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CLOUD-INTEGRATED WEARABLE SENSOR NETWORK SYSTEM FOR REAL-TIME DATA ANALYSIS

Dr. P.SHEKAR BABU, *Associate Professor &HOD, Dept of ECE,*
SAI SPURTHY INSTITUTE OF TECHNOLOGY(AUTONOMOUS),SATHUPALLY,KHAMMAM.

ABSTRACT: An IoT-enabled system of ubiquitous sensors for health and safety monitoring is detailed in this research. Protecting workers' well-being is of the utmost importance in industrial settings. That is why it is possible to greatly enhance workplace safety standards by setting up an IoT network architecture to track physiological and environmental variables. In order to track physiological and environmental variables, the suggested network system incorporates a number of wearable sensors. A number of people are linking their wearable sensors via Bluetooth in order to create an Internet of Things platform that includes various gadgets. A LoRa network facilitates communication and data exchange among these sensors. When a potentially dangerous situation is detected, the sensor node will quickly alert and provide advice to the users. In order to facilitate data processing, cloud connectivity, and local web server capabilities, an intelligent IoT gateway is set up. The data collected by the wearable sensors will be transmitted to an IoT cloud by the gateway, where it will be analyzed, stored, and displayed.

Keywords:Wearable sensors; LoRa; Connected health;Safety; BAN.*

I. INTRODUCTION

The IoT is a cutting-edge and ever-changing field of technology, and researchers are eager to learn more about it. The number of devices with internet access is predicted to reach 26–50 billion by 2020. Experts predict the number would rise to 100–200 billion by 2030. In several industries, including healthcare and environmental monitoring, wireless sensor networks (WSNs) might be made more effective with the help of the Internet of Things (IoT). Thanks to the IoT, people can easily and continuously track their vital signs and environmental data from any place using a mobile app or web browser.

A photoplethysmogram (PPG) monitor can be worn on the wrist. A WBAN with mobility and electrocardiogram (ECG) sensors for rehabilitation can also do this, as can an edge-based WBAN healthcare monitoring system with heart rate monitoring . A common use for wireless body area networks (WBANs) is the monitoring of physiological data in healthcare settings. By enhancing people's quality of life, these networks hope to improve their health and fitness. In addition to its use in healthcare, WBANs have found application in environmental monitoring. To keep everyone safe, it's part of the job to keep an eye on things like humidity, temperature, and UV levels.

A sensor network for building condition monitoring is created by the writers. Studies examining the tracking of physiological and environmental data are few and far between. Consistently tracking a person's vitals and environmental factors can help spot long-term health problems including chronic lung difficulties.

Particularly for workers who move freely between indoor and outdoor spaces, workplace safety must be a top priority at all times. When people spend time outside, they expose themselves to harmful levels of ultraviolet (UV), ozone, carbon monoxide (CO), and particulate matter (PM). According to reference [10], most Australians are aware that prolonged exposure to the sun causes skin cancer. It is the UV portion of sunlight that poses a threat. Skin cancer can be caused by prolonged exposure to UV levels of 3. In addition, UV rays might harm your eyes.

Carbon dioxide (CO2), cigarette smoke, carbon monoxide (CO), volatile organic compounds (VOCs), and ultraviolet radiation (UV) are the most common indoor contaminants. When atmospheric CO_2 levels above 600 ppm, people may confront symptoms such as hearing loss, disorientation, and rapid heartbeat. Signs of carbon dioxide poisoning include all of these. To keep tabs on industrial levels of UV and CO2, a wireless sensor network (WSN) gadget is needed.

Ensuring worker safety from potential threats is just as important as monitoring physiological data. When it comes to medical monitoring with WBAN, the two most investigated parameters are body temperature and pulse rate. Many people use environmental monitoring systems, which usually measure humidity and temperature, for different reasons.

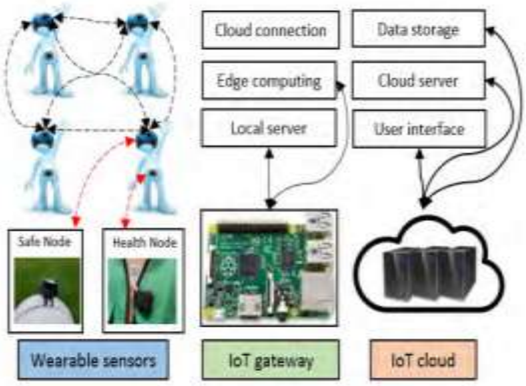

Fig. 1: The architecture of the proposed WBAN.

A variety of Internet of Things (IoT) sensor networks are presented in this research. Several occupational health and safety applications are compatible with their design. You can see the system's setup in Figure 1. The network is made up of a lot of different places where wearable sensors are linked together. There are two nodes for every person.

The first node, called the Safe Node, keeps an eye on environmental variables like humidity, UV radiation, and carbon dioxide levels. One more node, the Health Node, makes up the network. Its primary function is to track vital signs including temperature and heart rate. We use BLE and LoRa, two types of wireless technology, in our research projects. While Bluetooth Low Energy (BLE) can only carry data over relatively small distances, LoRa can cover far wider ground.

A number of devices can be integrated, including the Health Node that communicates over Bluetooth Low Energy (BLE) for short-range and the Safe Node that communicates over LoRa for long-range.

The Internet of Things' data has a limited transmission range. The goals are to improve long-distance data transmission and Internet connectivity. On the flip side, there are specific goals in mind while designing wearable sensors, such as improving communication and encouraging discourse. Building and using an effective Internet of Things gateway makes data administration, storage, and transfer to cloud infrastructure much easier. Both the gateway's local web server and a website located in the cloud make tracked data accessible. Customers will be able to receive emergency alerts on their mobile devices through text message.

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Sections II and III cover the software and hardware configuration, respectively, in this essay. The experimental results are discussed in Section IV. Summary and information about possible future research can be found in Section V of the paper.

II. HARDWARE IMPLEMENTATION

A. Safe Node Implementation

The Safe Node's block configuration is shown in Figure 2(a). For power regulation, each Safe Node has one microcontroller unit (MCU). To measure the surrounding environment, four more sensors and a LoRa module are used. The Safe Node is powered by an energy source and a rechargeable battery.

An integral part of Simblee, the MCU regulates the battery voltage to keep it at 3.3 V.

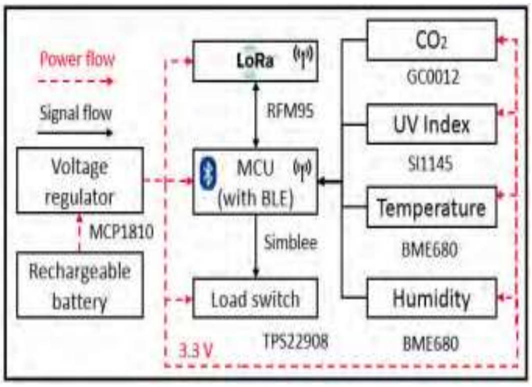
The features of Bluetooth Low Energy (BLE) are quite interesting.

One LoRa module that HoperRF Electronics makes is the RFM95. Even when not in use, a long-range (LoRa) transmitter will not drain its battery. Even while it's sleeping, it only draws 0.2 A. The Long Range Asynchronous Network (LoRa) allows the Body Area Network (BAN) to communicate with a distant gateway via long distances. Data is transmitted to the BLE by the Health Node, which is attached to the body.

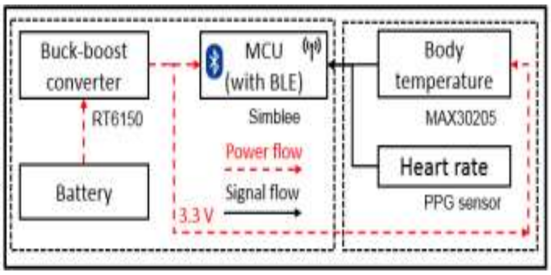
The BME680 measures temperature, the SI1145 measures relative humidity, and the SI1145. During environmental monitoring, the SI1145 also evaluates ultraviolet (UV) radiation. This gas is carbon dioxide, sometimes shortened as CO2. Because of their great accuracy, efficient performance, and low power consumption, these monitors were chosen.

B. Health Node Implementation

The block model's Health Node is shown in Figure 2(b). The Health Node is made up of a power management unit, two physiological monitors, and a SIMPLE microcontroller that is enabled by Bluetooth Low Energy (BLE).



(a) Safe Node



(b) Health Node

Fig. 2: Block diagram of the wearable sensor node.

Fig. 3: Hardware architecture of the gateway

The remaining circuit gets its 3.3 V from an RT6150, which is a low-power buck-boost converter. Flexible cables connect the MAX30205 temperature sensor and the PPG heart rate monitor to the MCU. The Safe Node will receive health data transmitted by the BLE network (WBAN).

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C. Edge Gateway

The hardware of the gateway is assembled, as shown in Figure 3. The WiFi capability is limited to a single Raspberry Pi Model 3.

A power source device is necessary in addition to the modules. Raspbian is the operating system that the Raspberry Pi runs on. It is open-source and anyone can modify it. Java, Node.js, Python, C, and C++ are just a few of the languages that the platform supports. The device can be efficiently powered by a portable battery bank, which only requires 2.5 A and 5 V of electricity.

The gateway can be moved without being tied to the main power supply, according to this. A LoRa receiver is linked to the Raspberry Pi. Connecting to the Safe Nodes and receiving data wirelessly is made possible by this. An extra XBee module can be connected to the Raspberry Pi if you're using an alternate Wi-Fi module like XBee.

III. SOFTWARE IMPLEMENTATION

A. Long Range Wireless Communication

The LoRa network is essential to every wireless network. LoRa lets all Safe Nodes communicate. LoRa networks use stars to transmit data. Any nearby LoRa node that matches the same conditions can access transmitted data without an address or encryption. The network is safer and more private since every file is encrypted before transmission.

1)Mode of Operation: The wearable sensor node, also known as the Safe Node, can function in three separate modes, as shown in Figure 1.

- The Safe Node keeps receiving RF signals even when nothing is happening.
- The Safe Node communicates with the gateway and other Safe Nodes in the area by radio frequency (RF) transmissions when it is in broadcast mode.
- The Safe Node is presently dormant, meaning it is not using much power. The microcontroller unit enters a low-power mode when all sensors and RF modules are turned off.

2) Wearable Communication: The purpose of wearable communication is to quickly notify all on-site staff of potential safety dangers so they may take the necessary steps without having to wait for a message from the gateway.

Class 1 and class 2 radio frequency communications are both within the capabilities of every Safe Node. A Class 1 packet conveys a great deal of environmental information when no harmful conditions are present. The IoT router is the intended recipient of this data transmission. Sending a Class 2 packet alerts the receiver to a possible dangerous circumstance. All subsequent wearable devices and the gateway node are the intended recipients of this signal.

Safe Node software methodology is presented in Figure 5. The low-power sensor node constantly monitors and records its surroundings. The Safe Node enters "inactive mode" and scans the RF channel for messages when turned on. We can distinguish environmentally dangerous RF data from Safe Nodes that emit warning signals using a function that separates RF data. A mobile app will notify the user if the info is hazardous. Unless this happens, the software will sleep and ignore the warning.

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Even without an RF connection, the Safe Node saves sensor data for a defined time. The Internet of Things gateway and all Safe Nodes get Class 2 radio frequency alerts about risky regions. Class 1 Internet of Things gateway packets are sent when no hazard exists.

B. Gateway Software Implementation

Figure 6 shows the software architecture of an IoT gateway for safety and health applications that connects to pervasive sensor networks. The database manager, cloud connectivity, local web server, wireless sensor network data manager, and data processing manager are listed in order. Five sections form the architectural framework.

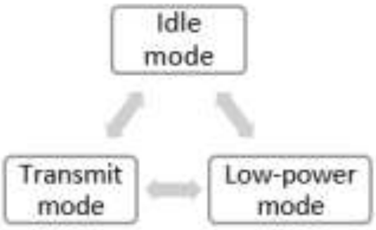

Fig. 4: Modes of operation

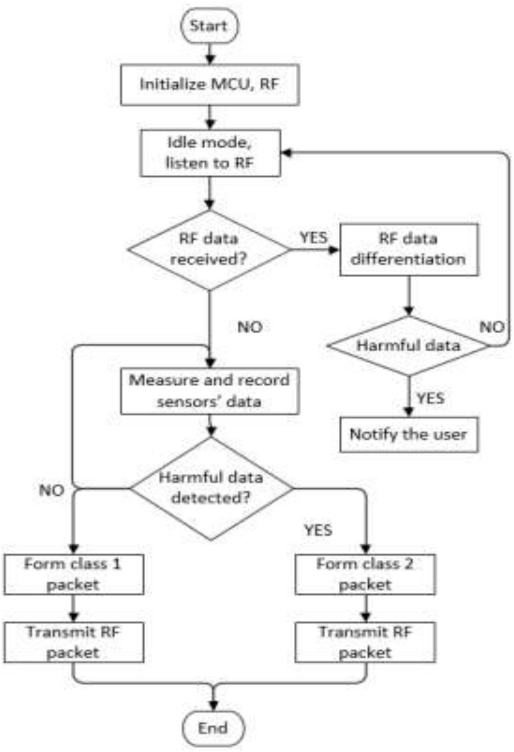

Fig. 5: Safe Node software diagram.

Python applications may establish connections with several wireless modules, including XBee, LoRa, Bluetooth Low Energy, and more.

The app sends and receives data to a DPM using a wearable LoRa network. Among DPM's many critical data processing functions is the transformation of WDM data into useful environmental information. Before saving the data to MySQL, DPM encrypts it to make sure it's secure and private. After that, you can access the information in the local MySQL database and analyze it more thoroughly. A website that shows real-time sensor data is built on a local server using Node.js, HTML, CSS, and JavaScript. The gateway can send information to the cloud using cellular, Wi-Fi, or Ethernet networks.

C. Cloud Implementation

Cloud server hosting is supplied by American company DigitalOcean. The server features 2 GB RAM and 25 GB storage. The OS is Ubuntu 16.04.5. Like the gateway website, a cloud-based website uses Node.js and Node-RED. A cloud server hosts a Mosquitto broker. It links the gateway's MQTT broker to the cloud. The server has a MySQL database for data storage. Users must provide credentials to access server data. Thus, data will be safer and more reliable. The server backs up Ubuntu weekly to protect data.

Fig. 6: Software architecture of the gateway

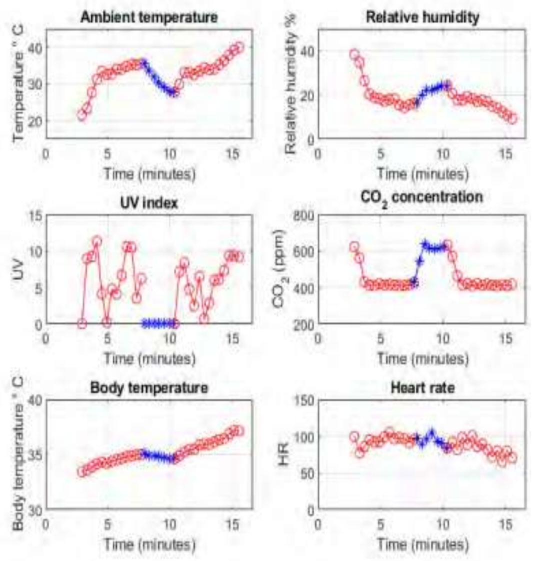

Fig. 7: Real-time measurements for different sensors.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

Sensors' performance

Data collected in real time from a person wearing multiple sensors is shown in Figure 7. The subject's body is connected to the Health Node, while the headgear is linked to the Safe Node. The problem is internal, as shown by the blue line, and external, as shown by the red curve. Indoor and outdoor settings have different temperature ranges and UV levels.

The greater ability of warmer air to retain moisture causes the relative humidity to drop in enclosed spaces. Inside, the CO_2 concentrations are higher than outside. Because trees block some of the sun's rays, the UV index changes as a person moves. In addition to that, the picture shows vitals like heart rate and temperature. In the absence of internal physiological processes, the core temperature of an adult human being rises steadily from 34 to 37 degrees Celsius. The reason behind this is that being in the sun causes your body's temperature regulator to increase. A range of one hundred to two hundred beats per minute was recorded for the subject.

V. CONCLUSION

An IoT network architecture for integrated safety and health applications in an outdoor industrial scenario is detailed in this paper. A network of sensors worn by employees might allow the system to track their physiological and environmental data. In order to keep each other safe, this gives the system operator and the workers vital information. Development of software and hardware for sensor nodes, as well as cloud deployment and gateway design, are all covered in this course. To make the system more versatile and usable in more settings, we plan to add more environmental and physiological sensors to it in the future. Establishing an Internet of Things (IoT) gateway on your smartphone can lessen the need for a fixed gateway.

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