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AirGeo Sense: Air Quality Monitoring With Real-Time Location Tracking

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Abstract:

Real-time location tracking and air quality monitoring are two separate modules that are combined in the internet of things project AirGeo sense. This project offers a comprehensive solution for individuals and communities to monitor their environment, stay informed about air quality, and ensure their well-being by smoothly combining the capabilities of both modules. The project involves the integration of two distinct Internet of things concepts: air quality monitoring and location tracking. The core of the suggested system is an Arduino-based architecture that supports both functionalities.

Keywords **—Location Tracking, Air Quality Index (AQI), Air quality Monitoring Technologies- Arduino UNO,SIM 800l, GSM module, Neo 6m GPS module, Firebase, React and vite**

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I. INTRODUCTION

AirGeo Sense is an IOT-based project that amalgamates two distinct modules, real-time location tracking and air quality monitoring. By seamlessly integrating the capabilities of both modules, this project presents a holistic solution for individuals and communities to monitor their environment, stay informed about air quality, and ensure their well-being. The project entails the fusion of two independent IOT concepts: location tracking and air quality monitoring. the proposed system revolves around an Arduino-based architecture, which serves as the backbone for both functionalitiesthe work emerges as a pioneering integration of two critical facets of modern living:location tracking and air quality monitoring. Rooted in the potential of Internet of Things (IOT)technology and powered by Arduino-based solutions,"AirGeo Sense" represents a transformative endeavor poised to empower individuals and communities with real-time information vital for their well-being.

This article contains the, explanation, methodologies used in the work AirGeo Sense. The section literature review focuses on the improvements and modifications that we have done to this work based on the referenced works. The technologies section contains all technologies that are used in the work and why they have been chosen, further all the device parts and modules used in building the device is explained with circuit diagrams, ER diagrams. This article also explains how both the AQI monitoring system and the location tracking system seemingly two different modules work together to provide a consistent reading of the AQI value together with location data. Finally, the article contains all the references of previous work that have been used for creation the creation of this work.

II. LITERATURE REVIEW

This work proposes a way in retrieving AQI together with real-time location data from where the reading was made. Previous works that monitor AQI doesn't integrate the location details from where the readings were taken from. AQI is one of the important factors that affect the human health, so monitoring the AQI becomes a crucial part to

ensure a healthy life to vulnerable and sensitive groups of people.

This work also implements an API for logging the AQI reading so it can be retrieved based on the time the readings were taken. In existing works once, the reading is taken the value is lost immediately once a new reading is made, the API implemented in this work overcomes this problem by logging the data on which further processing can be done to extract useful information like identifying the time when the AQI is the best and when the its the worst by analysing the data logged a pattern can be created to get more understanding.

III. TECHNOLOGIES

A. Internet of Things (IOT)

The convergence of many technologies, machine learning, embedded systems, and commodity sensors has led to a significant evolution in the term ”IOT.” IOT is a network of networked devices that have been given a unique identifier (UIDS), allowing for device control and data transfer across a network [17]. It lessened the need for direct human engagement when using a technology. Internet of Things sophisticated automation and analytics system that makes use of big data [13], networking, sensing, and technologies use artificial intelligence to provide full systems for a good or service. These technologies enable increased performance, control, and transparency in any sector or framework.

B. React and Vite

The dynamic pair in contemporary web development is React and Vite. Vite is an expedient build tool, while React is an open-source JavaScript toolkit for creating user interfaces. As its name implies, React facilitates the creation of interactive and responsive web applications by managing user interface components effectively. It is well known for using a virtual DOM for best performance and for having a component-based architecture. It’s a build tool with an emphasis on simplicity and speed. With features like rapid server start, lightning-fast hot module replacement, and nearly instantaneous changes while developing, Vite uses ES modules to enable a lightning-fast development experience. React and Vite work together to give web developers a powerful tool.

C. PostgreSQL

PostgreSQL is an RDBMS that efficiently manages and retrieves data by organizing and storing it in structured tables. It can be used for a variety of tasks, from basic data storage to sophisticated data analytics, because it supports complicated data types, indexing, and powerful SQL querying capabilities. PostgreSQL is unique in that it adheres to standards and supports both organized and unstructured data. Furthermore, it offers functions such as foreign keys, transactions, and advanced locking mechanisms to ensure data integrity and consistency. PostgreSQL’s extensibility further expands its capabilities by enabling developers to construct unique functions and extensions. Because it is open-source, it can be downloaded for free and has a strong community behind it, which makes it a popular option for both small and large-scale applications.

The back-end database that we have used for the API is PostgresSQL. It is a free and open-source relational database management system (RDBMS). It has features like transactions with atomicity, consistency, isolation, durability (ACID) properties, automatically updatable views, materialized views, triggers, foreign keys, and stored procedures. It is supported on all major operating systems and handles a range of workloads from single machines to web services with large number of users.

D. Firebase

Google created Firebase, a feature-rich cloud-based platform for creating and managing mobile and online applications. It provides a broad range of tools and services to improve user experiences, accelerate application development, and assist developers in expanding and managing their projects. Firebase is a feature-rich option for app development because of its abundance of functions.

E. API

An application programming interface, or API, provides communication between computers. It is an interface for software that serves other software.

API standards, also known as API specifications, provide instructions on how to design or use an interface. Computer systems that meet this standard are called applications or public APIs. While API controls how code is written to take advantage of the functionality of the system.

The API of the project is developed using FasAPI and PostgresSQL, the api provides AQI values that are logged when the sensor reads a new value. It stores the AQI value with the latitude, longitude of the location and and the timestamp of reading.

We have provide a way for the user to get the AQI values of certain time periods through API with request in the range of given timestamp.

F. Python

Python is a high-level, general-purpose programming language. FastAPI is a framework for Python. It uses trash collection and dynamic typing. It is compatible with various programming paradigms, such as object-oriented, functional, and structured (especially procedural). Because of its extensive standard library, it is referred to as" batteries included".

G. FastAPI

A high-performance web framework called FastAPI is used to create Python APIs. FastAPI, which is well-known for its simplicity, speed, and automatic documentation production, enables developers to rapidly and efficiently design reliable APIs. It seamlessly supports asynchronous programming and makes use of Python's type hints for effective code generation. FastAPI is a Python web framework that is highly recommended for API development due to its remarkable speed. It is easy to learn and use because it combines the ease of use of Python with automatic documentation production. Python type hints in conjunction with FastAPI's support for asynchronous programming guarantee code efficiency and dependability. It is a flexible solution for a variety of online applications because it comes with built-in features for authentication, WebSocket support, and request and response validation. With FastAPI, you can easily construct high-performance APIs as a corporate developer, data scientist, or startup developer. It is based on Pydantic and uses type hints to validate, serialize and deserialize data. It also automatically generates OpenAPI documentation for APIs built with it. It fully supports asynchronous programming and can run on Gunicorn and ASGI servers such as Uvicorn and Hypercorn, making it a good choice for production environments

H. Uvicorn

Uvicorn is a Python implementation of an ASGI web server. Our server machine hosts our API using Uvicorn. The server receives the web application's API request and responds with the API

I. Arduino C++

A programming language and environment called Arduino C++ was created especially for the Arduino microcontroller platform. Because it combines the flexibility and power of C++ with the streamlined coding structure of Arduino, it is usable by both novice and expert programmers. Arduino C++: Combining Power and Simplicity for Embedded Systems A specific programming language called Arduino C++ was created for embedded systems and microcontroller-based projects. It is based on the C++ language, gaining access to its robust functionality while streamlining hardware project creation. It is the preferred programming language for Arduino boards, allowing programmers to create code for a variety of uses [18], such as home automation and robotics and Internet of Things devices. With an emphasis on user-friendliness, Arduino C++ makes even the most novice engineers able to perform tasks like I/O management, sensor interfacing, and connection with other devices. Its extensive library ecosystem and open-source community support further increase its adaptability, making it the preferred language for creating unique electronic systems and fast prototyping. The Arduino C++ bridge allows developers to connect the worlds of software and hardware, enabling them to realize their ideas.

IV. HARDWARE

A. Arduino Uno WiFi Module

The Arduino Uno WiFi module [3] combines integrated Wi-Fi networking with the features of the original Arduino Uno. It makes it possible to construct Internet of Things projects with ease by fusing the ESP8266 Wi-Fi module and the ATmega328P microprocessor. The Arduino Uno's well known functionality, like digital and analog I/O ports, PWM outputs, and UART connection, are still present on this board, but it also has inbuilt WiFi for network and internet access..

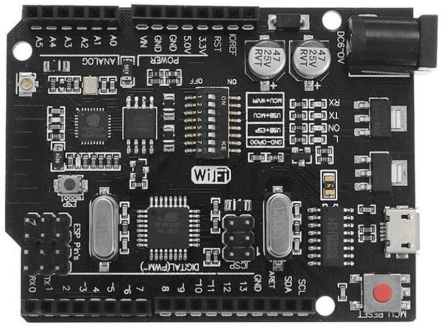

Fig. 1. Arduino Uno WiFi Module.

a) Application Focus: Because of this combination, it is perfect for projects that call for cloud-based interactions, data logging, and remote monitoring. Utilizing the extensive library of code examples and resources available through the Arduino IDE [6], you can program it to promote accessibility and user-friendliness among the Arduino community.

b) Evolution of Arduino: In 2003, a group of students founded Arduino with the primary goal of using it for educational reasons. It changed throughout time to accommodate 3D printing, embedded devices, and the Internet of Things. In spite of this development, enthusiasts can still purchase Arduino boards, which are supported by a vibrant and cooperative community that values the open-source character of the product.

c) Technical Specifications of Arduino Uno: Renowned microcontroller Arduino Uno runs on an open-source platform and has been through three major iterations [6]. It has 14 digital I/O pins, including 6 PWM pins, 6 analog input pins, 32KB of flash memory, and multiple connectivity choices (UART, I2C, SPI). It is based on the ATmega328P architecture. Among its technical details are:

- Operating Voltage: 5 Volts
- Input Voltage Range: 7 to 20 Volts
- Digital I/O Pins: 14
- PWM Pins: 6 (Pin 3, 5, 6, 9, 10, and 11)
- UART/I2C/SPI: 1 each
- Analog Input Pins: 6
- Flash Memory: 32 KB (0.5 KB used by bootloader)
- SRAM: 2 KB
- EEPROM: 1 KB
- Clock Speed: 16 MHz
- Dimensions: Length 68.6 mm, Width 53.4 mm, Weight
  25 g
- Power Sources: DC Power Jack and USB Port

d) Pin Functions: Important pins on the board include LED, VIN, 5V, 3.3V, GND, and IOREF, each of which performs a particular power supply or reference function. Both the digital and analog pins, which allow 5 volts and a maximum suggested working current of 20mA, provide flexible input/output capabilities. Important pins on the board include LED, VIN, 5V, 3.3V, GND, and IOREF, each of which performs a particular power supply or reference function. Both the digital and analog pins, which allow 5 volts and a maximum suggested working current of 20mA, provide flexible input/output capabilities.

e) Specialized Pin Functions: Furthermore, specialized pins facilitate a range of functionalities: six analog and fourteen digital pins, all of which can be programmed as inputs or outputs and come with an inbuilt pull-up resistor of 20–50K ohms. Six analogue inputs with a 10-bit resolution (1024 distinct values) are included in the Uno.

B. MQ135 Gas Sensor

One popular gas sensor that is well-known for detecting a wide variety of gases in the atmosphere is the MQ135 sensor [3]. It is mostly used to detect dangerous gases such as carbon dioxide (CO2), car-

bon monoxide (CO), ammonia (NH3), nitrogen oxides (NOx), and other chemical compounds. Its working principle is based on chemical resistance, which is the change in electrical conductivity of the sensor when it is exposed to various gases. Measurable gas detection is made possible by the translation of this change in conductivity into an analog voltage signal.

Fig. 2. MQ135 Gas Sensor.

a) Applications and Functionality: The MQ135 sensor is a widely used and easily accessible component that is frequently included into systems for environmental sensing, indoor air quality evaluation, gas leak detection, and air quality monitoring. [9] Real-time gas monitoring and control is made possible by its smooth interface with development boards and microcontrollers. It is important to recognize, though, that although the MQ135 sensor is versatile, ambient conditions and the particular gases being detected may have an impact on its accuracy. As a result, in order to obtain correct readings, compensation and calibration measures could be necessary.

b) Additional Features and Functions: In addition to its broad gas detection capabilities, the MQ135 sensor boasts the following features and functionalities:

- Interfacing Capabilities: Easily interfaces with microcontrollers and development boards for seamless integration into various systems.
- Cost-Effectiveness: Provides an economical solution for gas sensing applications[3], ensuring accessibility for a wide array of projects.
- Real-Time Monitoring: Enables real-time monitoring and control of gas levels within the environment, facilitating prompt responses to fluctuations.
- Widely Available: Readily accessible sensor, ensuring widespread availability for diverse applications.
- Versatile Application Scope: Suitable for a range of scenarios including air quality assessment, gas detection [9], and environmental monitoring.

C. Neo-6M GPS Module

Utilizing serial communication (UART), this module establishes seamless communication with microcontrollers or other devices, [1] furnishing real-time data encompassing latitude, longitude, altitude, speed, and time.

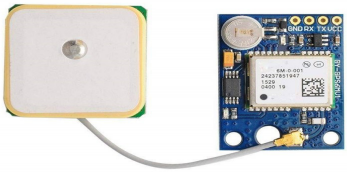

Fig. 3. Neo-6M GPS Module.

a) Module Description: The Neo-6M module, which is based on the NEO-6M GPS chip from the u-blox 6 series, is excellent at gathering precise position and time data. Applications for navigation, tracking, geocaching, and other location-based tasks are among its many uses. This module provides real-time data like latitude, longitude, altitude, speed, and time by establishing smooth communication with microcontrollers or other devices through the use of serial communication (UART).

b) Key Features: Notable features of the Neo-6M module include its small size, low power consumption, and compatibility with several satellite navigation [15] systems, such as GPS and GLONASS. It works best with 3.3V or 5V power supplies and connects to well-known development boards like Arduino and Raspberry Pi with ease.

c) Versatile Application Range: Applications requiring accurate position and timing data will greatly benefit from this module's streamlined integration of GPS features. The Neo-6M module has been widely used in hobby electronics, drone navigation, car tracking, and many other fields. It is an invaluable tool for a wide range of applications that need precise GPS performance.

d) Additional Features and Functions: Expanding on its functionalities, the Neo-6M module presents further attributes:

- High Precision: Ensures accurate and reliable acquisition of position and time data.
- Low Power Consumption: Optimal for power-efficient applications, enhancing overall system efficiency.
- Multiple Satellite System Support: Compatibility with GPS and GLONASS systems, broadening its navigation capabilities.
- Easy Interfacing: Seamless integration with popular development boards, simplifying project implementation.
- Diverse Applications: Versatile usage across various sectors, including hobbyist electronics, vehicle tracking, and drone navigation.

D. SIM800L GSM Module

The Global System for Mobile Communications (GSM) SIM800L module is a small and adaptable module that is essential to cellular connection in electronic devices.

Fig. 4. SIM800L GSM Module.

a) Module Description: The SIM800L module, which is made by SIMCom, is a GSM/GPRS module that makes it easy to connect to a mobile network. This module is widely used in applications that require voice calls, SMS (Short Message Service), and data transmission over cellular networks. Its small size and low power consumption make it flexible for a range of uses.

b) Key Features: The SIM800L module's primary features include support for quad-band GSM/GPRS frequencies, a serial UART interface, and interoperability with standard AT commands for communication and operational control.
Operating normally in the voltage supply range of 3.4V to 4.4V, it guarantees consistent performance in a variety of configurations.

c) Versatile Application Range: The SIM800L module is widely used in scenarios requiring cellular connectivity, such as vehicle tracking, remote monitoring and control systems, and Internet of Things installations. Because of its capacity to enable smooth data transfer via cellular networks, it is an essential part of incorporating wireless communication into a variety of technological projects.

d) Additional Features and Functions: Expanding upon its functionalities, the SIM800L module presents additional features:

- Low Power Consumption: Optimal power utilization enhancing energy efficiency across applications.
- Compatibility with AT Commands: Streamlines control and communication through standardized AT commands.
- Quad-Band Support: Facilitates connectivity across various GSM/GPRS [1] frequency bands, ensuring global operability.
- Compact Design: Space-efficient form factor, conducive to integration into diverse electronic setups.
- Enhanced Connectivity: Enables seamless data transmission over the cellular network, bolstering wireless communication capabilities.

E. ESP32 Microcontroller [5]

The ESP32 [5] is a widely recognized microcontroller module that combines Bluetooth and Wi-Fi connectivity with powerful computing power.

a) Module Description: The ESP32, a member of the ESP (Espressif) microcontroller family, is a

popular option for embedded systems development and the Internet of Things (IoT). [15] It is powered by a dual-core TensilicaXtensa LX6 processor that runs at high clock speeds and has a wide range of peripheral interfaces that make it suitable for a variety of uses.

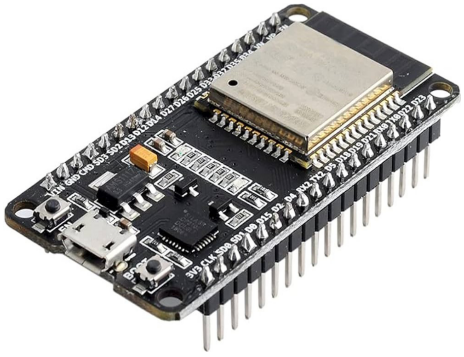

Fig. 5. ESP32 Microcontroller Module.

b) Key Features: Integral features of the ESP32 moduleencompass:

- Dual-Core Processor: Employs two potent CPU cores enabling efficient multitasking and task management.
- Wi-Fi and Bluetooth: Supports Wi-Fi (802.11b/g/n) and Bluetooth (Classic and BLE), catering to wireless communication prerequisites.
- Abundant I/O: Presents a multitude of GPIO pins, PWM channels, UART, SPI, I2C, and assorted interfaces, ensuring versatility across applications.
- Ultra-Low Power Consumption: Incorporates sleep modes for minimized power usage, pivotal for energy efficient and battery-powered devices.
- Rich Development Ecosystem: Backed by an expansive and dynamic developer community, featuring extensive libraries, documentation, and IDEs such as Arduino IDE and ESP-IDF for programming.
- Integrated Security Features: Offers hardware-accelerated encryption and secure boot options, enhancing security measures.
- Cost-Effectiveness: A cost-efficient option for integrating wireless capabilities and processing power into IoT projects.

c) Application Range: widely used in wearable technology, robotics, home automation, IoT applications [13], and other projects requiring strong computational power and wireless connection. Because of its combination of Wi-Fi, Bluetooth, and powerful processing power, the ESP32 is a popular choice for developers creating a wide range of applications.

V. LOCATION TRACKING SYSTEM

The location tracking system [1]is based on an ESP32 board and connects to a GPS and GSM module in order to provide a range of features. Acquiring position data is mostly done through the GPS module, which records exact geographic coordinates. Simultaneously, the GSM module allows SMS sending to the chosen owner's mobile device and coordinates communication with Firebase, a real-time database service.

- The GPS module is the core component of location data collecting. It uses satellite signals to pinpoint the precise geographic location of the device. This module provides steady streams of latitude and longitude coordinates, making accurate tracking capabilities essential to the accuracy of the system possible.
- The cloud-based real-time database Firebase and the GSM module interface easily, creating a strong connection for data exchange. By utilizing Firebase's features, the system guarantees effective and safe data synchronization, retrieval, and storage in real-time. In addition, the GSM module sends SMS [15] alerts to the owner's mobile device, guaranteeing prompt updates regarding the location status of the device or important occurrences.
- The solution provides a dynamic platform for managing and storing data thanks to its interaction with Firebase's [17] real-time database. It enables real-time data updates, guaranteeing that the most recent location data is always accessible for retrieval. Furthermore, Firebase gives the system access to scalable and secure

data storage, making it easy to access and manipulate location-related data.

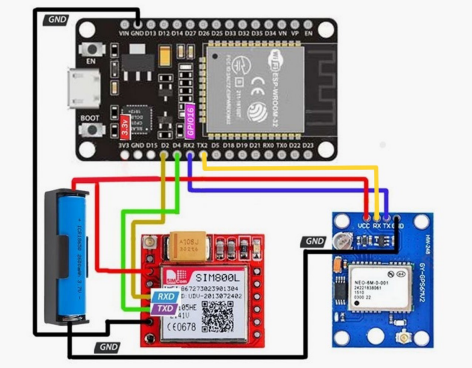

Fig. 6. Example of a figure caption.

- With the help of a specialized web application, the system expands its capability and makes use of Firebase's features for thorough monitoring and alerting. Users can observe and track the location of the device in realtime with the help of the web application's user-friendly interface. Moreover, it makes customized alerts and notifications possible, which improves user interaction and system responsiveness.
- A strong position tracking system is produced by the

ESP32 board's connectivity with the GPS and GSM modules, [1] Firebase integration, and the web application. It collects, saves, and transmits location data in an effortless manner, guaranteeing precise tracking and effective owner communication, improving user accessibility and control.

VI. AIR QUALITY MONITORING SYSTEM

By connecting a MQ135 sensor to an Arduino board [1] [2], the air quality monitoring system measures the quantity of various gases in the atmosphere and reports the results in" Parts per Million" (PPM). [7] In order to receive real-time position information, this system further interfaces with the position Tracking module. It then uploads the gathered air quality data to Firebase, a real-time database server.

- By connecting a MQ135 sensor to an Arduino board, the air quality monitoring system measures the quantity of various gases in the atmosphere and reports the results in" Parts per Million" (PPM). In order to receive real-time position information, [17] this system further interfaces with the position Tracking module. It then uploads the gathered air quality data to Firebase, a real-time database server.
- The MQ135 sensor, which is the heart of the system, was painstakingly created to identify and measure the presence of different gases in the air. To monitor the concentration levels of gases such carbon dioxide (CO2), carbon monoxide (CO), ammonia (NH3), nitrogen oxides (NOx), and different organic compounds, this sensor uses its chemical resistance mechanism. Accurate air quality assessment is made possible by the sensor's capacity to translate gas presence into measurable PPM values.
- The MQ135 sensor integrates with an Arduino board in a seamless manner, [11] taking advantage of its processing power to process the data on gas concentration. The Arduino board functions as the central control unit, coordinating the collection of data from the sensor and enabling the transfer and processing of the air quality data later on.

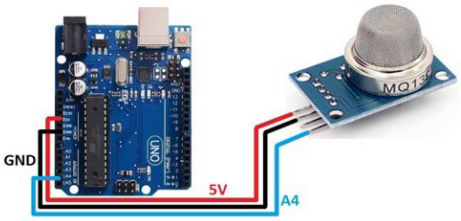

Fig. 7. Example of a figure caption.

- Alongside the evaluation of air quality, the device has a Location Tracking module to obtain current geographic coordinates [15]. By using this module, the device's current position is retrieved by the system, adding accurate location information to the air quality data.
- After the system obtains the combined location and air quality data, it uploads the data to Firebase's real-time database [17]. Firebase is a dependable and expandable platform that makes it easier to store, sync, and access air quality data

in real time. Trends and variations in air quality over time can be easily retrieved and visualized thanks to this interface.

- An extensive air quality monitoring system is achieved by integrating the MQ135 sensor [11] with the Arduino board, location tracking, and Firebase. This method is essential for environmental assessments in a variety of contexts, including industrial site inspections, outdoor pollution monitoring, [8] and interior air quality assessment. By enabling consumers to make knowledgeable decisions about air quality management and corrective measures, it promotes healthier living conditions.

VII. USER ACCESS AND INTERACTION

The system grants user access to device ownership through authentication, ensuring secure interaction with the system's functionalities. Authenticated users gain entry to a web application developed using React + Vite and backed by Firebase, enabling comprehensive management and monitoring of the device's whereabouts [10] and air quality parameters.

A. Authentication and Access Control

After completing the authentication process successfully, the user is granted access to the web application's interface, which offers real-time visualization of the device's location through integration with Mapbox. Furthermore, the user is granted access to critical air quality data related to the device's location, thereby enabling well-informed decision-making concerning environmental conditions.

B. Location Monitoring and Distance Settings

The user has the ability to establish a programmable distance [15] range for the device, which establishes a bound within which the device is expected to stay. Should the device exceed this pre-established range, the system will send an SMS [17] notification to the user's mobile device, guaranteeing prompt notifications regarding the device's movement over the designated distance.

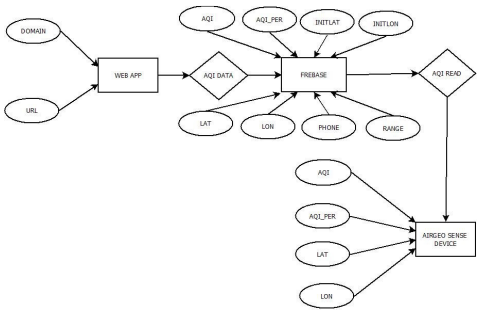

Fig. 8. erdiagram for User Access and Interaction.

C. User Interaction with Device Functions

Through the web application interface, users interact seamlessly with device functionalities. This includes:

- Air Quality Assessment: Viewing real-time air quality metrics specific to the device's location, empowering users to monitor environmental conditions remotely.
- Distance Range Configuration: Enabling users to set and adjust the distance range parameter for the device, customizing the geographical boundaries within which the device should operate.
- Location Tracking: Facilitating the visualization of the device's current geographical location on the Mapbox map interface, allowing users to track the device in realtime.

D. Technology Stack and Backend Integration

The web application includes Firebase as the backend infrastructure and uses React + Vite as the frontend framework. The efficient and dependable operation of the system is improved by this strong technology stack, which guarantees smooth data management, real-time updates, and safe user interactions.

E. User-Centric Experiences

The user's comfort and engagement are given top priority in the system's design, which offers a user-friendly and interactive interface for controlling device functions. The combination of SMS notifications, air quality monitoring, and location tracking allows users to actively monitor and control the device's behavior from a distance.

CONCLUSION

Since the quality of the air we breathe has a direct impact on our health, it is imperative that we monitor and evaluate it. This project uses inexpensive, portable technology to provide accurate measurements of the air quality as well as the location of each reading. This data is stored on a Postgres SQL server by an API created using the FastAPI framework to enable data logging. By interacting with the API server, the web application makes it possible to filter readings according to time and date. Long-term reading storage is ensured by this logging feature, supporting analytical goals.

REFERENCES

[1] MERAL, Erkan, and Mehmet Serdar GUZEL. ”Real-time geolocation¨ tracking and geofencing using GPRS+ GPS technologies with SIM908 shield over Arduino.” Communications Faculty of Sciences University of Ankara Series A2-A3 Physical Sciences and Engineering 58.2 (2016): 14-27.

[2] Saha, Arnab Kumar, et al. ”A raspberry Pi controlled cloud based air and sound pollution monitoring system with temperature and humidity sensing.” 2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC). IEEE, 2018.

[3] KalagotlaChenchireddy, Sandhya, Praveen, Karthik, Maruthi.” AirQuality Monitoring and Alert System Using MQ135 Gas Sensor with Arduino Controller.” Dept. of Electrical and Electronics Engineering, Teegala Krishna Reddy Engineering College, Hyderabad,pp 2022,ISSN 2582-7421.

[4] Guzel, Mehmet Serdar, and Erkan Meral. ”A novel real time geolocation¨ tracking tool.” arXiv preprint arXiv:1803.08325 (2018).

[5] Akram, Nusin, et al. ”Design and implementation of asset tracking system based on internet of things.” 2021 7th International Conference on Electrical, Electronics and Information Engineering (ICEEIE). IEEE, 2021.

[6] Perumal, B., Deny, J., Alekhya, K., Maneesha, V., and Vaishnavi, M. (2021, August). Air Pollution Monitoring System by using Arduino IDE. In 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC) (pp. 797-802). IEEE.

[7] Shah, H. N., Khan, Z., Merchant, A. A., Moghal, M., Shaikh, A., and Rane, P. (2018). IOT based air pollution monitoring system. International Journal of Scientific and Engineering Research, 9(2), 62-66.

[8] Zulkifli, Nor Saradatul Akmar, et al. ”IoT-based smart environment monitoring system for air pollutant detection in Kuantan, Pahang, Malaysia.” IOP Conference Series: Materials Science and Engineering. Vol. 769. No. 1. IOP Publishing, 2020.

[9] Alam, S. B., Biswas, R. V., Pritee, Z. T., Shahria, M. N., Hannan, N., and Sadik, W. (2023). Design of an Arduino-Based Autonomous Robot for the Detection of Harmful Gas Leakage and Air Pollution (No. 10205). EasyChair.

[10] Obodoeze Fidelis, C., A. Nwabueze Chris, and A. Akaneme Silas. ”Internet of Things (IoT) Based Real-Time Pollution Monitoring System for Awka Metropolis.” (2021).

[11] Rani, S. U., Rajarajeswari, S., Jaimon, J. G., and Ravichandran, R. O. S. H. A. N. (2020). Real-time air quality monitoring system using MQ-135 and thingsboard. Journal of critical reviews, 7(18), 4107-4115.

[12] Jha, Rohan Kumar. ”Air quality sensing and reporting system using IoT.” In 2020 Second international conference on inventive research in computing applications (ICIRCA), pp. 790-793. IEEE, 2020.

[13] Zakaria, Nurul Azma, et al. ”Wireless internet of things-based air quality device for smart pollution monitoring.” International Journal of Advanced Computer Science and Applications 9.11 (2018).

[14] Tong, T. Y., and Zainal, N. (2023). IoT-Based Portable and Tracking Device for Children Safety. Evolution in Electrical and Electronic Engineering, 4(2), 46-55.

[15] Chavan, P. A., Tidake, M. N., Tiwadi, S. S., Tighare, R. G., Tilekar, T. V., and Tidke, R. R. (2022). Smart Tracking Device. NeuroQuantology, 20(13), 3617.

[16] Tong, T. Y., and Zainal, N. (2023). IoT-Based Portable and Tracking Device for Children Safety. Evolution in Electrical and Electronic Engineering, 4(2), 46-55.

[17] Crisgar, Puji Valen, et al. ”GPS-based vehicle tracking and theft detection systems using

Google Cloud IoT core & Firebase." 2021 International Symposium on Electronics and Smart Devices (ISESD). IEEE, 2021.

[18] Husain, Ashish M., et al. "Air quality monitoring: The use of arduino and android." Journal of Modern Science and Technology 4.1 (2016): 86-96.

