IoT-Based Smart Wireless Communication System for Electronic Monitoring of Environmental Parameters with a Data-Logger

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***Abstract*—As the transition toward automated industrial environments gains momentum, the necessity for dependable, real-time environmental monitoring systems becomes increasingly critical. Addressing this urgent need, this paper unveils a sophisticated IoT-based wireless communication system specifically engineered for electronic monitoring of key environmental parameters. An Arduino Nano microcontroller is central to the system's design, which interfaces with a diverse suite of sensors to monitor temperature, humidity, gas concentrations, and even emergency conditions like fire hazards. Leveraging the capabilities of an nRF24L01 wireless module, the system transmits these multi-faceted sensor readings in real time to a control unit. Once received, the data is vividly displayed on an (organic light emitting diode) OLED screen and logged onto a Micro-SD card for subsequent analysis and historical trend monitoring. Additionally, the system features audio-visual alerts through an electric buzzer and LED, providing instantaneous warnings in critical situations. Notably, the sensor data undergoes rigorous validation by being compared with reference values obtained from NASA's official databases, ensuring high accuracy and reliability. This comprehensive solution significantly advances industrial safety and efficiency, serving as a robust tool for monitoring and responding to environmental changes in real time.**

***Index Terms*—smart wireless communication, monitoring system, environment parameter, data logger, Arduino microcontroller**

I. Introduction

In recent years, automated wireless communication systems have been considered as one of the most promising applications [1–3]. There is a variety of wireless communication applications; one of these is environmental monitoring, which tends to sense the ambient circumstances of that environment, such as ambient temperature, air humidity, soil moisture, presence and concentration of gases, the existence of flame dangerous, UV radioactivity and much more [4–7]. This paper illustrates the design and hardware implementation and results of an industrial environment monitoring system that senses ambient temperature and air humidity using a DHT-22 sensor, the presence of LNG, Co, and smoke gasses using an MQ-2 sensor, also examines the surroundings of the industrial environment for the possibility of fires using KY-026 flame sensor and reports them through several methods [8–13]. These measurements are sent wirelessly from a remote industrial unit to the monitoring and control room of the industrial facilities via a single-chip radio transceiver NRF24L01 at 2.4 GHz. It should be noted that the sensing process is recorded in real time thanks to the Real Time Clock RTC-DS1302 chip. Finally, all the received readings are data-logged into a micro-SD card using a storage expansion module. Also, there is the possibility of using a visual and audio alarm to warn users of any emergencies that may occur in the industrial facility. The proposed paradigm uses a low-cost, low-power, easy-to-use, open-source Arduino NANO controller, which is considered as the system's central part at both the transmitting and receiving sides.

By addressing the following points, this study significantly contributes to the fields of industrial internet of things (IoT) and environmental monitoring, especially with regard to the real-time wireless transmission and data-logging of crucial environmental parameters in automated industrial settings:

- Real-Time Data Transmission: One notable feature is the real-time transfer of various environmental parameters to a control unit. This makes it possible to act quickly and make decisions, which is essential in automated industrial settings with little human intervention.
- Data-Logging Functionality: Adding a Micro-SD card-based data-logging feature to the system adds a substantial layer of functionality. In the future, predictive maintenance and system optimization will be made possible by analyzing and identifying trends in historical data.
- Wireless Communication: Using the nRF24L01 unit to transmit data wirelessly is very creative. This makes the system more flexible and easier to

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implement without requiring much wiring in different industrial settings.

- Audio-Visual Alarms: More than just monitoring is involved in integrating real-time audio and visual alerts. Unlike many other solutions on the market, these alarms can be set off in response to real-time sensor readings, providing an extra degree of security and emergency preparedness.
- Testing and Validation: The system is well-founded empirically thanks to the thorough validation against accepted reference values, such as NASA's official temperature and humidity data. This illustrates the accuracy and dependability of the system in real-world settings, going beyond theoretical development.

The literature review clarifies the various research studies on IoT-based environmental monitoring systems, pointing out knowledge gaps, assessing multiple approaches, and placing our analysis in this field—especially with regard to wireless communication, real-time data transmission, and data-logging capabilities.

Wang and Chi [14] proposed a low-power, low-cost, and tiny-volume wireless environment monitoring system based on the ATmega328 built on the Arduino UNO board. The climate circumstances are read via the DHT11 sensor. This sensor reads the air temperature with moisture. The measured data is processed via the Arduino board and sent wirelessly via the nRf24L01 module on the transmitting side. On the receiving side, the same module, nRF24L01, receives a measurement reading and delivers it to Arduino. Finally, the temperature and humidity measurements are displayed on the dot-matrix LCD128641 display. The system will turn on the buzzer and flashing LED if the sensor readings exceed the normal range for temperature and humidity to give the user feedback.

Sidqi *et al*. [15] proposed a weather monitoring system that senses temperature, humidity, light intensity, and barometric pressure using DHT11, LDR, and BMP180 sensors. The proposed system sends the data readings wirelessly through the nRF24L01+ module to the receiver side. Both transmitter and receiver paradigms are based on Arduino UNO (R3) devices. The recording values are presented in "Graphical User Interface (GUI)," technologically advanced by C# within the receiving side. The GUI refreshes every second and can record entire received data into a special folder or file. The experimental work shows that the maximum transmitting range is about 30–32 m in the Line of Sight (LoS). The authors finally created compassion and estimated error percentages between sensed data by Arduino and measured data by thermometer and lux meter.

Li *et al*. [16] adopted a simple structure, easy-to-use, and entire-function monitoring system that uses the DHT11 sensor to measure both temperature and humidity and a wireless transceiver nRFL2401 for long-range measurement and monitoring. The authors also used the STC89C51RC one-chip as the central part of this monitoring system. The data readings were shown on an LCD on the receiving side with a wireless range of 200 meters. This system can also make a sound alarm through a buzzer when one of the readings, i.e., temperature or humidity, exceeds a preset value.

Saini *et al*. [17] developed a weather monitoring system based on an Arduino board, which used SHT25, BMP085, and wind sensors to calculate heat, moisture, atmospheric pressure, and airstream speediness and route and send those measurements wirelessly through the ZigBee transceiver module. The measured values were obtained via a GUI software planned explicitly for this purpose through the ZigBee board. The adopted system also can produce alerts depending on real-time weather readings. Finally, the authors compared the data results with Atmospheric Posting Chandigarh and Snowflake and Snow Slip Studies Formation Chandigarh Lab. The compression outcomes illustrate that the developed work is very accurate.

Sadiq *et al*. [3] illustrated the implementation and practical results of an environmental monitoring system that anticipates a DHT11 sensor for detecting the surrounding area's temperature and humidity readings. The authors used the Arduino UNO board as the central part of the system connected with the ESP 8266 Wi-Fi module to transmit data sensed to ThingSpeak, an open-source IoT API service. The authors also developed an Android program to access the ThingSpeak cloud and display the data readings in real time for the end-users. The proposed work can also trigger some action based on data-sensing temperature and humidity, just like controlling cooling and heating devices.

Kusriyanto *et al*. [18] proposed an IoT-enabled weather station that is accessible via a website for real-time monitoring of weather conditions. Utilizing an Arduino Mega 2560 as the central microcontroller, the system integrates multiple sensors: DHT-22 for temperature and humidity, FC-37 for rain detection, and BMP180 for air pressure measurements, which are also used for weather forecasting. The sensor data is displayed on a 2.2-inch TFT LCD, stored on an SD Card, and made available online through an ESP8266 Wi-Fi module. Rigorous validation against a PCE-THB 40 module showed an average error rate of 3.74% for temperature, 2.14% for humidity, and 0.32 hPa for air pressure.

Table I shows the main abbreviation used in this paper.

TABLE I: LIST OF ABBREVIATIONS

Abbreviation	Description	Abbreviation	Description
A0	Analog Pin	LoS	Line of Sight
CLK	clock pin	PPM	part per million
D0	Digital Pin	RST	reset pin
DAT	data pin	RTC	Real Time Clock
GND	Ground Pin	SCK	serial clock
GUI	Graphical User Interface	SDA	serial data
IDE	Integrated Development Environment	SPI	Serial Port Interface
IoT	Internet of Things	Vcc	voltage from a power supply

The following parts of this paper are ordered as follows: Section II discusses the hardware parts and system implementation of the proposed paradigm. The experimental results are introduced in Section III. Finally, the conclusion is illustrated in Section IV.

II. PROPOSED SYSTEM

The central unit of this system is the Arduino NANO microcontroller, which is used in transmitting and receiving ends. Arduino NANO was considered a minor in size, had little power dissipated, and had a low price. The Arduino NANO is based on ATmega328P microchip technology. It has 13 digital IP\OP terminals and six analog IP terminals with a USB type-b connection. Also, it can be programmed by using Arduino C (same as C) programming language using the software of Arduino integrated development environment (IDE), which is used for programming all types of Arduinos [10]. Fig. 1 illustrates the Arduino NANO microcontroller board. It should be noted that the Arduino NANO was analogous to the Arduino UNO controller in digital\analogue pins and power input\output. We suggested using the Arduino Nano instead of the Arduino Uno due to the small size and the more significant saving in energy spent in addition to the lower price [19]. Table II presents the Arduino NANO practical parameters.

Fig. 1. Arduino NANO microcontroller.

TABLE II: ARDUINO NANO TECHNICAL SPECIFICATIONS [20]

Parameters	Value
Microcontroller	ATmega328P
Normal Operational Voltage	5 V
Source Voltage Range	5 - 20 V
Input/Output digital pins	14 (6 for Pulse Width Modulation outputs)
Pins For Analogue Input	8
pin current	40 mA
Output current for each pin at 3.3 V pin	50 mA
Flash storage	32 KB, The memory allocated to the bootloader is 2 KB
Random-Access Memory (S-type)	2 KB
EPROM size	1 KB
clock Frequency	16 MHz
weight	7 g
Width	18 mm
Length	45 mm
USB	Mini-USB Type-B
In-circuit serial programming Header	Yes
Jack port for DC power	No

In developing this IoT-based environmental monitoring system, the microcontroller selection was a pivotal point in the design process. After a thorough evaluation, the Arduino Nano was chosen over other readily available options, such as the Arduino Uno, ESP modules, and Raspberry Pi. The Nano's compact footprint offers a distinct advantage, especially in industrial settings where space is often at a premium. Additionally, it operates at significantly lower power, making it an energy-efficient choice for applications requiring continuous, long-term operation. Another key consideration was cost; the Arduino Nano provides a highly cost-effective solution without compromising essential functionalities, thereby making the system more accessible for small to medium-sized industrial enterprises. Notably, the Nano has sufficient I/O pins to connect multiple sensors and modules, eliminating the need for additional hardware for I/O expansion. Its compatibility with the nRF24L01 wireless module used in our study also simplified integration, while the extensive community support for Arduino platforms expedited the development and troubleshooting phases.

The communication device used in this system is the nRF24L01, which is considered as transceiver, i.e., the same device can be used as a transmitter and receiver, as shown in Fig. 2. The nRF24L01 is a low-power, low-cost, high data-rate, and long-range transceiver compared to other transceiver modules like ZigBee, Bluetooth, and Wi-Fi [19]. The nRF24L01 consumes approximately 13.5 mA max current, like a small LED [21]. The Arduino microcontroller passes the sensed data from the sensors to the nRF24L01 chip to transmit it. The wiring configuration of the nRF24L01 is as follows: the Vcc and ground terminal of nRF24L01 were linked to 3.3V and ground on Arduino NANO. The CE and CSN terminals are connected to D9 and D8 on Arduino NANO. Finally, the MOSI, MISO, SCK terminal were linked to terminals D11, D12, and D13 on Arduino NANO. The IRQ pin on nRF24L01 remains open. Table III shows the specifications of the nRF24L01 transceiver module [22]. Based on our practical experiments, this module can cover a transmission distance of 80–100 m when there are obstacles and buildings, and 500–800 m in open transmission environments

Fig. 2. The nRF24L01 transceiver module.

TABLE III: SPECIFICATIONS OF THE NRF24L01 TRANSCEIVER MODULE [22]

Parameters	Value
Limit Frequency Spectrum	2.4 GHz ISM Band
Highest Data-Rate	2 Mb/s
Format of the Modulation.	GFSK
Highest value of Power Output.	0 dBm
Range of Voltage.	1.9 V–3.6 V
Maximum Current of operation	13.5mA
Standby Current.	26 µA
Logic Inputs.	Tolerance up to 5V
Distance Range of Communication.	800+ meter (line of sight)

The sensor, DHT-22, measures the temperatute and relative moisture for the surrounding environment. This type of sensor was chosen due to its ultra-low cost, low power consumption, easy programming, and high accuracy. Almost the only weak point in this type of sensor is its slow sampling rate, equal to 0.5 Hz, i.e., DHT-22 sends the data readings every two seconds to the microcontroller [23]. The DHT-22 has four pins; the Vcc and Data pins in DHT-22, which are the first two pins from left, are connected to 5V and Digital pin D2, respectively, on the Arduino NANO, which is used in this proposed system. The third pin remains open (not connected). Lastly, the fourth pin is the GND pin connected to the GND on the Arduino NANO. It is worth noting that the DHT-22 is also known as the AM-2302 sensor. Fig. 3 illustrates the DHT-22 with pin configuration. Also, Table IV presents the technical specifications of the sensor of DHT-22.

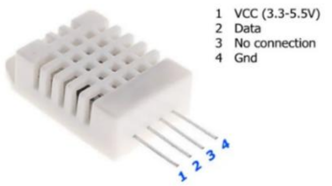


Fig. 3. Pin configuration for DHT-22.

TABLE IV: TECHNICAL SPECIFICATIONS OF DHT-22 [24]

Parameters	Value
Sensor Type (name)	DHT-22
Source Voltage Range.	3.3–6V DC
O/P signal.	Digital signal.
Component OF sensor.	Capacitor (Polymer Type).
Operation sensitivity range	humidity 0 to 100% RH. Temperature −40 to 80 ℃
Sensor's precision	humidity ±2%RH(Maximum ±5%). Temperature, less than 0.5 C.
Minimum sensitive value and Resolution	humidity 0.1%, temperature 0.1 ℃
Repeating sensing values	humidity ±1%, temperature ±0.2 ℃
Hysteresis.	±0.3%.
Long-term Stability period.	±0.5% per year
Frequency of Sensing	0.5 Hz or 2 seconds
Sensor Size	tiny size 14mm×18mm×5.5mm, big size 22mm×28mm×5mm

The MQ is one of the most reliable sensors. Also, it is better suited for monitoring airborne concentrations of alcohol, LPG, propane, smoke, methane, hydrogen, and carbon monoxide. A tiny heater and an electrochemical sensor are built into the MQ series of sensors that detect gas. These sensors are used indoors at room temperature and are sensitive to various gases [25]. The MQ-2 sensor measures the gas leakage into the surrounding air in the proposed system. MQ-2 measures the gasses in the unit of part per million (PPM). MQ-2 sensors can sense a lot of gasses such as LPG, CO, Smoke, Alcohol, Propane, Hydrogen, and even methane. The sensor used here is set to measure only LPG, CO, and Smoke gasses. The MQ-2 sensor module has four pins; the first two pins from the right V_{cc} and ground are linked to Arduino NANO's 5V and ground pins. Third pin D0 remains open (not connected). Finally, pin A0 is connected to the A6 pin in Arduino NANO. Fig. 4 represents the gas sensor MQ-2.

Fig. 4. MQ-2 gas sensor.

Also, the KY-026 flame sensor is used to detect any fire-related dangers. The working principle of this sensor module is detecting the infrared emitted by fires and receiving it by the infrared sensor built on this module [26]. The KY-026 sensor module has both digital and analog O/P. The proposed work uses the analog one due to the ability to determine the presence of fires far or close to the sensor or may be considered weak or severe. This sensor has four pins, a power line (+) pin, and a ground (G) terminal linked to 5V and GND pins in Arduino NANO, respectively. Also, the digital output (D0) pin remains open in the proposed work. Finally, the analog output pin (A0) is connected to the A2 pin in Arduino NANO. Fig. 5 presents the KY-026 sensor module.

On the receiver side, the proposed system also uses the Arduino NANO and "nRF24L01" transceiver module mentioned previously. Furthermore, the instantaneous clock module "RTC DS-1302" is also used to determine the actual time of the information readings and record it for data analysis. The RTC chips hold the real-time even if the device is not powered on, thanks to the battery cell, which lasts for a long time. The RTC DS-1302 module is a low-cost, highly accurate module that can be essential in remote sensing and data analysis [27]. RTC-DS-1302 module can show the time in seconds, minutes, hours, days, months, and years. It is worth noting that this module can determine if the month has 29, 30 or 31 days and if this is a leap year. This feature is available till the year 2100. This module has five pins, Vcc and ground terminal linked to 5V and ground pins on Arduino NANO. Furthermore, a 3-wire serial communication pins, which are the clock pin (CLK), data pin (DAT), and reset pin (RST) that are connected to the digital pins D5, D4, and D3 respectively, on the Arduino NANO. Fig. 6 illustrates the RTC DS-1302 module.

Fig. 5. KY-026 flame sensor.

Fig. 6. Real Time Clock (RTC) DS-1302.

Another component used on the receiver side is the OLED 0.96" monochrome display, which shows the temperature, gases, and flame data readings sent from the transmitter module in addition to the real-time. This display has a resolution of 128×64 pixels. The OLED display is considered to have low power consumption and high contrast compared to other displays like LCDs because it does not require a backlight. In addition, OLED pixels consume power only in on-state [28].

It should be mentioned that Arduino OLED displays come with two communication protocols: the I2C protocol (used in the proposed work) and the SPI protocol. The I2C protocol is more straightforward in connection because it has only four pins, while the SPI protocol is faster than the I2C protocol but must be connected to more pins on Arduino. The SH1106 driver is used in the I2C OLED display in the proposed system. As mentioned above, Arduino I2C OLED has four pins; GND and V_{cc} are connected to GND and 5V on Arduino NANO. Also, the serial clock (SCK) and serial data (SDA) pins are also connected to analog pins A5 and A4, respectively. Fig. 7 illustrates the Arduino OLED display.

The last module used in the proposed system is the micro-SD card adapter. The micro-SD card is considered the most common module for data logging. Other data-logging modules are used with Arduino, such as full-size SD card adapters and Arduino shields [29]. This module runs on 3.3 volts. Therefore, a built-in voltage regulator is required to reduce the most common output voltage 5-volt supply to 3.3-volts. The micro-SD card adapter has six pins connected as follows: ground and Vcc terminals were linked to ground and 5V of Arduino, respectively. The (CS) terminal was linked with the D4 terminal on Arduino NANO. Serial Port Interface (SPI) pins, MISO, MOSI, and SCK, are connected to 12, 11, and 13 pins on Arduino NANO.

We faced a problem: the nRF24L01 module and micro-SD card adapter must be connected to the same pins 11, 12, and 13, the only pins on Arduino that support SPI protocol. The abovementioned problem is solved using the method mentioned in this reference [30]. Fig. 8 illustrates the SD card adapter after modification. Also, it has been discovered that the SD card adapter used in the proposed system cannot read memory cards with an internal capacity of more than 8 GB.

Fig. 7. 0.96" OLED display.

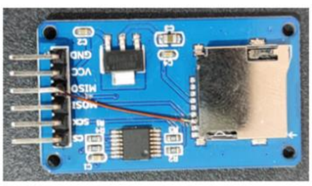
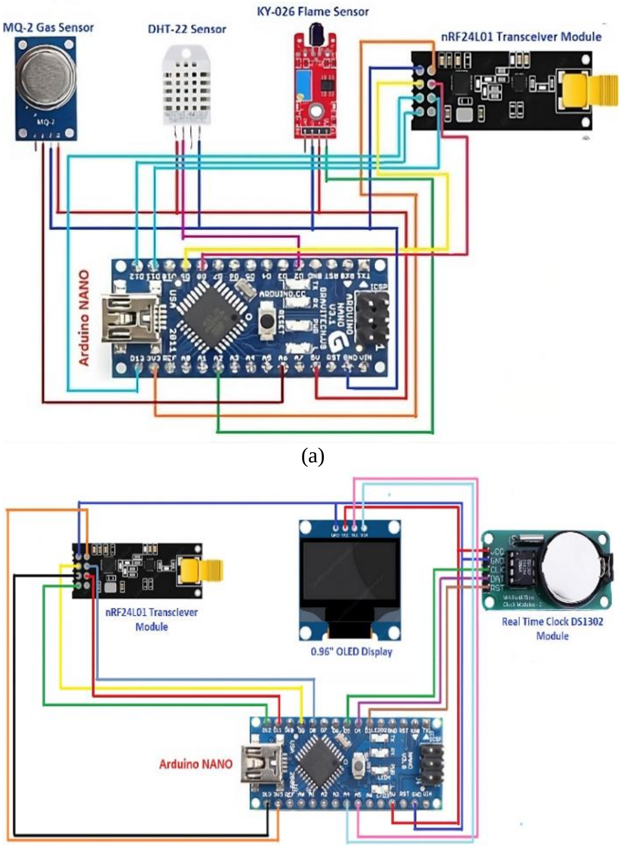


Fig. 8. SD-card adapter after modification.



(b)

Fig. 9. The wiring diagram of the connection for (a) Transmitter circuit, (b) receiver circuit.

Finally, the proposed system used an electrical buzzer and red-color LED to make an alarm for emergencies such as fires, gas leakage, or out-of-limits temperature and humidity measurements. Also, there are other connection components: breadboard and jumper wires. The wiring diagrams for transmitter and receiver circuits are presented in Fig. 9.

III. Experimental Results and Discussion

As mentioned before, the transmitter system consists of sensing devices, which read the surrounding environment measurements and deliver them to the Arduino NANO to make the necessary processes and pass those readings to the nRF24L01 module to transmit the sensor readings. The hardware part of the proposed transmitter system is shown in Fig. 10.

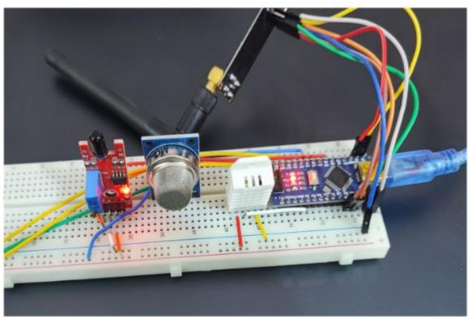


Fig. 10. Transmitter side of the proposed system.

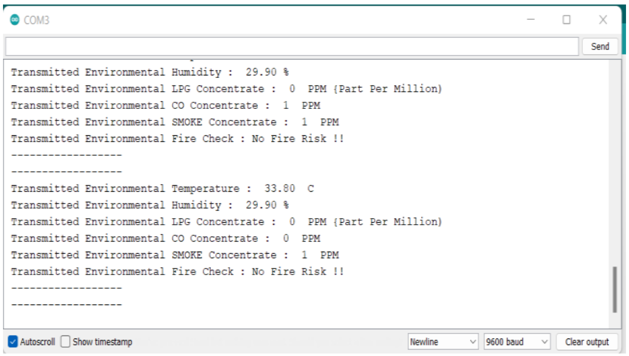


Fig. 11. Monitor of the transmitter side.

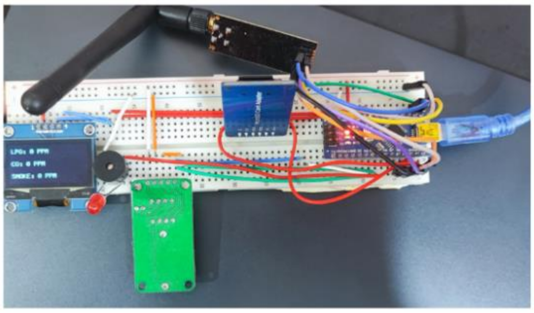


Fig. 12. Receiver side of the proposed system.

The Serial Monitor is a feature inside the (Arduino IDE). The Arduino IDE is software for writing and uploading codes to an Arduino microcontroller. The Serial Monitor presents the sensors' real-time measurements at the transmitter side. A symbol of the transmitter side readings from the serial monitor is shown in Fig. 11.

It is noteworthy that the proposed system is set to transmit the environmental condition measurements every ten seconds for easy monitoring of the sensed data on the OLED display of the receiver side, except the flammable detection, which is continuously sensed because of the great importance of this parameter, which cannot be ignored.

On the other hand, on the receiving side, the hardware part of the proposed paradigm consists of the following modules: "nRF24L01" receiving module, OLED display, RTC unit, and the micro-SD card module. The 0.96" OLED screen shows the various sensing readings that come from the sensed environment. The RTC part delivers the real-time of received data that is just late by a limited number of milli-seconds from the interpretation in the detected location. Finally, the micro-SD card provides the incoming data's storage ability to the proposed system's receiver side. The received system's hardware section is illustrated in Fig. 12.

Again, the serial monitor is programmed to display the incoming data measurements of the environmental circumcenter, providing the actual time of each data set. Fig. 13 shows the serial monitor data containing information in an SD card by the microSD unit as a text folder.

The benefit of the feature mentioned earlier is to ease storing and reviewing data to know and analyze the conditions of the tested factory environment. It should be noted that the proposed receiving system is programmed to save data one time every hour to decrease the unwanted repetitive data. We can view the contents of the micro-SD card on a personal computer or mobile device (running on the Android operating system) and then monitor the industrial environment. The figure below shows the file in which the sensors' readings were stored. The storage periods - at the rate of one reading every hour - can reach very long periods that extend to tens of years, especially when using the largest possible volume of the micro-SD card, which is acceptable by the used module, which is 8 GB.

It is worth noting that the transmitter side of the proposed system sends the sensors' reading of temperature, humidity, LPG concentration, CO concentration, smoke concentration, and the presence of flammable danger every ten seconds to the receiver side of the applicable system. The receiver side has been set to display these readings in three separate groups via the OLED display, with a period of approximately three seconds for each display group. The details of the actual date and time provided by the RTC module are displayed, after which the details of temperature, humidity, and ignition hazard are displayed together. Finally, a evaluations for MQ-2 sensor for gas are displayed, which include LPG, CO, and smoke concentrations. Fig. 14 shows how the OLED displays the sensor readings, Fig. 15 illustrates the measuring data stored in SD card.

Fig. 13. Monitor of the receiving part for proposed system.

Fig. 14. OLED display on the receiver side for all parameters.

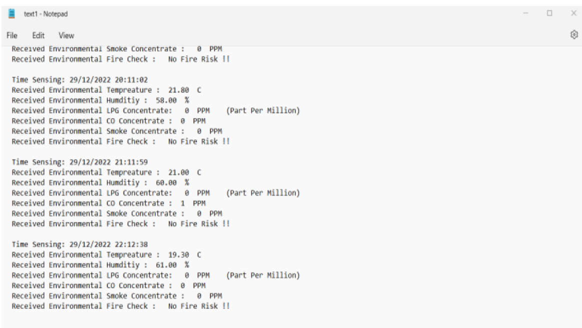
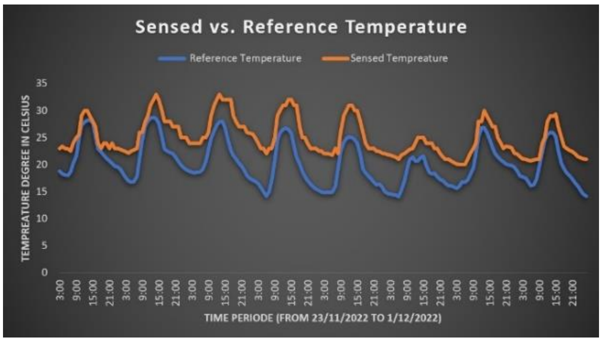
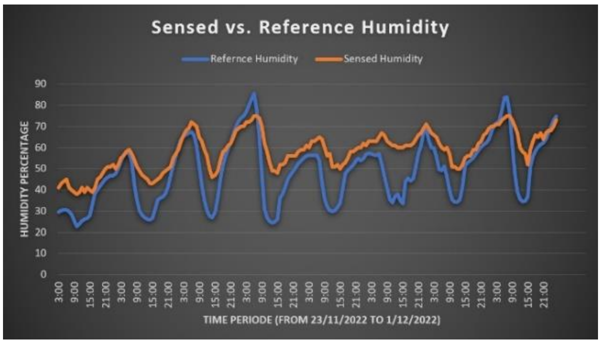


Fig. 15. The text file stored in the micro-SD card.



(a)



(b)

Fig. 16. Comparison Results between reference and sensed data for (a) temperature and (b) Humidity.

So as to ensure the excellent type and dependability of sensors work in the appropriate structure. the fire sensor is verified by illuminating a fire close to it and observing the opportunity and speediness of its hazard analysis. It became zero mistakes by applying more than ten actual examination trials for the sensor besides a summary reply time not surpassing 3 s. The process of the spare warning scheme was similarly established. An electric signal is triggered as well as LED irregular, which is automatic with a rate of 100 ms on versus 250 ms off, with ten times recurrences; at that point, the environmental circumstances are also verified [31]. The heat and moisture sensor, DHT-22 device, was also confirmed by comparing its readings with reference information obtained from the (NASA) website [32] by a testing time of a single week from 23/11/2022 to 1/12/2022. The comparison results showed significant similarity concerning the temperature, as the measured temperature is slightly higher than the reference temperature, and this is because the measured temperature was indoors, while the reference temperature is measured in outdoor environments. It must be distinguished that not one kind of air conditioner was used, whether space heating or chilling, within the time that was occupied to get the temperatures through the appropriate scheme. As for the relative humidity, the comparison outcomes show that the humidity ratio in the internal environments remained at a constant range, while there was a significant fluctuation in the measured values in the external surroundings of the position information. Fig. 16 shows the comparison results, where (a) is the temperature and (b) is the humidity results.

Table V shows the features and advantages of our proposed IoT-enabled system for environmental monitoring.

TABLE V: COMPARATIVE OVERVIEW OF IOT-BASED ENVIRONMENTAL MONITORING SYSTEMS

Paper Ref.	Sensor Type	Microcontroller	Wireless Module	Data Logging	Emergency Alerts	Validation	Wireless Range (meters)
[14]	DHT11	Arduino UNO	nRF24L01	No	Yes	Not Specified	Not Specified
[15]	DHT11, LDR, BMP180	Arduino UNO	nRF24L01+	Yes, By Special Folder	No	Thermometer and Lux Meter	30-32 m (LoS)
[16]	DHT11	STC89-C51RC	nRFL2401	No	Yes	Not Specified	200 m
[17]	SHT25, BMP085	Arduino	ZigBee	Yes, By Special Software	Yes	Atmospheric Posting Chandigarh	Not Specified
[3]	DHT11	Arduino UNO	ESP8266	Yes, by ThingSpeak	Yes	Not Specified	Not Specified
[18]	DHT-22, FC-37, BMP180	Arduino Mega 2560	ESP8266	Yes, By SD-Card	No	PCE-THB 40	Not Specified
Our Work	DHT22, MQ, Fire Sensor	Arduino Nano	nRF24L01	Yes, By Micro-SD Card	Yes	NASA Official Data	Up to 1000 m (LoS)

IV. CONCLUSION

The proposed system is divided into the transmitting and receiving parts. In the transmit portion - in the distant manufacturing services parts - the environmental circumstances of the industrial services surroundings were observed. The projected scheme does this via the use of numerous devices, such as the DHT-22 device, which calculates the amount of heat and air moisture. Also, the MQ gas sensor senses LPG, CO, and smoking attention. A fire sensor has also been used, which senses the fire risk in the industrial environment. These devices are governed through a microcontroller (Arduino Nano). This is regarded as the master-mind of the complete structure. as it assembles this information and permits it to the wireless spreader and receiver element recognized as the nRF24L01 unit. That is, in turn, directs these amounts wirelessly to the reception portion of the projected structure.

The receiving part is often found in the control and monitoring room in industrial facilities. The sensors' readings are received and displayed on the OLED screen, possibly indicating those readings in real-time for those devices' appreciation of the RTC module. The system also allows storing the received sensor values on a micro-SD card for easy review and analysis later. It should be noted that the sensor readings are received from the transmitter, displayed on the OLED screen every ten seconds, and saved to a Micro-SD card at a rate of once every hour. There is also a light and sound alarm feature employing LED flashing and an electric buzzer in case of a fire hazard or exceeding the temperature, humidity, and gas concentrations to pre-specified values.

Lastly, the values were established by the manual test with the fire device. This is with zero mistakes, which got with the excellent act and quick reply period. As for the temperature and humidity readings, these readings were compared with reference values (obtained from the NASA official website), where the comparison results showed a good convergence of the readings. It should be noted that the gas sensor has not been tested accurately.

Future research could focus on enhancing the system's accuracy through advanced sensor technologies and calibration techniques. Integrating machine learning algorithms for intelligent data analysis, such as predictive maintenance and anomaly detection, is another promising avenue. Investigating scalability issues and real-world deployment challenges, including energy efficiency and compatibility with existing industrial control systems, will also be pivotal for the system's broader application.

Conflict of Interest

The authors declare that there is no conflict of interest for this paper.

Author Contributions

The contribution of authors for this paper can be briefly describe as: Raad Farhood Chisab and Hamood Shehab Hamid conducted the research and wrote the paper with all related arrangements while Ammar A. Majeed completed all the hardware and software requirements by assembling the equipment for this paper and was responsible for extracting the graphs and figures for this paper. All authors had approved the final version.

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References

[1] S. A. Laghari, S. Manickam, and S. Karuppayah, "A review on SECS/GEM: A machine-to-machine (M2M) communication protocol for industry 4.0," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 10 no. 2, pp. 105–114, 2022.

[2] M. M. Abualhaj and Y. H. Alraba'nah, "Pygmy: Innovative technique to increase the utilization of IEEE 802.11n networks while running IPv6 telephony," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 12, no. 2, pp. 105–111, 2023.

[3] M. J. Sadiq, M. J. Zaiter, and R. F. Chisab, "Improving the energy efficiency of contention resolution mechanism in translucent optical burst switched (OBS) networks," *International Journal of Microwave and Optical Technology*, vol. 17, no. 5, pp. 574–581, 2022.

[4] O. E. Toyin, A. D. Oluwole, and A. Z. Kayode, "Speech enhancement in wireless communication system using hybrid spectral-Kalman filter," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 11, no. 5, pp. 363–372, 2022.

[5] M. Karthik and S. Mohanapriya, "Improved compressive sensing protocol with nergyefficient clustering and routing in WSNS," *ARPN Journal of Engineering and Applied Sciences*, vol. 17, no. 2, pp. 209–218, 2022.

[6] H. S. Hamid, R. F. Chisab, M. J. Mnati and Q. A. Al-Jarwany, "Design a new smart monitoring micro-grid photovoltaic system network based on mobile technology," in *Proc. 2021 Int. Conf. on Advance of Sustainable Engineering and Its Application*, Wasit, Iraq, pp. 37–42, 2021.

[7] V. Priya and S. Mohanapriya, "Traffic priority and bandwidth-aware adaptive rate adjustment with routing stability measure for congestion avoidance in WSNs," *ARPN Journal of Engineering and Applied Sciences*, vol. 17, no. 3, pp. 369–376, 2022.

[8] S. P. Rao and M. Sushama, "An IoT-based sensor technology for improving reliability and power quality in smart grid systems," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 12, no. 4, pp. 264–271, 2023.

[9] K. R. Rani and N. Chaithanya, "Performance analysis of a DG based inverter connected with microgrid," *ARPN Journal of Engineering and Applied Sciences*, vol. 17, no. 1, pp. 47–52, 2022.

[10] Y. Zhu, Z. Ding, F. Zhang, M. Gan, F. Wang, and L. Sun, "New pulse recognition system for coronary heart disease patients based on pressure sensors," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 12, no. 4, pp. 288–293, 2023.

[11] I. Alodat, "Wireless networks encryption by simulation of attacks," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 11, no. 5, pp. 351–355,2022.

[12] L. K. Qabajeh, "A scalable secure routing protocol for managed-open mobile ad-hoc networks," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 11, no. 1, pp. 54–66, 2022.

[13] M. M. Qabajeh, "SGMRP: Scalable geographic multicast routing protocol for mobile ad hoc networks," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 11, no. 4, pp. 304–316, 2022.

[14] Y. Wang and Z. Chi, "System of wireless temperature and humidity monitoring based on Arduino Uno platform," in *Proc. 2016 Sixth Int. Conf. on Instrumentation & Measurement, Computer, Communication and Control*, Harbin, China, pp. 770–773, 2016.

[15] R. Sidqi, B. R. Rynaldo, S. H. Suroso, and R. Firmansyah, "Arduino based weather monitoring telemetry system using NRF24L01+," *IOP Conference Series: Materials Science and Engineering*, vol. 336, no. 1, 2018. doi: 10.1088/1757-899X/336/1/012024

[16] B. Li, Z. Li, and L. Wei, "The design of remote temperature monitoring system," *AIP Conference Proc.*, vol. 1864, 2017. https://doi.org/10.1063/1.4992939

[17] H. Saini, A. Thakur, S. Ahuja, N. Sabharwal, and N. Kumar, "Arduino based automatic wireless weather station with remote graphical application and alerts," in *Proc. 3rd Int. Conf. on Signal Processing and Integrated Networks*, Noida, India, 2016, pp. 605–609.

[18] M. Kusriyanto and A. A. Putra, "Weather station design using IoT platform based on Arduino Mega," in *Proc. Int. Symp. on Electronics and Smart Devices*, Bandung, Indonesia, 2019, pp. 8–11.

[19] M. F. Mahmood, S. L. Mohammed, and S. K. Gharghan, "Energy harvesting-based vibration sensor for medical electromyography device," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 9, no. 5, pp. 364–372, 2020

[20] Arduino NANO. [Online]. Available: https://store.arduino.cc/products/arduino-nano

[21] W. T. Sung, C. W. Sung, and C. Y. Hsiao, "Environment monitoring system based on architecture of IoT by wireless sensor

network," in *Proc. of 2018 Int. Symp. on Computer, Consumer and Control*, 2018, pp. 330–333.

[22] How nRF24L01+ Wireless Module Works & Interface with Arduino. (accessed Oct. 30, 2022). [Online]. Available: https://lastminuteengineers.com/nrf24l01-arduino-wireless-communication/

[23] Q. Y. Wong and Y. B. Chu, "A mobile production monitoring system based on internet of thing (IoT) and random forest classification," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 10, no. 4, pp. 243–250, 2021.

[24] DHT22—Digital Temperature and Humidity Sensor. [Online]. Available: https://cityos-air.readme.io/docs/4-dht22-digital-temperature-humidity-sensor

[25] B. K. Mohammed, M. B. Mortatha, A. S. Abdalrada, and H. T. S. ALRikabi, "A comprehensive system for detection of flammable and toxic gases using IoT," *Periodicals of Engineering and Natural Sciences*, vol. 9, no. 2, pp. 702–711, 2021.

[26] J. M. S. Waworundeng, M. A. T. Kalalo, and D. P. Y. Lokollo, "A prototype of indoor hazard detection system using sensors and IoT," in *Proc. 2020 2nd Int. Conf. on Cybernetics and Intelligent System*, Manado, Indonesia, pp. 1–6, 2020.

[27] T. Khan and M. K. Chattopadhyay, "Smart health monitoring system," in *Proc. 2017 Int. Conf. on Information, Communication, Instrumentation and Control*, Indore, India, 2017, pp. 1–6.

[28] C. K. Ng and N. A. Jumadi, "IoT-based instrumentation development for reaction time, kick impact force, and flexibility index measurement," *International Journal of Electrical and Electronic Engineering and Telecommunications*, vol. 11, no. 1, pp. 82–87, 2022.

[29] H. T. S. AL Rikabi, A. H. M. Alaidi, and F. T. Abed, "Attendance system design and implementation based on radio frequency identification (RFID) and arduino," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 10, no. 4, pp. 1342–1347, 2018.

[30] M. T. Ali, Y. R. Muhsen, R. F. Chisab, and S. N. Abed, "Evaluation study of radio frequency radiation effects from cell phone towers on human health," *Radioelectronics and Communications Systems*, vol. 64, no. 3, pp. 155–164, 2021.

[31] B. K. Mohammed, R. F. Chisab and A. H. Alwaily, "The powerful method for smart classroom communication rely on IoT," in *Proc. of 2021 Int. Conf. on Advance of Sustainable Engineering and its Application*, Wasit, Iraq, 2021, pp. 33–36.

[32] Power | Data Access Viewer. (Dec. 20, 2022). [Online]. Available: https://power.larc.nasa.gov/data-access-viewer/

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