

Implementation of a long range-based monitoring system for environmental remote safety schemes

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ABSTRACT

The effects of poor air quality on people are profound. Air pollution and health issues are linked to millions of deaths. The World Health Organization (WHO) and the environmental protection agency (EPA) have produced several regulations and guidelines to control and enhance air quality. Several authors have recently suggested low-cost tools for instantly assessing air quality. the abundance of inexpensive ways to assess air quality and collect sensor data. The design and employment of remote safety monitoring for humidity, temperature, and carbon monoxide has been merged into a single tool in this work. The results findings can be observed on the actual measured instrument's organic light-emitting diode (OLED) show and the liquid crystal display (LCD) remote monitoring system. This device uses ESP32 microcontroller with long range (LoRa) wireless communication technology. The DHT22 sensor is used to detect humidity and temperature, while the MQ-7 sensor is used to monitor carbon monoxide levels. Testing measurements are calibrated using instruments that meet industrial standards (AS8700A CO meter and 4,000 NV weather tracker) used in environmental station. If the abnormalities in the recorded parameters are detected, then alert will be triggered. This instrument can help patients and workers to check their surroundings and provide remote monitoring to health service providers.

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1. INTRODUCTION

In recent years, the need for effective and efficient environmental monitoring systems has become increasingly important. Remote monitoring of environmental safety schemes plays a vital role in ensuring the well-being of ecosystems and human populations. The emergence of low-power, long-range wireless communication technologies such as long range (LoRa) has opened up new possibilities for developing cost-effective and scalable monitoring systems [1]. The primary objective of this implementation is to monitor various environmental parameters, such as air quality, water quality, temperature, humidity, and noise levels. The collected data will be transmitted wirelessly over the LoRa network to a central monitoring station for analysis and decision-making. The LoRa-based approach offers several advantages over traditional monitoring systems, including reduced infrastructure costs, increased coverage range, and scalability.

The biomedical sector needs to monitor temperature and humidity to develop medications and cell culture techniques. Safety-controlled settings are also necessary for the healthcare sector for people who pose a hazard. The negative effects of indoor air pollution on human health have garnered considerable attention. Detecting and enhancing indoor air quality (IAQ) are two benefits of existing indoor safety monitoring [2]. Indoor air pollution is one of the key causes that endanger human health, according to the United State environmental protection agency (US EPA). Numerous types of research have been conducted, and it has been found that indoor air contaminants can range from two to five times higher than those found outside. According to a home survey, urban people spend about 22 hours each day indoors, especially the physically infirm, on whom the quality of indoor air has a significant bearing. To enhance interior safety, it is essential to intensify monitoring [3]. Thermocouple temperature measurement sensors, resistance temperature instruments, infrared sensors, bimetallic instruments, fluid expansion instruments, and change of state temperature instruments are just a few of the sensors that can detect temperature. One of the three most used sensor technologies thermal conductivity, capacitive, and resistive is employed for humidity measurements [4]. Nowadays, due to their rapid rate of implementation, wireless sensor networks (WSN), or WSNs, constitute an active and significant study topic. A WSN is made up of several sensor nodes that may wirelessly interact with one another or with an external base station. They are mostly utilized in low bandwidth, delay-tolerant applications like real-time environmental monitoring [5]. Headaches, vertigo, nausea, concentration issues, and other issues might influence people's safety and quality of life at home. These are sick building syndrome's typical symptoms (SBS). Inadequate ventilation, cigarette smoke, chemical pollutants from indoor or outdoor sources, and biological contaminants can all result in issues. These issues can include issues with comfort brought on by insufficient temperature, high relative humidity levels, and inadequate illumination. To overcome these issues, it is required to monitor IAQ, which gives useful information [6].

Particulates, carbon monoxide (CO), interior temperature, and humidity make up the detection index of IAQ [3]. The World Health Organization (WHO) predicts that by 2030, chronic obstructive pulmonary disease (COPD) would overtake heart disease as the third greatest cause of mortality globally (WHO 2008). COPD prevalence varied from 0.23 to 18.3 percent over the world. According to statistics, 6.5% of persons over the age of 40 have COPD [7]. In COPD patients, there was a strong interaction between temperature and humidity. Patients with COPD were at increased risk due to the low temperature and excessive humidity. The greatest strategy to prevent COPD exacerbation for patients should be to maintain indoor safety. The health of COPD patients will suffer from the combination of the chilly temperature and the high moisture/humidity safety. To reduce the symptoms of COPD, the living room should be maintained at least at 18.2 °C and with humidity below 70% [8].

The most prevalent illnesses in the world are respiratory tract infections, which are also the most expensive to treat. Coronaviruses got their name from the spikes that resemble crowns that they have on their surface. They can cause an upper respiratory illness in people and are divided into four primary genus sub-groups known as Alphacoronavirus, Beta coronavirus, Gamma coronavirus, and Delta coronavirus [9]. Numerous variables, including host immunity, population density, migration patterns, medical care standards, and, presumably, climatic conditions, can have an impact on transmission (such as temperature and humidity) [10]. The results addressing the impact of temperature and humidity on the seasonal viability and transmissibility of COVID-19 were quite homogeneous. The transmission of the virus was accelerated by cold and dry weather. According to the available scientific data, COVID-19 appears to be less likely to propagate in warm, humid areas [11]. The permissible thermal comfort range is from 23 °C to 27 °C, according to the standard (ASHRAE 55-1992 is a worldwide society enhancing human well-being via sustainable technology for built safety).

According to MS:1525 Malaysian standards: (MS) 1525: 2019-energy efficiency and use of renewable energy for non-residential buildings, the recommended humidity is between 55% and 70%. Malaysian standard 55-1992 advises maintaining the indoor humidity level between 30% and 60%. Low levels of humidity are deemed inappropriate since they might induce dry air effects on the skin and eyes. On the other hand, if humidity levels are higher than 60%, the atmosphere may foster the growth of pathogenic or allergic bacteria [12]. Nowadays, the rising levels of CO throughout the world have become a critical environmental problem that has been emphasized in the majority of countries worldwide [13]. CO is a gas that, by definition, has no color, no smell, and no taste, making it a danger that cannot be seen. It results from hydrocarbons being burned insufficiently. Hemoglobin's ability to carry oxygen is greatly hampered by CO poisoning. CO causes tissue hypoxia after inhalation, notably in regions with high blood flow and oxygen demand. It frequently results in morbidity and death [14]. Clinically, there is a quick progression from nausea and vomiting to unconsciousness and unexpected death. Patients frequently have non-specific symptoms such as headaches, vertigo, weakness, disorientation, shortness of breath, chest discomfort, and vision problems. The thrombotic propensity and danger of deep toxic thrombosis rise as a secondary effect of CO poisoning [15].

In terms of health, CO limits the amount of oxygen that is carried by the blood and is especially detrimental for people who have heart disease. When CO levels are high, it can affect eyesight and coordination

and induce flu-like symptoms including headaches, dizziness, disorientation, and nausea. Low levels of CO can cause weariness in healthy individuals and chest discomfort in those who have heart disease and other lung-related conditions. Each year, the effects of CO gas on safety result in more than 500 fatalities and more than 20,000 hospital admissions [16]. Estimating toxic waste, which has a significant impact on human health, has become the focus of the most active study in recent years. Several gases are harmful to human health. Here, CO is regarded as one of the poisonous gases that, depending on the dose to which a victim is exposed, is thought to result in a variety of health problems. Cars, trucks, and another fossil fuel-burning machinery are the main producers of CO in the outside air.

In houses, fuel-burning appliances and machinery including gas stoves and ovens, water heaters, wood stoves, and tobacco smokes are common sources of CO [17]. Depending on how long they are exposed to the gases, workers are at high risk of developing a variety of health problems. CO is a class-III hazardous gas that is colorless, has a neutral odor, is tasteless, and is slightly less dense than air. This gas is easily breathed and rapidly mixes with the air. Complete gas combustion creates nonhazardous carbon dioxide (CO₂) in an oxygen-rich safety, whereas incomplete gas combustion creates CO in an oxygen-deficient safety. CO forms 200-250 times stronger hemoglobin connections in the blood than oxygen does. To create CO hemoglobin, CO substitutes oxygen and attaches to hemoglobin (COHb). This lowers hemoglobin's ability to carry oxygen, resulting in a lack of oxygen in bodily tissues and the onset of symptoms of CO poisoning [18]. There have been several reports of CO poisoning from various nations. When the concentration exceeds 1,200 parts per million (ppm), which is the threshold level, there is a very significant danger of death [19]. Parts per million is a unit of measurement used to determine the amount of CO concentration (ppm). For healthy people, a CO concentration of 70 ppm is sufficient to have deleterious consequences. If the concentration is 400 ppm, death occurs in just a few hours. CO has no color, taste, or smell, making it similar to a silent killer. The majority of those who are exposed are unaware of it. Therefore, it is crucial to gauge the level of CO concentration in a particular location [20].

For occupationally exposed personnel, the National Institute for Occupational Safety and Health (NIOSH) and the occupational safety and health administration (OSHA) have, respectively, suggested time-weighted allowable exposure limits of 50 ppm, 35 ppm, and 25 ppm [21]. WSN are used in modern healthcare applications to track stress levels, breathing problems, panic attacks, and cardiac problems. To prevent CO poisoning, technology may be utilized to monitor safety at home, office, or place of employment [22]. Because DHT11 and DHT22 sensors have a digital signal calibration that may offer temperature and humidity information, several research has employed these sensors to measure temperature and humidity. These sensors are regarded as a part with a high degree of stability, premium goods, quick reading responses, and interference-free trays, all at a reasonable cost [23]. Additionally, a lot of research employed MQ-7 sensors to measure CO levels since they work well for detecting airborne CO concentrations. From 20 to 2,000 ppm of CO-gas concentration may be detected using the MQ-7. This sensor responds quickly and with excellent sensitivity. The driving circuit is quite straightforward, however, the heating coil must be powered by 5 V, a load resistance must be added, and the output must be connected to an analog to digital converter (ADC) [24]–[27] and many communications technique used for monitoring temperature, humidity, and CO wirelessly like Bluetooth, Zigbee, Wi-Fi and LoRa [28], [29].

2. RESEARCH METHOD

2.1. Components of the instrument

This section will show the hardware circuit designing and the parts used in the suggested system. The design that was used for the instrument will also be explained, along with aits connecting and programed processes. This article will outline the components of the proposed safety station system. Every sensor listed therein will be connected to a Heltec Wi-Fi LoRa 32 (V2) board so that data from those sensors can be transmitted via LoRa to the monitoring station.

2.1.1. Humidity and temperature sensor

The humidity and temperature sensor (DHT22), also known as the RHT03, is a popular sensor used for measuring both humidity and temperature in various applications. It is a digital sensor that provides accurate and reliable measurements with a high degree of precision. Some key features and characteristics of the DHT22 sensor represented with measurement range: the DHT22 sensor can measure temperature in the range of -40 °C to 125 °C (-40 °F to 257 °F) with an accuracy of ±0.5 °C, and humidity in the range of 0% to 100% with an accuracy of ±2%. The DHT22 sensor is designed to operate with low power consumption, making it suitable for battery-powered applications or energy-efficient systems. The DHT22 sensor has a fast response time, typically around 2 seconds for temperature readings and 2-5 seconds for humidity readings as shown in Figure 1 [30]. This allows for real-time monitoring and quick detection of changes in environmental conditions.

The sensor communicates using a single-wire digital protocol, which makes it easy to interface with microcontrollers or other devices. It provides a 16-bit digital output for both temperature and humidity readings. The sensor can be interfaced with microcontrollers or other devices using digital input/output pins. Libraries and code examples are available for popular platforms like Arduino, Raspberry Pi, and other microcontroller boards. The DHT22 sensor has a limited sampling rate, usually around 0.5 to 2 Hz, which means it may not be suitable for applications requiring very high-frequency measurements.

The DHT22 sensor can be connected to the Heltec Wi-Fi LoRa 32 (V2) board, starting with connecting the voltage common collector (VCC) (+) pin of the DHT22 sensor to a 3.3 V or 5 V pin on the board, depending on the voltage requirements of the specific DHT22 sensor. Then, connect the ground (GND) (-) pin of the DHT22 sensor to a GND pin on the board. This will complete the power supply circuit. Finally, connect the data (OUT) pin of the DHT22 sensor to a general purpose input/output (GPIO) pin on the Heltec Wi-Fi LoRa 32 (V2) board and choose any available GPIO pin and remember the pin number. Once these connections have been made, one can use a library to read data from the DHT22 sensor using the specified GPIO pin [31].



Figure 1. DHT22 sensor

2.1.2. Carbon monoxide sensor

The carbon monoxide sensor (MQ-7) is a gas sensor module specifically designed for detecting CO gas. It is commonly used in applications where monitoring CO levels is crucial, such as in IAQ monitoring systems, gas leak detection, and industrial safety systems. The important details about the MQ-7 carbon monoxide sensor include the MQ-7 sensor module uses a tin dioxide (SnO_2) semiconductor-based sensing element to detect CO gas. The presence of CO gas causes a change in the electrical conductivity of the sensing element, which is then measured to determine the gas concentration. While, detection range of this sensor can detect CO concentrations in the range of 10 to 500 ppm. It is particularly sensitive to low levels of CO, making it suitable for applications where early detection is essential.

The operating conditions of the MQ-7 sensor operates optimally within a specific range of environmental conditions. It is designed to work at temperatures between $-10\text{ }^\circ\text{C}$ to $50\text{ }^\circ\text{C}$ ($14\text{ }^\circ\text{F}$ to $122\text{ }^\circ\text{F}$) and humidity levels between 20% to 90% RH (non-condensing). Operating the sensor outside of these ranges may affect its performance. This module includes an integrated preheating circuit that helps maintain a stable operating temperature for the sensor. This circuit ensures reliable and consistent performance of the sensor over time. It like most gas sensors, the MQ-7 sensor requires periodic calibration to maintain accurate readings. Calibration involves exposing the sensor to a known concentration of CO gas and adjusting the readings accordingly. The calibration process may vary depending on the specific application and requirements. It's important to note that the MQ-7 sensor is specific to CO detection and may not be suitable for detecting other gases. Additionally, the sensor's sensitivity may decrease over time, so regular maintenance and replacement might be necessary for optimal performance. When using the MQ-7 sensor, it is crucial to follow the manufacturer's guidelines and integrate appropriate safety measures, especially in applications where CO gas poses potential risks. Regular maintenance, calibration, and adherence to safety standards are essential to ensure accurate and reliable CO monitoring. The heater inside sensor provides necessary work conditions for the work of sensitive components, this sensor has four pins as illustrated in Figure 2. The connection of the MQ-7 sensor to the Heltec Wi-Fi LoRa 32 (V2) board is done by connecting the VCC pin of the sensor to 5 V, the GND pin to the ground, and the A0 pin to the GPIO pins of the Heltec Wi-Fi LoRa 32 (V2) board. The A0 pin was responsible for data transfer from the sensor to the microcontroller.



Figure 2. MQ-7 sensor

2.2. Circuit design of the safety station

To design the circuit for a safety station, which may include sensors for monitoring environmental parameters like temperature, humidity, and CO levels, as well as other safety features, may contain firstly the microcontroller that choose a suitable microcontroller board like Arduino or Raspberry Pi to serve as the central processing unit for the safety station. It will receive data from sensors, control outputs, and manage overall system functionality. Then some environmental sensors which include sensors like DHT22 for temperature and humidity monitoring and an MQ-7 sensor for CO detection as shown in Figure 3 with its circuit diagram. Connect these sensors to appropriate input pins of the microcontroller for data acquisition in addition to integrate a gas alarm or buzzer to provide an audible alert when the CO level exceeds a predetermined threshold. Connect it to a digital output pin of the microcontroller.

The liquid crystal display (LCD) add to provide real-time feedback on the environmental parameters. Connect it to the microcontroller using the appropriate interface (e.g., inter-integrated circuit (I2C) or serial peripheral interface (SPI)) and display relevant data such as temperature, humidity, and CO level. Incorporate buttons or a keypad to allow users to interact with the safety station. Finally include wireless communication capabilities like Wi-Fi or Bluetooth to enable remote monitoring or control of the safety station. This would require appropriate modules or shields and relevant software implementation on the microcontroller. The safety station measuring is comparing with a benchmark devices see in Figure 4 with type AS8700A CO meter Figure 4(a) and 4,000 NV pocket weather tracker, as shown in Figure 4(b).

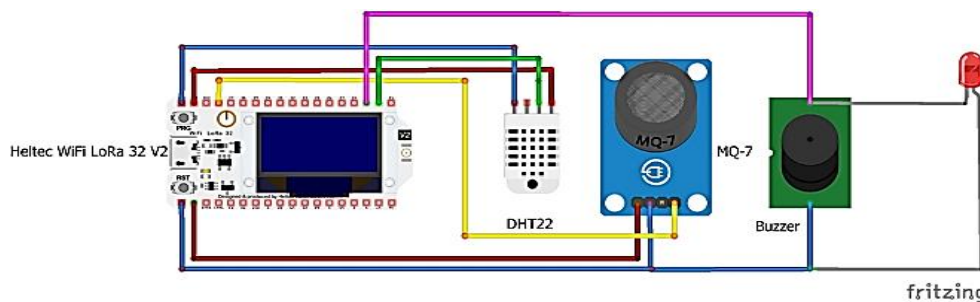


Figure 3. The diagram of the safety station



(a)



(b)

Figure 4. The benchmark of (a) carbon monoxide meter and (b) humidity and temperature meter

2.3. Components of the monitoring station

To display the data received from the safety station monitoring station was made by using Heltec Wi-Fi LoRa 32 (V2) board as a communication board with LoRa and 4×20 (LCD) to display the parameters of the safety (humidity, temperature, CO level). 20×4 LCD display module is an I2C interface. Incorporate a display unit to provide visual feedback and data visualization. This can be an LCD screen, organic light-emitting diode (OLED) display, or even LED indicators see in Figure 5, depending on the complexity and requirements of the monitoring system as illustrated in Figure 5(a). Then including a communication module, such as Wi-Fi, Ethernet, or cellular connectivity, to transmit data from the monitoring station to a remote location or cloud server. This enables real-time monitoring and data analysis. Also utilizing storage media, such as an SD card or cloud-based storage, to store historical data for analysis and reference. Implement data processing algorithms on the microcontroller or single board computers (SBC) to derive meaningful insights from the collected data. Finally, choosing a suitable enclosure to protect the components from environmental factors, such as dust, moisture, or physical damage. The enclosure should be designed to allow proper ventilation and access for maintenance or sensor calibration. the standard LCD, requiring only four GPIO pins. It works with 5 V and has 4 pin (VCC, GND, serial data line (SDA), and serial clock line (SCL)) with default I2C Address: 0×27. as shown in Figure 5(b), the monitoring station during receiving and reading safety station parameters shown in Figure 6.

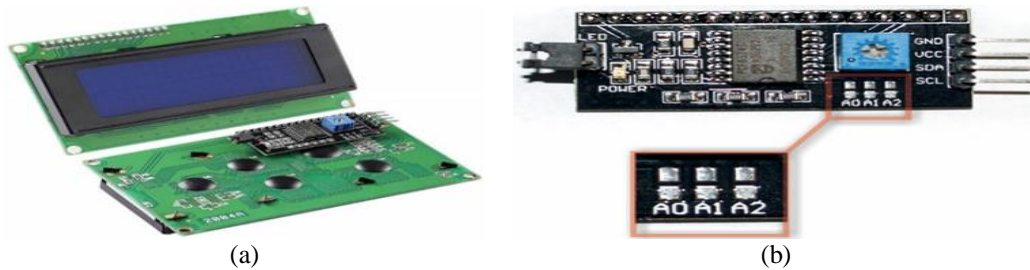


Figure 5. Display modules (a) LCD 4×20 and (b) I2C board



Figure 6. Monitoring station during receiving and reading safety station parameter

2.4. Heltec Wi-Fi LoRa 32 (V2)

The Heltec Wi-Fi LoRa 32 (V2) is a development board that combines Wi-Fi, Bluetooth, and LoRa capabilities in a single compact module. It is based on the ESP32 microcontroller and features an on board LoRa transceiver and antenna, making it ideal for internet of thing (IoT) applications requiring LoRa wireless communication, also battery management system Li-Po, 0.96" OLED may be also involved as presented in Figure 7. For makers of IoT devices as well as smart homes, farms, and cities, this is the greatest option. A Wi-Fi module manufactured by Heltec automation, a Chinese company [32]. Featuring current usage of not more than 130 mA and a 20 dB LoRa output, this module operates on both 3.3 V and 5 V. It provides the ability to link the microcontroller on the internet employing IEEE 802.11 b/g/n Wi-Fi standards and includes Wi-Fi, BLE, along with LoRa functionalities. Furthermore, the capability to link the microcontroller to a smartphone via the BLE and LoRa protocols that our system uses. The 0.96" OLED that is also included on the same board eliminates the need for an external display, which lowers power consumption, and is another benefit of utilizing the Heltec Wi-Fi LoRa 32 (V2) [33].

The microcontroller used in our system is ESP32 powered by the ESP32-D0WDQ6 microcontroller, which is a powerful dual-core processor with integrated Wi-Fi and Bluetooth connectivity. It operates at a clock speed of up to 240 MHz and has 520 KB static random access memory (SRAM). OLED is a more sophisticated electronic device compared to LCD panels. Since the OLED creates visible light, it does not require a backlight. In comparison to LCD panels, it is lighter, more thin, also has a higher resolution, allowing it to display deeper black levels. An OLED panel may produce a larger disparity proportion over an LCD screen in low light environments (such as a darkroom) [34]. It uses less power-less than 10 milliamperes-and provides a high resolution (128×64 pixels). As a result, it serves to illustrate safety parameters (humidity, temperature, and CO). In the planned system the Heltec Wi-Fi LoRa 32 (V2) which is shown in Figure 7 was employed to be a wireless network interface, establishing the connection and enabling real-time data transmission across the ESP32 microcontroller with the distant monitoring station.



Figure 7. Heltec Wi-Fi LoRa EPS32 (V2)

2.5. Communication technology of the system

The communication technology used in this work is LoRa. This technology was chosen because it has a wide range of communication and low energy consumption compared to other communication technologies like Wi-Fi. The Tx power of Wi-Fi is ~80 mW, while LoRa is ~20 mW, and the distance coverage by Wi-Fi is ~50 m while LoRa is ~2-5 km Therefore Wi-Fi requires a large power consumption and limited distance [35]. LoRa is a low-power, LoRa wireless communication technology that is designed for IoT applications. It enables devices to communicate over long distances while consuming minimal power, making it ideal for applications that require low data rates and extended battery life.

LoRa is optimized for applications that require low data rates, typically ranging from a few bytes to a few kilobytes per transmission. This makes it suitable for scenarios where periodic updates or sensor readings are transmitted. LoRa signals have good penetration capabilities, allowing them to pass through obstacles such as walls and buildings. This makes LoRa suitable for indoor and outdoor applications, even in challenging environments. It incorporates built-in security features, such as encryption and authentication, to ensure the confidentiality and integrity of transmitted data. This helps protect against unauthorized access and tampering. LoRa supports a scalable network architecture, where multiple devices can communicate with a single gateway. This enables the deployment of large-scale IoT networks, accommodating a large number of devices spread across wide areas. LoRa technology can seamlessly integrate with cloud platforms, allowing data from LoRa devices to be securely transmitted and stored in the cloud. This facilitates data analysis, visualization, and integration with other applications and services.

2.6. Validation between the proposed safety station and benchmark device

When comparing the performance and accuracy of a proposed safety station with a benchmark device, it is important to conduct a validation process to ensure reliable and consistent results, then determine the key parameters and metrics that will be used to evaluate the performance of both the safety station and the benchmark device. For example, this may include measurements such as temperature, humidity, CO levels, response time, accuracy, and stability. Calibrate the sensors of both the safety station and the benchmark device using standardized reference sources or calibration equipment. This step is crucial to ensure accurate and comparable measurements. The data were compared with benchmarks (BM) for each case reading, whose they were taken manually at the same time as the proposed device, and where the two special readings of the proposed device and the BM were compared using statistical and graphical methods as shown in Figures 8 and 9 to demonstrate the validation of the proposed system.



Figure 8. During the measurements in hospital wards



Figure 9. During the measurements in the generator room

The proposed system provided a warning system for the safety station to warn patients or workers in the situation of abnormal levels of CO levels where is a fired buzzer sound and LED blinking if the level of CO is more than 15 ppm. An editor for composing code, a message area, a text terminal, a toolbar with buttons for basic operations, and a number of menus are all included in the Arduino integrated development environment (IDE), sometimes known as the arduino software. It establishes a connection with the microcontroller hardware and communicates with it to upload applications. By using this software, we write our program for the two stations to make sending and receiving protocols among them and set the warning system. The complete systems algorithm is shown in Figure 10.

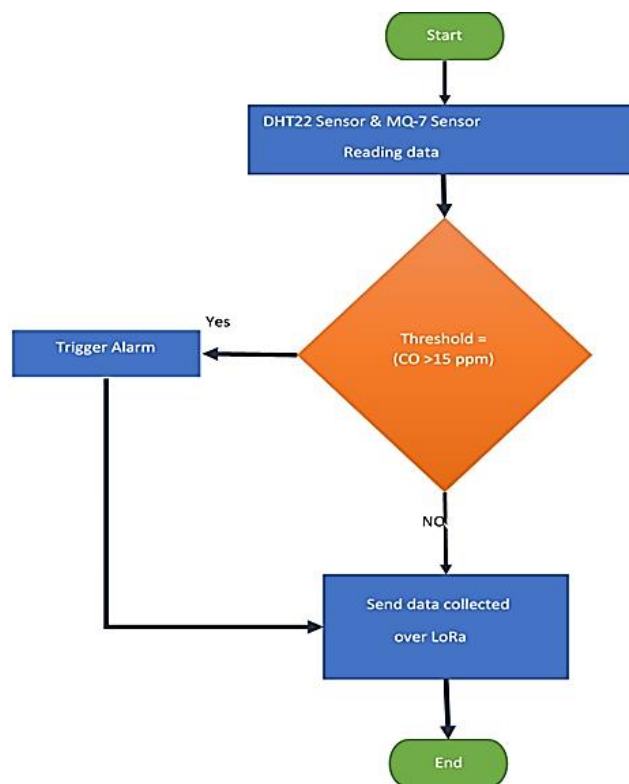


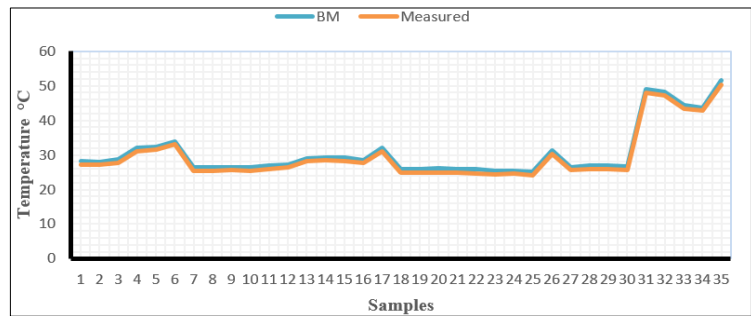
Figure 10. The safety station algorithm

3. RESULTS AND DISCUSSION

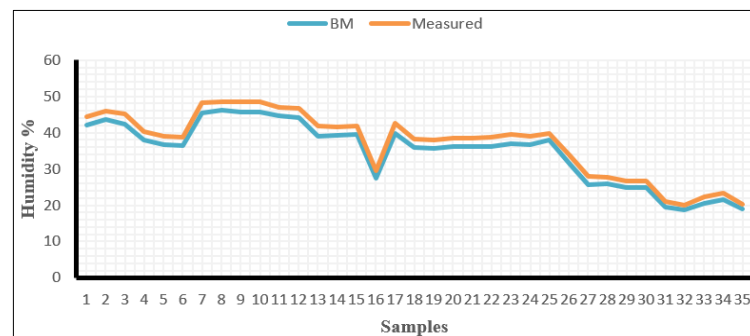
There will be a presentation and discussion of the safety station’s results. The verification of the measurements performed between the safety stations with the benchmark device (BM) and the comparison of the LoRa performance between the recommended safety station and associated works are the two categories in which these results are categorized. The statistical evaluation (i.e., error testing and pearson correlation factor) and the precision of the system of the suggested safety station in comparison to the BM is going to be presented, explained, and debated in the measurement validation.

3.1. Safety station measurement validity

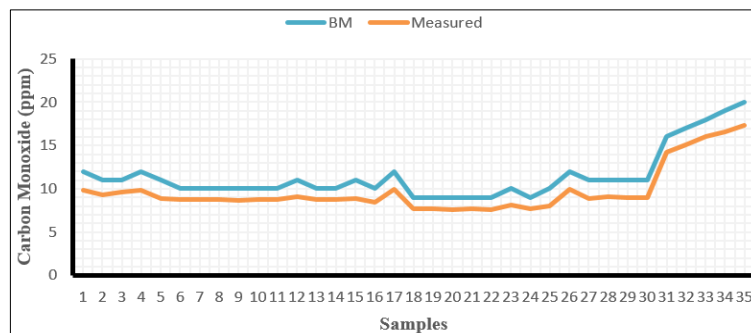
In order for deciding how precise, the system is, a statistical assessment between the safety station and the BM was performed in this section. Using the safety station, more than 35 samples were taken-35 for each of the three variables of temperature, humidity, and CO. Additionally, BM was used to obtain the same number. The measurements shown in Figure 11 as demonstrated in Figures 11(a) to 11(c) which compare the safety station and BM temperature, humidity, and CO, respectively, a little difference was found between the safety station and the BM findings when they were compared to one another. The subsequent statistical trainings, such as whether or not these differences are acceptable will be shown by the variance testing and pearson correlation coefficient.



(a)



(b)



(c)

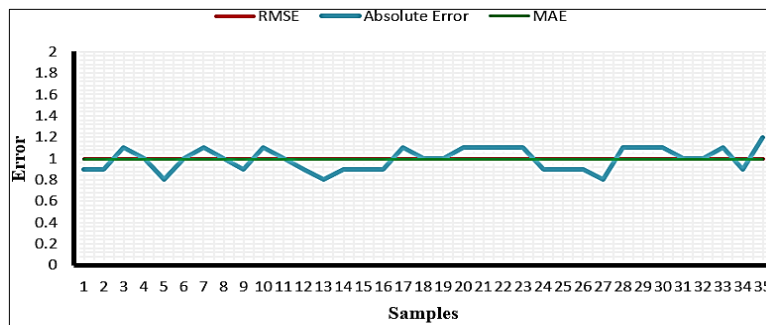
Figure 11. Measurement of; (a) temperature, (b) humidity, and (c) CO for the environment station and BM

3.2. The MAE and RMSE

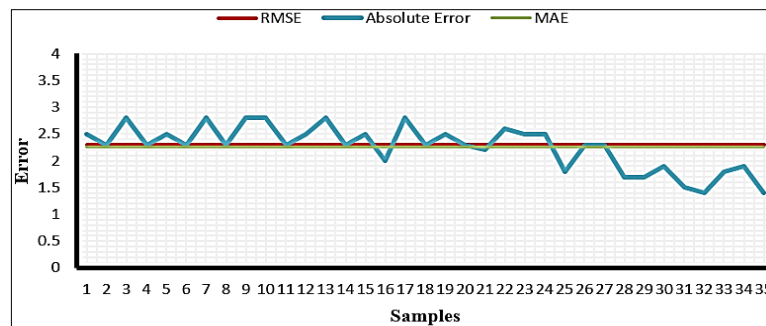
Mean absolute error (MAE) and root mean squared error (RMSE) are commonly used metrics to evaluate the accuracy or predictive performance of a model or system. While we mentioned using these metrics in the context of validating the measurement between the safety station and the BM, it is important to note that MAE and RMSE are typically used for comparing predicted values to actual values in a regression analysis. It is important to note that the interpretation and significance of MAE and RMSE values may vary depending on the specific context and domain of the measurement comparison. These metrics provide numerical measures

of error but should be interpreted in conjunction with other relevant information, such as the specific measurement units, acceptable tolerances, and any specific requirements or standards for accuracy in the safety-related domain. Based on the provided information, Figure 12 displays the MAE, RMSE measurements, and absolute error of the temperature variable in Figure 12(a). The MAE is reported as 0.991, while the RMSE is reported as 0.996. The MAE of 0.991 suggests that, on average, the absolute difference between the measured temperature values obtained from the safety station and the corresponding values from the BM is approximately 0.991. The MAE provides an average measure of the absolute discrepancy and indicates the average magnitude of the errors. Similarly, the RMSE of 0.996 indicates the typical or average discrepancy between the measured temperature values from the safety station and the BM, taking into account both magnitude and direction.

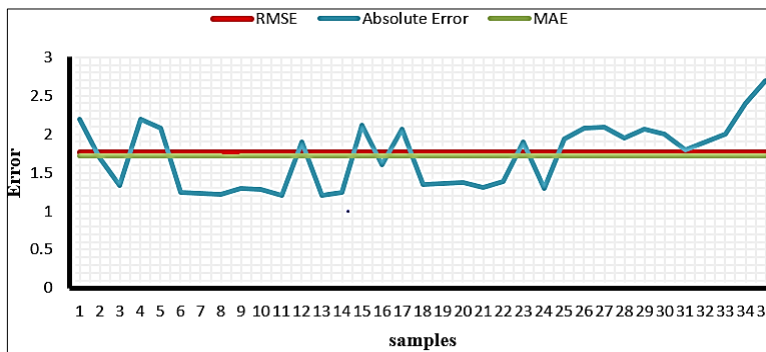
While for additional information provided, Figure 12(b) displays the MAE and RMSE for the humidity variable. The MAE is reported as 2.26, while the RMSE is reported as 2.29. The MAE of 2.26 indicates that, the absolute difference between the measured humidity values obtained from the safety station and the corresponding values from the Benchmark device is approximately 2.26. Correspondingly, the RMSE of 2.29 indicates the normal or usual difference, taking into account both size and direction, between the observed humidity readings from the safety station and the Benchmark device. Whereas, Figure 12(c) displays the MAE and RMSE for the CO variable. The MAE is reported as 1.71, while the RMSE is reported as 1.76.



(a)



(b)



(c)

Figure 12. The absolute error, MAE, and RMSE for; (a) temperature, (b) humidity, and (c) CO

3.3. Pearson correlation coefficient (r)

By Pearson to determine whether or not there was a linear association between both quantitative variables, the real value versus the calculated amount of each environmental data of the surroundings station were compared using the descriptive statistical method of correlation. The relationship (r) between both quantitative factors is depicted in Figure 13. There is a positive association because the values of (r) for temperature Figure 13(a), humidity Figure 13(b), and CO Figure 13(c) were all 0.99. The BM's actions are identical to those of the environment station.

$$r = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2}\sqrt{\sum(Y-\bar{Y})^2}} \tag{6}$$

Y is the actual value, and $(Y)\bar{}$ is the mean of the actual values, where X is the measured values and $X\bar{}$ is the mean of the measured values. The deviation is $X-X\bar{}$ and $Y-(Y)\bar{}$.

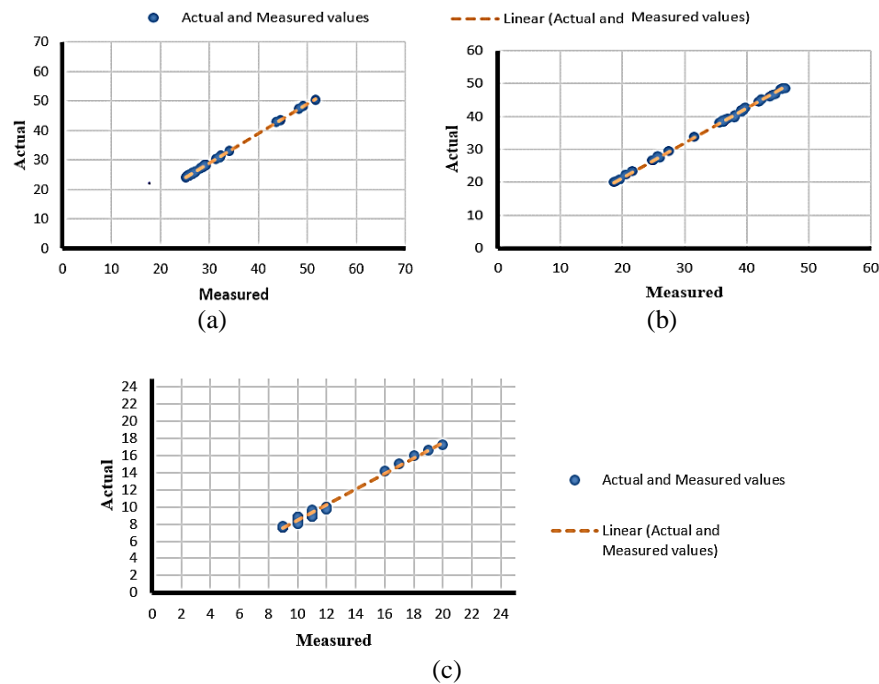


Figure 13. The Pearson correlation coefficient for; (a) temperature, (b) humidity, and (c) CO

3.4. Comparison of LoRa performance

The associated improvements and the healthcare station were compared. Regarding the range of LoRa outside of the workplace, four studies [36]–[39] have been conducted. The system's benefit was shown in this comparison at a range of 1,400 meters. Figure 14 shows how the healthcare station differs from other systems.

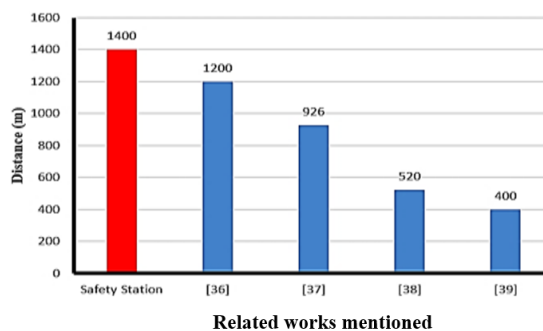


Figure 14. LoRa performance comparison between the safety station and other systems

4. CONCLUSION

Using the DHT22 and MQ-7 sensors, the current study has effectively constructed and put into operation a safety station for monitoring temperature, humidity, and CO to patients as well as maintenance personnel. Temperature and humidity can be measured using the DHT22 sensor, and CO can be measured with the MQ-7 sensor. LoRa was used to send the measurement data from the ESP32 node to a monitoring station, enabling both indoor and outdoor system operation. A buzzer and blinking LED alarm will sound if anomalies in the parameters that were recorded are found. As a result, the instrument is usable and in good working order.




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


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