PROJECT REPORT ON

IoT BASED SYSTEM FOR SAFETY AND HEALTH MONITORING OF INDUSTRIAL WORKERS

in partial fulfilment of the requirements for the award of B. Tech Degree in Electronics and Communication Engineering

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CERTIFICATE

This is to certify that the project report entitled **"IoT Based System for Safety and Health Monitoring of Industrial Workers"** is a bonafide account of the project presented by **AKHILESH K (TKM16EC014), ALAN A THOMAS (TKM16EC019), ANEKHA K (TKM16EC026), VAISHAKH E (TKM16EC113)** in partial fulfilment of the requirement for the award of Bachelor of Technology in Electronics and Communication Engineering of APJ Abdul Kalam Technological University during the academic year 2019-2020.

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It is with great pleasure and pride that we present this report before you. At this moment of triumph, it would be unfair to neglect all those who helped us in the successful completion of this report.

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ABSTRACT

Internet of Things acts as a gateway for various smart things as well as in the field of cloud networking servers. A hybrid wearable sensor network system towards the Internet of Things (IoT) connected safety and health monitoring applications is resented. The system is aimed at improving safety in the outdoor workplace. The proposed system consists of a wearable body area network (WBAN) to collect user data and a low-power wide-area network (LPWAN) to connect the WBAN with the Internet.

The wearable sensors in the WBAN are exerted to measure the environmental conditions around the subject using a Safe Node and monitor the vital signs of the subject using a Health Node. A standalone local server (gateway), which can process the raw sensor signals, display the environmental and physiological data, and trigger an alert if any emergency circumstance is detected, is designed within the proposed network. To connect the gateway with the Internet, an IoT cloud server is implemented to provide more functionalities, such as web monitoring and mobile applications.

LIST OF ABBREVIATIONS

WBAN	Wearable Body Area Network
LPWAN	Low Power Wide Area Network
IoT	Internet of Things
HR	Heart Rate
RR	Respiration Rate
ECG	Electrocardiogram
BP	Blood Pressure
MCU	Micro Controller Unit
PPG	Photoplethysmogram
LoRa	Long Range
NSA	National Security Agency
BLE	Bluetooth Low Energy
UV	Ultra Violet
BSN	Body Sensor Network
HTTP	Hyper Text Transfer Protocol
MQTT	Message Query Telemetry Transport
Wi-Fi	Wireless Fidelity
OS	Operating System
WSN	Wireless Sensor Network
PM	Particulate Matter
VOC	Volatile Organic Compound
PPM	Parts Per Million
WAN	Wide Area Network
IP	Internet Protocol
API	Application Programming Interface
LED	Light Emitting Diode
PMU	Power Management Unit
SPI	Serial Peripheral Interface
TTL	Transistor Transistor Logic
IC	Integrated Circuit
QOD	Quick Output Discharge
LDO	Low Drop Out

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CHAPTER 1

INTRODUCTION

The Internet of Things (IoT) is the leveraging technology which has great importance in our daily day life. Within 2021, It is expected to connect 50 billion devices across the world. IoT has wide range of application in manufacturing, Industry, Healthcare, Wearables, and Home. And it supports various fields such as smart transportation, smart city, smart healthcare, smart manufacturing.

Safety is one of the most significant considerations in an industrial workplace, where occupational injuries and illness may change the life of workers permanently. Wearable sensor nodes are generally deployed inside a wearable body area network (WBAN) to monitor physiological signals, such as the heart rate (HR), respiration rate (RR), electrocardiography (ECG), body temperature, body position, and blood pressure (BP). In addition to medical applications, WBAN can also be used to monitor environmental conditions around people. Such applications can provide useful information for users to gain a deeper understanding of their surroundings, especially for safety-related applications. For instance, in a construction site, workers' safety and health are always a major concern in the industry.

A hybrid IoT network system that can monitor real-time physiological and environmental conditions to prevent workers from being exposed to risky and hazardous situations is of great importance. If users can react to emergency or accidents in time with the access to both data at the same time, risks can be reduced. When dealing with healthcare monitoring, privacy and data security should be carefully considered. Developers can help to integrate security into devices, applications, and systems. For data sharing, developers can use a Client-Server model, in which the server shares a certain type of information with clients while keeping other information protected by appropriate credentials.

Original LoRa transmission does not require encryption; however, this can be resolved by adding data encryption to LoRa transmission. Speck by National Security Agency (NSA) is a lightweight block cipher which has been optimized for performance in software implementations and is used in our Safe Node to encrypt the wireless data transfer and improve the data security.

When the users need to access the data on the server, users will be asked to enter their credentials in our web application.

CHAPTER 2

LITERATURE REVIEW

[1] F. Wu, T. Wu, and M. R Yuce, “An internet-of-things (IoT) network system for connected safety and health monitoring applications,” Sensors, vol. 19, no. 1, p. 21, 2019.
This paper presents a hybrid wearable sensor network system towards the Internet of Things (IoT) connected safety and health monitoring applications. The system is aimed at improving safety in the outdoor workplace. The proposed system consists of a wearable body area network (WBAN) to collect user data and a low-power wide-area network (LPWAN) to connect the WBAN with the Internet. The wearable sensors in the WBAN are exerted to measure the environmental conditions around the subject using a Safe Node and monitor the vital signs of the subject using a Health Node. A standalone local server (gateway), which can process the raw sensor signals, display the environmental and physiological data, and trigger an alert if any emergency circumstance is detected, is designed within the proposed network. To connect the gateway with the Internet, an IoT cloud server is implemented to provide more functionalities, such as web monitoring and mobile applications.

A hybrid IoT network system that can monitor real-time physiological and environmental conditions to prevent workers from being exposed to risky and hazardous situations is of great importance. If users can react to emergency or accidents in time with the access to both data at the same time, risks can be reduced. This paper presents a hybrid wearable sensor network system with edge computing to improve the safe working environments and reduce the health risks in the construction industry. The proposed IoT infrastructure incorporates two networks: a WBAN for data collection using Bluetooth low energy (BLE) and an LPWAN for the Internet connection using LoRa. The environmental conditions (temperature, humidity, UV and CO2) and vital signs (HR and body temperature) of the subject are measured by the wearable sensors deployed in the WBAN. The data from individual sensors are transmitted using BLE within the WBAN, which will be collected and transmitted to a gateway using LoRa within the LPWAN. The gateway can act as a local server for edge computing, namely pre-processing sensor signals, displaying data and triggering alerts when emergency incurred. Finally, an IoT cloud server is designed and implemented for data storage and further functionalities, such as web monitoring and mobile applications.

[2] M. R. Yuce, “Implementation of wireless body area networks for healthcare systems,” Sensors and Actuators A: Physical, vol. 162, no. 1, pp. 116–129, 2010.

This paper describes the implementation of a complete wireless body-area network (WBAN) system to deploy in medical environments. Issues related to hardware implementations, software and wireless protocol designs are addressed. In addition to reviewing and discussing the current attempts in wireless body area network technology, a WBAN system that has been designed for healthcare applications will be presented in detail herein. The wireless system in the WBAN uses medical bands to obtain physiological data from sensor nodes. The medical bands are selected to reduce the interference and thus increase the coexistence of sensor node devices with other network devices available at medical centers. The collected data is transferred to remote stations with a multi-hopping technique using the medical gateway wireless boards. The gateway nodes connect the sensor nodes to the local area network or the Internet. As such facilities are already available in medical centers; medical professions can access patients’ physiological signals anywhere in the medical center. The data can also be accessed outside the medical center as they will be made available online. Wireless body-area network (WBAN) is a special purpose wireless-sensor network that incorporates different networks and wireless devices to enable remote monitoring for various environments. One of the targeted applications of WBAN is in medical environments where conditions of a large number of patients are continuously being monitored in real-time. Wireless monitoring of physiological signals of a large number of patients is one of the current needs in order to deploy a complete wireless sensor network in healthcare system.

[3] Wu, F.; Redouté, J.M.; Yuce, M.R. WE-Safe: A Self-Powered Wearable IoT Sensor Network for Safety Applications Based on LoRa. IEEE Access 2018, 6, 40846–40853.

Poor environmental conditions can lead to severe health problems. It is essential to develop effective, reliable, and fast response systems for people working in hazardous environments. This paper presents a wearable Internet of Things sensor network aimed at monitoring harmful environmental conditions for safety applications via a Lora wireless network. The proposed sensor node, called the WE-Safe node, is based on a customized sensor node, which is self-powered, low-power, and supports multiple environmental sensors. Environmental data is monitored by the sensor node in real-time and transmitted to a remote cloud server. The data can be displayed to users through a web-based application located on the cloud server and the device will alert the user via a mobile application when an emergency condition is detected. The experimental results indicate that the presented safety monitoring network works reliably using energy harvesting. Wearable sensor nodes are generally deployed in wireless body area networks (WBAN) to monitor physiological parameters, such as body skin temperature, photo-plethysmogram (PPG), or electrocardiogram (ECG). In addition to medical signals, they can be deployed to monitor environmental conditions around the human body as well, such as in the safety application, and environmental monitoring applications.

This paper presents a self-powered wearable IoT sensor network, named as WE-Safe IoT project, for safety environmental monitoring. Each sensor node consists of a micro-power manager, a sensing unit, and a wireless module. The micro-power manager is designed to harvest energy both indoors and outdoors to enable a continuous energy supply for the sensor node. The total sensor node is low power consuming 5.6 µA in sleep mode. The data collected is transmitted to a gateway via a long-range LoRa wireless technology.

[4] Gope, P.; Hwang, T. BSN-Care: A secure IoT-based modern healthcare system using body sensor network. IEEE Sens. J. 2016, 16, 1368–1376.

Advances in information and communication technologies have led to the emergence of Internet of Things (IoT). In the modern health care environment, the usage of IoT technologies brings convenience of physicians and patients, since they are applied to various medical areas (such as real-time monitoring, patient information management, and healthcare management). The body sensor network (BSN) technology is one of the core technologies of IoT developments in healthcare system, where a patient can be monitored using a collection of tiny-powered and lightweight wireless sensor nodes. However, the development of this new technology in healthcare applications without considering security makes patient privacy vulnerable. In this paper, at first, the major security requirements in BSN based modern healthcare system are highlighted. Subsequently, proposed a secure IoT-based healthcare system using BSN, called BSN-Care, which can efficiently accomplish those requirements.

The body sensor network (BSN) technology is one of the most imperative technologies used in IoT-based modern healthcare system. It is basically a collection of low-power and lightweight wireless sensor nodes that are used to monitor the human body functions and surrounding environment. Since BSN nodes are used to collect sensitive (life-critical) information and may operate in hostile environments, accordingly, they require strict security mechanisms to prevent malicious interaction with the system. This article, at first addresses the several security requirements in BSN based modern healthcare system. Then, proposes a secure IoT based healthcare system using BSN, called BSN-Care, which can guarantee to efficiently accomplish those requirements.

[5] Yang, Z.; Zhou, Q.; Lei, L.; Zheng, K.; Xiang, W. An IoT-cloud Based Wearable ECG Monitoring System for Smart Healthcare. J. Med. Syst. 2016, 40, 286.
Public healthcare has been paid an increasing attention given the exponential growth human population and medical expenses. It is well known that an effective health monitoring system can detect abnormalities of health conditions in time and make diagnoses according to the gleaned data. As a vital approach to diagnose heart diseases, ECG monitoring is widely studied and applied. However, nearly all existing portable ECG monitoring systems cannot work without a mobile application, which is responsible for data collection and display. This paper proposes a new method for ECG monitoring based on Internet-of-Things (IoT) techniques. ECG data are gathered using a wearable monitoring node and are transmitted directly to the IoT cloud using Wi-Fi. Both the HTTP and MQTT protocols are employed in the IoT cloud in order to provide visual and timely ECG data to users. Nearly all smart terminals with a web browser can acquire ECG data conveniently, which has greatly alleviated the cross-platform issue. Experiments are carried out on healthy volunteers in order to verify the reliability of the entire system. Experimental results reveal that the proposed system is reliable in collecting and displaying real-time ECG data, which can aid in the primary diagnosis of certain heart diseases.

In this paper, the architecture of an ECG monitoring system based on the Internet-of-Things (IoT) cloud is firstly proposed. Based on this architecture, designed and implemented a wearable ECG monitoring system. The ECG data gathered from the human body will be transmitted directly to the IoT cloud using Wi-Fi without the need of a mobile terminal. Compared with Bluetooth or Zigbee, Wi-Fi can provide higher data rates and wider coverage areas. In order to provide convenient and timely access to ECG data for users, both the HTTP and MQTT servers are deployed in the IoT cloud. The gathered data are stored in a nonrelational database, i.e., Redis, which can greatly improve the speed and flexibility of data storage. A web-based graphical user interface is implemented so that it provides ease of access for doctors and patients alike using smart phones of different OS platforms to access to the data services provided by the IoT cloud. The proposed system has been successfully deployed and fully tested with demonstrated effectiveness and reliability in ECG monitoring.

[6] Wu, T.; Redouté, J.M.; Yuce, M.R. A Wearable Wireless Medical Sensor Network System towards Internet-of-Patients. In Proceedings of the 2018 IEEE Sensors, New Delhi, India, 28–31 October 2018.
This paper presents a wireless, medical network system for vital signs monitoring with a low-power wearable sensor node. The proposed implementation consists of a master sensor board, a sensor node and a gateway (mobile or fixed). The master board has a microcontroller for signal processing, a Bluetooth low energy (BLE) module for data transmission, and a power management circuit for charging a 120 mAh rechargeable battery. The sensor node, with a temperature sensor and a photoplethysmography (PPG) sensor, is aimed to be attached to the subject's chest to measure the vital signs, including heart rate (HR), respiration rate (RR) and body temperature. Experimental results demonstrate that the proposed wearable device can monitor and transmit the subject's vital signs to the gateway for data storage and further healthcare analysis.
The modern healthcare industry is emerging with the technology of Internet of Things (IoT). This paper submitted to IEEE Sensors 2018, proposes and demonstrates a wearable wireless medical sensor network towards the Internet of Patients. The implementation consists of a master sensor board, a sensor node and a gateway for subject's health monitoring. The sensor node, with a temperature sensor and a green light photoplethysmography (PPG) sensor, is targeted to be attached to the subject's chest to measure the main vital signs, including heart rate (HR), respiration rate (RR) and body temperature. The data from the sensor node are processed by a microcontroller (MCU) on the master board, and transmitted by a Bluetooth low energy (BLE) module to the gateway (a mobile phone or a laptop).

CHAPTER 3

EXISTING SYSTEM

The existing system presents a wearable sensor network system for Internet of Things (IoT) connected safety and health applications. Safety and health of workers are important for industrial workplace; therefore, an IoT network system which can monitor both environmental and physiological parameters can greatly improve the safety in the workplace. The existing network system incorporates multiple wearable sensors to monitor environmental and physiological parameters. The wearable sensors on different subjects can communicate with each other and transmit the data to a gateway via a LoRa network which forms a heterogeneous IoT platform with Bluetooth-based medical signal sensing network. Once harmful environments are detected and, the sensor node will provide an effective notification and warning mechanism for the users. A smart IoT gateway is implemented to provide data processing, local web server and cloud connection. After the gateway receives the data from wearable sensors, it will forward the data to an IoT cloud for further data storage, processing and visualization.

Wearable body area network (WBAN) is a special purpose WSN that is generally used in healthcare environments to monitor physiological signals that can improve the quality of life, and consequently health and wellness. Apart from healthcare applications, WBANs have also been used to monitor environments. For instance, the work monitors temperature, humidity, and ultraviolet (UV) for safety applications. There is not much work covering both environmental and physiological parameters monitoring. For instance, the work continuously monitors the environment and health of the subject for chronic respiratory disease. Safety is very important for industrial workplace, especially for workers constantly switching working environments between indoor and outdoor. In outdoor environments, UV, ozone, carbon monoxide (CO) and particulate matter (PM) are harmful to human health. UV radiation is the component of sunlight which is harmful. Long-term exposure to UV index level of 3 or above can lead to skin cancer. UV exposure is also a cause of eye diseases. In addition to UV, carbon dioxide (CO_2), smoke, CO, and Volatile organic compounds (VOC) are some commonly indoor pollutants. Symptoms of CO_2 poisoning, such as hearing loss, headache and rapid pulse rate, may happen to some occupants when the CO_2 level is above 600 ppm. Therefore, it is essential to have a WSN system to monitor both UV and CO_2 for industrial workplace. To prevent workers from being exposed to any risky and hazardous situations, some physiological parameters of workers should also be monitored. Body temperature and heart rate are the most studied parameters in WBAN-based medical monitoring works. Among different wearable environmental monitoring applications, temperature and humidity are the most commonly monitored parameters.

The wearable network consists of multiple wearable sensor nodes which are capable of communicating with each other. Each person is equipped with two nodes: the first node is named Safe Node for environmental condition monitoring including ambient temperature, relative humidity, UV, and CO2; the second node named Health Node is for physiological signals monitoring including body temperature and heart rate. Two wireless technologies are utilized in our work including BLE for short range data transmission and LoRa for long range data transmission.

Heterogeneous devices including LoRa-based long-range Safe Node and BLE-based short-range Health Node enable the short-range IoT data to be transmitted at longer distance and connected to the Internet. An IoT gateway is designed and implemented to process, store and pass the data to cloud infrastructure. Monitored data can be displayed from a local web server located in the gateway and a website in the cloud server. If any emergency condition is detected, the system can notify users by pushing notifications to their smartphone.

CHAPTER 4

PROPOSED SYSTEM

4.1 INTRODUCTION

The proposed system is an IoT based system for health and safety monitoring of industrial workers using Wearable Body Area Networks (WBAN). We designed the system to connect LoRa WAN which enables transfer of collected sensor data to the cloud with low power consumption and high range. Also, we use both Safe node and Health node for monitoring the factory worker which is a methodology adopted from the existing system. Also, we have made modifications in the communication part of the existing system and also varied some parameters which are to be sensed.

4.2 SYSTEM ARCHITECTURE

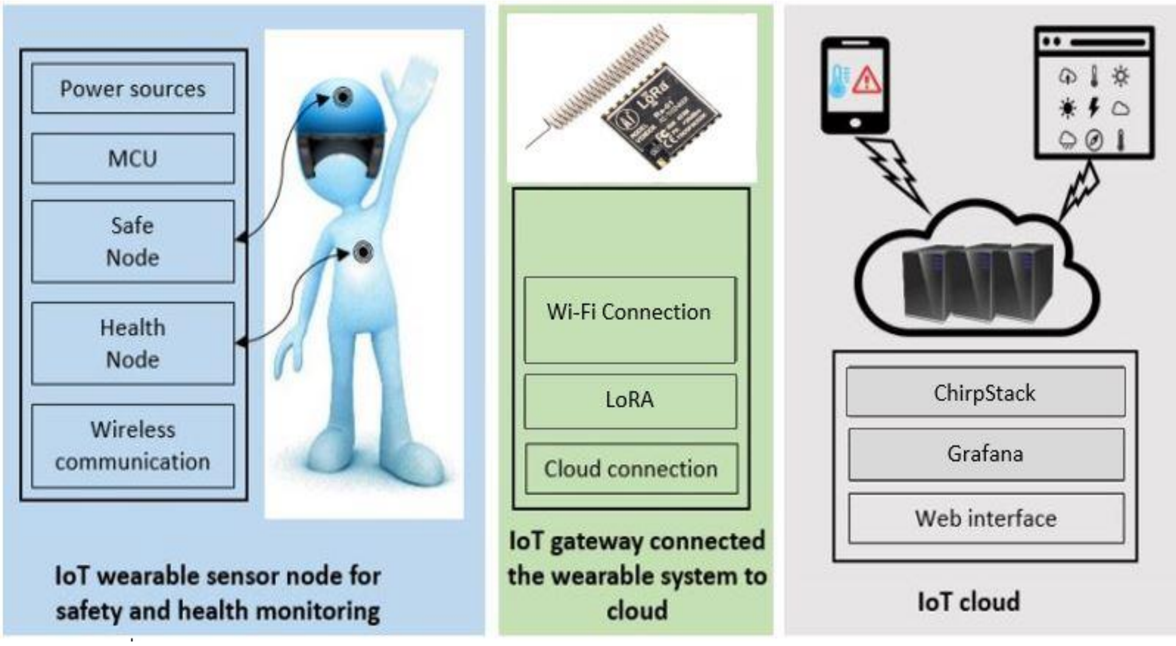

Fig 4.2.1 System architecture of the wearable sensor network for environmental and health monitoring.

4.2.1 WEARABLE NETWORK

There are two wearable sensor nodes on each subject: The Safe Node for environmental monitoring and the Health Node for physiological parameters' measurements. The Health Node comprises a Node-MCU module enabling WBAN communication, a sensor for heart rate monitoring and a body temperature sensor. We use two sensors in the Safe Node which is a Temperature & humidity and an Air Quality sensor. The Safe Node comprises two modules: the Node MCU for communication within the WBAN and LoRa for transmission in the LPWAN. The MCU in the Safe Node is responsible for receiving sensor data from the Health Node within the WBAN, which will be transmitted to a remote gateway via the LoRa network. MCU can transmit data at low power consumption and high data rate, but it is limited by the transmission range. LoRa can transmit data over a long distance while sacrificing the data rate and increasing power consumption. Therefore, in the proposed design, LoRa is adopted for long-range data transmission and MCU is used to transmit data inside the WBAN.

4.2.2 IoT GATEWAY

The role of the IoT gateway is to connect the wearable network to the IoT cloud. The gateway consists of a LoRa module. The LoRa network utilizes a telecommunications network called LoRaWAN that provides the routing of the data from the end node via a LoRaWAN gateway to the required entities. LoRaWAN also defines the way in which data is sent around the network, detailing the responses of the LoRaWAN gateways, and the LoRa network server. The gateway receives the communications from the LoRa endpoints and then transfers them onto the backhaul system. This part of the LoRa network can be Ethernet, cellular or any other telecommunications link wired or wireless. The gateways are connected to the network server using standard IP connections. In this way the data uses a standard protocol, but can be connected to any telecommunications network, whether public or private. In view of the similarity of a LoRa network to that of a cellular one, LoRaWAN gateways may often be co-located with a cellular base station. In this way they are able to use spare capacity on the backhaul network.

4.2.3 SOFTWARE

CHIRPSTACK

The ChirpStack open-source LoRaWAN Network Server stack provides open-source components for LoRaWAN networks. Together they form a ready-to-use solution including an user-friendly web-interface for device management and APIs for integration. The modular architecture makes it possible to integrate within existing infrastructures. All components are licensed under the MIT license and can be used for commercial purposes.

The LoRaWAN devices are the devices sending data to the ChirpStack Network Server (through one or multiple LoRa Gateways). These devices could be for example sensors measuring air quality, temperature, humidity, location. A LoRa Gateway listens to (usually) 8 or more channels simultaneously and forwards received data (from devices) to a LoRaWAN network-server (in this case the ChirpStack Network Server). The software running on the LoRa Gateway responsible for receiving and sending is called a Packet Forwarder.

The ChirpStack Network Server is a LoRaWAN Network Server, responsible for managing the state of the network. It has knowledge of device activations on the network and is able to handle join-requests when devices want to join the network.

GRAFANA

Grafana is a multi-platform open source analytics and interactive visualization web application. It provides charts, graphs, and alerts for the web when connected to supported data sources. It is expandable through a plug-in system. End users can create complex monitoring dashboards using interactive query builders. As a visualization tool, Grafana is a popular component in monitoring stacks, often used in combination with time series databases. The graphical representation of the collected sensor data is to be plotted and observed in this platform.

4.2.4 NETWORK IMPLEMENTATION

There are mainly two networks in the proposed system: one is in local environments—LPWAN including the WBAN, and the other one is the IoT network connecting to the cloud. As mentioned previously, the data from the Health Node and Safe Node will be transmitted to the IoT gateway and then finally to the cloud server. MQTT (message queuing telemetry transport) can be used in our IoT network system to transfer the information between the gateway and the cloud server.

4.3 HEALTH NODE

The Health Node consists of a signal processing board for data processing and a sensor board for the measurements of HR and body temperature. The schematic of the health node is given in Fig 4.3.1.

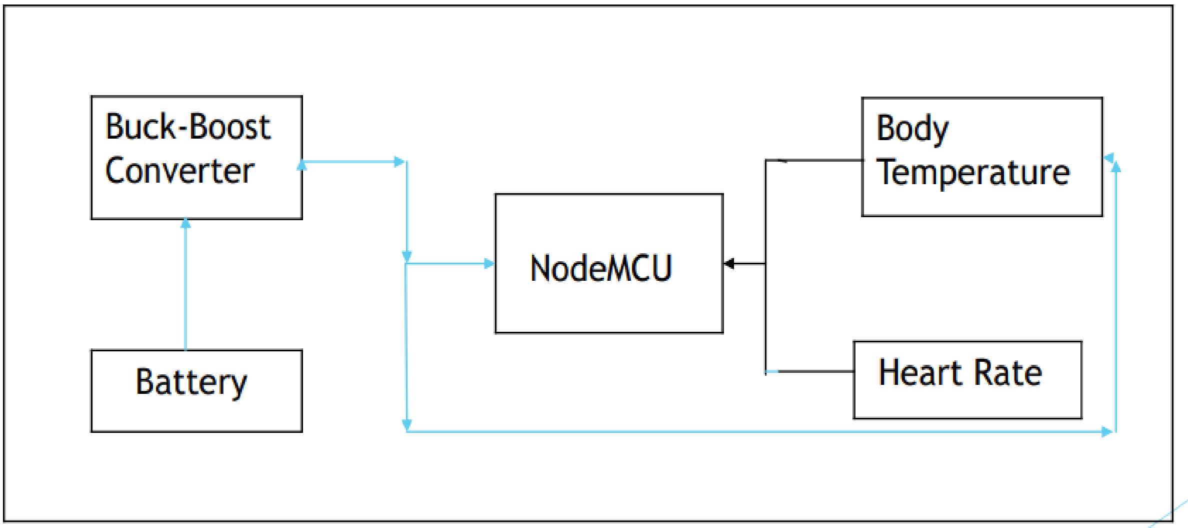

Fig 4.3.1 Schematic of health node

The master board of the Health Node is designed for signal processing, data transmission, and power management. It uses the same MCU as the Safe Node, which will collect and process the signals from the sensor board. The calculated HR and body temperature will be sent to the Safe Node within the WBAN by MCU. All the environmental and physiological data are transmitted to the gateway of the LPWAN by LoRa, which will be stored and analyzed on the cloud.

4.3.1 PHYSIOLOGICAL SENSORS

The PPG sensor will be implemented with a green LED (AM2520ZGC09 from Kingbright, Taipei, Taiwan) and a surface-mounted photodiode (APDS9008 from Avago, San Jose, CA, USA). The PPG uses a green LED as it is relatively less affected by motion artifacts compared with other light. The original signal from the photodiode (PD) will be pre-processed by an active low-pass filter and amplifier on the back side of the sensor board. LM35 is a temperature measuring device having an analog output voltage proportional to the temperature. It provides output voltage in Centigrade (Celsius). It does not require any external calibration circuitry.

4.4 SAFE NODE

The Safe Node is designed to be comprising of a power management unit (PMU), environmental sensors, a microcontroller (MCU) and a long-range RF module (LoRa). The sensor node from the work is imported and used as the main shield for LoRa and sensors. The sensor node from the work is used as the main MCU. Two boards will be joined together using flexible wires by connecting the Vcc (3.3 V), Ground (GND), Inter-integrated Circuit (I2C) interface and Serial Peripheral Interface (SPI) interface. The safe node schematic is shown in Fig 4.4.1.

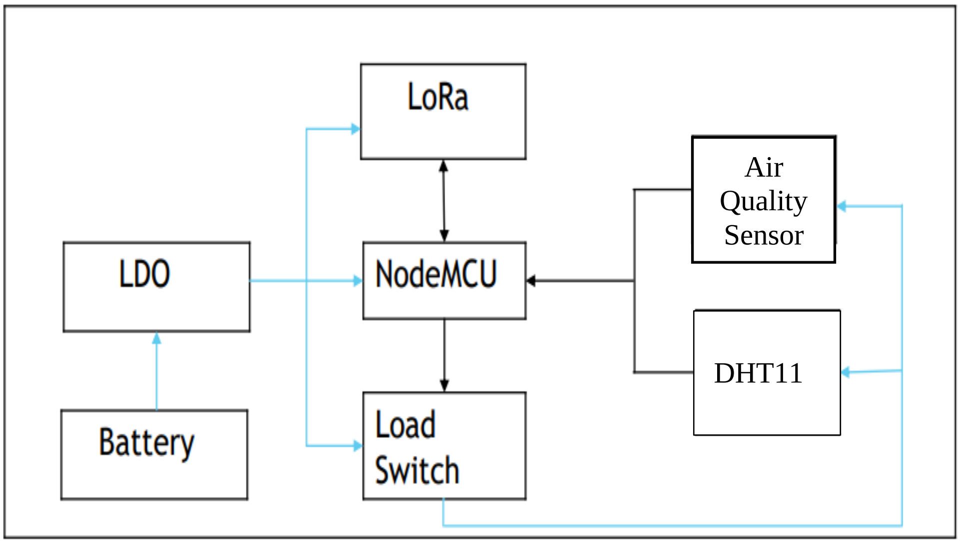

Fig 4.4.1 Schematic of safe node

4.4.1 ENVIRONMENTAL SENSORS

The DHT11 is a basic, ultra-low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It’s fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds, so when using our library, sensor readings can be up to 2 seconds old. For air quality check, Air quality sensor, MQ135 will be used. It can detect a wide range of gases, including NH3, NOx, alcohol, benzene, smoke and CO2. MQ135 gas sensor has high sensitivity to Ammonia, Sulfide and Benzene steam, also sensitive to smoke and other harmful gases.

CHAPTER 5

SYSTEM HARDWARE

SENSORS

5.1 SAFE NODE

ENVIRONMENTAL SENSORS

5.1.1 MQ135

MQ135-Air quality sensor is used for detecting a wide range of gases, including NH3, NOx, alcohol, benzene, smoke and CO2. Its low cost and efficient detection makes it suitable for Air quality monitoring application.

It has high sensitivity to poisonous gases. It has a stable and long life so that it can be used for long term applications with less maintenance. In this project we have used it as an Industrial air pollution detector.

The air quality sensor is a signal output indicator instrument. It has two outputs: analog output and TTL output. The TTL output is low signal light which can be accessed through the IO ports on the Microcontroller. The analog output is concentration, i.e. increasing voltage is directly proportional to increasing concentration. It is a simple drive circuit.

5.1.2 DHT11

DHT11 is a low-cost digital sensor for sensing temperature and humidity. Here, we have interfaced this sensor with NodeMCU to obtain the temperature and humidity in an industrial atmosphere. DHT11 is a relative humidity sensor. To measure the surrounding air this sensor uses a thermistor and a capacitive humidity sensor.

DHT11 sensor consists of a capacitive humidity sensing element and a thermistor for sensing temperature. The humidity sensing capacitor has two electrodes with a moisture holding substrate as a dielectric between them. Change in the capacitance value occurs with the change in humidity levels. The IC measures and process this changed resistance values and change them into digital form.

For measuring temperature this sensor uses a Negative Temperature coefficient thermistor, which causes a decrease in its resistance value with increase in temperature. To get larger resistance value even for the smallest change in temperature, this sensor is usually made up of semiconductor ceramics or polymers.

The temperature range of DHT11 is from 0 to 50 degree Celsius with a 2-degree accuracy. Humidity range of this sensor is from 20 to 80% with 5% accuracy. The sampling rate of this sensor is 1Hz.i.e. it gives one reading for every second. DHT11 is small in size with operating voltage from 3 to 5 volts. The maximum current used while measuring is 2.5mA.

DHT11 sensor has four pins- VCC, GND, Data Pin and a not-connected pin. A pull-up resistor of 5k to 10k ohms is provided for communication between sensor and NodeMCU.

5.2 HEALTH NODE

PHYSIOLOGICAL SENSORS

5.2.1 PULSE RATE SENSOR

Pulse Sensor is a well-designed plug-and-play heart-rate sensor. The sensor clips onto a fingertip or earlobe and plugs right into NodeMCU.

The front of the sensor has a Heart logo. This is the side that makes contact with the skin. On the front you see a small round hole, which is where the LED shines through from the back, and there is also a little square just under the LED. The square is an ambient light sensor. The LED shines light into the fingertip or earlobe, or other capillary tissue, and sensor reads the light that bounces back. The back of the sensor is where the rest of the parts are mounted.
The Pulse Rate Sensor connections are as follows:

- Signal(S) to A0
- Vcc (+) to 5V
- Gnd (-) to Gnd

5.2.2 LM35

LM35 is an integrated analog temperature sensor whose electrical output is proportional to Degree Centigrade. LM35 Sensor does not require any external calibration or trimming to provide typical accuracies. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry convenient.

LM35 is linear i.e. 10mv/°C which means for every degree rise in temperature the output of LM35 will rise by 10mv. So, if the output of LM35 is 220mv/0.22V the temperature will be 22°C. So, if room temperature is 32°C then the output of LM35 will be 320mv i.e. 0.32V. It is suitable for remote applications and hence, it is suitable for industrial applications.

CHAPTER 6

IMPLEMENTATION

6.1 SYSTEM SOFTWARE

THINGSPEAK

ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud. You can send data to ThingSpeak from your devices, create instant visualization of live data, and send alerts. Send sensor data privately to the cloud. Analyze and visualize your data with MATLAB. Trigger a reaction. ThingSpeak is open source platform made for Internet of Things (IoT) device developers and learners where developers can send and log data to the server, analyze, retrieve and store results using graphs with MATLAB support.

Fig 6.1.1 Data Representation in ThingSpeak Dashboard

API stands for "Application programming Interface", on ThingSpeak it is a string of random character containing alphabets of lower and upper case, numbers and even special characters to identify your account and ensures that your sent data doesn't end on someone else's account and vice-versa. There are two API keys generated while creating an account; one is called **read**

API key and another is called **write API key**. We will be using only the write API key as we are going to write data to the ThingSpeak.

6.2 ARCHITECTURE

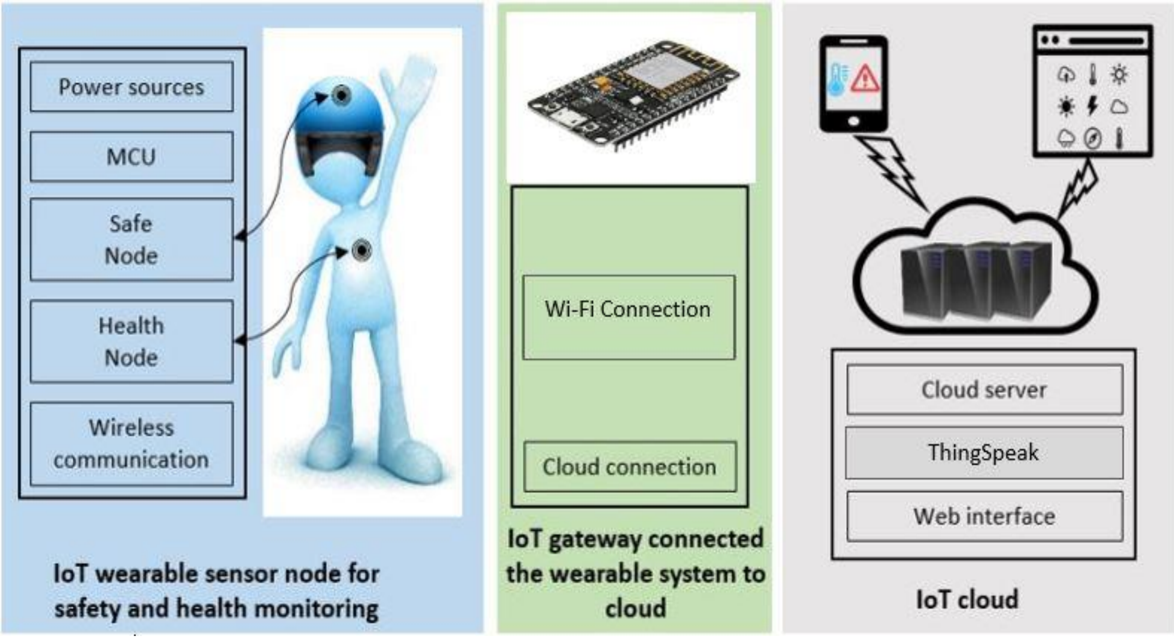

Fig 6.2.1 Implemented Architecture

The physiological data of the worker is collected using the pulse rate sensor and the temperature sensor at the health node. The environmental data is collected using the air quality sensor and the temperature and humidity sensor at the safe node.

Now the ThingSpeak communication library is installed in the Arduino software. A separate ThingSpeak channel is created and configured channel ID and write API key. Using the ThingSpeak write fields (channel ID, write API keys), the data is send to ThingSpeak. An alarm is set to indicate when the collected sensor data exceeds the threshold.

CHAPTER 7

RESULTS

Fig 7.1.1 Sensor Characteristics

Health node and Safe node were implemented by interfacing the respective sensors with the NodeMCUs. One of the main aims of this research work is to make the real-time data available to authentic users anywhere in the world. This is possible using a cloud platform which can store the real-time data readings. These data points can be used for further processing and visualization. For this purpose, ThingSpeak is chosen due to its ease of use and user-friendly interface. The recorded data by the sensors is further up-loaded to the ThingSpeak. It is stored and retrieved over HTTP which works on the basis of a request and response system. The client makes a request and the server has to respond accordingly. In ThingSpeak, the data can be stored either in a private or a public channel but by default, it is stored in the private channel. The data sent by the sensors through an HTTP request is processed by the IOT service in ThingSpeak which communicates with a virtual server. The server and the IOT service communicate directly with the application. Different ThingSpeak channels have been used for the respective sensors. Fig.7.1.1 shows the variation in sensor values with time. The Graphs are plotted in ThingSpeak according to the sensor data received and an alarm is created in the ThingSpeak interface dashboard to notify any rise in sensor value above the preset threshold level.

CHAPTER 8

BUDGET

ITEM	MODEL	NO OF UNITS	PRICE PER UNIT
Air Quality Sensor	MQ135	2	200
Pulse Rate Sensor		2	200
Temperature and Humidity Sensor	DHT11	2	150
Body Temperature Sensor	LM35	2	100
NodeMCU	ESP8266	4	400
Lora Module	SX1278	2	600
Analog Extender	ADS1115	2	300
Rechargeable Battery	Lithium-ion	2	500
Helmet		2	600
Gloves		4	100
LDO	SGM2019	2	20
Load Switch		2	30
TOTAL			**7400**

CONCLUSION

This report presents the design of an IoT augmented Health Monitoring System for Industrial Workers. It comprises a WBAN for short-range wireless communication and an LPWAN for long-distance data transmission. Two sensor nodes, the Safe Node and Health Node, are designed to be deployed in the WBAN to collect the environmental and physiological data of the subject respectively, which will be further sent to an IoT gateway via the LPWAN infrastructure. The gateway (local server) is designed to perform functions including receiving sensor signals, processing raw data, real-time display, emergency notification, as well as sending data to the Internet cloud server. The safe node is to be attached to the safety helmet of the workers and health node on their working gloves, so that their data can be constantly obtained without any interference. By using the LoRaWAN technology, the data of large number of workers in an industry can be monitored simultaneously. By monitoring the workers' conditions (both environmental and physiological), it will be possible to alert them about critical situations.

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APPENDIX

NODEMCU CODE

```
#include <ThingSpeak.h>
#include <ESP8266WiFi.h>

//dht11
#include <dht.h>
dht DHT;
#define DHT11_PIN 2


//MQ135
#include "MQ135.h"
#define ANALOGPIN A0    //  Define Analog PIN on Arduino Board
#define RZERO 178.64    //  Define RZERO Calibration Value
MQ135 gasSensor = MQ135(ANALOGPIN);


// Network parameters
const char* ssid     = "ES_1279";
const char* password = "";


// ThingSpeak information
char thingSpeakAddress[] = "api.thingspeak.com";
unsigned long channelID = 1039140;
char* readAPIKey = "RKFJF5VKCAK5DD3W";
char* writeAPIKey = "HVHSRQ90BNE1G7PU";


const unsigned long postingInterval = 120L * 1000L;

//Fields declaration
unsigned int dataFieldOne = 1;                          // Field to write temperature data
unsigned int dataFieldTwo = 2;                       // Field to write temperature data
unsigned int dataFieldThree = 3;
```

```
//Fields for calliberation
unsigned int aField = 6;                    //Field to hold first constant of the thermistor calibration
unsigned int bField = 7;                    //Field to hold second constant of the thermistor calibration
unsigned int cField = 8;                    //Field to hold third constant of the thermistor calibration


// Global variables
// These constants are device specific.  You need to get them from the manufacturer or determine
      them yourself.
float aConst = 2.25E-02;
float bConst = -0.003422894649;
float cConst = 0.00001518485044;

unsigned long lastConnectionTime = 0;
long lastUpdateTime = 0;
WiFiClient client;


void setup() {


  Serial.begin(115200);


  //setup for Mq135
  float rzero = gasSensor.getRZero();
  Serial.print("MQ135 RZERO Calibration Value : ");
  Serial.println(rzero);




  //setup for WiFi Connection
  Serial.println("Start");
  WiFi.begin(ssid, password);           // connects to the WiFi router
  while (WiFi.status() != WL_CONNECTED)
  {
    Serial.print(".");
    delay(500);
  }
  Serial.println( "Connected" );
```

```
  ThingSpeak.begin( client );



  // Read the constants at startup.
  aConst = readTSData( channelID, aField );
  bConst = readTSData( channelID, bField );
  cConst = readTSData( channelID, cField );
}

void loop()
{

    //declaration of dht11 variables
    float chk = DHT.read11(DHT11_PIN);
    float temp = DHT.temperature;
    float humid = DHT.humidity;


    //dht11 values on Serial monitor
    Serial.print("Temperature = ");
    Serial.print(temp);
    Serial.print("\nHumidity = ");
    Serial.print(humid);


    //declaration of mq135 variable
    float ppm = gasSensor.getPPM()*10;


    //mq135 values on Serial monitor
    Serial.print("CO2 ppm value : ");
    Serial.println(ppm);


    //writing sensor data to thingspeak
    write2TSData( channelID , dataFieldOne , temp , dataFieldTwo , humid , dataFieldThree , ppm
       );

}
```

```
//function for reading sensor data
float readTSData( long TSChannel,unsigned int TSField )
{

  float data =  ThingSpeak.readFloatField( TSChannel, TSField, readAPIKey );
  Serial.println( " Data read from ThingSpeak: " + String( data, 9 ) );
  return data;

}



// function for writing sensor data
  int writeTSData( long TSChannel, unsigned int TSField, float data )
  {
  int  writeSuccess = ThingSpeak.writeField( TSChannel, TSField, data, writeAPIKey ); // Write the
          data to the channel
  if ( writeSuccess ){

    Serial.println( String(data) + " written to Thingspeak." );
    }

    return writeSuccess;
  }


// Use this function if you want to write multiple fields simultaneously.
int write2TSData( long TSChannel, unsigned int TSField1, float field1Data, unsigned int TSField2,
          long field2Data, unsigned int TSField3, long field3Data){

  ThingSpeak.setField( TSField1, field1Data );
  ThingSpeak.setField( TSField2, field2Data );
  ThingSpeak.setField( TSField3, field3Data );

  int writeSuccess = ThingSpeak.writeFields( TSChannel, writeAPIKey );
  return writeSuccess;
}
```