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WSN-Based Real-Time Coal Mine Safety Monitoring System Using IOT

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ABSTRACT

Nowadays different kinds of sensors play life-saving role in various fields. In Modern age, the uses of sensors are increasing rapidly. Spontaneous heating, increasing level of toxic gas and fire in coal-mines are the major problems worldwide and has been a great concern both for the industry and researchers in this field. Majority of fires existing today in different coalfields are mainly due to spontaneous combustion of coal and increase in the level of toxic gases. The main aim of this paper is to monitor safety measures for mine workers using Wireless Sensor Network (WSN) technology which is the most essential in underground mining areas. In this paper there are two sections: the first section is underground section and another section is ground section. In underground section the system is build using different sensors network based on MEMS used to monitor the surrounding's parameters such as temperature, humidity, different type of toxic gases of underground mine places and drives all sensed parameters and values to Atmega328 based micro-controller unit by initiating HC05 module based on Bluetooth communication. We have designed an android app that contains a UI that displays the sensed data from underground section. In ground section Real-Time Data analysis and data monitoring has been done. When we observe the sensors exits their threshold level we can take essential instantaneous action to prevent severe damage of miner's life and mine properties by monitoring the data.

Key words: Wireless Sensors Network; Microcontroller; Bluetooth communication; Real-Time Data; Android app

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1. INTRODUCTION

Internet of Things describes a general concept for the ability of network devices to sense and gather the data from the world around us, and then send that data across the Internet where it can be processed and utilized for various interesting purposes. The Internet of Things is the interconnection of physical devices with embedded sensing and communication possibilities [6]. Internet of Things (IoT) is currently a hot technology that is widely used nowadays as a solution to various problems worldwide. The applications IOT are widespread applications such as innovative shopping systems, infrastructure management, health monitoring, environment monitoring, underwater monitoring and emergency notification systems, and transportation systems, which are gradually relying on IoT-based systems. In this project, we have used this technology to monitor the underground coal mine's environmental parameters to avoid any hazards.

Spontaneous combustion generally takes place due to auto-oxidation of the coal which is the major cause of fire in coal mines in coal-producing countries like India, Australia, and China. Auto-oxidation depends upon the different characteristics and properties of coal. If the combustion of coal is started once it tough to control the fire spreading and it may cause major lose in the mines including lives and property present in the mine [15]. Spontaneous heating liability of different coals differs, it is required to know the degree of proneness to avoid occurrence of mine fires to avoid loss of lives, property, coal reserves, environment etc. The ultimate factor which comes to our mind in running any industry successfully is to ensure the safety and protection other person working that Place undergrounound coal mining industry comes to the same category, where each and every parameter such as methane gas, carbon dioxide gas high temperature, fire accidents and so on has to monitor regularly [8]. Every mining industry follows some basic precautions to avoid any type of unwanted incidents. Designing prototype of IoT systems in Coal Mines for Safety and Efficient Monitoring is based on wireless sensor network can be sensible and correctly redirect dynamic condition of workers in the underground areas to monitoring work areas [6]. This paper we designed a monitoring system based

on WSN technology using different Sensors. The sensor are sensed the surrounding's parameters such as temperature, humidity, different type of toxic gases of underground mine places and drives all sensed parameters
and values to Atmega328 based micro-controller unit by initiating HC05 module based on Bluetooth communication on an android app to monitor.

1.1 Internet of Things

One of the buzzwords used heavily in the IT industry for the past couple of years is the term IoT, which stands for Internet of Things. IoT refers to all of the things that are, well, connected to the Internet, and that's how it got its name. However, IoT isn't really a new concept, because for as long as we can remember, we've been connecting devices to the Internet. According to Wikipedia, IoT is defined to be: "...the network of physical objects - devices, vehicles, buildings and other items - embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data".
Although this is a fairly accurate description of the roles played by IoT systems, it's our opinion that IoT is more than the collection of data-using sensors. More specifically, IoT involves the processing of the data (often Big Data) collected to derive useful information and support better decision-making. For example, in some countries, rain gauges have been installed to measure the amount of rainfall throughout the year, and the data collected have been analyzed and used to better manage flash floods. In this article, we use IoT to ensure the safety of coal mines by measuring different hazardous elements inside the mine

1.2 Motivation of the Work

Wireless networks provide advantages in deployment, cost, size, and distributed intelligence when compared with wired networks. This technology allows users to set up a network quickly and allows them to set up networks where it is impossible or inconvenient to wire cables. Wireless networks are more cost-efficient than wired networks in general.
The Existing monitoring systems in underground of coal mines mostly use cable network. This kind of network has poor performance of expansion. The cables are easy to aging and wear, and have high incidence of failures. With the working surface expanded, a blind area for monitoring appears, and then the new cost for installation and maintenance is needed. When an accident happened, especially explosion and fire the sensors and cables usually were damaged fatally, and couldn't provide information for rescue search and detection events. Wireless sensor network can solve the key issues of communication bandwidth, mobile data transmission, staff orientation, working surface real-time monitoring, synchronization monitoring and so on [9].

1.3 Background History of Coal Mine Fires in Asia scenario

The whole world stood shocked by a disaster on 8th August, 1956 in the Charleroi coalfield of Belgium where 262 miners lost their lives underground as a result of outbreak of fire in the Bois du cazier mine at Marcinelle [15]. In India, occurrence of New Kenda mine fire disaster at Raniganj coalfield is fresh in our minds where 55 miners lost their lives. When all of a sudden fire occurs in underground mines, then there is no sufficient time for safe withdrawal of man and equipment. Human life is being endangered due to release of noxious and poisonous gases. Fire is not only dangerous to the workers employed in the mine, but it also results in heavy loss of valuable coal, a national asset being the primary source of energy. Self-heating of coal extends to spontaneous heating is the most substantial cause of fires in coal mines across the world [15]. Bangladeshi mines have a historical record of extensive fire activity for over thirty years. The scenario of fire in Bangladeshi mines is very complex because of the involvement of different seams simultaneously. Such conditions do not exist elsewhere in the world.

2. OVERVIEW OF DIFFERENT SENSOR

Sensors are advanced gadgets those are used to identify and react to electrical or optical signals. Physical parameters like temperature, humidity, distance, motion are converted in term of digital or analog signal with sensors. Based on their working principal there are different type of sensors. Some of them has been discussed below.

- **Ultrasonic Sensor:** The ultra sonic or ultra sound sensor is a sensor that works on the properties of sound wave. It works on properties like the bat and dolphin works. It sends a sound wave from its emitter and the reflected sound wave is then collected by the collector and from there the distance of an object can be measured.
- **Temperature Sensor:** Temperature sensor is such a sensor that can measure the temperature of a room environment and it also can measure the humidity.
- **Gas sensor:** There are many gas sensors some of them are MQ-135, MQ-2, MQ-3, MQ7 etc. these sensors are divided based on their sensitivity towards different gases.
- **Speed sensors:** Speed sensors are used for calculation the speed of an object. For detecting the speed there are many types of sensors. Some of them are wheel speed sensors, speedometers, LIDAR, ground speed radar, Doppler radar, air speed indicators and so on.

- **Proximity Sensors:** A Proximity Sensor is a non-contact type sensor that detects the presence of an object. Proximity Sensors can be implemented using different techniques like Optical (like Infrared or Laser), Ultrasonic, Hall Effect, Capacitive, etc. Some of the applications of Proximity Sensors are Mobile Phones, Cars (Parking Sensors), industries (object alignment), Ground Proximity in Aircrafts, etc.
- **Infrared Sensor:** IR Sensors or Infrared Sensor are light based sensor that are used in various applications like Proximity and Object Detection. IR Sensors are used as proximity sensors in almost all mobile phones. There are two types of Infrared or IR Sensors: Transmissive Type and Reflective Type. In Transmissive Type IR Sensor, the IR Transmitter (usually an IR LED) and the IR Detector (usually a Photo Diode) are positioned facing each other so that when object passes between them, the sensor detects the object The other type of IR Sensor is a Reflective Type IR Sensor. In this, the transmitter and the detector are positioned adjacent to each other facing the object. When an object comes in front of the sensor, the sensor detects the object. Different applications where IR Sensor is implemented are Mobile Phones, Robots, Industrial assembly, automobiles etc.

3. SYSTEM DESIGN

The Hardware I have used to complete this project is Arduino UNO, MQ-135 sensor, MQ-04 sensor, DHT-11 sensor, HC-05 Bluetooth Module, Buzzer Alarm Module, Connecting wires, Breadboard.

3.1 Raspberry Pi 4

The Raspberry Pi was developed by Eben Christopher Upton, Welsh CEO of Raspberry Pi (Trading) Ltd, at the University of Cambridge in the United Kingdom, and it was launched in 2012. There have been several iterations and variations of it released since then. Raspberry Pi is the well-known name of a series of single-board computers developed by the Raspberry Pi Foundation, a UK charity. Raspberry Pi boards are hugely popular single-board computers (SBCs) that are well suited to DIY IoT devices due to their small size and exhaustive capabilities. There are many different models of Raspberry Pi boards, with different combinations of ports and sensors.

3.2 Arduino UNO:

Arduino UNO is a micro controller which is based on ATmega328. It is having 14 digital input and output pins. It has a USB connector, a power jack, ICSP header and a reset button. By simply connecting it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

3.3 Zigbee

Zigbee is a standards-based wireless technology developed to enable low-cost, low-power wireless machine-to-machine (M2M) and internet of things (IoT) networks. Zigbee is for low-data rate, low-power applications and is an open standard. Zigbee is based on the Institute of Electrical and Electronics Engineers (IEEE) Standards Association's 802.15 specification. Zigbee is built for control and sensor networks on the IEEE 802.15.4 wireless standard for wireless personal area networks (WPANs). The Zigbee WPANs operate on 2.4 Ghz, 900 MHz and 868 MHz frequencies.

3.4 DHT-11 Sensor

DHT-11 is a temperature and humidity sensor and it has a calibrated digital signal output. It ensures high reliability and stability as it uses a digital signal acquisition technique and temperature and humidity sensing technology. This sensor includes a NTC temperature measurement component and a humidity measurement component and it is connected to a high performance 8-bit micro controller. This sensor module has 3 pins. Positive, Negative and Out. DHT-11's power supply is 3-5.5V DC to the Positive pin, the negative pin goes to the ground and the OUT pin is for Analog pin in the arduino micro controller board. The working rage is from -40 °C to +125 °C.

3.5 MQ-135 Sensor Module

MQ-135 is a gas sensor and it can sense a wide range of gases like NH_3, Alcohol, Benzene, CO_2 etc. The working voltage is DC 5 V, it has a dual signal output (analog output, digital output).This sensor also has a good sensitivity for LPG gas and natural gas. It provides long service life and reliable stability rapid response and recovery characteristics.

3.6 MQ-04 Sensor Module

MQ-04 is a gas sensor and it can sense a wide range of gases like CH_4, Natural gas, Small sensitivity to alcohol, smoke., etc. The working voltage is DC 5 V, it has a dual signal output (analog output, digital output). This sensor also has a good sensitivity for CH_4 gas and natural gas. It provides long service life and reliable stability rapid response and recovery characteristics.

3.7 Buzzer Alarm Module

Piezo buzzer is an electronic device commonly used to produce sound. Piezo buzzers are used for making beeps alarms and tones. They can be used in alarm systems, for keypad feedback, or some games. Light weight, simple construction

and low price make it usable in various applications like car/truck reversing indicator, computers, call bells etc. Also they are fun to play around with. The working voltage of the module is 5V.

3.8 HC-05 Module

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. HC-05 is a more capable module that can works as either Master or Slave. In this module the VCC goes to +5V Power supply, GND is System / arduino Ground, TX transmits serial data from HC-05 to arduino serial receive and RX receives serial data from arduino serial transmit

3.9 ESP8266 WiFi Module

The ESP8266 WiFi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your WiFi network. The ESP8266 is capable of either hosting an application or offloading all WiFi networking functions from another application processor.

3.10 HCSR-04 Sensor:

HCSR-04 is an ultrasonic sensor that works one the properties of sound wave. It has one emitter and one collector. The emitter produces sound wave and when the sound reflected by an obstacle it is then collected by the collector and from there the distance is measured. It uses the same technique like the bat and dolphin do. Its rage is 2cm to 400cm with an accuracy of 3mm.There are four pins VCC (Power), Trig (Trigger), Echo (Receive), and GND (Ground).The working voltage of the module is 5V.

4. METHODOLOGY

In this project there are two sections.

- Section A: Underground section
- Section B: Ground Section

In underground section the sensors will senses the environment conditions of underground coal mine such as temperature, humidity, gas etc. The ground Section is the monitoring section. The data from the sensor node is received through initiating Bluetooth communication and display on Android app wirelessly. So that we can observe and monitor the data to avoid any Hazardous situations.

4.1 Section A (Underground Section)

Underground section consists of MQ-135, HC-05 Blue- tooth module and MQ-135 DHT-11, MQ-04 sensors MQ135 it has 4 pins, A0, D0, GND, Vcc. The A0 pin has been connected to the analog A0 pin of the arduino board and the D0 pin has been connected to the digital pin no 8 of the arduino board. The Vcc and GND pin has been connected to +5V DC supply from the arduino board and GND has been connected to the ground GND pin.MQ-04 it has 4 pins, A0, D0, GND, Vcc. The A0 pin has been connected to the analog A1 pin of the arduino board and the D0 pin has been connected to the digital pin no 9 of the arduino board. The Vcc and GND pin has been connected to +5V DC supply from the arduino board and GND has been connected to the ground GND pin For DHT-11 module it has 3 pins Positive, Negative and OUT. The Positive pin has been connected to the +5V DC supply and the Negative pin has been connected to the GND ground pin of the arduino board. The Out pin has been connected to the digital pin 7 of the arduino board. HC-05 Bluetooth module has 4 pins, Rx, Tx, GND, Vcc, STATE, EN. Here the STATE and EN pins has been remain unused. The Rx and Tx pins has been connected to the Tx and Rx pins of the arduino board. The GND and Vcc has been connected to the GND ground pin of the arduino and +5V DC supply voltage.

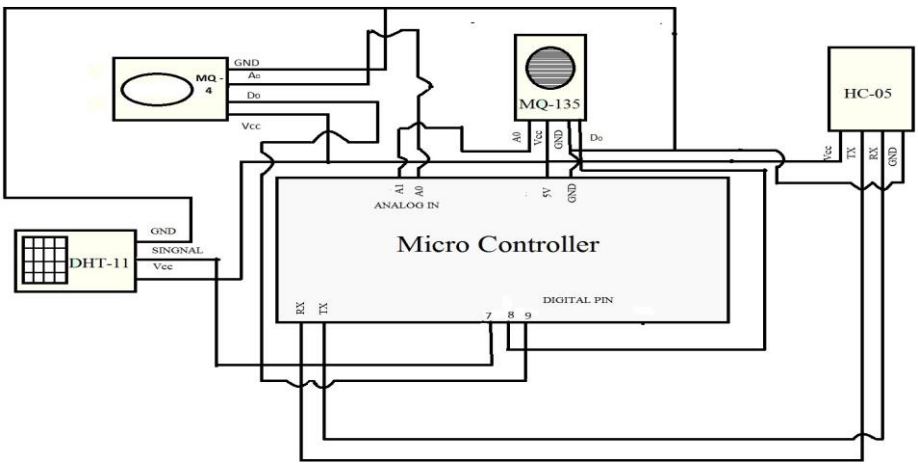

Fig. 4.1 Block Diagram of Underground Section

4.2 Section B (Ground Section)

This section is designed for Monitoring the data. We designed a Android application that contains a UI which can display the received data from the ground section.

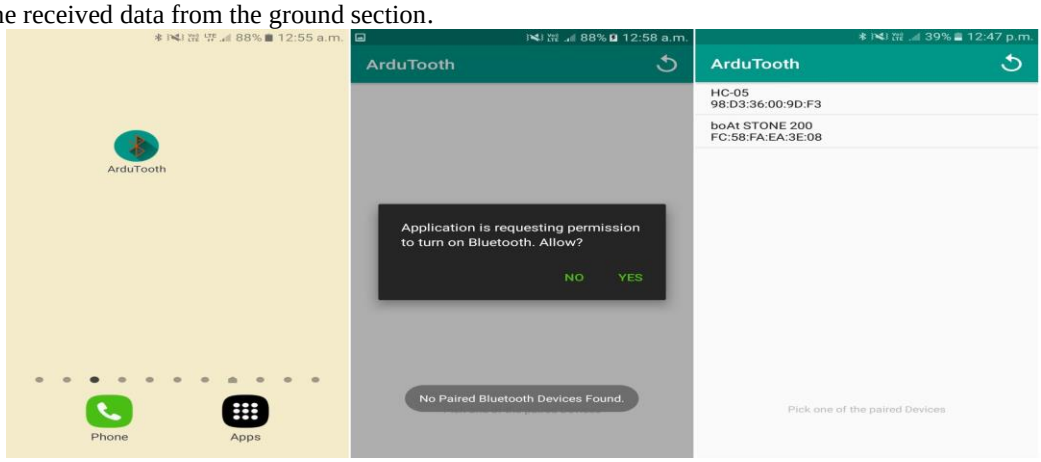

Fig. 4.2 System out put on android app

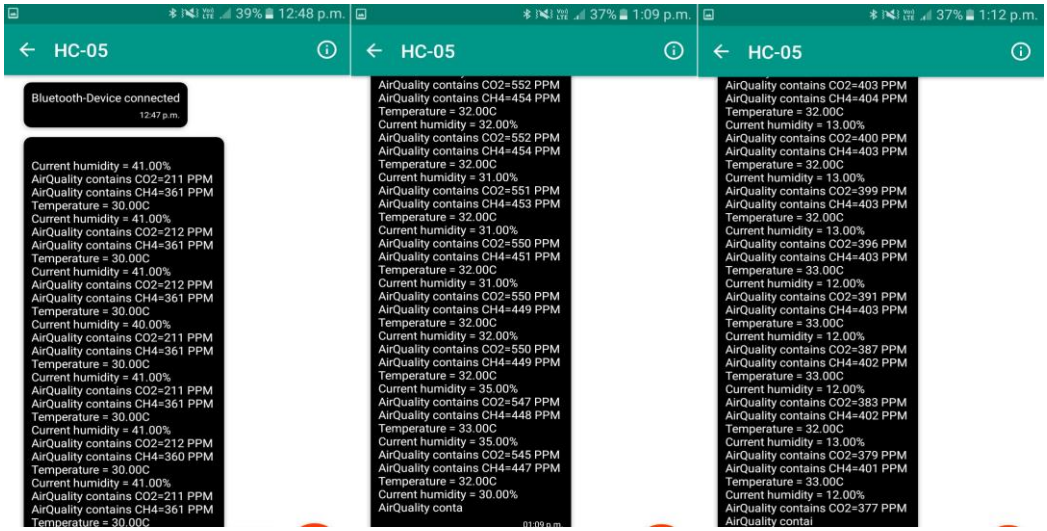

Fig. 4.3 System out put on android app

In this figure we can see that the icon of our android app. When you are going to open it, it will ask for the permission of your device to switch on the bluetooth. After switch on the Bluetooth it will search for the near by Bluetooth devices those are in the range of that device. If our system is i^{th} in the range of that device then it will appear on the list of available bluetooth device. We need to connect our HC-05 module with the device. After connecting our system with the android phone it will start to display the data received from the ground section (Figure:5.3). We can observe that data are coming from the underground section. By monitoring this outputs we can monitor the condition of coal mines If the output values of underground section increases and cross the threshold value then one alarm system will activated automatically in order to indicate the hazards inside the coal mine.

4.3 System Output

Here the temperature, humidity and different poisonous gases (CO_2, CH_4) has been recorded in different places.

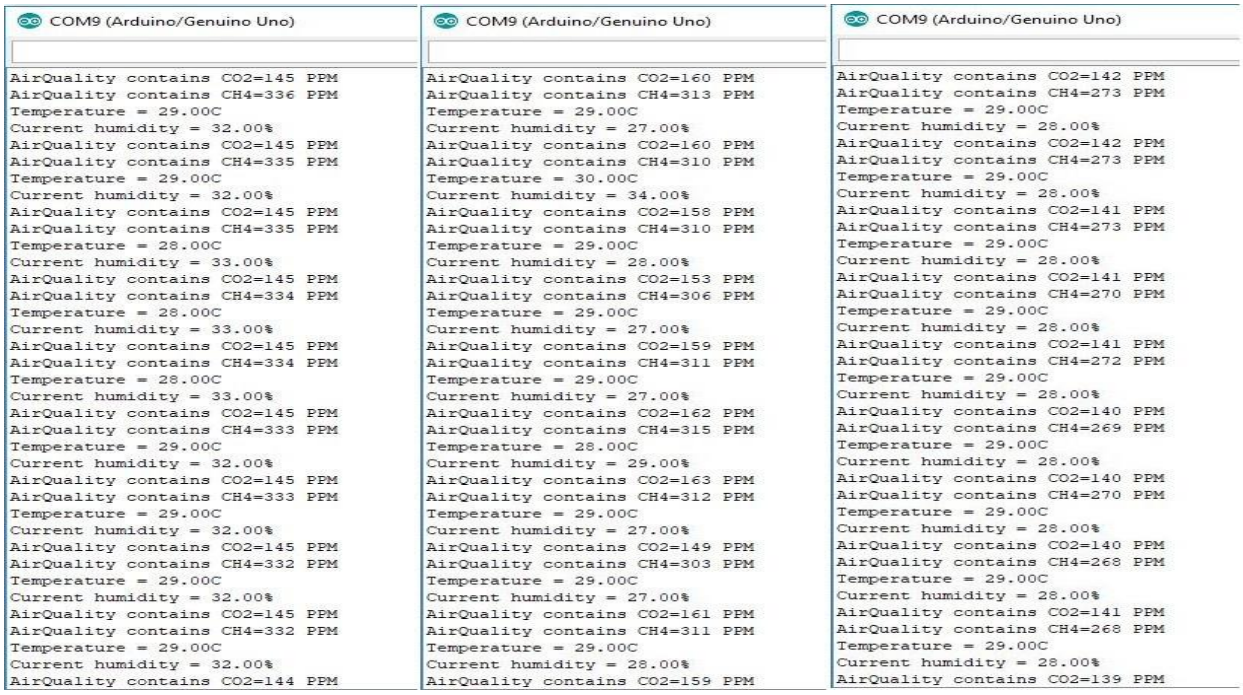

Fig. 4.4 System output (Academic Area NBIU)

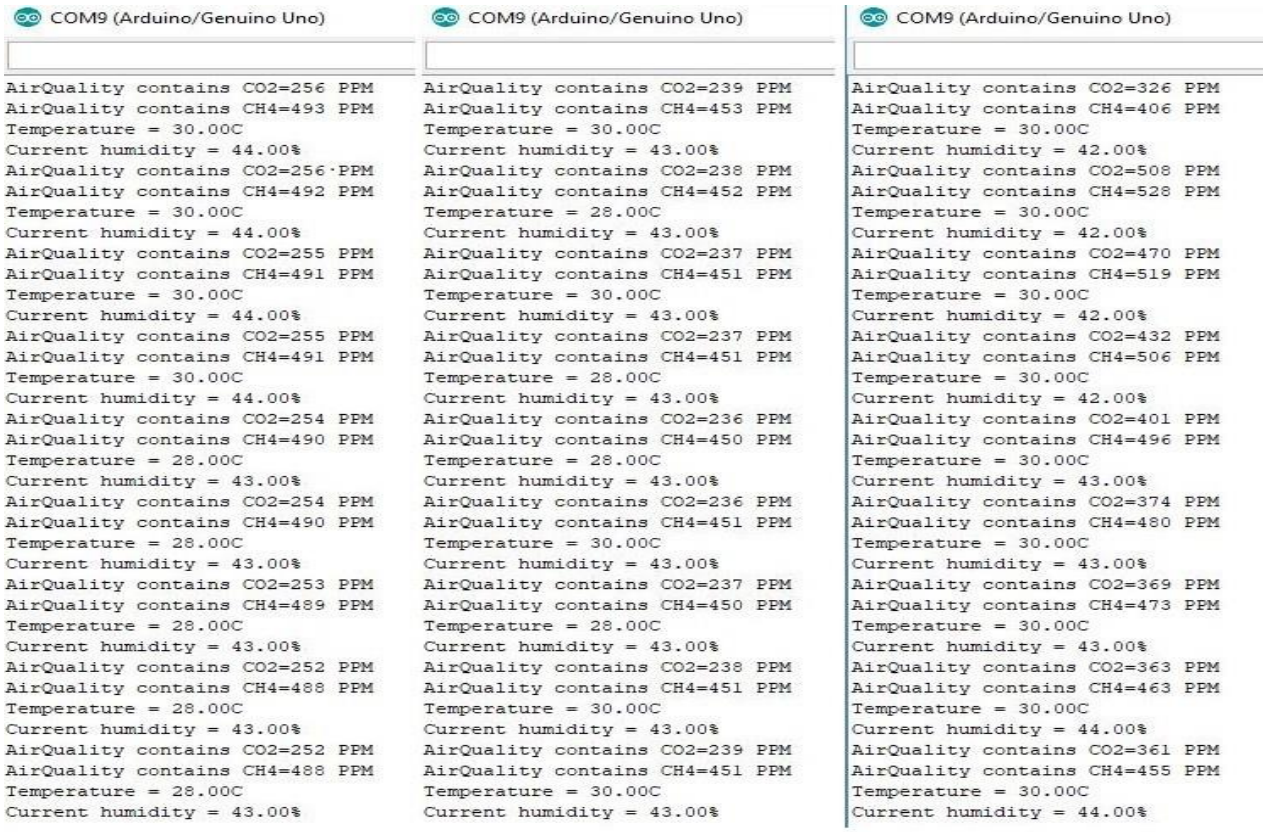

Fig. 4.5 System output (Residential Area)

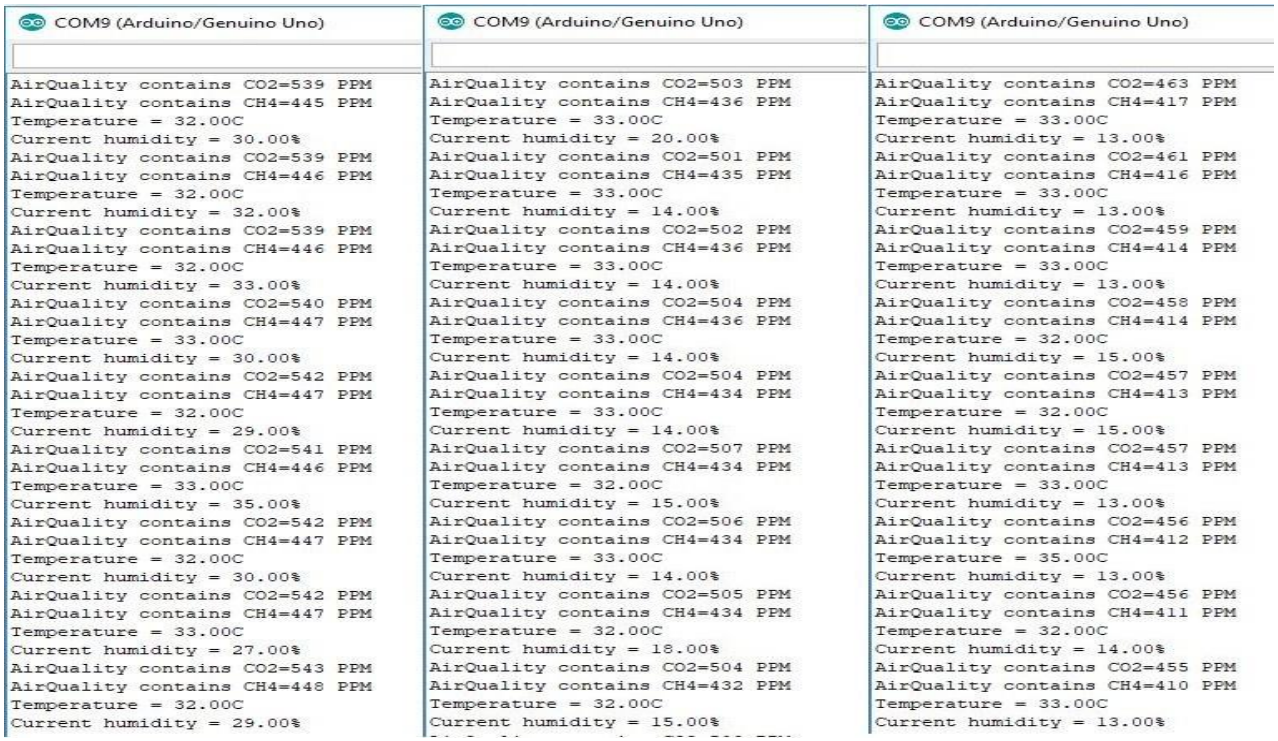

Fig. 4.6 System output (Construction Area NBIU)

5. RESULT AND ANALYSIS

5.1 Temperature

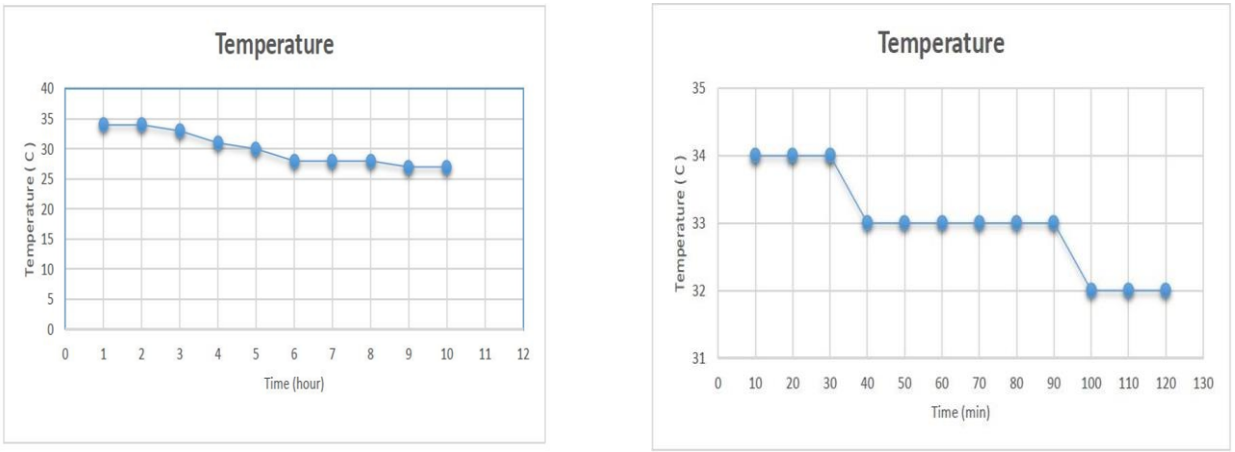

Fig. 5.1 Temperature

5.2 Humidity

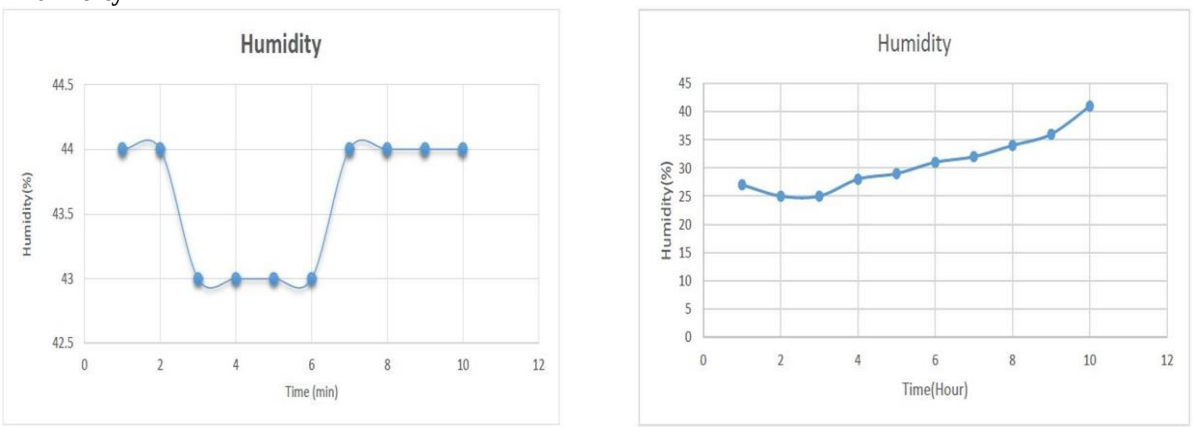

Fig. 5.2 Humidity

5.3 Gas

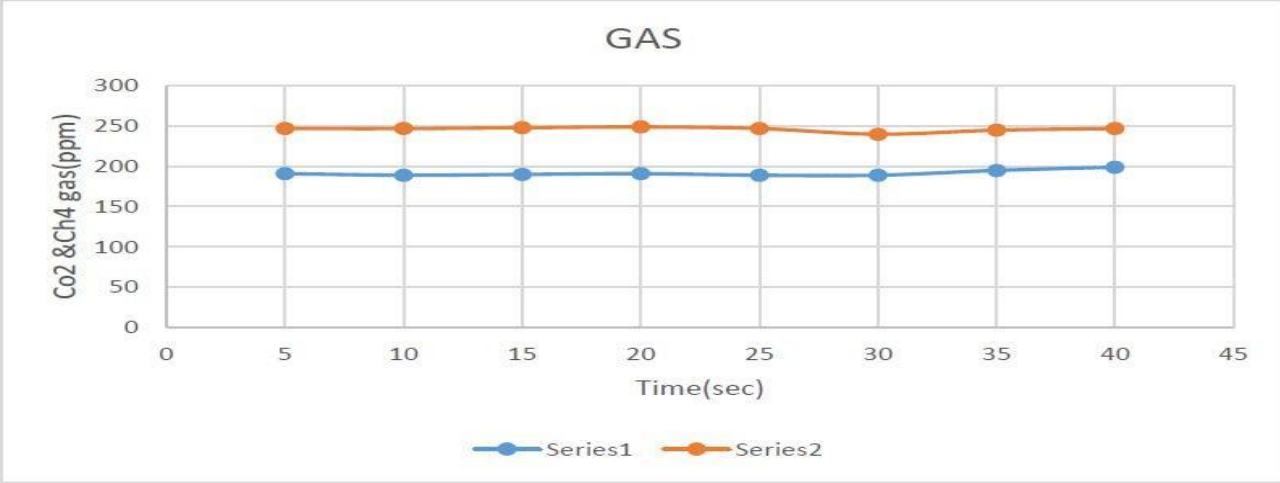

Fig. 5.3 Gas

5.4 Analysis

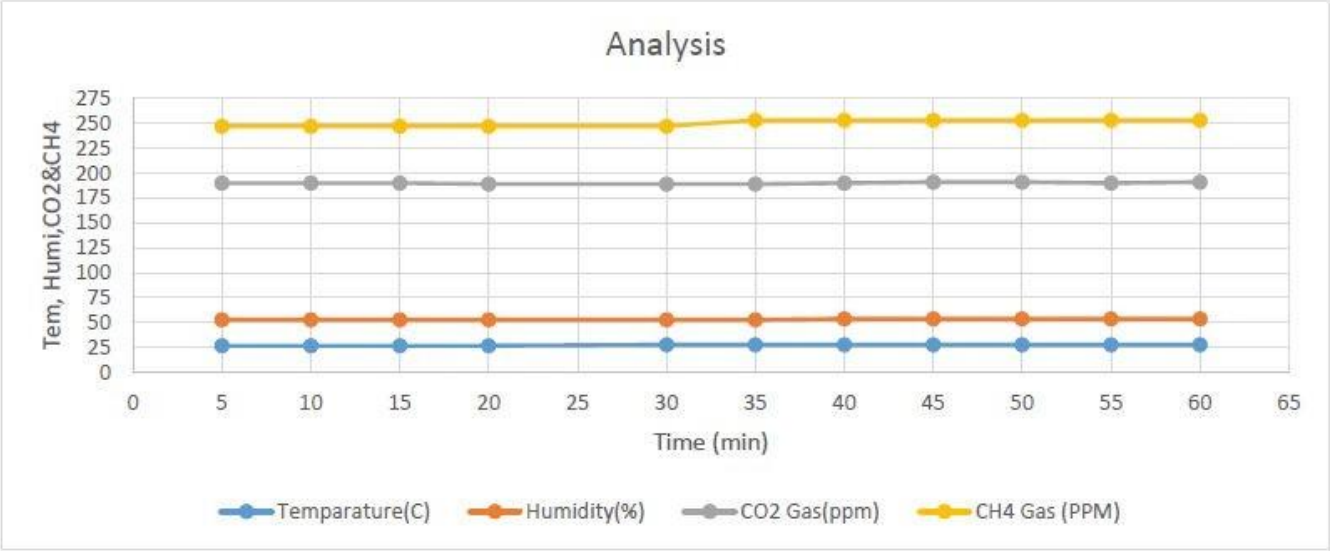

Fig. 5.4 Analysis

6. CONCLUSION

Wireless sensor networks continue to emerge as a technology that will trans- form the way we measure, understand and manage the natural environmental parameters like temperature, humidity air quality, gases etc. The WSN provides a remote way for monitoring and controlling hazards in coal mine which eliminates the risk of human Exposure to hazardous environments and enhances the human safety in monitoring tasks The application of wireless sensor network will improve the safety of coal mine. The main advantages are as follows:

- The wirelesses are more flexible can avoid the trouble of rewiring, because wireless network can meet the moving and changing of topology
- It will greatly improve the performance and efficiency of data transmission of the coal mine safety system, and reduce the costs of extending the system.
- The application of WSN can realize the real-time monitoring of working regions.
- With the help of the Android application, we can take necessary steps to avoid any hazards in coal mine

For the first time, data of different types and places can be merged together and accessed from certain distance wirelessly. Some significant progress has been made over the last few years in order to bridge the gap between theoretical developments and real deployments in WSN technology. Available design methodologies and solutions are still relatively immature to cover the whole mining areas but with the help of new technologies of WSN we can do it successfully

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