DESIGN AND IMPLEMENTATION

OF A WEARABLE SENSOR NETWORK SYSTEM FOR IOT-CONNECTED SAFETY AND HEALTH APPLICATIONS

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ABOUT THE PAPER

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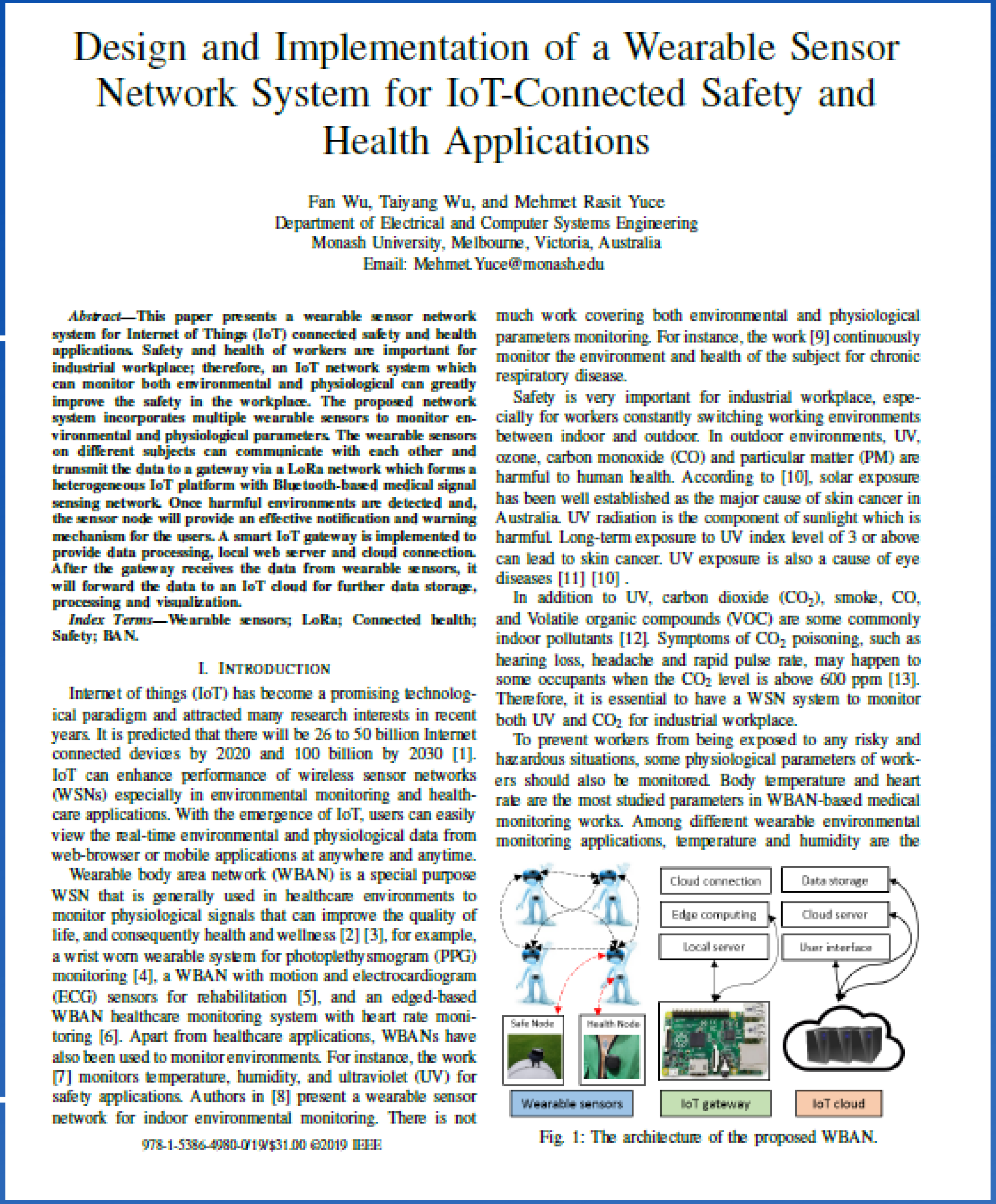

Design and Implementation of a Wearable Sensor Network System for IoT-Connected Safety and Health Applications

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***Abstract*—This paper 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 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 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.**

***Index Terms*—Wearable sensors; LoRa; Connected health; Safety; BAN.**

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 Internet connected devices by 2020 and 100 billion by 2030 [1]. IoT can enhance performance of wireless sensor networks (WSNs) especially in environmental monitoring and healthcare applications. With the emergence of IoT, users can easily view the real-time environmental and physiological data from web-browser or mobile applications at anywhere and 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 [2] [3], for example, a wrist worn wearable system for photoplethysmogram (PPG) monitoring [4], a WBAN with motion and electrocardiogram (ECG) sensors for rehabilitation [5], and an edged-based WBAN healthcare monitoring system with heart rate monitoring [6]. Apart from healthcare applications, WBANs have also been used to monitor environments. For instance, the work [7] monitors temperature, humidity, and ultraviolet (UV) for safety applications. Authors in [8] present a wearable sensor network for indoor environmental monitoring. There is not much work covering both environmental and physiological parameters monitoring. For instance, the work [9] continuously monitor 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 particular matter (PM) are harmful to human health. According to [10], solar exposure has been well established as the major cause of skin cancer in Australia. 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 [11] [10] .

In addition to UV, carbon dioxide (CO_2), smoke, CO, and Volatile organic compounds (VOC) are some commonly indoor pollutants [12]. 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 [13]. 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

Fig. 1: The architecture of the proposed WBAN.

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Presentation Agenda

Overview and Problem Statement.

The architecture of the proposed System.

Hardware Implemenation.

Software Implemenation.

Experimental Results.

Future Work.

1

Overview and Problem Statement

Challenges in Safety and Health Monitoring in industrial Workspaces:

In industrial workplaces, ensuring the safety and health of workers is of paramount importance. However, existing safety monitoring systems often lack the capability to comprehensively address both environmental and physiological factors simultaneously. While wearable sensor networks (WSNs) and Internet of Things (IoT) technologies have shown promise in enhancing safety and health monitoring, there remains a gap in the development of an integrated system that can monitor environmental conditions and physiological parameters concurrently.

Proposed Solution: IoT-Connected Wearable Sensor Network

The presented research aims to design and implement a wearable sensor network system that leverages IoT connectivity to monitor both environmental and physiological parameters. This system seeks to create a seamless integration of wearable sensors capable of communicating with each other and transmitting data to a central gateway. The data collected from these sensors will be processed, stored, and visualized in real-time through an IoT cloud platform.

The ultimate goal is to provide a comprehensive safety and health monitoring solution that can promptly detect hazardous conditions, thereby enabling timely interventions and notifications to safeguard workers' well-being.

2

The architecture of the proposed System

- Wearable Network
- IoT Gateway
- IoT Cloud

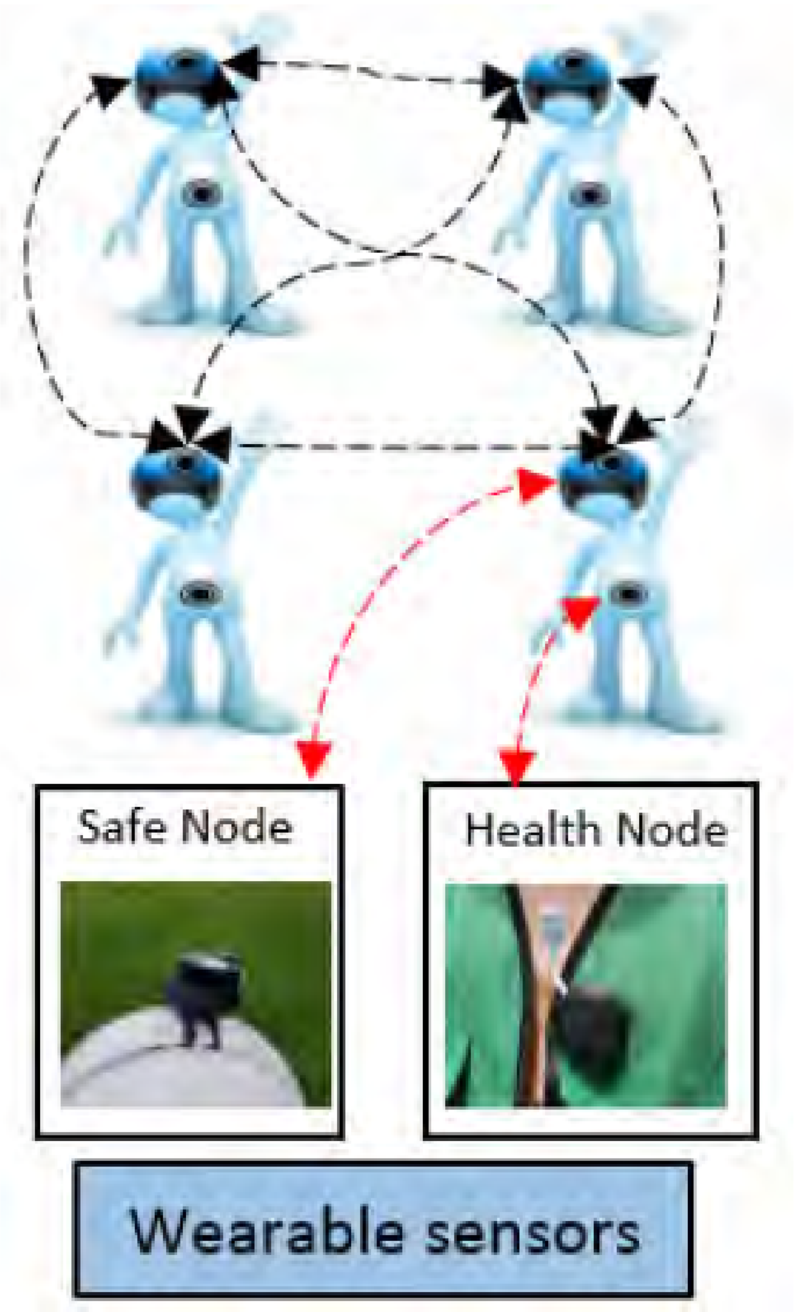
WEARABLE NETWORK

The system architecture incorporates multiple wearable sensor nodes that enable communication between individuals and their surroundings. Each participant is equipped with two nodes:

🌟**Safe Node:** for monitoring environmental conditions (ambient temperature, humidity, UV, and CO_2).

🌟**Health Node:** for tracking physiological signals (body temperature and heart rate).

The architecture employs Bluetooth Low Energy (BLE) for short-range data transmission and Long-Range (LoRa) technology for extended-range connectivity, forming a heterogeneous network.

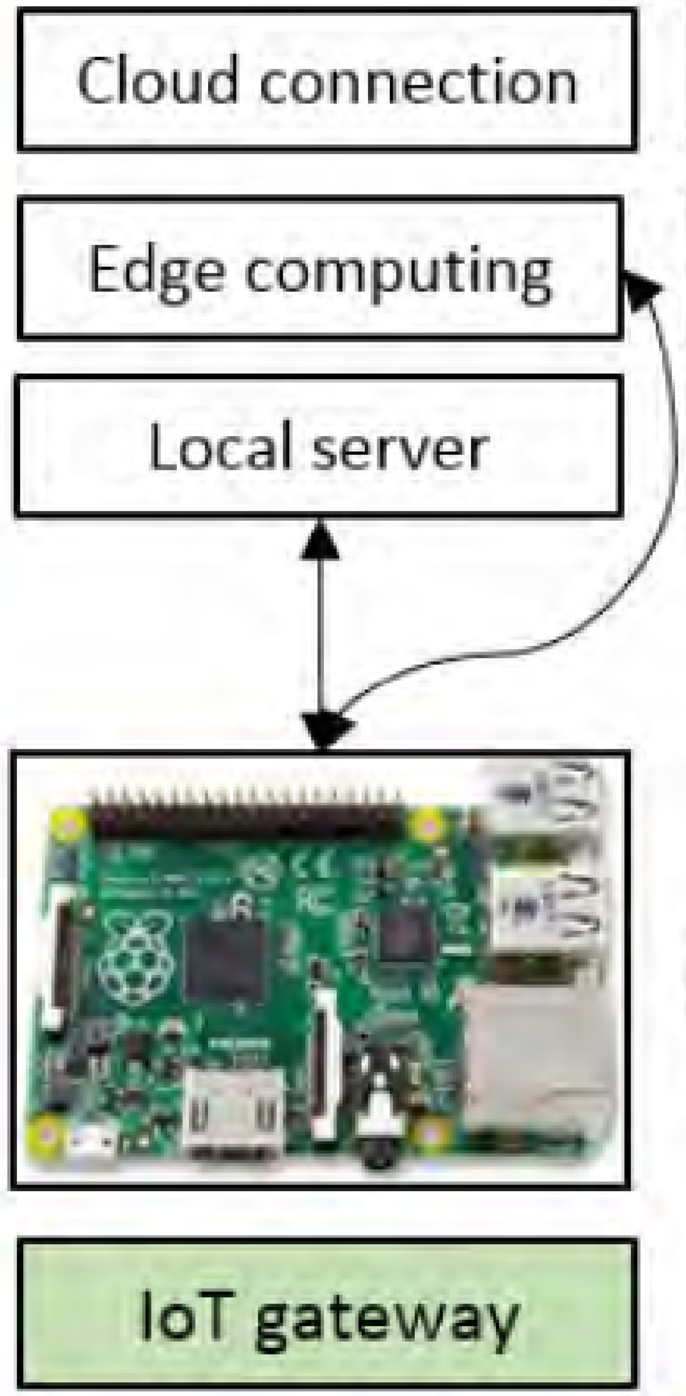


IOT GATEWAY

The IoT gateway serves as an intermediary between the wearable sensor nodes and the cloud server. Its primary purpose is to :

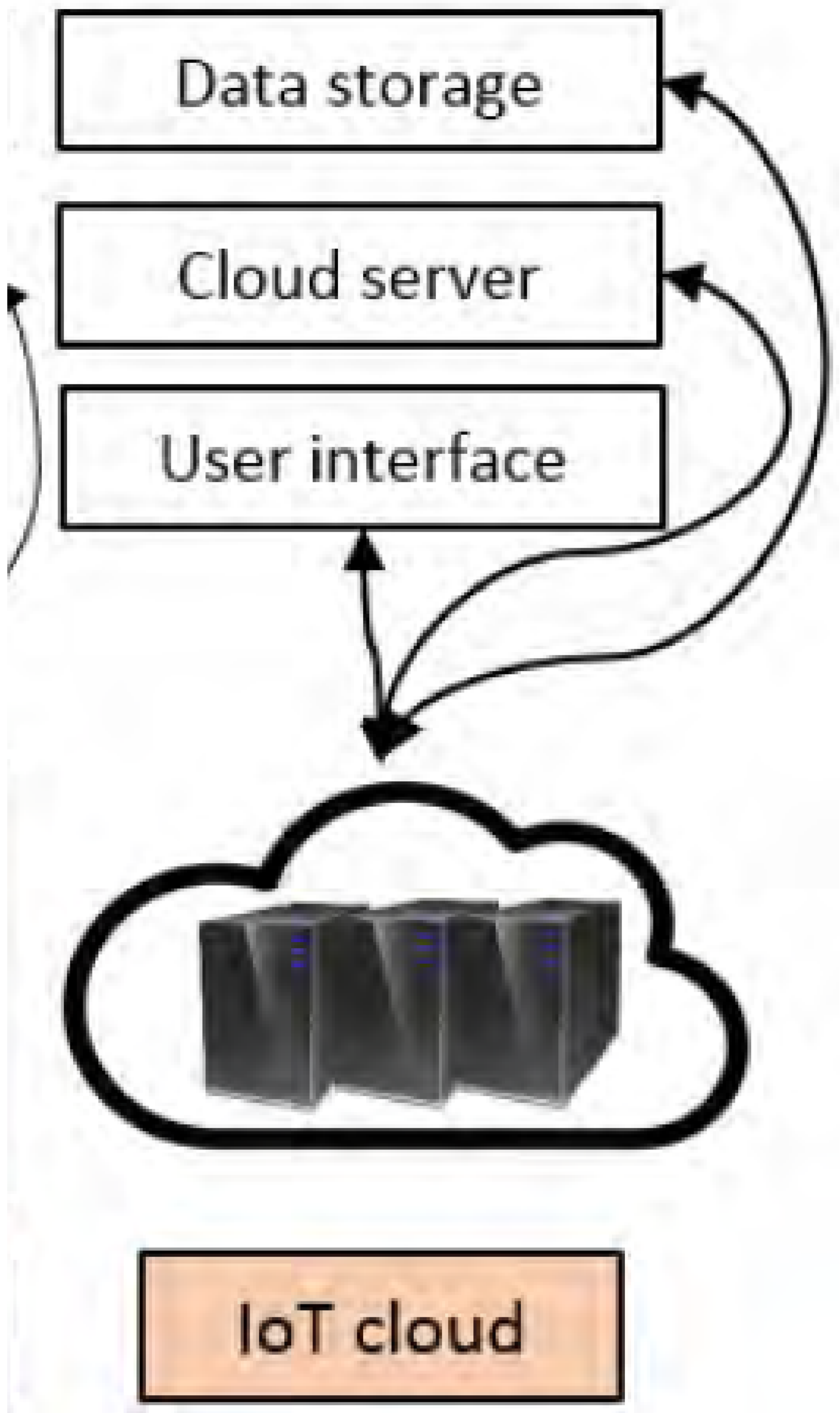
🌟 Process.
🌟 Aggregate.
🌟 Manage.

the data collected from the various wearable devices.



IOT CLOUD

The cloud server serves as a central repository for the data collected from the wearable sensors. Once the gateway forwards the data to the cloud server, it can be stored securely and efficiently. Cloud servers are highly scalable, allowing them to accommodate large amounts of data from numerous devices. This data can then be accessed, managed, and analyzed remotely.



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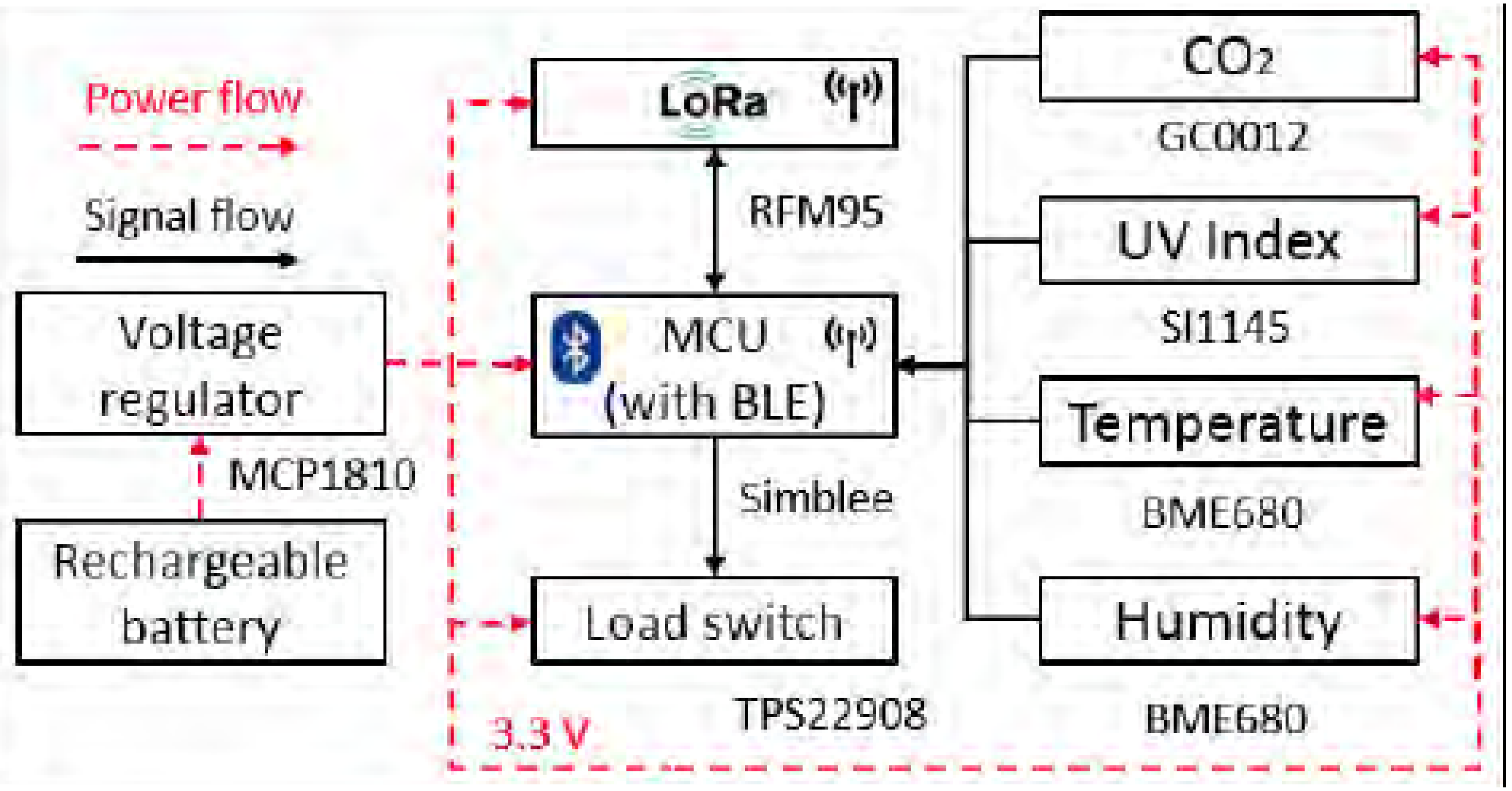
Hardware Implemenation

- Safe Node
- Health Node
- Edge Gateway

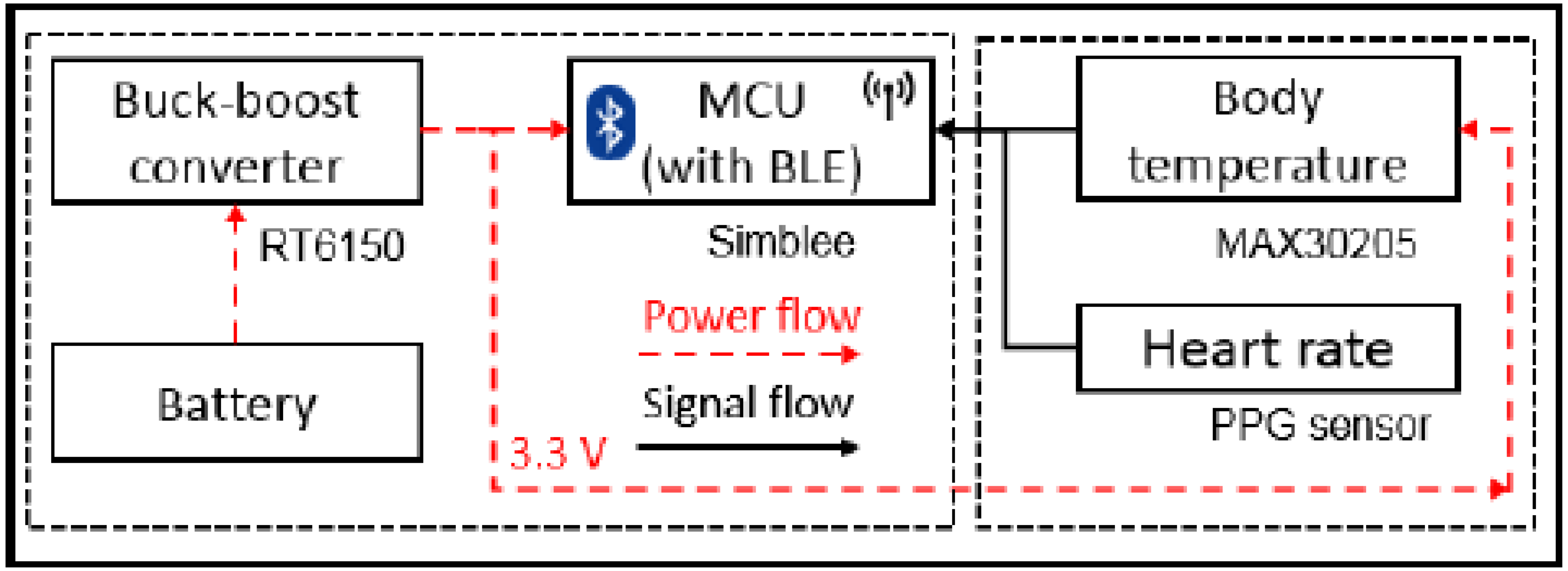
SAFE NODE HARDWARE IMPLEMENTATION

Each Safe Node incorporates a power management unit, an MCU (Microcontroller Unit), a LoRa module, and four environmental sensors. A rechargeable battery, regulated by MCP1810, maintains a constant voltage (3.3V). The Simblee MCU integrates BLE functionality. The LoRa module, an RFM95 by HoperRF Electronics, is a low-power, Long-Range transceiver responsible for long-distance data transmission to the remote gateway.



HEALTH NODE HARDWARE IMPLEMENTATION

In the following is outlined in its block diagram. It integrates a power management unit, a Microcontroller Unit (MCU) equipped with Bluetooth Low Energy (BLE) capabilities (Simblee), and two physiological sensors. Both health parameters are subsequently transmitted via the BLE network to the Safe Node for further processing and integration.



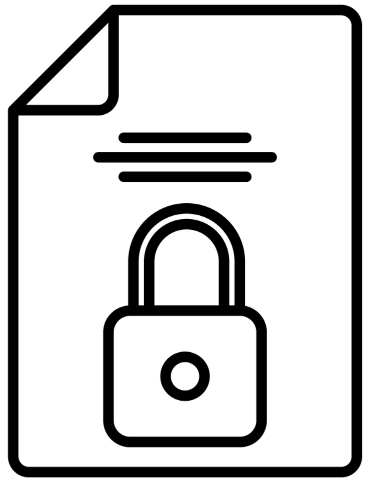
EDGE GATEWAY HARDWARE IMPLEMENTATION

🌟 **Processor:** comprising a Raspberry Pi Model 3, supports 5 different languages.
🌟 **Power:** The gateway is low-power consumption with 5V and 2.5A. Because of the Portable Power Bank, the gateway can be easily relocated without being permanently attached to a main power supply.
🌟 **Wireless Module:** LoRa module is additionally attached to the Raspberry Pi and communicates with the Pi to receive the wireless data from the Safe Nodes.

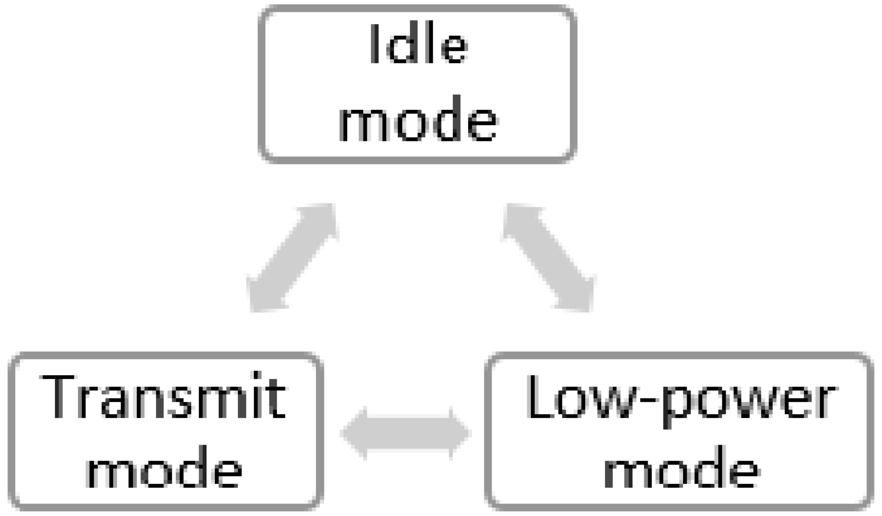
4 Software Implemenation

1. Long Range Wireless Communication
2. Gateway Software Implementation
3. Cloud Implementation

Long Range Wireless Communication



💡The wearable network is **based on the LoRa network**. Each Safe Node is able to communicate with each other via LoRa. So, **LoRa transmits the data from point to point**, and as a result, these data must be **encrypted** before transmitting the packet to improve the security and privacy of the network.



💡**There are three modes of operation for the wearable sensor node:**

- **Idle Mode:** The Safe Node listens to the RF channel and receives RF data.
- **Transmit Mode:** The Safe Node switches to this mode to transmit RF data to both the gateway and neighboring Safe Nodes.
- **Low-Power Mode:** This mode involves the Safe Node entering a low-power sleep state.

Wearable Communication

💡Each Safe Node can transmit two types of RF packets:

Class 1 packet

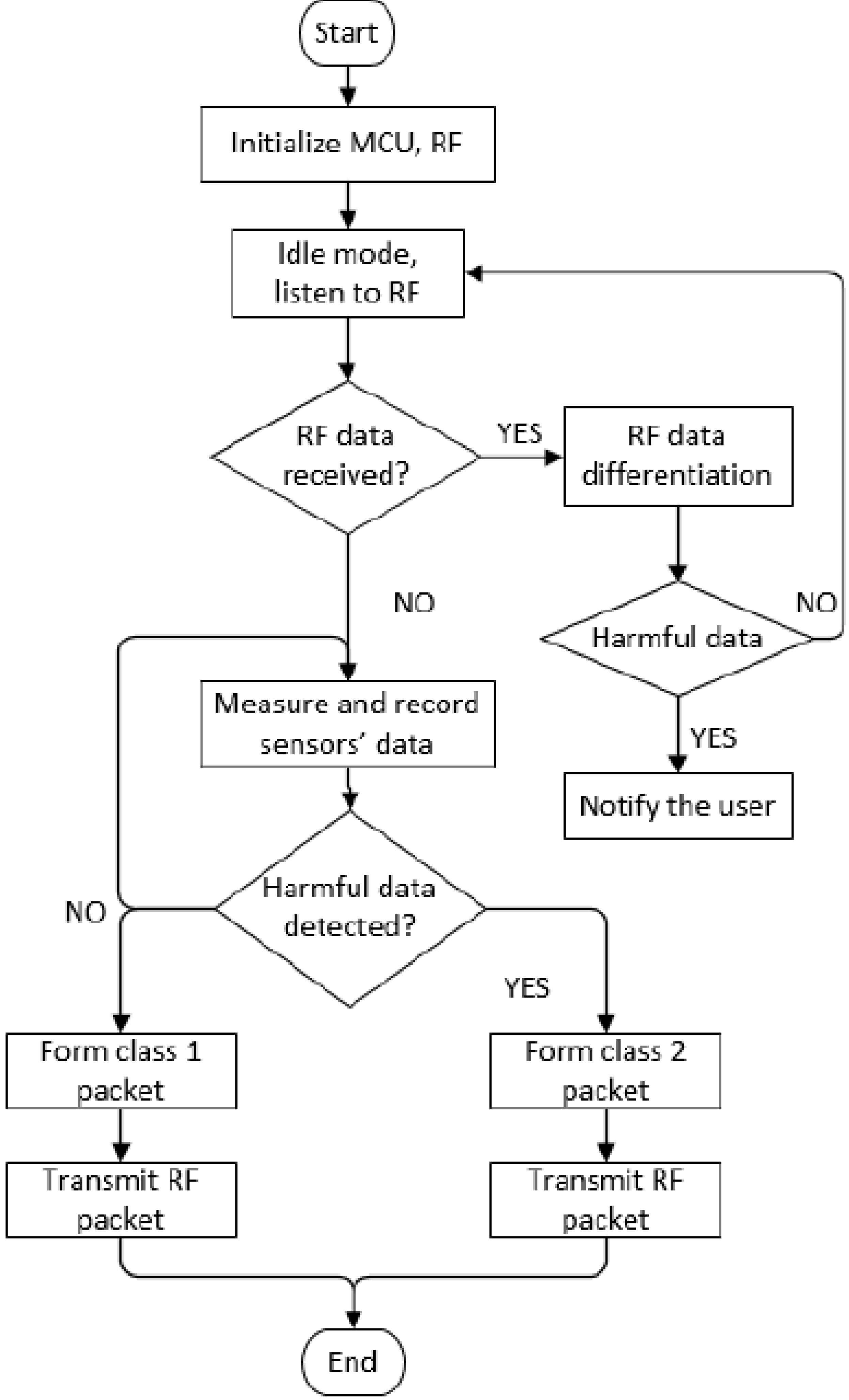
Transmitted when no harmful environments are detected. The targeting destination of this message is the IoT gateway.

Class 2 packet

Class 2 packet is transmitted when harmful environments are detected. This packet is transmitted to other wearable devices as well as the gateway node.

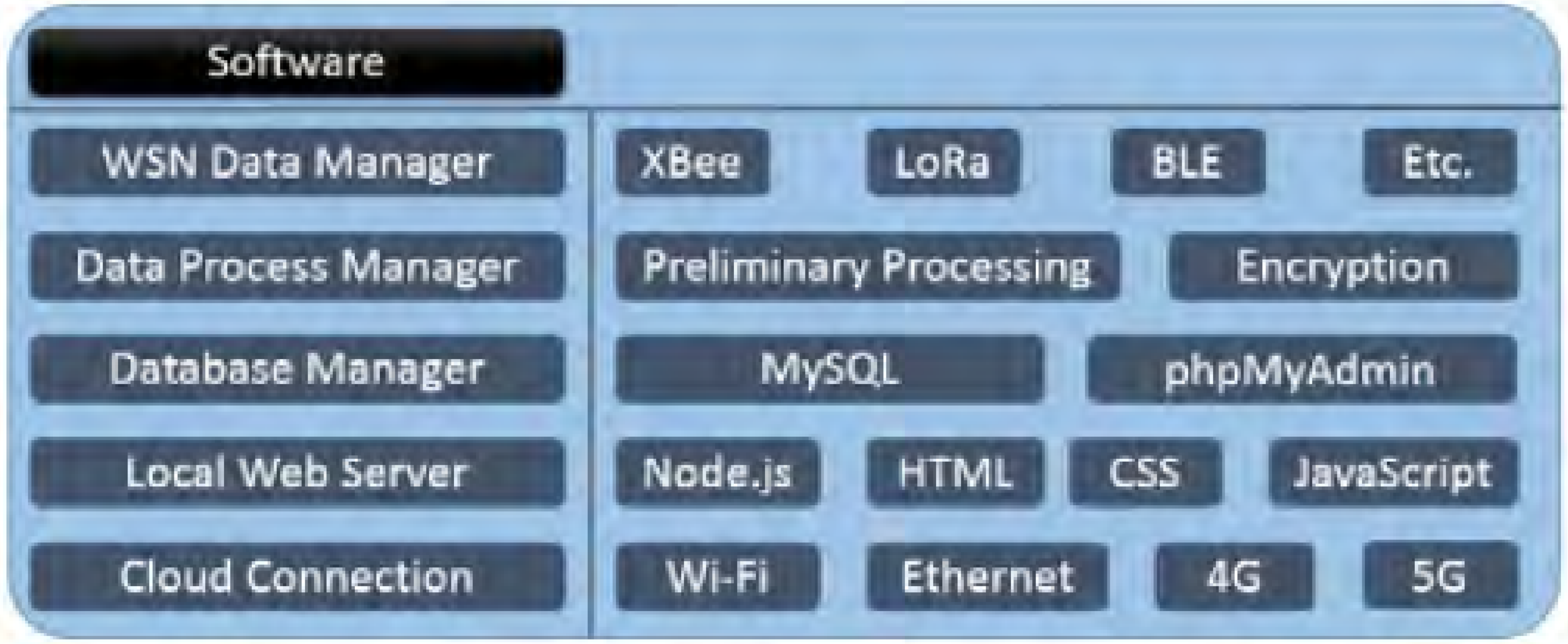
Software Diagram

- Initialization and Idle Mode
- RF Data Reception
- No RF Data Received
- Harmful Environment Detection.
- No Harmful Environment Detected.



Gateway Software Implementation

- After receiving the data from WDM, DPM will do a preliminary **data processing including filtering the data and transforming** the data into useful environmental data. DPM will **encrypt** the data before storing the data in MySQL.
- The data stored in the **local MySQL database** can be retrieved in the future for further analysis.
- A website running at the local server which is based on Node.js, HTML, CSS, and JavaScript is developed to **visualize the sensors' data in real-time.**
- Data from the gateway can be transferred to the **cloud** via Wi-Fi Ethernet, and cellular network.



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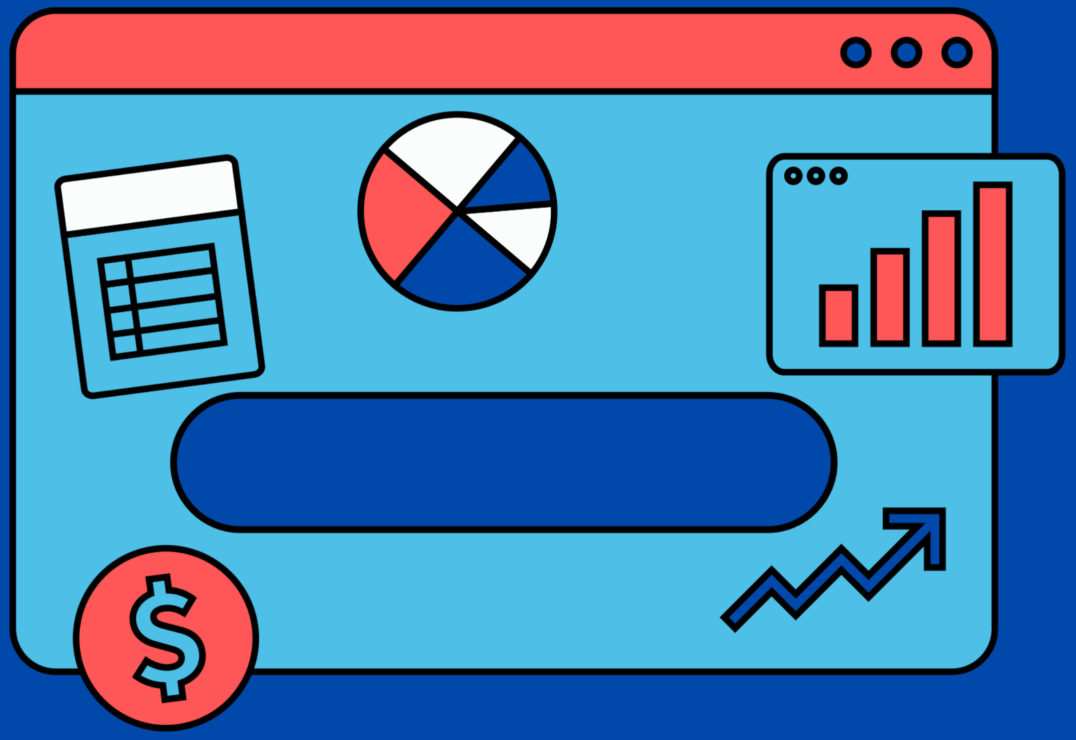
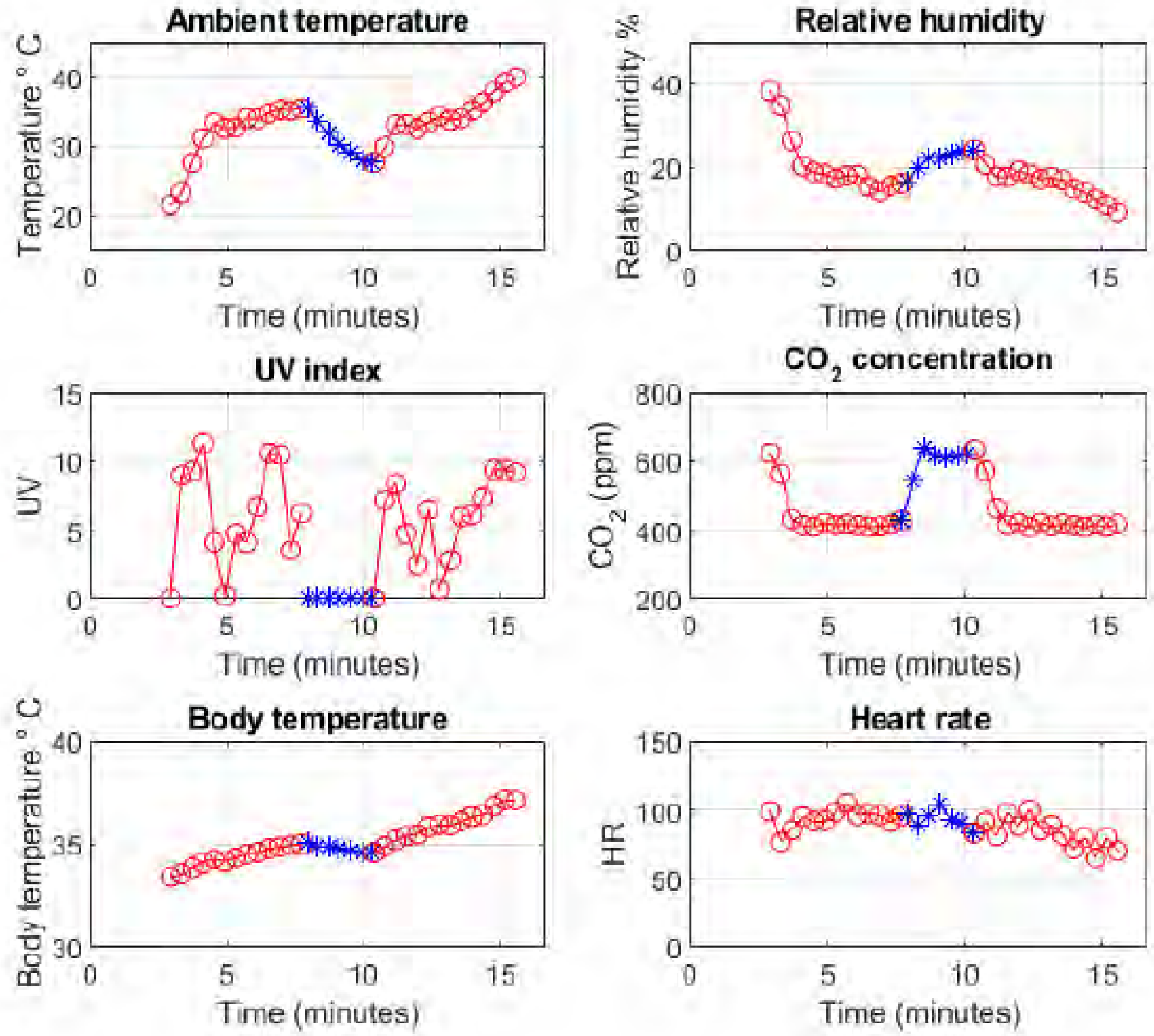
EXPERIMENTAL RESULTS



Real Experimental Results

Some real-time measurements from different sensors worn by one subject. The Safe Node is attached to the helmet while the Health Node is attached to the subject’s chest.

The **red curve indicates that the subject is outdoors** and the **blue line represents indoors.**



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Conclusion and Vision

Conclusion

- In this paper, we present an IoT network system for connected health and safety applications for the industrial outdoor workplace.

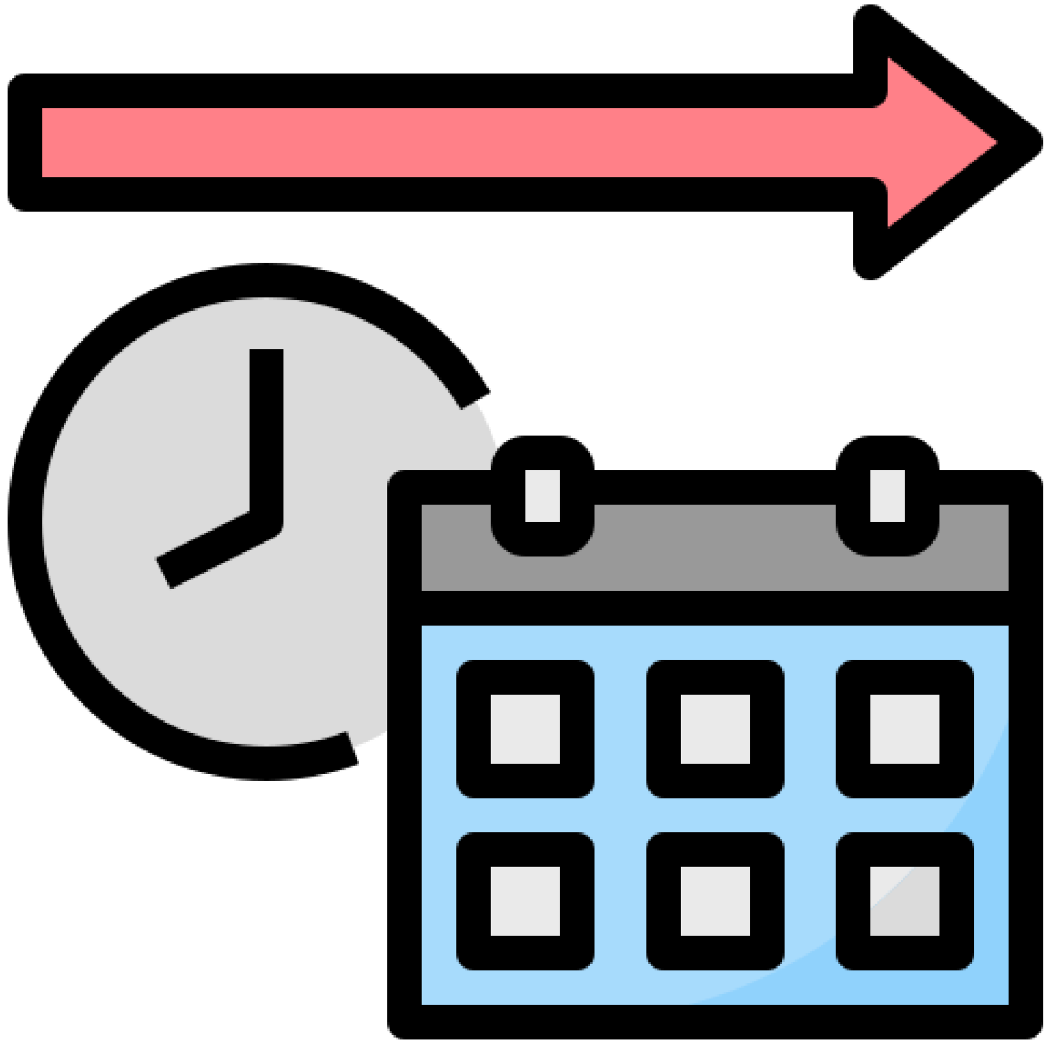
- The system is able to monitor both physiological and environmental data forming a network from wearable sensors attached to workers' body and provide invaluable information to the system operator and workers for safetyand health monitoring.

Future Works

For our paper, there are 56 external papers or works that have referenced the original paper in their citations.

Future Works

- **Advanced Sensor Integration**: Explore the integration of a wider range of environmental and physiological sensors to cater to diverse workplace environments such as monitoring specific pollutants, gases, particulate matter
- **Machine Learning and Analytics:** This could involve developing predictive models for early hazard detection, anomaly detection, and real-time risk assessment based on historical data and sensor trends.



- **Integration with External Systems:** Such as facility management systems, emergency response systems, or personal health records.

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