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Wireless Mine Surveillance with Data Logging

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ABSTRACT*:* The safety for the mining environment is becoming very important for sustainable and safe progress in this technology sector. In early days mining was a very arduous job where many accidents were often reported. The smart mine safety system is basically a wireless sensor network in mines which aims at providing a safer environment through complex wireless network to monitor all the parameters continuously. It enables the miners to work in a safe environment as it assures the real-time monitoring with the help of electronic sensors and transducers as well as wireless communication**.**

KEYWORDS: Zigbee, Microcontrollers, Arduino, sensors, Wireless, Underground Mines, IoT

I. INTRODUCTION

The mining industry contributes largely to a country's economy. Underground mining is considered as one of the dangerous job as the environmental parameters (gas, temperatureand humidity) are not constant with time. These parameters may exceed a certain limit and become hazardous which for the humans to work there. The gaseous underground atmosphere is potentially hazardous as it can cause fire or explosion and asphyxiation or other health issues to the miner, which proves fatal to the miner most of the times. For monitoring of such time varying parameters, the current communication and monitoring systems are cable based and are discrete in nature. Cable based communication and monitoring systems have the following shortcomings:

- Susceptible to failure of the entire monitoring system during any type of cable breakage at the time of disaster.
- Possibility of sparks or flames between connections of cables.
- Communication only from point to point is available. It cannot establish a connection from a random place in the mine. Hence, it is unable to communicate with the moveable miner.
- With the working surface expanded, blind spotsfor monitoring appear, and thus, new installation and maintenance is needed. These cables are costly and the whole scalability of the system becomes non-economic.

Therefore, development of cost-effective, reliable, maintenance-free, continuous monitoring and safety solution of underground mine workers' is a burning need today.

In this paper, we propose an efficient and smart alternative to the currently employed cabling mine monitoring system. Real time sensor data is displayed using a live plot and corresponding sensor values are wirelessly transmitted using a Wireless Personal Area Network (WPAN) in the current research work. A low cost and low power Data Acquisition System (DAS) is emulated for effective sampling and transmission of sensor data in a standardized format.

II. THE ACTUAL SYSTEM.

The developed system can be divided into two sections. First is a hardware circuit that will be mounted on the body of the mine workers. This may be preferably fitted with the safety kit which the miner wears around their waist. The circuit has a sensor module consisting of gas, temperature, humidity and pulse-rate sensors. Gas concentration is meant for the harmful gases like methane, ammonia and carbon-monoxide and is measured in units of ppm (parts per million).

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A microcontroller is used with the sensors to receive the sensor outputs and to take the necessary decision. Once temperature or humidity exceeds the safety level pre-programmed at microcontroller, it will either setup a flag value or increment a semaphore value. Similarly, when gas concentration crosses the safety level or the pulse-rate of the miner will go beyond the normal levels, microcontroller will decode siren alarm. In all such cases, this will send an alarm through an urgent message and alarm sound to the ground control terminal through ZigBee. ZigBee is a wireless communication protocol according to the IEEE 802.15.4 WPAN (Wireless Personal Area Network) standard.

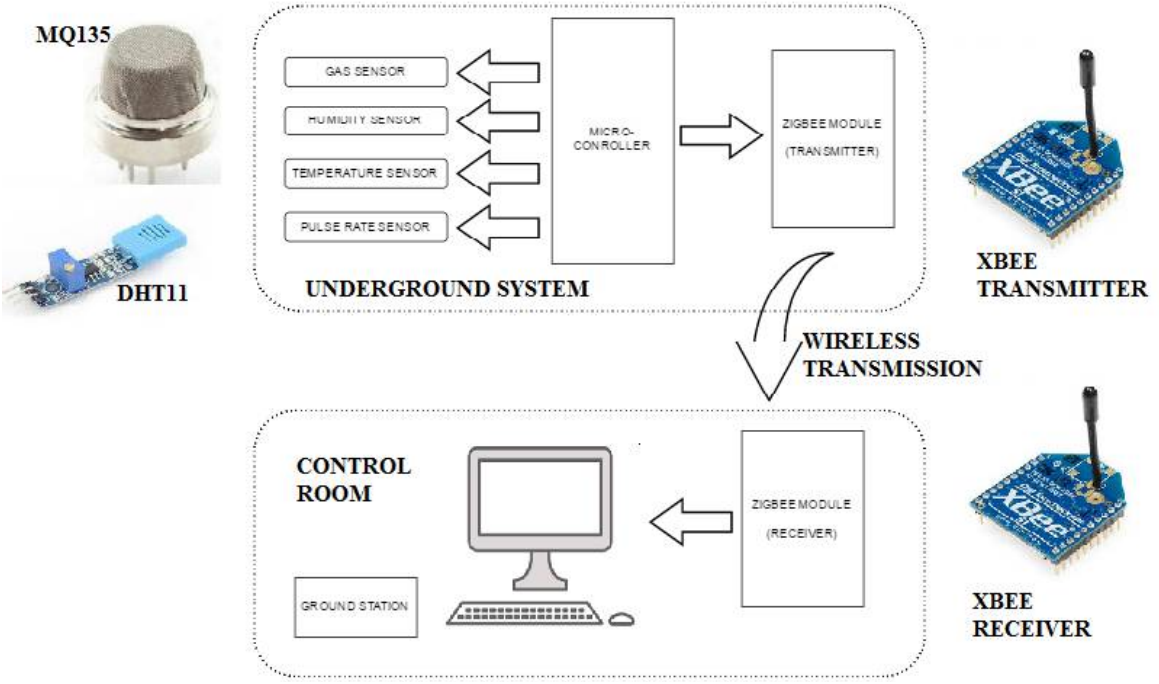

Fig.1: Block Diagram

Application of IEEE 802.15.4/ZigBee, defines a whole new protocol stack for a low-rate, low power wireless network standard designed for automation and control network. It is gaining popularity because of its simplicity, reliability, low power and low cost application. Wireless sensor networks are an emerging technology for low-cost, real-time monitoring of a wide range of hazardous environments. It provides a transmission speed typically 250 kbps over a range of 10 to 100 meters and can be configured in star, mesh or peer-to-peer topologies. It currently operates in 2.4GHz ISM bands worldwide.

The sensor nodes send the collected data to an embedded network controller based on Arduino through multi-hop method. And then the controller receives the data and sends them to the ground PC by the conversion of ZigBee protocol to Ethernet protocol. The monitoring centre can monitor the data and publishes them to the LAN for remote users. The whole monitoring system can be divided into monitoring management layer, underground data collection and transmission layer according to the location. Underground data collection and transmission layer can be divided into the ZigBee data collection network and information receiving and processing terminal.

III. WIRELESS COMMUNICATION

ZigBee was designed to provide high data throughput in applications where low dutycycle and low power consumption are important considerations. Many devices that use ZigBee are powered by battery. Because ZigBee is often used in industrial automation and physical plant operation, it is often associated with machine-to-machine (M2M) communication and the Internet of Things (IoT). In the current research work, two wireless XBEE modules (a pair of transceivers) based on the IEEE 802.15.4 WPAN standard was used to establish the wireless network. XBEE modules are supported by the company Digi.com.

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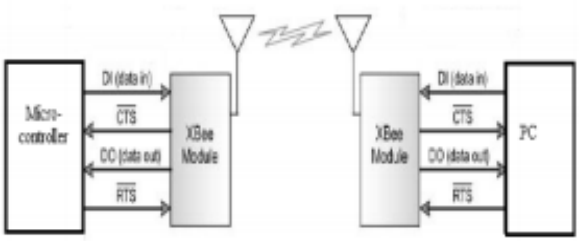

Fig2: ZigBee Interface

There are three ZigBee specifications: ZigBee, ZigBee IP and ZigBee RF4CE. ZigBee IP optimizes the standard for IPv6 full mesh networks and ZigBee RF4CE optimizes the standard for partial mesh networks. In this smart mine safety, we use multi-hop communication which is efficient because of using multiple ZigBee Modules. Two modules are used as transmitter and receiver, while at least one module acts as a buffer through which the commands and signals are passed and communication is achieved. There are 2 modes of operation of the ZigBee module, the API mode and the AT command mode. In AT command mode, for sending a packet, one has to issue a number of AT command to set the destination address for instance. This mode is not flexible. The ZigBee module can operate in API mode, in which case it can accept structured frame containing all the required information (such as the destination address) needed for sending the data packet. The ZigBee can also be accessed with a serial tool such as XCTU (Xbee Configuration and Test Utility software) and programmed online with AT commands. Even if we use the API mode, we can always have access to the ZigBee module with XCTU for instance. This is only for sending packets from a program. By default, the ZigBee is in AT command mode (also called transparent mode).

In the current research work, modules were configured in AT command mode and both the modules were programmed as coordinators since at least one coordinator is required to establish a network. The baud rate was set to 9600. XCTU software is used to configure the ZigBee S1 modules as end device and router. The sensors are connected to the end device ZigBee node, while the data is sent through ZigBee configures as router to the main co-coordinator ZigBee module. The figure below show the successful wireless transmission displaying the temperature and humidity values in an XCTU window.

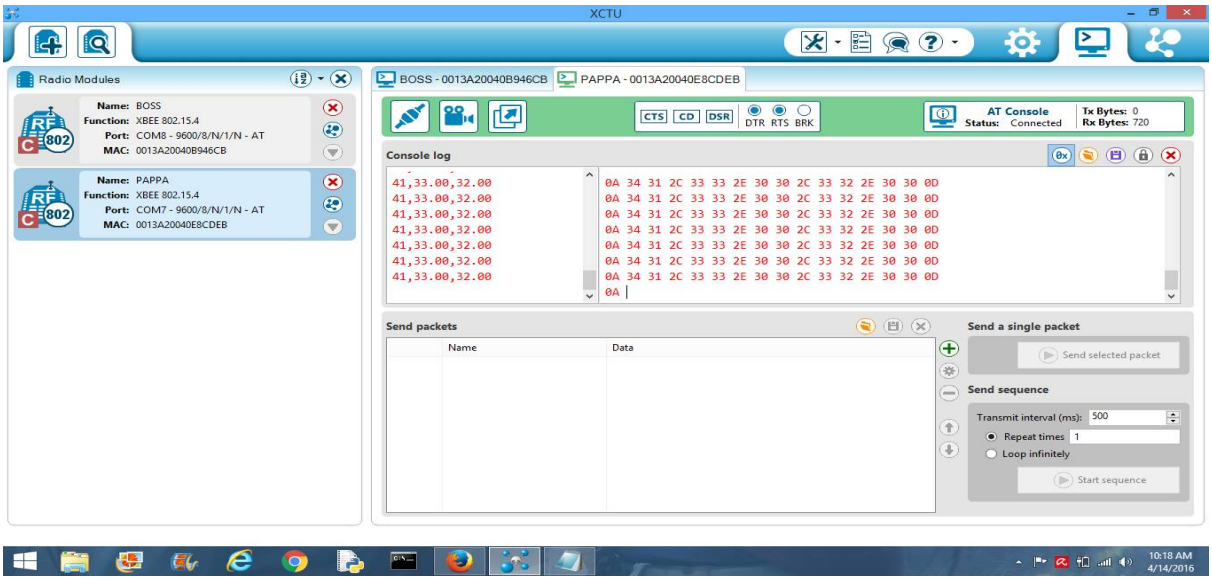

Fig3: (XCTU Image from prototype demonstration video)

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IV. SENSORS

A. GAS SENSOR:

Methane gas is an asphyxiant and may displace oxygen in an enclosed space. An asphyxiant gas is a non-toxic or minimally toxic gas which reduces or displaces the normal oxygen concentration in breathing air. Breathing of oxygen-depleted air can lead to death by asphyxiation (suffocation). Because, asphyxiant gases are relatively inert, colourless and odourless. So, their presence in high concentration may not be noticed. . Asphyxia may result if the oxygen concentration is reduced to below about 16% by displacement, as most people can tolerate a reduction from 21% to 16% without ill effects. The concentration of methane at which asphyxiation risk becomes significant is much higher than the 5–15% concentration in a flammable or explosive mixture.

The smart mine safety system uses a MQ-135 gas sensor modules for gas leakage detection, and it is suitable for detecting of methane, carbon monoxide, ammonia and Natural gas. It also avoids the noise of alcohol and cooking fumes and cigarette smoke.

On testing this sensor, it is generally observed that when the sensor is stable at a value of 400 units as seen on the Serial Monitor and it can be programmed at value 500-600 units, which depicts the hazard level of methane gas in the mine.

B. HUMIDITY AND TEMPERATURE SENSOR:

Humidity is another important parameter under consideration in mining as excessive quantity of humidity may result into suffocation and undesirable working conditions. Hence, in this system we use humidity and temperature sensor-DHT11 which uses new moisture-sensitive components of organic polymer materials, has a sense of wet wide range, fast response, anti-pollution ability, without heating the cleaning and long-term use of reliable performance and many other features.

Deep mines and mines sunk in hot countries are hot work sites. Some underground mines in moderate geographic zones are hot because of the unusually high heat flow from the earth. In mining, as in other industries, the exposure of workers to very hot conditions is unhealthy and unproductive. Persons working in hot, humid work sites tend to be inefficient; quite often workers prefer to stay away from work or ignore unsafe working situations. Studies have shown that high temperatures reduce the work output of miners.

Outlook in selecting this sensor is smart, long-term stability, wide temperature and humidity measuring range, high and low temperature humidity measurement precision.The humidity sensor aims at measuring the humidity underground monitor to maintain in a specific limit. This parameter is important as every human reacts differently to the different levels of humidity.

C. HEART RATE SENSOR:

The underground environmental conditions cause a long term negative effects on human health. Tunnels in underground mines are generally long and narrow, with lengths in kilometres and several meter width. The heart rate sensor is based on Infrared (IR) light reflection and refraction approach. Heart rate sensor is based on Lambert-Beer Law.

This is the special highlight of the system which makes the system robust and efficient.the use of pulse measurement for hundreds of years to determine stress, relaxation, physical fitness levels, medical conditions, and more. This information is easy to gather using tactile measurement; you can determine your pulse rate by touching your arteries in your wrist or neck. Since every human body responds to all the mentioned underground parameters differently this pulse rate sensor is a must inclusion in the smart mine safety system. There is a device which is a microcontroller and a pulse rate sensor with every miner. This device measures the pulse rate of the miner continuously and sends the data to nearby ZigBee transceiver which is further sent to ground station for appropriate action through multi-hop communication. If the pulse falls below the pre-programmed safe limit which can endanger the human life, the ground station acts immediately and sends team to rescue the person.

V. DATA LOGGING

An excel file would be generated which is implemented using python language and xlsx-writer library having columns such as the date-time stamp and all the gas, temperature and percentage humidity values. This database file is monitored at control room and can be used to predict the future fluctuations in the mine atmosphere. Also, if the readings from the sensors are constant over a period of time then the controller can increase the interval between two

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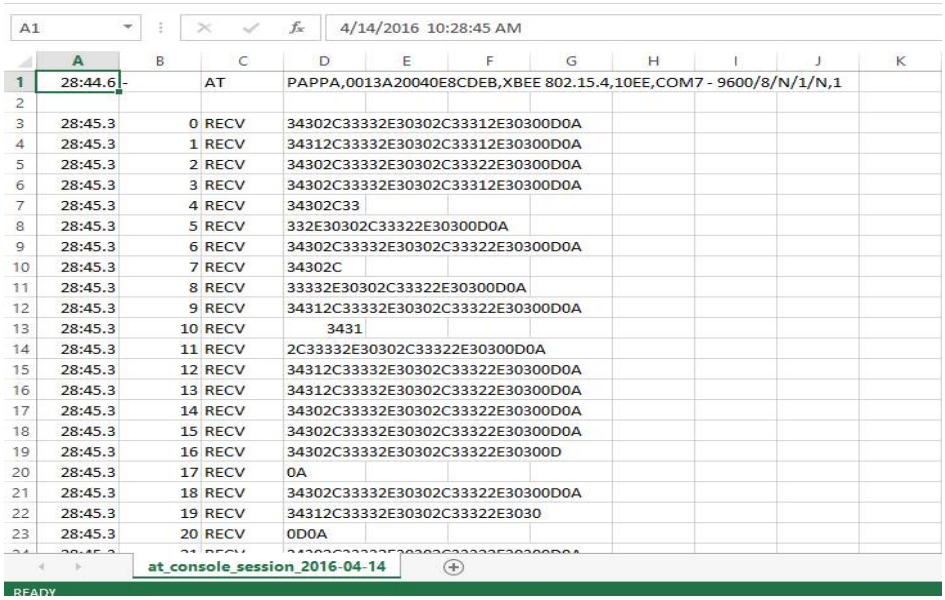
readings from the sensor, thus saving a huge amount of power. An example of excel file created duration demonstration is as follows.



A1 | 4/14/2016 10:28:45 AM

	A	B	C	D
1	28:44.6	-	AT	PAPPA,0013A20040E8CDEB,XBEE 802.15.4,10EE,COM7 - 9600/8/N/1/N,1
2				
3	28:45.3	0	RECV	34302C33332E30302C33312E30300D0A
4	28:45.3	1	RECV	34312C33332E30302C33312E30300D0A
5	28:45.3	2	RECV	34302C33332E30302C33322E30300D0A
6	28:45.3	3	RECV	34302C33332E30302C33312E30300D0A
7	28:45.3	4	RECV	34302C33
8	28:45.3	5	RECV	332E30302C33322E30300D0A
9	28:45.3	6	RECV	34302C33332E30302C33322E30300D0A
10	28:45.3	7	RECV	34302C
11	28:45.3	8	RECV	33332E30302C33322E30300D0A
12	28:45.3	9	RECV	34312C33332E30302C33322E30300D0A
13	28:45.3	10	RECV	3431
14	28:45.3	11	RECV	2C33332E30302C33322E30300D0A
15	28:45.3	12	RECV	34312C33332E30302C33322E30300D0A
16	28:45.3	13	RECV	34312C33332E30302C33322E30300D0A
17	28:45.3	14	RECV	34302C33332E30302C33322E30300D0A
18	28:45.3	15	RECV	34302C33332E30302C33322E30300D0A
19	28:45.3	16	RECV	34302C33332E30302C33322E30300D
20	28:45.3	17	RECV	0A
21	28:45.3	18	RECV	34302C33332E30302C33322E30300D0A
22	28:45.3	19	RECV	34312C33332E30302C33322E3030
23	28:45.3	20	RECV	0D0A

at_console_session_2016-04-14

READY

Fig4: Database of values

VI. SIMULATION & RESULTS

The graph of live reading of gas value and graph of live reading of gas value and humidity value from the working mine is as follows:

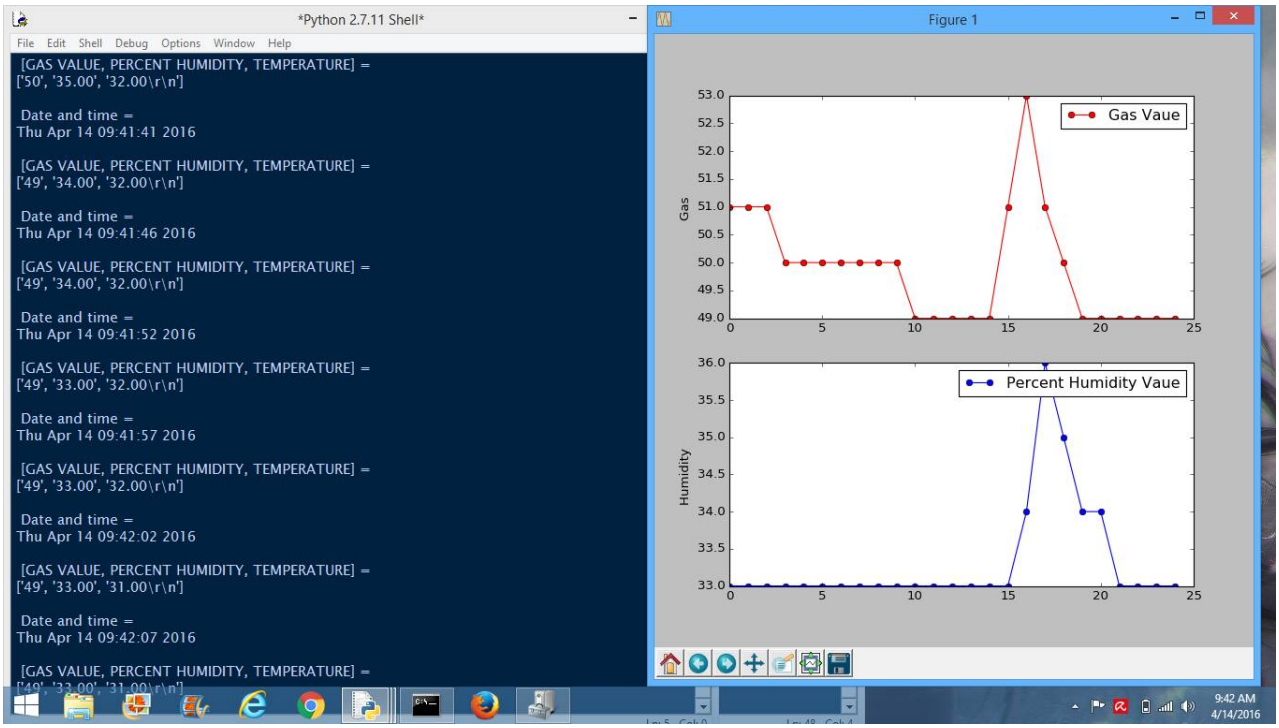


Fig5: Live Plot with Time Stamping

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VII. APPLICATIONS

The Mining industry in India is a major economic activity which contributes significantly to the economy of India. The GDPcontribution of the mining industry varies from 2.2% to 2.5%. However, the activity is hampered by mining explosions, water rush-in, gas leaks which results in high number of casualties and loss to the Industry. The mine safety system proposed in the report can be assimilated under the venture of **"Make In India"**.

Significant advances are made in UHF technologies in recent times which can overcome electromagnetic noise and accommodate high traffic. But those require lot of infrastructure like repeaters, routers to overcome the attenuation around bending. The underground mine infrastructure is continuously changing which demands reconfiguration of wireless access points to maintain the network integrity. Blind spots also occur regularly resulting missed assignments and reduced efficiencies. Recently advanced wireless multi-hop mesh network automatically locates, optimizes path and configures sensor nodes or access points within its range and this can be integrated with the existing mine computer network. The sensor nodes for their miniature size, low power and mobility, can be attached with the mine workers, resulting in a flexible expandable mobile information network. So, there is tremendous scope of future research in this direction.

VIII.CONCLUSION

The Present work, coal mine safety monitoring system based on wireless sensor networks, and hardware and software design of wireless sensor network are described in detail, this system can detect concentration of the gas, temperature, humidity, wind speed and trace the location of miners in underground mine tunnels.
Wireless sensor networks applied in monitoring coal mine security, breaks through the traditional methods and ideas, which improves the practical ability and flexibility of monitoring system. This system not only can monitor all kinds of parameters under the coal mine, but also can alarm automatically when environmental parameters are abnormal to exceed the limitation, which help improve the level of monitoring safety production and reduce accidents in the coal mine. Therefore, the Mine Safety Monitoring system put forward in this article quite meets the need of the hour. Traditional mine security system can be effectively replaced by the surveillance and safety system proposed in the paper.

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