ZIG-BEE BASED SMART HELMET FOR COAL MINERS

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Abstract—*A sensible helmet has been developed that is ready to notice of dangerous events in the mines trade. within the development of helmet, we've thought of the 3 main varieties of hazard like air quality, helmet removal, associate degreed collision (miners square measure affected by an object). the primary is that the concentration level of the dangerous gases such as CO, SO2, NO2, and material. The second dangerous event was classified as a labourer removing the mining helmet off their head. associate degree IR sensing element was developed unsuccessfully however associate degree off-the shelf IR sensing element was then accustomed with success confirm once the helmet is on the miner's head. . The third venturesome event is outlined as an incident wherever miners ar stricken by associate object against the top with a force extraordinary a price of a thousand on the HIC (Head Injury Criteria). associate measuring system was accustomed live the acceleration of the top and therefore the HIC was calculated in software package. The layout of the visualization software package was completed, but the implementation was unsuccessful. Tests were with success done to calibrate the measuring system. PCB's that were designed and created enclosed a break board and a example board. A whole computer code implementation was done supported Contiki OS so as to try and do the management of the activity of sensors and of calculations done with the measured values. This paper presents the undertaken style description solutions to problems raised in previous analysis.*

Keywords—air quality; mining; safety; wireless sensor networks; ZigBee,GPS system, vibration sensor, IR sensor

1. INTRODUCTION

South Africa is understood for its intensive and numerous natural resources and huge mining trade [1]. Supervisors ar command answerable for all injuries sustained underneath their supervising, and may thus bear in mind of probably risky things [1]. the matter self-addressed during this paper was the development of a mining helmet so as to confirm a lot of safety awareness between miners. once operating with reedy instrumentality, being conscious of one‘s surroundings will generally be difficult [2]. within the mining trade miners tend to get rid of a number of their safety gear as a result of the gear is simply too significant, heat or uncomfortable to figure with. However, miners typically don't take away their helmets. Presently mining safety helmets solely have the aim of protective the miner‘s head against potential venturous bumps. the security helmets don't have any technology adscititious to that to let mineworkers apprehend once a fellow miner has
safety helmet to form the helmet even safer by adding a wireless device node network The task was extended to designing the system sufficiently small to suit into the security helmet and last long enough whereas running on battery power. an extra challenge was to change the helmet while not dynamical its organic structure. The more weight had to be unbroken to a minimum.A mining helmet must be changed to enhance mineworker safety by adding intelligence to the helmet. once a mineworker removes his helmet he must be warned. If associate object falls on a mineworker even once sporting his helmet he will become unconscious or immobile. The system should confirm whether or not or not a mineworker has sustained a serious injury. These 2 events square measure outlined as dangerous events. Thirdly, dangerous gases got to be detected and proclaimed.In the space of mining technology, period monitor and management of mine hazard square measure additional complicated. Mine safety modules square measure organized to speak to communication system or a central station. a true essential issue in mines is dangerous gases. Systems utilized in a mine will produce intense vibrations and increase the amount of dangerous gases like CO, SO2, NO2 and particulate matter. The operating conditions will be terribly reedy and miners don‘t watch every different perpetually. Miners tend to remain in teams and can be no over five meters (m) from one another. A warning system must be incorporated which will warn labourers at intervals a five m radius that a miner is experiencing a dangerous event. this method must method and transmit the event at intervals one second (s). These systems live the atmosphere round the labourer with gas sensors and square measure then wont to implement evacuations. In recent years, gathering technology has vie a vital role within the space of mine applications. The literature on mines technology is out there however terribly restricted. Nutter, et al. planned a technique for distinctive safety hazards inherent in underground observance and management. They additionally designed potential safety hazard instrumentation. They developed methodologies supported analytical physics and computer- based mostly

hardware/software systems [6]-[8]. Kock, et al. developed the technology in terms of health, safety, and productivity for the South African coal mining business. They additionally investigation the coal interface detection (CID), productivity, communication channels (infrared, power line, optical fibers, and radio) [9]. Misra et al. presents a case study for mines. They reviewed on communication techniques like through the wire (TTW), through the air (TTA), and thru the planet (TTE) [10]. Forooshani, et al. presents a compressive. survey of wireless propagation in tunnels and underground mines with attention on current wireless channel modeling, technologies, and applications [11]. The Internet-of-Things, wherever all devices area unit good and interconnected, area unit more and more getting used in additional industrial applications [12], [15], and it's thus conjointly a principle that may build a distinction in mining safety with smarter instrumentation. The literature conjointly shows that despite some engaging solutions; only a few are enforced and tested within the real- world, characteristic the existence of a gap between theory and planet application at scientifically accepted level. during this paper good helmet in compliance with IEEE 21451 standards is bestowed. It has varied advanced options such as quick interval low, movableness, and low price with exactly acceptable accuracy.

2. SYSTEM OVERVIEW

Solving the matter of miners removing their safety instrumentality was a challenge, taken that any new safety instrumentality that's not light-weight and non-distracting, can simply be removed, like all the opposite safety instrumentality. Because the helmet is that the solely safety gear miners tend to stay on, this is often wherever the new safety instrumentality was value-added on to. 3 sensors were used, Associate in Nursing measuring device, air quality Associate in Nursingd an Infra-red (IR) detector. These were used either to discover if a manual laborer has older a bump to the top or removed his helmet and close air quality. The 3 sensors were connected to a ZigBee module. This module will all the process and additionally controls the wireless communication between separate helmets through the Contiki OS (OS). the entire system was analyzed throughout the planning method so as to stay the facility consumption to a minimum because the system is running on battery power. Different sensors were thought-about for every separate element so as to stay the ability level as low as attainable. . In order to explain the entire system and the alternatives of each component, the system will be explained component by component. The system consists of six components, helmet remove sensor, collision sensor, air quality sensor, data processing unit, wireless transmission and alerting unit so as to clarify the whole system and therefore the alternatives of every element, the system are explained element by element. The system consists of six elements, helmet take away device, collision device, air quality device, processing unit, wireless transmission and alerting unit. Figure one represents the diagram of the sensible helmet for mining safety

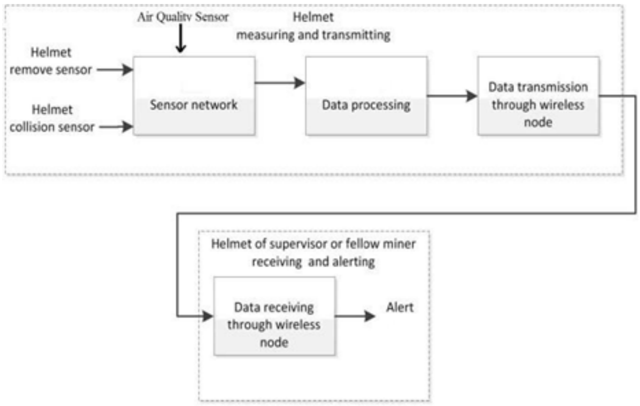

Fig. 1. Functional Block diagram of Smart Helmet.

A. *Air Quality Sensor*

Air pollution from coal mines is in the main due to emissions of particulate matter and gases embrace methane series (CH4), gas (SO2), and oxides of N (NO2), likewise as carbon monoxide gas (CO). From completely different studies, it's acknowledge that once human being comes in contact these chemicals/ pollutants it may have adverse result on their health. These unbalanced ratios of pollution gases, like suspended particulate matter, increase metastasis diseases such as respiratory disorder, bronchitis, and vessel issues [13]. during this article we've measured the CO, SO2, and NO2. Per the literature we've chosen the chemical science gas sensing element as a result of its accuracy and low power consumption within the development of air quality detectors. These sensors are terribly selective to the target gas.

TABLE 1 SENSOR USED IN THE DEVELOPMENT OF HAZARDOUS ENVIRONMENTAL GASES

Sensor	Target Gas	Range (ppm)	Resolution (ppm)	Response Time (seconds)
EC4-500-CO	CO	0-500	1	<30
EC4-20-SO2	SO_2	0-20	0.1	<35
EC4-20-NO2	NO_2	0-20	0.1	<35

We have used electrochemical sensors for CO, SO2, and NO2 from SGX Sensor Tech. The electrochemical sensor‘s advantages, disadvantages, typical signal conditioning circuit, mathematical formulation (output sensor signal conversion to gas concentration) was reported in [13]. Regarding the concentration of CO: healthy people can tolerate a CO without serious health effects, but it should always be kept below 4 ppm [13].. If increases in the concentration level of air quality parameters are observed, then a signal is transmitted through a ZigBee transmitter module to the alerting unit of the helmet.

B. Helmet Removal Sensor

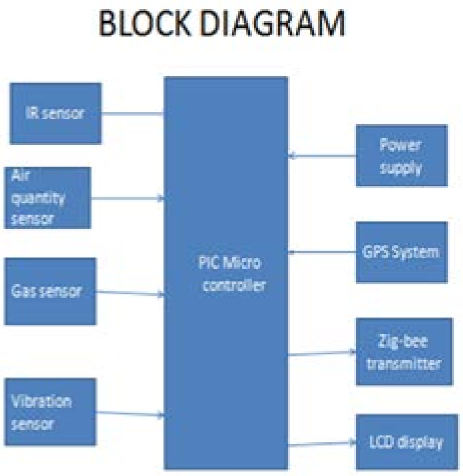

Fig. 3. Block diagram of the device for air quality monitoring and alerting of the critical level of hazardous gas.

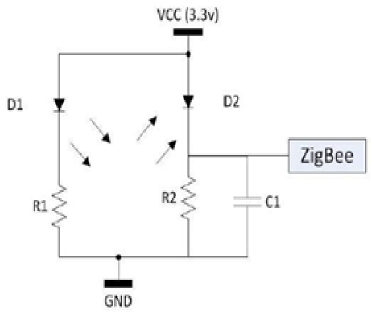

Fig. 4. Circuit diagram of IR circuit designed based on IEEE21451 standards.

C. Collision Sensor

In order to conclude that a bump is truly dangerous, the bump must exceed an exact threshold for an exact quantity of your time. in line with the Federal car Safety normal 208 (FMVSS 208) a Head Injury Criteria (HIC) shouldn't exceed a price of quite one thousand. The variable t1 is offset, t2 is that the finish time, a(t) is that the acceleration over time. Associate in Nursing measuring device was required to live the acceleration of the system. The measuring device required to be ready to live a minimum of seventy g in three axes. ADXL377 measuring system glad the specifications. There are a number of limitations once victimisation the HIC equation. The measure t2-t1 ought to be restricted to a most of solely thirty six milliseconds (ms). The time limitation is to limit The variable t1 is starting time, t2 is the end time, a(t) is the acceleration over time. An accelerometer was needed to measure the acceleration of the system. The accelerometer needed to be able to measure at least 70 g in 3 axes. The equation to impacts and not sustained accelerations. it's additionally mentioned that the accelerometers will offer inaccurate measurements owing to scull deformation. To compensate and to over style, the measuring system is placed on the helmet itself and not on the plastic harness holding the top. this may permit the measuring system to succeed in acceleration full-fledged by the helmet which will be larger than the particular acceleration full-fledged by the miner‘s head would be connected to the Raspberry Pi. The Raspberry Pi would measure the sensors and control the ZigBee module. The Raspberry Pi would then be used to create the user interface for the user to examine the data that has been logged. Two problems turned up: the first being power consumption and the second interfacing with the Raspberry Pi. The power consumption was a problem as the system would be running off a battery, even though the Raspberry Pi uses very little power it is much more than what is used by the ZigBee module. The interfacing problem was caused by the difficulty of connecting to the Raspberry Pi, because it would not have a built-in display as this would dramatically reduce the durability of the product. The only other option is to connect to the Raspberry Pi through a network cable. The user interface would only then be accessible. This network configuration would be a complex and impractical process for the mining environment. After further examination it was decided to choose the ZigBee module ATZB-24-A2 wireless chip. It has an adequate amount of processing power and a built-in electrically erasable programmable read-only memory (EEPROM). Any other additional processing units would use more space and consume additional power as well.

D. Alerting Unit

Alerting miners in a mine will be a troublesome method bearing in mind the everyday operating conditions that ar encountered in a mine. Underground mines ar terribly dark places and thus the miners use safety helmets with built- in or tie-on mining lights. The instrumentation employed in underground mines will produce plenty of noise and vibrations, that ar combined by the incommodious conditions within the underground tunnels. the matter related to the noise is that warning a labourer with a speaker or Associate in Nursing warning device once a fellow labourer is experiencing a venturous event would most likely be vainly because the labourer wouldn't hear the alarm. A second choice was thought- about with the utilization of a vibratory unit among the mining helmet. It was so set to implement a system that can warn the mineworker by flashing the mining light- weight a few times. victimization this warning technique has the additional advantage of victimization the mining helmet light-weight of the mineworker World Health Organization is experiencing the venturesome event. Flashing the sunshine perpetually at the same time show World Health Organization is experiencing the matter still as indicate the placement of the mineworker.

3. EXPERIMENTAL WORK

A. *Air Quality Test*

In the air quality testing process, we have used the known gas concentration cylinder and follow the static chamber method for the development of the AQ sensor. An incubator is used for testing of the developed system. The incubator is simply a rectangular plastic box with a hole on the side to fit a pipe that is used to pump in gas. The sensor node is powered on and placed inside the incubator that is then closed. Gas cylinders were used to pump the gas into the incubator. The sensor node then takes measurements of the gas concentration. Off-the- shelf air quality monitoring devices are very expensive and thus there was nothing to compare the measurements to, however the concentration levels were estimated and the accuracy of the system was determined.

B. *Helmet Removal Test*

The purpose of this test is to show that the system will detect when the helmet is completely removed from the dummy head. For the system to pass the test it needs to detect the removal of the helmet with an accuracy of above 90%. The helmet was connected to the computer through the USB port. The helmet was placed on the dummy head. The node was configured to transmit the data through the USB port, which would have been sent through the wireless network. The computer displayed the serial data constantly. The helmet was then removed slowly until the IR sensor triggered the serial port to display that the helmet was removed. The distance was measured from the top of the dummy up to the inside of the helmet. The test was repeated ten times.

C. *Impact Test*

In this section, we have tested to the impact reading that the accelerometer gives when in two situations. The first is a hazardous force like a hammer, showing that it would trigger a hazardous event. The second is a bumped with a non- hazardous force like a human hand hitting the helmet, showing that would not trigger a hazardous event. The test with the hammer was changed a few times as discoveries were made through the results. The final test with the hammer was dropping the hammer for ten repetitive tests from a height of 1 m above the helmet. The accelerometer was placed on the inside of the safety helmet with a wooden bowl used as the dummy head with a sampling rate set to 250 Hz. The data was sent through the USB to the computer and then imported into Matlab to give the graphs shown in Fig. 5. The test with the hand was done with two impacts. The first impacts are simulating a fellow miner making a joke and hitting the miner lightly on the helmet. The second impact are simulating a harder blow but still with a non-hazardous force. The results are shown in Fig. 6.

D. *Wireless Transmission Test*

The purpose of this test was to determine whether or not the wireless transmission between the nodes meets the minimal requirement of transmitting data more than 5 m and how successful the data transmission. Placing the one node at distance 0 m (stationary point) configured to transmit every second continuously. The second node was placed at distances varying from 1 m to 13 m, 8 m further than specified. The second node was configured to receive and transmit the data through the USART. Connecting a computer and storing the first hundred seconds, of the system clock, that was received. The data of each distance was stored and analyzed. The test was done in an environment with people moving through the line of sight and the presence of a Wi-Fi network with the router situated in the middle of the transmission . This was done in an environment with people moving through the line of sight and the presence of a Wi-Fi network with the router situated in the middle of the transmission

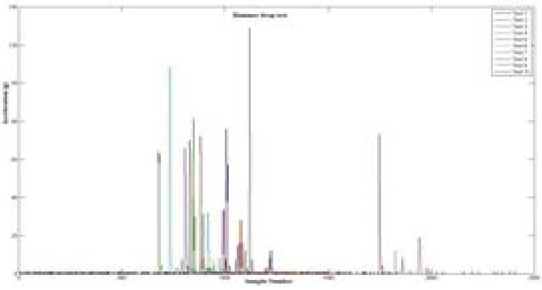

Fig. 5. Accelerometer measurements from impact test on helmet with hammer dropped

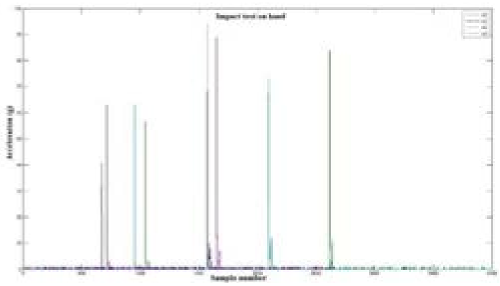

Fig. 6. Accelerometer measurements from impact test on helmet with hand.

The results showed the data received and the corresponding system time. It was then determined which of the hundred transmitted signals were received successfully, which were skipped and which ones were received more than once. The data of the thirteen distances were then imported into Matlab. These results were then plotted onto the graph in Fig. 7. The top blue line shows the amount of numbers that were received more than once, the green peaks show the amount of transmissions that were not received.

4. RESULT AND DISCUSSION

The important levels of the dangerous gases such as CO, SO2, and NO2 within the mines trade has been indicated through alerting unit. The helmet removal take a look at was done with success with associate degree off the-shelf IR distance sensing element. The IR sensing element designed from initial principles was operating device. It was discovered, when the system was integrated, that the transmitted IR signals reflects off the dummy head and unbroken reflective off the helmet‘s surface till it reached the receiver. The signal at the receiver aspect was near constant amplitude because the signal received once the helmet was far away from the top.

The system will thus not distinguish between whether the helmet is removed or not. The check results for this check weren't side because the system perpetually triggered the alert signal.

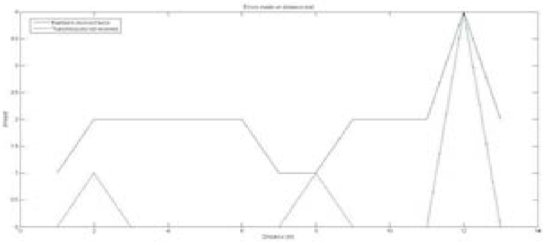

Fig. 7. Distance test error, showing a transmission that was not received and transmission received more than ones.

The test was then done using an off-the-shelf IR sensor. It gave the results that were expected and needed for the test to be successful. The system successfully detected when the helmet is removed 10 cm off the dummy head with an average deviation of 0.3% too far. The result showed that the output of the accelerometer was scaled inaccurately and that the accelerometer needed to be calibrated more accurately. The test could not be repeated with the correct accelerometer calibration being 80% g of the values as seen above. The test also indicated that the sampling interval of the accelerometer was not sufficient enough. According to the environment of coal mine, this paper presents a rectangula deployment strategy based on the coverage of WSN nodes. The nodes will be arranged on both sides of the tunnel to achieve 2 connection. From the results of theoretical analysis and simulation experiments, we can see that the nodes deployment strategy of rectangular partition can not only satisfy the requirments of WSN‘s coverage and connectivity but also saving nodes number and reducing the forwarding routing hops.The Contiki OS works by repeating procedures on the interval of eTimers. eTimers however can only be configured for a 8 MHz chip to repeat every 4 ms. This means that a single axis of the accelerometer can only be measured every 12 ms.. The transmission was successful at distances more than double than were specified.

5. CONCLUSION AND FUTURE SCOPE

A smart mining helmet was developed that is able to detect three types of hazardous events such as danger level of hazardous gases, miner helmet removing, and collision or impact(miners are struck by an object). The hazardousvents were classified as a miner removing the mining helmet off their head. An off-the-shelf IR sensor was then used to successfully determine when the helmet is on the miner‘s head. The paper has been successfully presented and tested with integrated features of each hardware component for its development. Significance of each block has been resonated out and placed carefully, thus contributing to the best working of the unit. Hence the system is reliable with simple and easily available components, making it light weight and portable. A whole software implementation was done based on Contiki OS in order to do the control of the measuring of sensors and of calculations done with the measured values. The system was extensively tested in order to determine whether or not the system works to the requirements. It was observed that the accelerometer should be placed on the inside of the helmet and not on the plastic harness inside the helmet to compensate for the weight difference. The accelerometer calibration was then modified to correctly calibrate the accelerometer. A few aspects of the system can be improved. Adding an external antenna would extend the range or improve the signal strength in order to allow for more human interference. The distance might still want to be limited as it would be impractical to warn miners that are too far away to find the miner who is experiencing a hazardous event. The processing speed of the system can be improved to allow for more accurate accelerometer measurement. The IR sensor can be improved to work within the helmet by not triggering because of reflections. Node hopping can be implemented to allow transmissions to the supervisor or even a central control station. The paper has been successfully presented and tested with integrated features of each hardware component for its development. Significance of each block has been resonated out and placed carefully, thus contributing to the best working of the unit. Hence the system is reliable with simple and easily available components, making it light weight and portable.

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