pi zero v1.3 consists of a 40 pin connector, mini HDMI video out, microSD card holder, USB port, Camera connector. The Raspberry Pi zero v1.3 board consists of an 1GHz ARM v7 single core processor working at 700MHz clock speed which is same as that of the Raspberry Pi Model B/B+ and model A/A+ boards. It has a memory of 512 Mb RAM. The uSD slot to the run the OS. The Raspberry Pi zero v1.3 board supports Operating system like Raspbian, Noobs, Raspberry Pi Desktop and other third party OS like RISC OS, UBUNTU MATE, Windows 10IOT core, PINET, OSMC etc.. The Raspberry Pi Desktop OS is used in the project. A 8Gb SD card is used to install the Operating System in the Raspberry Pi. The base station functional blocks include gateway application, database and web application. The Gateway application is programmed in Python which comes in-built with the Raspberry Pi Desktop OS. The gateway application is the layer between the sensor network and the database. Apache HTTP web server is used to built a web application and the PHP programming language is used to build the web server services. WiFi or Ethernet can be used within the local area network to access the HTML web interface.Fig 5. Shows the functional diagram of Base Station.

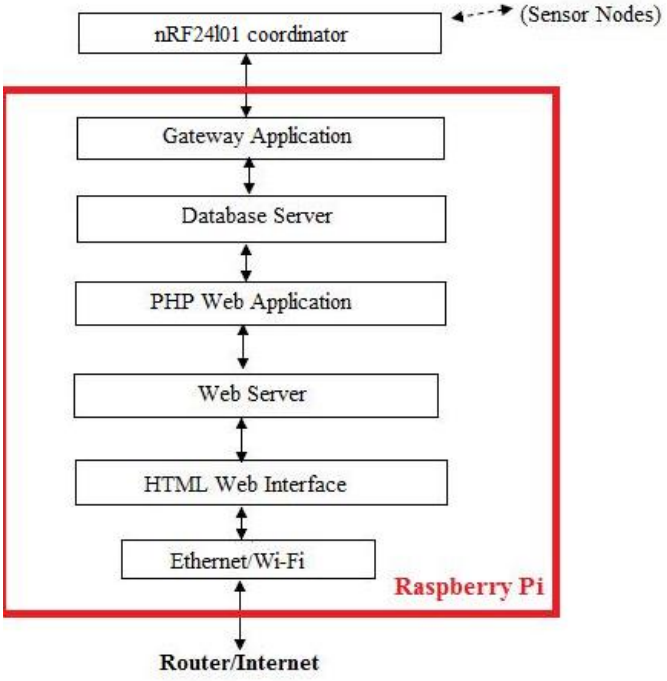

Fig 5. Functional diagram of Base Station

C. WEB SERVER INTERFACE:

The Web Server Interface is the interface between the web serrvers and the web frameworks for the Python programming language. HTML, PHP and MySQL languages are used to built the web server. SQL stands for Structured Query Language and is used to communicate with a database. MySQL statements are used to perform actions like updating or retrieving the data from the database. The most common SQL commands are "Select", "Insert", "Update", "Delete", "Create", "Drop". These SQL commands are enough to perform all the task required with a database. MySQL is an open source database management system. Database is an application that stores data. A database management system is a software that enables implementation of database with tables, columns and indexes. MySQL works on many Operating System. MySQL also works with PHP, C,C++, Java, PERL etc.. PHP stands for Hypertext Preprocessor and is very friendly with MySQL. PHP language is the mostly used language for web development. PHP is a server side scripting language. PHP is the intermediate link between the HTML and MySQL. PHP performs functions like creating, opening, reading, writing, closing the files on the system. Users can insert, delete, modify data within the SQL database through PHP. PHP also provides security by encrypting the data. It also restricts the access of some pages on the website. HTML stands for Hyper Text Markup Language which is used to write web pages. HTML is a markup language ; means the language is used to mark up a text document with tags so as to tell the web browser the structure of the display. Using the HTML tags the web pages can be formatted accordingly. Using all these languages the web server is being created for the storage of the sensor data and then displays the sensor data on the created web page. The users can access the real time sensor data by logging into it. The sensor node and the coordinator node can work independently. The users can access the sensor data by logging into the Raspberry Pi.

IV. EXPERIMENTAL SETUP AND RESULTS

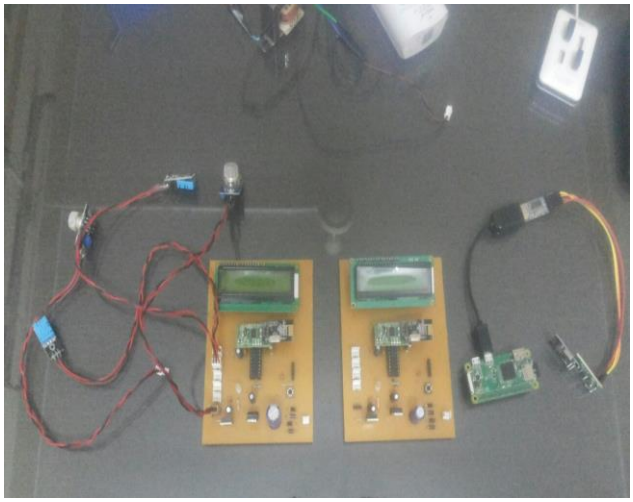

Fig 6. Experimental setup of the system

Fig 6. Shows the experimental setup of the system. The system consists of two sensor nodes and one sink node. The sensor node shown the figure 7. consists of sensors, Atmega328, nRF24l01 transceiver module, 16*2 LCD Display and power supply. Fig 8. Shows the Sink node that is designed using the Raspberry Pi v1.3 board and nRF24l01 module. Here the transceiver module acts as a coordinator. Fig 9. Shows the values of sensors displayed on the LCD. The values displayed on the LCD are the Humidity, Temperature, Air quality, Methane and Hydrogen gases.

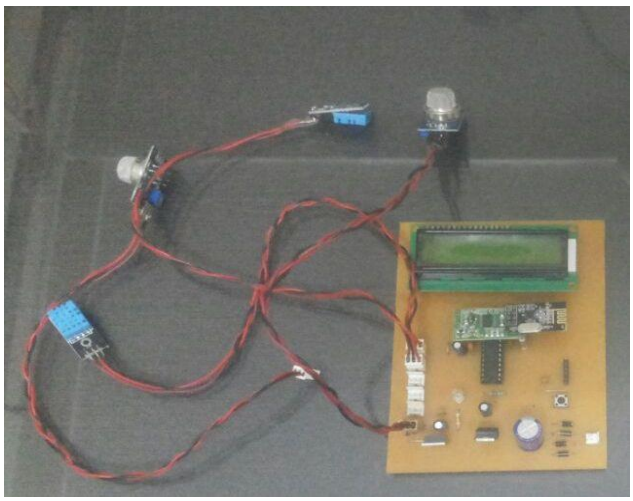

Fig 7. Sensor node

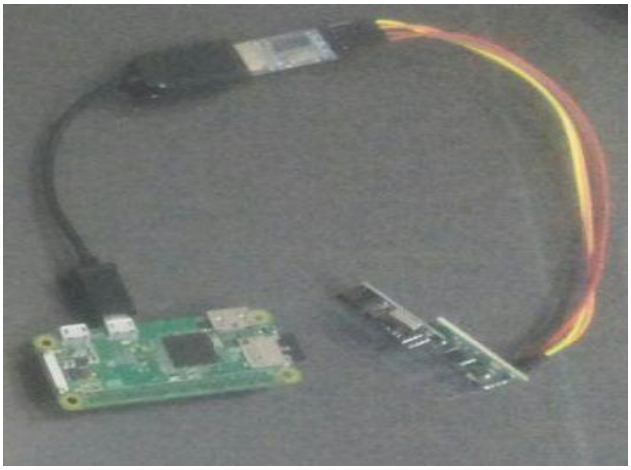

Fig 8. Sink Node

V. CONCLUSION

The paper describes a system for monitoring the Environmental parameters in the Chemistry Laboratory. The system is designed by using the Wireless Sensor Network. The sensor nodes are designed using the ATmega328 microcontroller, sensor, nRF24l01 module. The sensor records the concentration of gases in the Laboratory along with the temperature and humidity. The sink node is designed using the Raspberry Pi v1.3 board. The sink node collects the data from all the sensor nodes and displays it on the web application. The overall architecture of the system makes the system low cost, consumes low power, more reliable and easy to manage. The web server interface provides even more flexibility to the system due to the increase use of the internet. The users can access the sensor data on the web page by connecting to the internet.

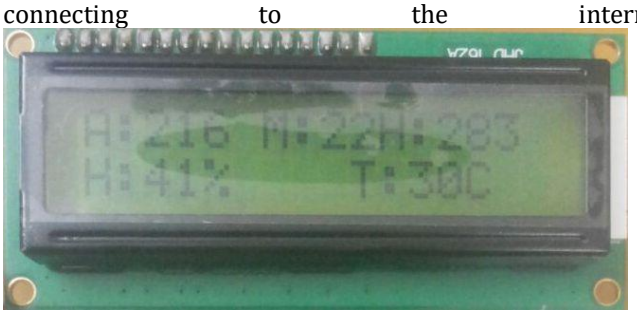

Fig 9. Sensor values displayed on LCD

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