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# Wearable Sensor Network System for Safety and Healthy Applications in Industrial Workplace

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## ABSTRACT

In this paper, we develop 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 can greatly improve the safety in the workplace. The proposed 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 Wi-Fi network which forms a heterogeneous IoT platform with Bluetooth-based medical signal sensing network. Once harmful environments are detected, the sensor node will provide an effective notification and warning mechanism for the users. The data from the sensors can be processed, analyzed and stored in the cloud and all the data is transferred with the help of Wi-Fi.

**Keywords :** Wearable Sensor Network, Wi-Fi, BLE, Wearable Body Area Network (WBAN).

## I. INTRODUCTION

Internet of things (IoT) has become a promising technological paradigm and attracted many research interests in recent years. It is predicted that there will be 26 to 50 billion Internets connected devices by 2020 and 100 billion by 2030 [3]. IoT can enhance performance of wireless sensor networks (WSNs) especially in environmental monitoring and healthcare applications. With the exposure of IoT, users can easily view the real-time environmental and physiological data from web-browser or mobile applications sitting anywhere and at anytime. 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 [4][8], for example, a wrist worn wearable system for photoplethysmogram (PPG) monitoring [5][7], a WBAN with motion and electrocardiogram (ECG) sensors for rehabilitation [12], and an edged-based WBAN healthcare monitoring system with heart rate monitoring [1]. Apart from healthcare applications like monitoring body temperature, humidity, heart rate WBANs have also been used to monitor environmental conditions. .For instance, the work [2] monitors temperature, humidity, and ultraviolet (UV) for safety applications Safety is very important for industrial workplace, especially for workers constantly switching working environments between indoor and outdoor. 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.

In addition to UV, carbon dioxide (CO2), smoke, CO, and Volatile organic compounds (VOC) are some commonly indoor pollutants [13]. Symptoms of CO2 poisoning, such as hearing loss, headache and rapid pulse rate, may happen to some occupants when the CO2 level is above 600 ppm [11]. Therefore, it is essential to have a WSN system to monitor both UV and CO2 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

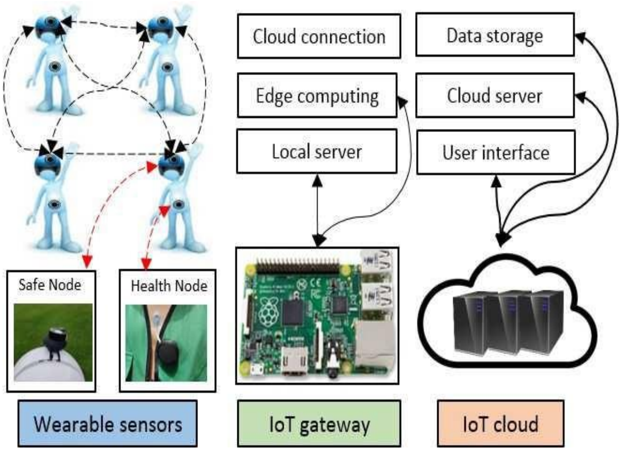


Figure 1 Block Diagram of Proposed Product

works. Among different wearable environmental monitoring applications.

## II. LITERATURE REVIEW

Any devices that can be worn on the body are wearable computers. There is no precise definition of wearable computers, but they can be defined by their perceptible characteristics [9]. Rhodes in 1997 and Hendrik Witt in 2008 explained wearable computers by describing many of their properties, for instance portability, limited capability, context awareness, operational constancy, and handsfree or limited use of hands [10]. In 2014, Genaro Motti et al. gave a simple definition of wearable sensors as body-worn devices, such as clothing and accessories, that integrate computational capabilities to provide specific features to users [9]. The term wearable, as well as the terms wearable technology and wearable devices, is indicative of consumer electronics technology that is based on embedded computer hardware that is built into products that are worn on the outside of one's body [6]. The first report on wearable computer was written by Thad Starner in 1995 and was called "The Cyborgs are Coming". His perturbation was with wearable computer interfaces, and he recognized two main characteristics: persistence and constancy [9]. Endurance describes the permanent availability of wearable computers and the ability to use them while simultaneously performing other tasks. Reliability describes how one wearable computer can be used in every situation. In 1998, Professor Kevin Warwick implemented a sensor embedded in the median nerves of his left arm [8]. This task has been applied to controlling a wheelchair and an artificial hand by measuring transmitted signal and creating artificial sensors through electrodes on the arm.

## III. METHODOLOGY

The wearable sensor network is based on Wi-Fi network. Each Safe Node is able to communicate with each other via Wi-Fi. Wi-Fi network is based on a star network topology, which means data is transmitted from point to point. If the data is not addressed and encrypted, it can be received and seen by all the Wi-Fi node in the same region with same specifications. To improve the security and privacy of the network, data encryption is embedded before each packet transmission.

### *A. Safe Node*

The block diagram of the Safe Node is shown in Figure 2.

Each Safe Node has a power management unit, one NodeMCU ESP8266, a Wi-Fi module, and four environmental sensors viz carbon component sensor (MQ-7), UV Index sensor (ML8511) and DHT11 which is both humidity and temperature sensor. The Safe Node is powered by the power bank. The safe node will be having BLE function with the help of HC05.

The Wi-Fi is responsible for transmission long range data from the BAN to the remote gateway. The BLE receives the data from the Health Node that is attached to the wrist.

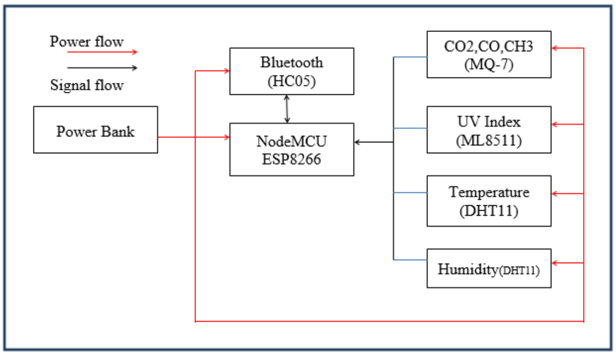


Figure 2 Block Diagram of Safe Node

### *B. Health Node*

Figure 3 presents the block diagram of the Health Node. The Health Node comprises a power management unit, an Arduino Nano, HC05 for Bluetooth connectivity and two physiological sensors. The health node is powered by power bank. Body temperature sensor (LM35) and heart rate sensor (PPG) are connected to the Arduino by flexible wires. Both of the health parameters will be transmitted to the Safe Node via the BLE network (WBAN).

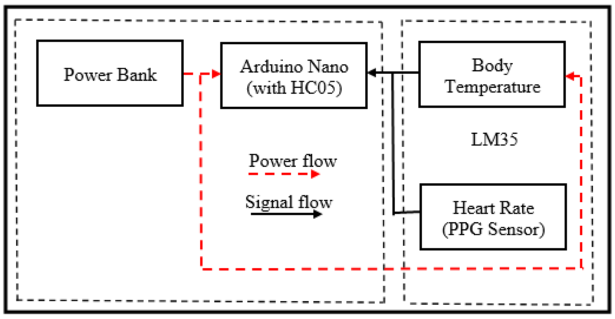


Figure 3 Block Diagram of Health Node

### *C. Cloud Implementation*

ThingSpeak is an IoT analytics platform service that allows you to collect, visualize and analyze live data streams in the cloud. ThingSpeak provides abrupt visualizations of data posted by your devices to ThingSpeak. With the ability to execute MATLAB code in ThingSpeak we can perform online analysis and processing of the data as it comes in. ThingSpeak is usually used for prototyping and proof of concept IoT systems that require analytics. ThingSpeak provides access to MATLAB to help us make sense of data. We can: i) Convert, combine, and calculate new data. ii) Schedule calculations to run at certain times. iii) Visually understand relationships in data using built-in plotting functions. iv) Combine data from multiple channels to build a more sophisticated analysis.

The NodeMCU of the safe node is programmed to send the data to the ThingSpeak channel where it allows to aggregate, visualize and analyse live data streams in the cloud. The transfer of data to the ThingSpeak with the help of Wi-Fi.

## IV. EXPERIMENTAL RESULTS

The experimental results show how the data obtained from the sensors is represented in the form of graph. The images of how the nodes look is also shown below.

*A. Wearable Health Node*

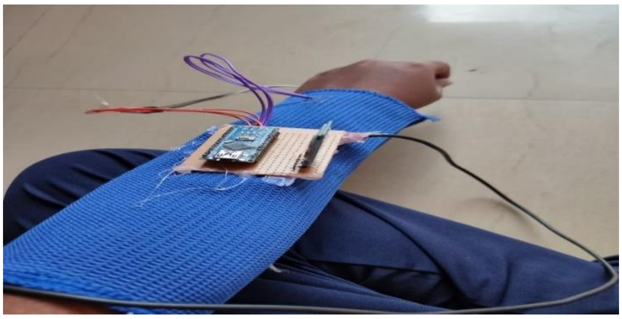

Figure 4 Wearable Health Node

The Health Node comprises a power management unit, an Arduino Nano, HC-05 for Bluetooth connectivity and two physiological sensors. Body temperature sensor (LM35) and heart rate sensor (PPG) are connected to the Arduino by flexible wires. Both of the health parameters will be transmitted to the Safe Node via the BLE network (WBAN).

*B. Wearable Safe Node*

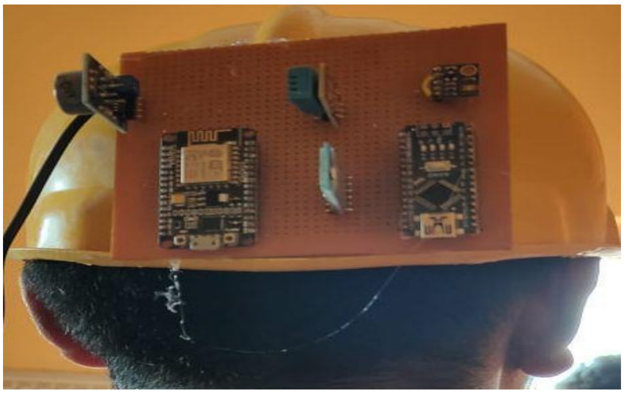

Figure 5 Wearable Safe Node

Each Safe Node has a power management unit, one NodeMCU, a Wi-Fi module, and four environmental sensors. The Safe Node is powered by a power bank. The safe node will be having BLE function with the help of HC-05. The Wi-Fi is responsible for transmission long range data from the BAN to the remote gateway. The BLE receives the data from the health node that is attached to the hand.

*C. Sensors' performance*

The Safe Node is attached to the helmet while the Health Node is attached to the subject's hand. The red curve indicates that the subject is outdoors and the blue line represents indoors. It can be clearly seen that, when the subject is outdoors, the ambient temperature and UV are higher than indoors. Because warmer temperature can absorb more moisture, relative humidity is lower when the subject is indoors. For CO2 concentration, it is higher in indoors as compared to outdoors. There are some fluctuating of UV index reading, which is due to the tree shades when the subject is walking around.

Body temperature and heart rate data is also presented is shown in the Figure 6. Body temperature keeps increasing except when the subject is indoors from just below 34 °C to approximately 37 °C. This is because when the subject is outdoors, the body temperature sensor is heated by the direct sunlight. The subject's heart rate reading is fluctuating around 100 bpm.

*D. Test data*

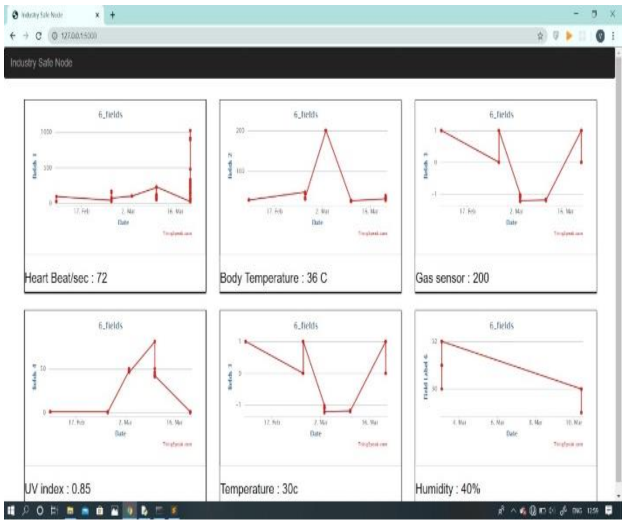


Figure 6 Real-time Monitoring of Sensor Data

The output of the results observed is very accurate when compared with the real word values.

The sensor data taken from the sensors network is in real-time and the data is persistent and can be used for future medical analysis of the health of the worker.

When the particular parameters cross the threshold values set, the notification will be sent to the system operator/supervisor via ThingSpeak so that he can monitor the health and look after the situation that would cause harm to the workers and the workplace.

## V. CONCLUSION

In this paper, we develop a wearable sensor network system for connected health and safety applications for industrial workplace. The system is able to monitor both physiological and environmental data forming a network from wearable sensors attached to workers' body and provide valuable information to the system operator/supervisor and workers for safety and health monitoring. Aspects such as sensor node hardware and software design, gateway and cloud implementation are used. A smart phone-based IoT gateway can be developed to reduce the dependency.

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