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IoT based Smart Helmet for Industrial Workers

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Abstract: Safety is very important in every workplace, but very often we hear about accidents in factories industries causing loss of life. The labours and workers working in any factory, industries, construction site or mine is vulnerable to accidents and therefore they should be with safety guards properly. In most of the accidents, number of deaths or severe injuries is maximized because the labours and worker are not wearing safety equipmentor wearing low grade safety equipment.
Working environment hazards include radiation leakage, fall due to suffocation, poisoning gas leakage and gas explosion. Hence air quality and hazardous event detection is very important factor in industry. In order to achieve those safety measures, the proposed system provides wireless sensors network for monitoring real time situation of working environment from monitoring station.
Keywords: Industries; Helmet; Cloud Computing; ThingSpeak Internet of Things; Sensors; Ubiquitous Sensing

I. INTRODUCTION

Since May, there has been more than 30 industrial accidents in India, killing at least 75 workers, injuring over a hundred. These numbers are based on reported incidents and the real number may be far higher [1]. From 2014 to 2017, 8,004 such incidents occurred in Indian workplaces killing 6,368 employees. Most such incidents took place in Delhi, Maharashtra and Rajasthan.[2]. Of the 32 incidents between May 3 and July 5, the maximum of seven incidents were reported from Chhattisgarh followed by six in Gujarat and four in Maharashtra.[3]. Six workers were killed and several moreinjured when a ruptured water pipe at the Bhilai Steel Plant resulted in a gas leak in 2014 [4].

Konnect: An Internet of Things (IoT) based smart helmet for accident detection and notification [5], a prototype was proposed for detection of accidents on road. We provide an improved version of this by implementing more sensors and notmaking it exclusively for road accidents but also for industrial workers. In "IoT Based Smart Helmet for Underground Mines" [8], authors proposed a system in which smart helmet consists of various sensors. The only area where this work lags is it is only specific to mining industry. In LabVIEW Based Coal MineMonitoring and Alert System with Data Acquisition [11], the authors proposed a LabView based data acquisition system in which different types of sensors are used for sensing the physical conditions in coal mine like gas, humidity, fire, temperature and fire etc. The proposed system was not efficientin cloud storage and further analysis.

In this project we are trying to make less expensive but best effective Smart Helmet based on IoT which will not onlymonitor the real time working conditions of workers but also alert the control centre in case of accidents.

Main features of the helmet include sensing workers body temperature, temperature of surroundings, detection of harmful gases, measuring of workers heartbeat, crash and fall detection, position of the worker in the plant. The helmet is capable of sending the measured data to the cloud platform for monitoring purpose and an alert buzzer is turned on in the industry for warning against any harmful conditions, also it will send an alert via email to the supervising team. Arduino uno is used as the microcontroller for prototyping purpose and ThingSpeak is used as the cloud computing platform.

Related works in this domain is discussed in section II. Industry review and discussion is included in section III. Proposed Systemis discussed in section IV. Section V shows the algorithm of the system. Cost Analysis is done is section VI. Helmet Design is included in section VII. Implementation of the system is discussed in section VIII. Result analysis is done in section IX. The conclusion of the project is done in section X and all the reference is given in section XI.

II. RELATED WORKS

In this section we are going to review few works related to IoTbased smart helmet.

Konnect: An Internet of Things (IoT) based smart helmet for accident detection and notification [5], is a prototype of the smart helmet called Konnect. It consists of an integrated network of sensors, Wi-Fi enabled processor, and cloud computing infrastructures are utilized in making of smart helmet for detection of accidents and notification. It is designed to detect an accident and immediately notify emergency contacts. The orientation of head of driver and the helmet's position is continuously monitored by a 3-axis accelerometer and hence the possibility of accident is calculated. When the calculated values cross threshold limit text message containing the location of the driver is automatically send to the emergency contacts. The text messages are initiated in real time and at regular intervals to make sure that contacts locate the driver easily.

In “Design of Smart Helmet for Accident Avoidance” [6], authors proposed a way, where the data from sensors such as IR sensor, vibration sensor and gas sensor are recorded. The gas sensor detects the amount of liquor consumed by checking the breath of a person using the helmet. The bar control of the vehicle is handled by MEMS. Vibration sensor is used to detect any accident. Load of the vehicle is detected by load checker. The sensors are integrated with microcontroller. If the gas sensor detects user consumed alcohol then it will display on theLED. In case of any accident detected by the vibration sensor, information will be sent to nearby hospital informing about the accident through GPS. If MEME sensor detects any rash driving is done by the rider then the penalty is debited frompersonʼs bank account. IR sensor ensures that the rider is wearing the helmet. The precision and accuracy of the system is high and ambulance is called automatically based of the accident location. In “IoT Based Safety and Health Monitoring for Construction Workers” [7] authors proposed a method in which safety to the workers is provided and also identify any fall of workers in working area

The prototype has two components. One is the wearable helmet embedded with sensors and electronic elements and another component is the cell phone. The communication between the two components is established by GSM module. It continuously monitors the health and safety of the worker. It provides good fall detection and also alerts the emergency contact person for medical attention.

In “IoT Based Smart Helmet for Underground Mines” [8], authors proposed a system in which smart helmet consists of various sensors such as Gas Sensor, Temperature Sensor, Humidity Sensor, LDR for light intensity, and IR sensor to detectthat workers are wearing helmet or not. Microcontroller Raspberry Pi is used which process all the sensor data and if the values exceed certain threshold value, the embedded IoT systemautomatically sends alerts to the supervisor. ThingSpeak is usedas cloud-computing and analytics tool. The only area where thiswork lags is it is only specific to mining industry and thethreshold values are set manually.

In “Smart Helmet for Accident Prevention and Coal MinesSafety Monitoring and Alerting System” [9], authors proposed away for safety of person in coal mines as well as in roadways. Also giving the assurance for the person that he can identify thehazardous gases present. Sensors such as gas sensor and vibration sensor are used. GPS and GSM module are used for sending alert in case of accident. This system is sensing only some basic parameters and not very accurate without any cloud computing it may send false accident data. In the Application of ARM and ZigBee Technology Wireless Networks in Monitoring Mine Safety System [10], the authors proposed a system of Coal Mine Safety Based on ZigBee technology. It consists of wireless sensor networks and themature communication technologies of CAN BUS; real-time monitoring is implemented with intelligent alerts forunderground environment and production parameters. This system consists of a low power ARM processor chip S3C2410 as the core controller and ZigBee is used for communications platform of wireless network of sensors.

In LabVIEW Based Coal Mine Monitoring and Alert System with Data Acquisition [11], the authors proposed a LabView based data acquisition system in which different types of sensorsare used for sensing the physical conditions in coal mine like gas,humidity, fire, temperature and fire etc. The parameters are continuously sensed from the sensors and collected by base station and send to station on the ground. A ZigBee is used for the communication between underground mine base station andground station. These signals are given to LabVIEW as input which is a signal processor and monitoring system. LabVIEW compare the received data with the threshold values set for safetyand then gives alert to the GSM system through the micro- controller which further forwards it to supervisor. It stores all the sensors data in the form of excel sheet.

In “Development and Application of the Smart Helmet for Disaster and Safety” [12], the authors developed a new software framework enable to integrate devices and services and efficiently manage resources. The smart helmet collects, generates and converts information on sensors (infrared camera, electro optical camera, drone camera, oxygen residual sensor, 6- axis inertial sensor, and smart watch) that can be monitored through head mounted display (HMD) and the Command Center.

The paper also presents a developed simulator and a generated data based on scenarios, and also tests all devices and service outdoors. In IOT Based Smart Helmet for Air Quality Used for the MiningIndustry [13], authors developed a cost effective based wireless mine supervising system with early-warning security system on carbon monoxide, carbon dioxide in mining area. An IR sensor monitors whether the miners are wearing the helmet or not. GPRS module used to transmit data from mining industry to server. Cloud IOT technology is used to transmit data. Only IR sensor and Gas sensor are used for measuring the physical conditions. In Smart Helmet for Air Quality and Hazardous Event Detectionfor the Mining Industry [14], the authors developed a Smart Helmet that is able to detect of hazardous events in the mines industry. In the development of helmet, the authors have considered the three main categories of hazard such as air quality, helmet removal, and collision (miners are struck by an object). The layout of the visualization software was completed;however, the implementation was unsuccessful. The system consists of six components, helmet remove sensor, collision sensor, air quality sensor, data processing unit, wireless transmission and alerting unit. Tests were successfully done to calibrate the accelerometer.

III. INDUSTRY REVIEW AND DISCUSSION

A proper field study has been done by consulting industrial person. The selected industry for the field work is coal mine.We carried out an industrial survey from one of the coal industries, through a Skype video call with a senior at South Eastern Coal Fields Limited, Chhattisgarh].

A. Physical Overview And Constraints Of TheCoal Mine

1) *Location of the coal mine, yearly output (in terms of tons),brief description of the coal mine?*

a) *Location:* Bhatgaon underground colliery, Surajpur District,Chhattisgarh.

b) *Brief Description of the Coal Mine:* 2 fields in Bhatgaon colliery, both having a dip of 1 in 37 i.e., to go one-meter-deep, you have to travel 37 meters horizontally.

c) *Yearly Output:* 4 lakh tons per year and the total reserve are 19.01 million tons.

2) *Dimension of the mining area - how deep / long theunderground mine is?*

The area of the coalfield is nearly 2.9 kilometers squared.

3) *How is the electricity/network connectivity in theunderground mine?*

a) *Electricity:* There is a surface substation over the underground mine. From the surface substation, electricity is supplied to the working area underground through different cables. Transformers, VCBs, and MCBs are connected throughout the mine. There are also substations underground that are flameproof and use intrinsically safe apparatus. Due to DGMS rules, only flame safe apparatus can be used in underground mines. Network connectivity: No mobile connectivity underground, only telephonic line (landline) is there. The telephonic line is intrinsically safe, i.e. the apparatus cannot produce a spark.

4) *Would a Wi-Fi network be feasible inside the coal mine?*

Yes, it can be feasible if an instrument is similar to the use of intrinsically safe landline connectivity. The "phase" is verycritical since combustible and inflammable gases are present. Thus, we need to be very careful about the instrument we are using for sensing. The apparatus should be safe with respect to the gases in the working place.

5) What is the normal gases (concentration, types) and temperature in the underground mine?

a) *Gases:* Normal gases found are O2, CO2, CO, NO2, SO2, H2S and C2H2. Most dangerous/poisonous are CO and H2S. In terms of explosive nature: methane (CH4). It is the primary gas in the coal mine explosion. In terms of CH4 concentration inside the mine, it is degree 1, degree 2 and degree 3. The percentage of CH4 is frequently watched and noted. If there is CH4 present, every third day a report is sent to a higher authority. Degree 2 and Degree 3 concentration is viewed very seriously.

b) *Temperature:* DGMS allows not more than 33.5-degree temperature. If it is more than 30.5 degree, the air currentventilation is set to a speed of more than 1m/s.

6) *How many workers works in the particular shift in the coal mines?*

Size of the group that goes to a single location? A number of workers depend on the size of the mine. In a small mine: 50-80 workers per shift, and for large underground mines 200-300 workers per shift. Total employment is around 1500 to 2000 workers. In the Bhatgaon mine, there are 900 workers and an average shift has 200 workers.

7) *Is there any communication method (walky-talky)?Intrinsically safe landlines are used.*

B. Current Situation Of The Problem And How It Is Handled

1) *How often the gases like methane, butane, and carbon monoxide leak in the mines?*

In coal mines the combustible gas leakage is rare, but if there is an even small amount of the gas present in the coal mines it will quickly mix with ventilation system inside the mines and can cause explosion or suffocation.

2) *Past accidents due to gas leakages or similar events? Elaborateon the accidents – how it happened, what happened there, how many people have died?*

This type of accident fortunately has not happened in this coal mine at Bhatgaon, but some accidents have occurred in the nearby coal mines.

3) What is the present method to detect gases?

We have combustible gas detecting equipment approved the Director general of mines safety authority for the safe working of the mines. The equipment mentioned is intrinsically safe.

4) Is there any solution implemented for the problem? - evacuation, communication to the base station.

The areas are supervised on the routine basis with the equipment like for detecting CO there are CO detectors, for methane there are methane-o-meters and a multi-gas detector is used for general detection of the gases.

5) If a problem is detected, how much time does it take for evacuation?

All the workers start the rescue operation of workers fromunderground. Simultaneously, they inform the higher authority and use their ventilation system to maintain the temperature andgas concentration.

6) How the evacuation is done?

The entries into and exits from the mine depend upon the area. The escape route is usually same as the entry. There are differenttypes of entries, e.g. entries through the well-called shaft. In mountain areas, they call the horizontal entry as edits. Theprovision says that there should be two modes of the entry, in case of explosion or accident, so that the people can get out. However, they are not used often.

C. Review Of Our Proposed Solution

1) Will this model be able to help solve the problem andminimize human loss?

The idea is good and can be used in the coal mines.

2) How effective do you think this project could be?

The project requires real-time research to check how it works inthe underground mines with dust presence, humidity, temperature and connectivity for the proper working of thehelmet.

3) Would you wish to have additional features in this helmet? Please elaborate.

Keep in check if the helmet is intrinsically safe or not. As even asmall spark can lead to an accident inside the mine.

4) What problems/constraints do you see in the deployment of this model?

A large amount of dust present in the mine, which often causesa problem with coal mine equipment and its working. Try to keepa check on this problem as well.

5) Would you like to test this model on coal mines?

As only one supervsor supervises the mine at a given time, so ifthe all the mining engineers working in the mines with a smart helmet, they can be updated with gas concentration and temperature condition of mine, can help to improve the reactiontime of the workers. Sure, we would love to check the instrumentin the coal mine.

IV. PROPOSED SYSTEM

1) *Temperature Sensor:* For measuring temperature we used LM35 sensor which gives analog output and it has output range of -25oC to +125oC. It has sensitivity of 10mv/oC that is 1oC produces 10mv change in output.
2) *Gas Sensor:* There are many types of gas sensors which detects different gases and its concentration. For coal mines where methane is maximum so for that is MQ4 with a concentration range of 300 ppm to 10000 ppm.
3) *Humidity Sensor:* This are cheap and provide great performance. It consists of thermistor element which produce changing output as the humidity changes. Its operating range is 3-5 Volt.
4) *Fall Sensor:* This will be used to detect if the working wearingthe helmet has fall down. It could be because of various factors in mine like unconsciousness due to low oxygen etc.

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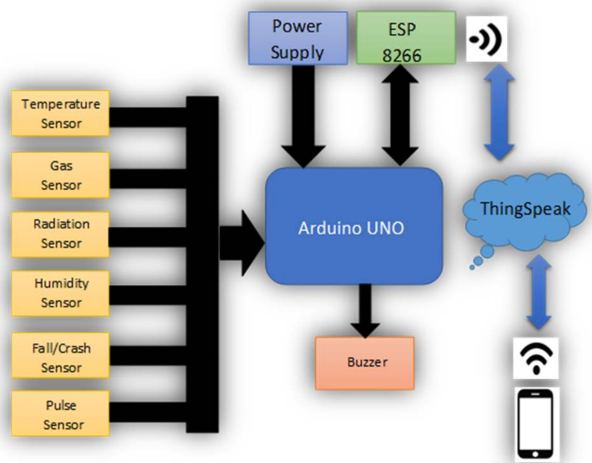

Figure 1 Block Diagram of the proposed system.

V. ALGORITHM

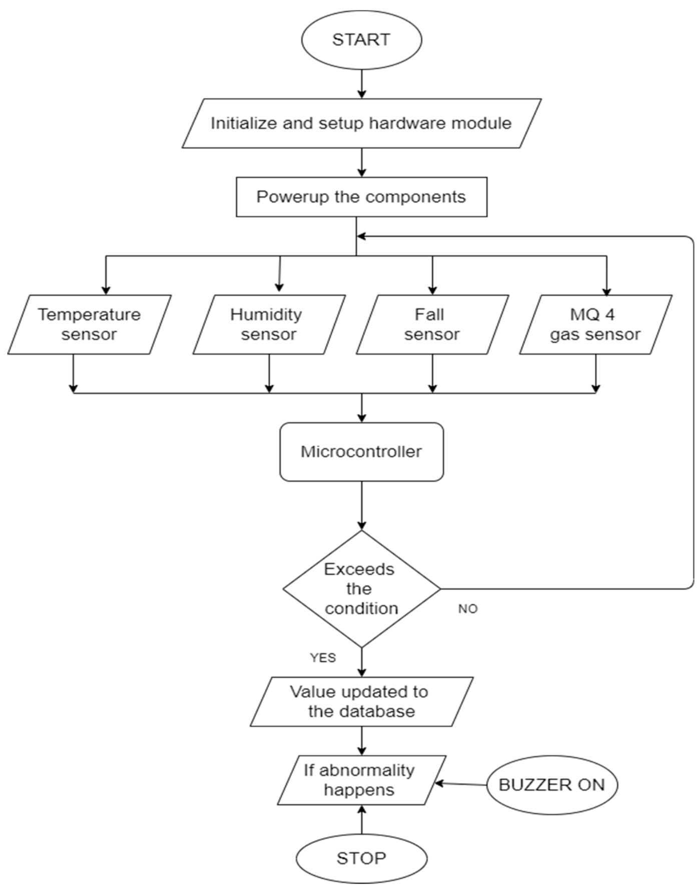

Figure 2 Algorithm of the proposed system

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VI. COST ANALYSIS

To determine whether a price is fair and reasonable in a hazardous working environment, it is essential to know how to identify and utilize the correct resources during the assessment process. Identifying the best price involves using the price analysis strategy, which requires performing a workplace competition comparison. Cost analysis, a more complex process,is a thorough assessment of the direct and indirect costs leading to the final price of the product or service, an Industrial Helmet in our case. Once either of these strategies is applied and expenses are identified, negotiation and hence the implementation may be necessary to ensure the best price. We with our prototype and idea of a large scale making of thesehelmets plan on establishing an open line of communication with the manufacturer in the early stages of the contract process so that they are aware that a request for individualized prices on items will be an ongoing process.

Safety is our main and only major concern followed by others.

We aim to convince our mining industry or more specifically ourtargeted mine managerial body that our intent in obtaining costing information is not to reduce their profit or an unnecessarydeal but it is primely for the safety of the workers and reductionin the cases of accidents and accidental deaths. To understand the cost analysis behind our product prototype, wehave identified direct costs and indirect costing. Direct Costing, which we describe as elements—the helmet, the sensors, the wiring, the servers, the assembly or otherwise—andprofit, which can be attributed to the final cost of the product. This list includes base salary, labor, materials, and workers such as subcontractors, fringe benefits, which we may cites as 30- 33%, travel, and all that can be billable to the final SMART HELMET. The Indirect costs, are generally less evident, materials and non-materials that are not directly associated with the final product. Examples of indirect costs may include advertising and marketing, indirect labor, legal fees, travel, rent and repairs, communication and office supply costs, insurance, taxes, depreciation, and utilities, as well as additional "non-project specific expenses,". Both indirect and direct costs are usually factored with profit, which is essentially the complexity of the work performed and the risk assumed during the work performed for the project.

Overhead rates typically vary by industry, and may sometimes—but not always—indicate that there is business efficiency. These rates can be determined by internet research or by formulating an overheat rate formula. While overhead rates differ according to industry, averages are generally between 1.35 and 2.90. One effective method/formula that to determine a fair and reasonable overhead rate is the total indirect costs divided by direct costs. Or the pricing may perform what is called a break-even multiplier, the formula, "Total Indirect Costs + Direct Costs, divided by Direct Costs".

In Conclusion, not all alternatives suggested to improve costs orincrease value will be feasible or compatible therefore a careful evaluation should be made before any implementations are made. Evaluation matrices or quality function deployment may be helpful in considering the alternatives. If the functional cost analysis results in changes to the helmet design, we need to be sure to manage these changes carefully and update all necessarydocumentation including specifications.

QUANTITATIVE ANALYSIS	PRICE PER UNIT / SERVICE	PRICE PER 50 UNITS	TOTAL
NON-RECURRING COSTS			
Hardware			
Miner Helmet (with Torch Light System)	RS.200	50.00	RS.10000
Pulse Sensor	RS.100	50.00	RS.5000
Fall Detection Sensor	Rs.100	50.00	RS.5000
Temperature and Humidity Sensor	Rs.200	50.00	RS.10000
Gas Sensor	Rs.200	50.00	RS.10000
Telecommunication equipment	Rs.500	50.00	RS.25000
Software (packaged or custom)	Rs.400	50.00	RS.20000
Installation Costs	Rs.80	50.00	Rs.4000
TOTAL NON-RECURRING COSTS			RS.89000

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MISCELLENIOUS SERVICES
Computer room upgrades
Project organizational/support costs
Planning (upon approval)
Procurement
Contract negotiations
Labour
Infrastructure
Development
Business Process owners (users)
Management
Training of employees (pre-implementation)
Transition costs (parallel systems)
Post implementation reviews

RECURRING COSTS	
Hardware/Software	
Software maintenance and upgrades	
Computer supplies	
Desktops (incremental to the project)	
Help Desk support	
Ongoing Additional Labour	
IT staff costs (incl. benefits)	
User training	
Other	
Telecommunications	
TOTAL RECURRING COSTS	
	TOTAL
COST SAVINGS	
Savings from Business process improvements	
Productivity gains	
Savings from structural changes	
Savings from optimized information (or flow)	
Decreased compensatory finances	
Reduced staffing cost	
TOTAL COST SAVINGS	
COST AVOIDANCE	
(Enter Cost Avoidance Here)	

VII. HELMET DESIGN

The Mining Industry requires a range of high-quality CE certified (DIN EN 397) miners safety helmets (hard hats) suitable for mining, construction and utility companies.

Carbide lamps were used with hard protective helmets, but helmets that used electric lamps would have a cord holder to keep the cord out of the miner's way. A form of this helmet and electric lamp combination is still worn today, with improvements in the area of battery life and weight, a change to tungsten and LED bulbs, and breakaway or segmented cords to allow the miner to be less inhibited by the battery pack. Thesafety Standards should not be compromised.

We have used the CATIA V5 software to design our IndustrialMiner Helmet.

Compartments or Sockets are designed with respect to each sensors' dimension specification.

The outer top of the shell has an fall detection sensor socket (for detecting falling debris) , the sides have a compartment for the Temperature and Humidity sensor, the back of the helmet is supposed to have gas sensor, Our 4th and the important pulse sensor is placed on the strap of the helmet which starts from behind the ear and ends at the chin.

Apart from these the helmet has a normal design including thetypical safety brackets under the shell this suspension system not only fasten the mining helmet to miners' heads, but also provide excellent shock resistance by keeping an empty space between miner's head and the hard shell of the helmet, Built-inlight bulbs make the miners easy to see in the darkness. Maybewe can have provision for a metal bracket on the helmet for easy attachments.

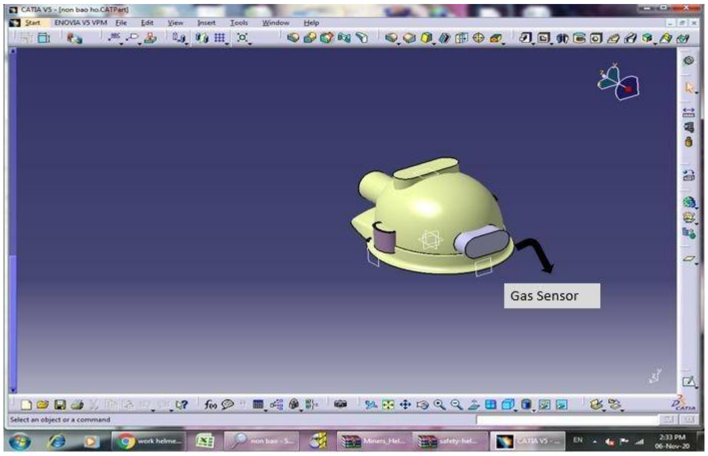

Figure 3 Back view of the helmet design

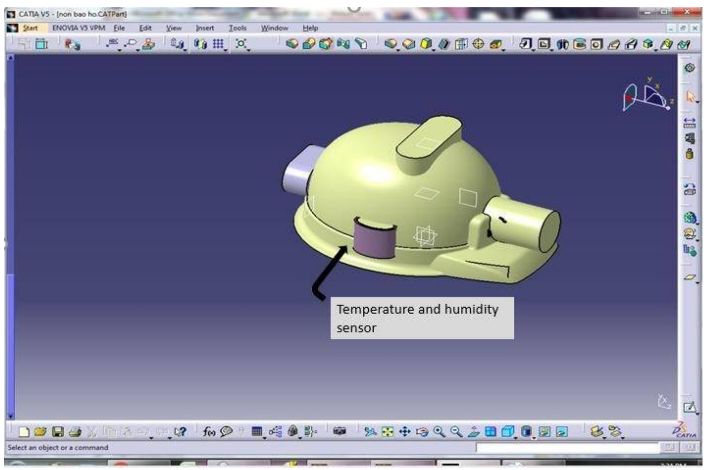

Figure 4 Sideview of Helmet design

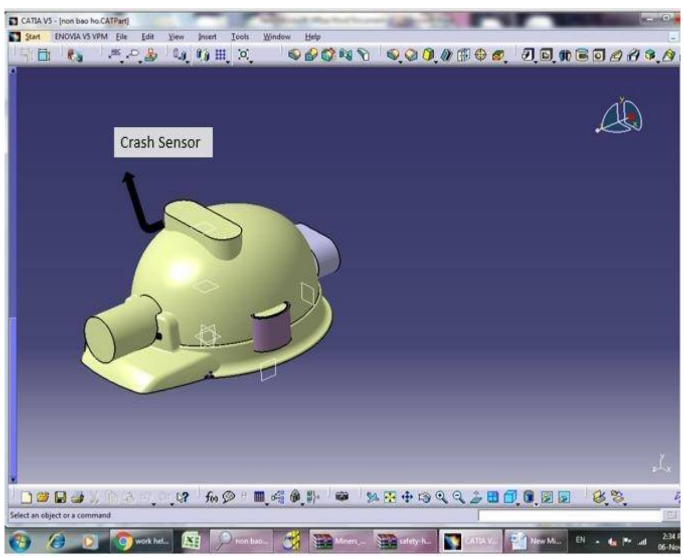

Figure 5 Front view of helmet design

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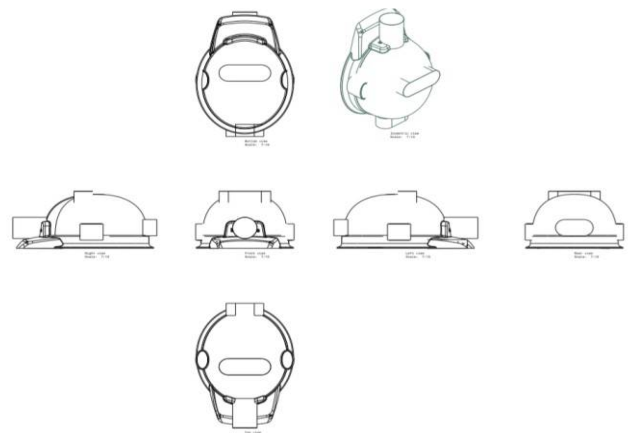

Figure 6 Schematic of helmet.

VIII. IMPLEMENTATION

The project prototype is implemented in Tinkercad and the circuit includes gas sensor and temperature sensor with buzzer,green and red led. The WIFI module (ESP8266) is used for communicating withthe WIFI network inside the industry or factory. It will send the real time data to the cloud. During normal conditions the green led will glow and buzzer will be off. Whenever the smoke or temperature value cross the threshold level the red led will glow and the buzzer inside the factory will switch on and alsoan email will be sent to the supervisor alerting against the unsafe condition inside the factory.

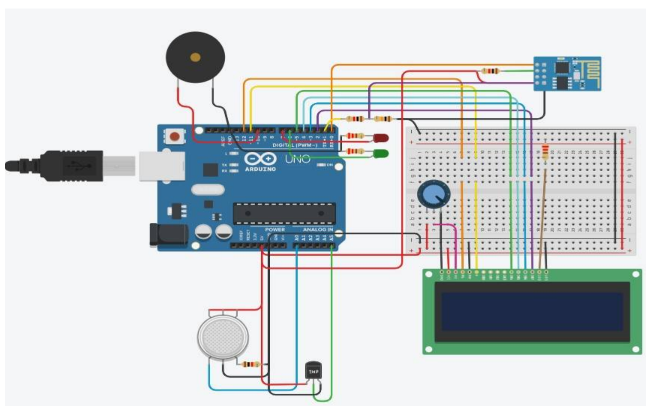

Figure 7 Circuit Diagram of the helmet circuit

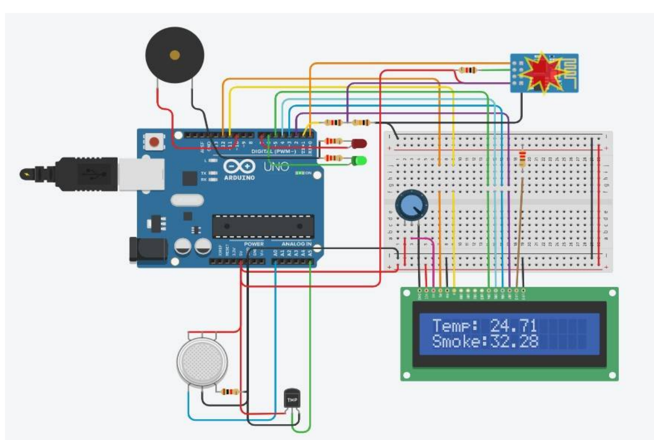

Figure 8 Working of the circuit in the normal conditions of temperatureand smoke

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The figure given below demonstrates the circuit during the unsafe condition of temperature. The threshold set for temperature is 45ºC and the measured temperature was 56.93ºC so the buzzer is on and red led is glowing.

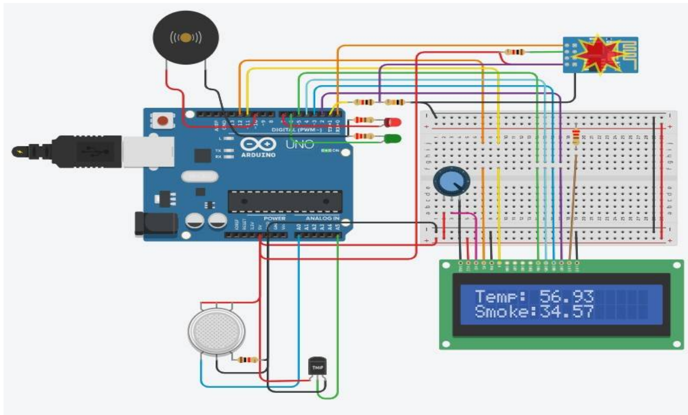

Figure 9 Working of the circuit when the temperature is above thethreshold level.

The working of circuit in unsafe condition of smoke is show below. The threshold set for temperature is 40 and the measured smoke value was 43.43, so the buzzer is on and red led is glowing.

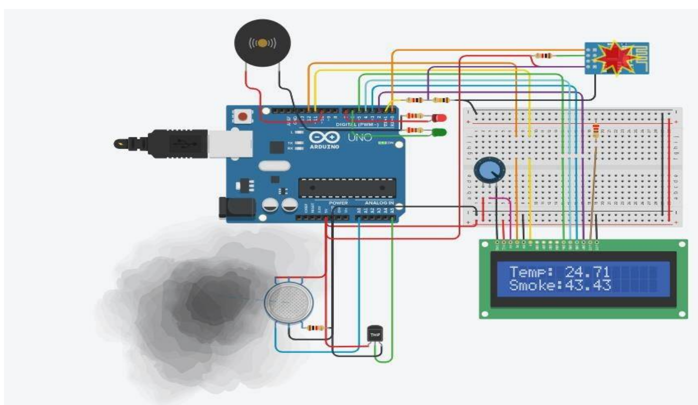

Figure 10 Working of the circuit when the smoke is above the thresholdlevel.

IX. RESULT AND ANALYSIS

The real time data of smoke and temperature are sent to the ThingSpeak cloud and displayed in form of graphs. Field 1 shows the Smoke Value and Field 2 shows Temperature valuesin (ºC).

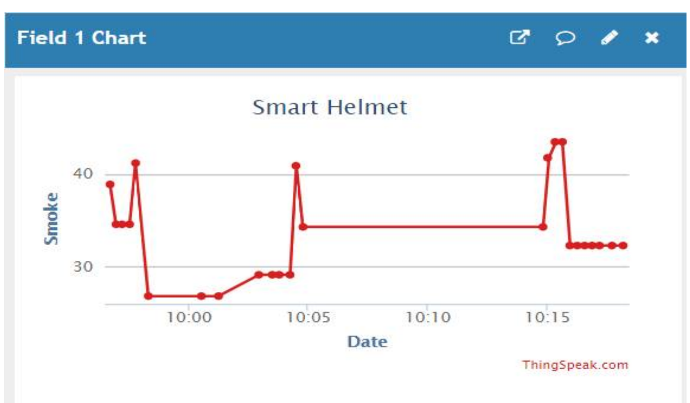

Figure 11 ThingSpeak smoke chart.

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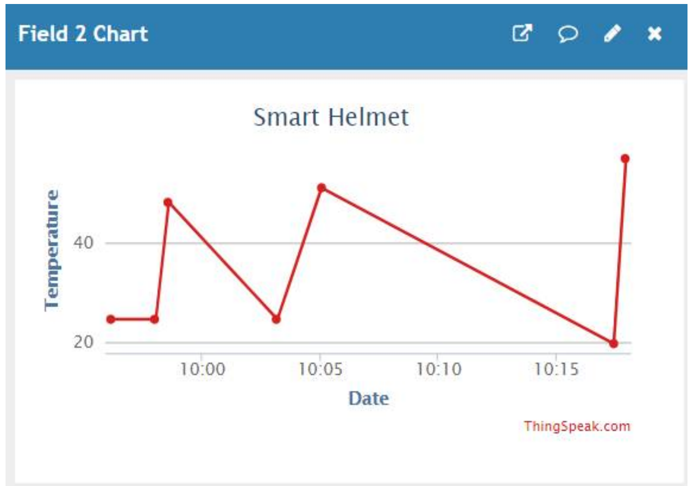

Figure 12 ThingSpeak Temperature chart

When the received value of smoke and temperature exceeds the threshold value, the ThingSpeak will trigger the corresponding react. For smoke, smoke_alert will be triggered and for temperature, temp_alert will be triggered.

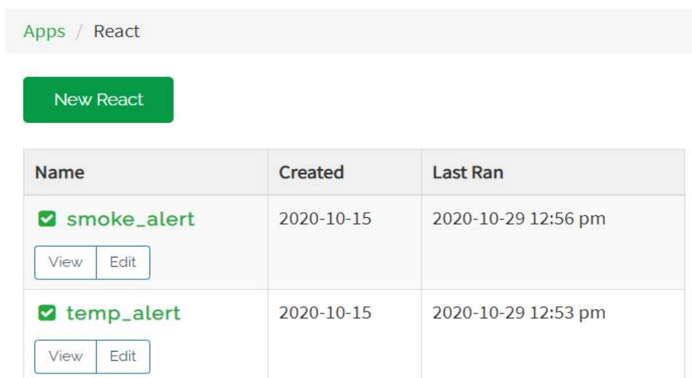

Figure 13 React app of ThingSpeak

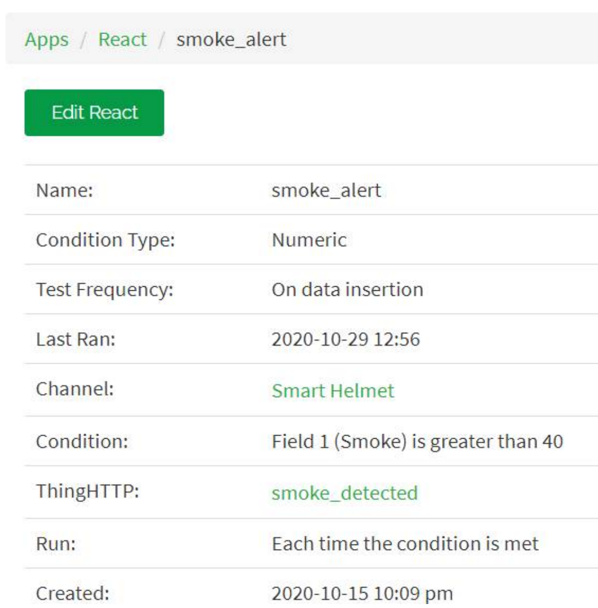

Figure 14 Settings of smoke_alert.

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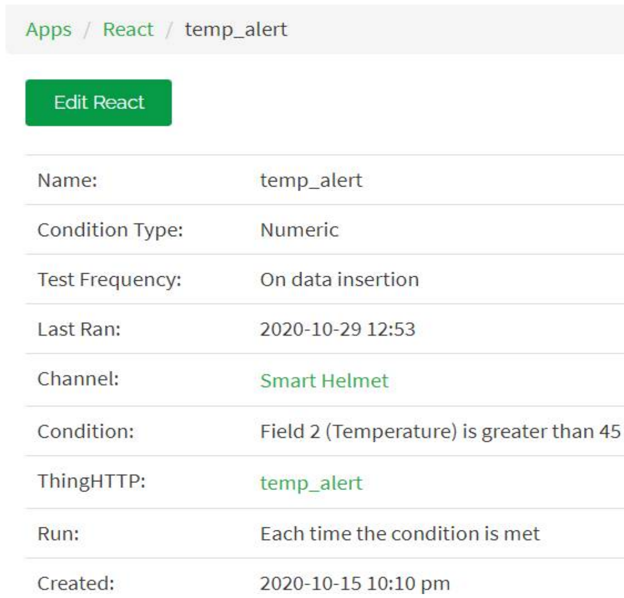

Figure 15 Settings of temp_reacts

When react is triggered, it triggers ThingHTTP. Thecorresponding ThingHTTP are made and show below:

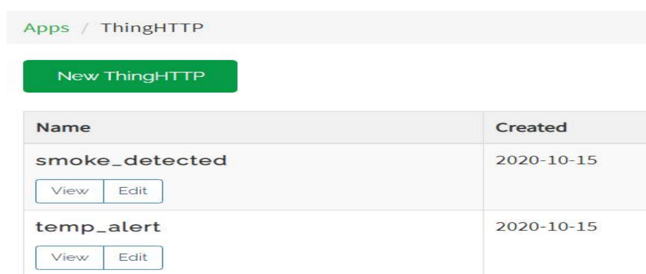

Figure 16 ThingHTTP app of ThingSpeak

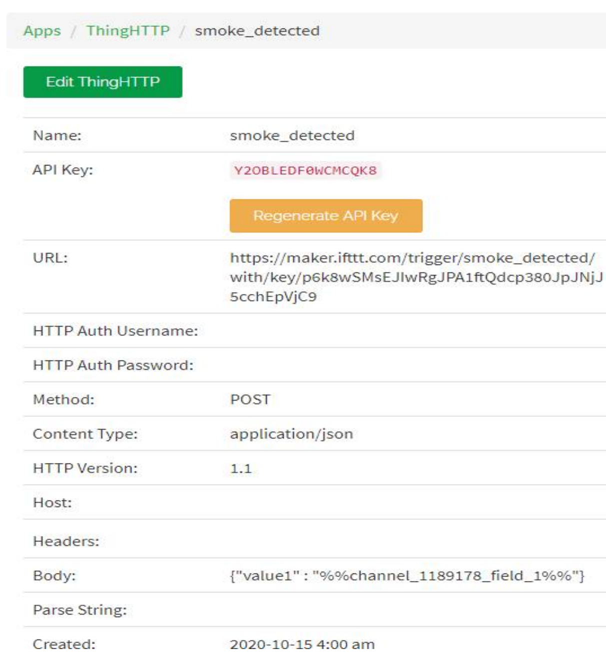

Figure 17 Settings of ThingHTTP for smoke alert

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X. CONCLUSION

A mining helmet has been developed which detect different typesof hazardous events such as, humidity, temperature, concentration of combustible gases and many more parameters. The helmet sends the readings of the parameters to the base station PC through cloud which is being inspected continuously. If any reading exceed its limit the helmet sends information through IoT to the base station and alert the miner through buzzer. As the system requirement and the required components can be easily made available and this project can be implemented easily. It will provide safety to worker and change the way of their working, as well as system controlling the various environmental changes in mines. It is reliable system with quick response and easy installation. And the helmet has a flexible design where different sensor can be added or removed according to different industrial use.

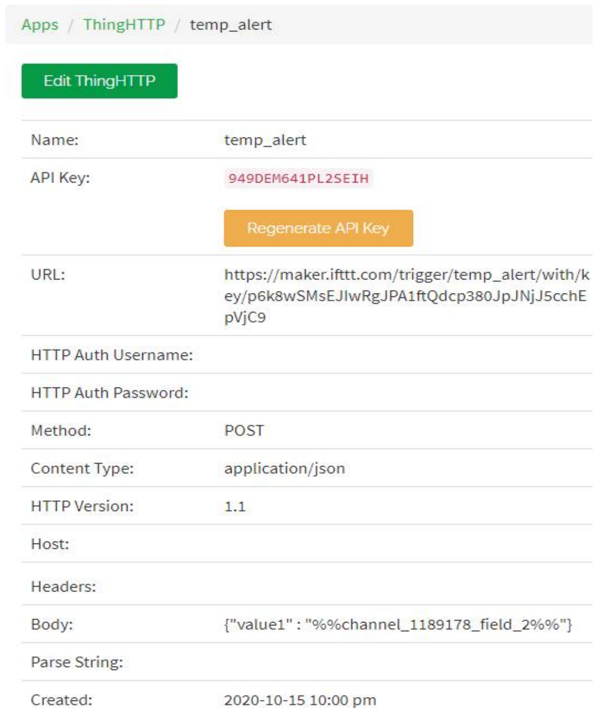

Figure 18 Settings of ThingHTTP for temperature alert

When ThingHTTP is triggered, an email alert is sent to thegiven email.

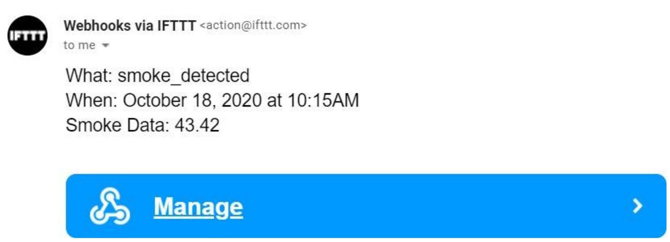

Figure 19 Email alert for smoke.

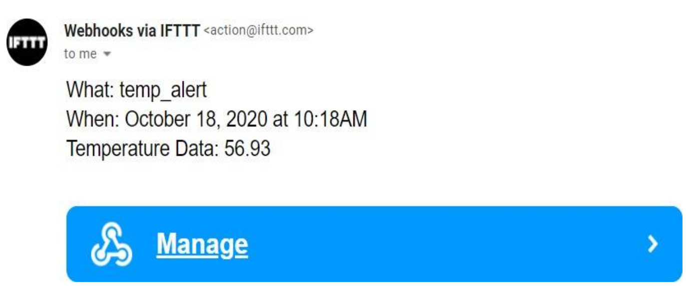

Figure 20 Email alert for Temperature alert

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