**LIVE AIR QUALITY MONITORING SYSTEM**

**USING IOT**

**A PROJECT REPORT**

***Submitted by***

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**BONAFIDE CERTIFICATE**

Certified that this project report “LIVE AIR QUALITY MONITORING SYSTEM USING IOT” is the bonafide work of “Mohammed Shabeer, Abhishek M” who carried out the project work under our supervisor.

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**ABSTRACT**

Air pollution is a growing concern worldwide, with significant impacts on public health and the environment. To address this issue, we present a comprehensive solution—a Live Air Quality Monitoring System using IoT technologies. This system employs the ESP32 microcontroller interfaced with DHT11, MQ-135, and MQ-7 sensors to measure temperature, humidity, and concentrations of CO2 and other harmful gases in real-time. The collected data is seamlessly transmitted to Google Firebase for efficient storage and management.

The heart of the project lies in its ability to provide users with live air quality information through an intuitive Flutter mobile application. This application not only visualizes the data from the sensors but also incorporates an alert feature. When the CO2 concentration surpasses a predefined threshold, the app triggers an alert, notifying users of potential air quality concerns. The integration of Firebase ensures that historical data is readily available for analysis, allowing users to track trends and make informed decisions regarding their environment.

This project aims to raise awareness about air quality and empower individuals to take proactive measures to mitigate the impact of poor air quality on their health. The combination of IoT, cloud computing, and mobile app development showcases a versatile and scalable solution that can be adapted for various applications in environmental monitoring and public health.

CHAPTER – 1

**INTRODUCTION**

The rapid pace of urbanization and industrialization has brought forth unprecedented challenges to environmental sustainability, with air pollution emerging as a critical concern affecting both public health and the ecosystem. In response to the escalating need for real-time air quality monitoring, we present a comprehensive project—a Live Air Quality Monitoring System utilizing cutting-edge Internet of Things (IoT) technology. This system integrates a suite of sensors, including the DHT11 for temperature and humidity measurement, the MQ-135 for detecting air quality parameters, and the MQ-7 for monitoring carbon monoxide levels.

The central processing unit for this system is the ESP32 microcontroller, a versatile and powerful platform that facilitates seamless sensor integration and data communication. The gathered sensor data is transmitted to the cloud-based Google Firebase service, offering a robust and scalable solution for data storage, retrieval, and analysis.

The cornerstone of user interaction in this project is a dynamic Flutter mobile application. This application provides a user-friendly interface for visualizing real-time air quality metrics, ensuring accessibility for individuals seeking to monitor their immediate surroundings. Beyond real-time data visualization, the app incorporates an alert mechanism, triggered when the concentration of carbon dioxide (CO2) surpasses predefined safety thresholds. This feature aims to empower users by providing timely notifications, allowing them to take proactive measures when air quality becomes a concern.

The synthesis of IoT, cloud computing, and mobile app development in this project exemplifies a holistic approach to address the challenges posed by air pollution. By enabling individuals to monitor air quality in real-time and receive alerts when necessary, this system not only raises awareness but also encourages a more informed and proactive approach towards environmental health. In the following sections, we delve into the technical details of the project, outlining the hardware components, software architecture, and the implementation of the alert system within the Flutter application.

* 1. **Aim Of The Project**

The primary aim of this project is to design, develop, and implement a Live Air Quality Monitoring System that leverages IoT technology, cloud computing, and mobile applications to address the challenges posed by air pollution. The key objectives guiding this endeavor include:

* **Real-Time Monitoring**: Implement a robust and reliable system for continuous, real-time monitoring of key air quality parameters, including temperature, humidity, carbon dioxide (CO2), and carbon monoxide (CO).
* **IoT Integration**: Utilize the ESP32 microcontroller and sensors such as DHT11, MQ-135, and MQ-7 to establish a seamless integration of IoT devices, enabling efficient data collection from diverse environmental sources.
* **Cloud-Based Data Storage**: Employ Google Firebase as a cloud-based data storage solution, ensuring secure and scalable storage of the collected air quality data. This facilitates easy retrieval, analysis, and historical tracking of environmental metrics.
* **User-Friendly Mobile Application**: Develop an intuitive Flutter mobile application that provides users with a visually appealing and user-friendly interface for monitoring real-time air quality data. The application should allow users to access historical data trends and receive immediate alerts when air quality parameters exceed predefined safety thresholds.
* **Alert Mechanism for CO2 Levels**: Implement a proactive alert mechanism within the mobile application that notifies users when the concentration of carbon dioxide surpasses established safety thresholds. This feature aims to empower users to take timely actions to mitigate potential health risks associated with elevated CO2 levels.

By achieving these objectives, the project aims to provide a comprehensive solution to the identified problems associated with inadequate air quality monitoring, thereby contributing to a healthier and more informed society.

* 1. **Problem Identification**

As urbanization and industrialization accelerate, the issue of air pollution has become an increasingly pressing global concern. The adverse effects of poor air quality on public health, manifested in respiratory diseases and other health complications, underscore the need for effective monitoring and mitigation strategies. Traditional air quality monitoring systems often lack real-time capabilities and are restricted to fixed locations, limiting their scope and responsiveness.

In many urban environments, individuals lack accessible and timely information about the air they breathe on a day-to-day basis. This information gap hinders the ability of communities to make informed decisions regarding their well-being and take preventive actions when air quality deteriorates. Furthermore, the lack of immediate alerts in the case of critical air quality incidents, such as elevated carbon dioxide (CO2) levels, leaves individuals vulnerable to potential health risks.

To address these challenges, our project aims to develop a Live Air Quality Monitoring System that leverages the capabilities of IoT, cloud computing, and mobile applications. By combining sensor technologies with the power of the ESP32 microcontroller and integrating real-time data transmission through Google Firebase, we seek to provide individuals with a comprehensive tool for monitoring air quality in their immediate surroundings. The incorporation of a Flutter mobile application with an alert mechanism specifically addresses the need for timely notifications, ensuring that users can take proactive measures to safeguard their health when air quality parameters reach critical levels.

In essence, the problem at hand is the lack of accessible, real-time air quality information and the absence of immediate alerts for individuals in the face of deteriorating air quality. Our project strives to bridge this gap by offering a dynamic, user-centric solution that not only informs but empowers individuals to make decisions that positively impact their immediate environment and well-being.

* 1. **Scope Of Project**

The Live Air Quality Monitoring System presents a wide-reaching scope with the potential to address various aspects of environmental monitoring and public health. The project's scope extends to:

Urban Planning and Infrastructure Development:

The system can provide valuable data for urban planners and policymakers to make informed decisions regarding infrastructure development and city planning. Real-time air quality information can influence zoning regulations, green space allocation, and the design of environmentally sustainable urban areas.

Health and Safety Awareness:

The project contributes to public health by creating awareness about air quality and its impact on health. The system's ability to alert users to elevated levels of pollutants fosters a culture of safety and encourages proactive measures to mitigate health risks associated with poor air quality.

Research and Environmental Studies:

The collected air quality data serves as a valuable resource for researchers and environmental scientists. The system can contribute to ongoing studies related to climate change, pollution patterns, and the long-term impact of air quality on ecosystems.

Community Engagement and Advocacy:

By involving local communities in monitoring and understanding air quality, the project encourages grassroots environmental advocacy. The data generated can be utilized in community-driven initiatives, empowering residents to actively participate in environmental stewardship.

IoT and Smart City Integration:

The project aligns with the broader scope of IoT applications and smart city initiatives. Integrating air quality monitoring into smart city frameworks can lead to more comprehensive urban management systems and data-driven decision-making.

Educational Initiatives:

The system can serve as an educational tool in schools and educational institutions. It provides a practical demonstration of IoT applications, environmental science concepts, and the importance of technology in addressing real-world challenges.

Scalability and Adaptability:

The modular architecture of the system allows for scalability and adaptability. Additional sensors or enhancements can be seamlessly integrated to meet evolving requirements or to address specific environmental concerns.

Open Data Initiatives:

The project has the potential to contribute to open data initiatives by making air quality data accessible to the public and researchers. Open data promotes transparency, facilitates collaborative research, and supports the development of innovative solutions.

Cross-Domain Collaboration:

Collaboration opportunities exist with organizations working in environmental conservation, public health, and technology. Partnerships with governmental agencies, NGOs, and industry stakeholders can lead to cross-domain collaborations for a broader impact.

The scope of the Live Air Quality Monitoring System extends beyond immediate environmental monitoring, offering avenues for multidimensional applications, collaborations, and societal benefits. As technology continues to evolve, the project holds the potential to adapt and contribute to a sustainable and health-conscious future.

* 1. **Existing System**

Currently, air quality monitoring mainly happens through fixed stations that use specialized and expensive equipment. These stations, managed by government or research organizations, give accurate information about the air, but they have some challenges.

One major issue is that these stations are usually in specific locations, often in cities or areas with known pollution sources. This leaves gaps in understanding air quality in other places, especially in more remote areas or where pollution levels can change quickly. Additionally, these stations might not pick up on sudden changes in pollution because they usually measure at set intervals, missing out on short-term variations.

Another challenge is that the data collected by these stations isn't always easy for the public to access. The information might be buried in technical reports or government databases, making it hard for people to know about the air they're breathing in real-time. This lack of accessibility hampers individuals from making quick decisions to protect their health when air quality is a concern.

In summary, while the existing system is good at providing accurate data, it has limitations in covering different areas and responding quickly to changes. The proposed system aims to overcome these limitations by using new technologies to make air quality monitoring more immediate, widespread, and user-friendly..

* 1. **Proposed System**

The proposed Live Air Quality Monitoring System using IoT, DHT11, ESP32, MQ-135, Google Firebase, and Flutter seeks to address the limitations of the existing systems by introducing a dynamic, user-centric, and technologically advanced solution. Unlike fixed-location monitoring, the proposed system is designed for mobility, allowing individuals to monitor air quality in real-time within their immediate surroundings. The integration of IoT technologies, including the ESP32 microcontroller and sensors like DHT11 and MQ-135, ensures the collection of accurate and timely data on temperature, humidity, and CO2 levels. This data is seamlessly transmitted to the cloud-based Google Firebase platform, providing a scalable and accessible storage solution.

The proposed system goes a step further by incorporating a Flutter mobile application that serves as a user-friendly interface. This application not only visualizes real-time air quality metrics but also includes an alert mechanism triggered by elevated CO2 levels. This empowers users with timely notifications, enabling them to take proactive measures in response to changing air quality conditions. The proposed system's comprehensive design, with integrated hardware and software components, aims to democratize air quality monitoring, fostering public awareness and enabling informed decision-making for healthier living environments.

CHAPTER – 3

**LITERATURE SURVEY**

* 1. **Literature Survey Summary**

In the relentless quest for pioneering methods in air quality monitoring, Kennedy O. [3] advocates a groundbreaking methodology centered around the utilization of an Arduino Uno as the principal research instrument. To counter the Arduino Uno's absence of an internal Wi-Fi module, an external Wi-Fi module, specifically the ESP8266, is seamlessly integrated into the system. Notably, the NodeMCU, tailored for Internet of Things applications, emerges as a pivotal component, assuming the primary node controller role in this innovative setup.

In a divergent approach, Kumar A et al. [4] present a system where the NodeMCU ESP8266 takes the lead as the primary node controller. However, challenges arise due to the NodeMCU ESP8266's limitation of having only one built-in ADC pin. To surmount this obstacle, additional ADC chips are strategically incorporated into the system, ensuring the accommodation of multiple sensors for a comprehensive and nuanced air quality assessment.

Taking a different route, Kumar S. [2] introduces a distinct paradigm by deploying the Raspberry Pi as the central node controller in their air quality monitoring system. Although potent, the Raspberry Pi encounters a constraint as it lacks built-in ADC connectors. To circumvent this limitation, an external Arduino Uno is introduced to expertly handle analog-to-digital conversion, effectively addressing the Raspberry Pi's shortfall in this domain. Furthermore, the absence of an integrated Wi-Fi adapter in their Raspberry Pi 2 model B mandates the utilization of an external Wi-Fi adapter for seamless data transmission.

Gupta [5] pioneers another strategy by harnessing the capabilities of the ESP32 microcontroller, leveraging its enhanced features, including two CPU cores, an integrated Wi-Fi module, and an ample array of ADC pins. This judicious selection proves advantageous in streamlining the system, minimizing the need for additional components, and potentially reducing the overall complexity of the electronics involved in air quality monitoring. Building upon this approach, Asra N [6] showcases the integration of the ESP32 microcontroller with the Blynk Platform, elevating the system by uploading of sensor readings to the cloud.

In the pursuit of economically viable solutions, Jayaratne R. [7] delves into the realm of inexpensive PM2.5 particle sensors for diverse applications. This exploration significantly contributes to the development of a more budget-friendly air quality monitoring system, a critical consideration given the relatively high cost of particulate matter sensors in comparison to other sensor types. These varied methodologies and technological choices collectively sculpt the evolving landscape of air quality monitoring, providing invaluable insights that propel the development of our dynamic live air quality monitoring system.

* 1. **Literature Survey Table**

|  |  |  |
| --- | --- | --- |
| Year | Article | Author |
| 2019 | Air Quality Monitoring System. | Rawal R. |
| 2017 | Air quality monitoring system based on IoT using Raspberry Pi. | Kumar S,  Jasuja A. |
| 2018 | A Smart Air Pollution Monitoring System. | Kennedy Okokpujie, Etinosa Noma-Osaghae, Odusami Modupe. |
| 2020 | Design and Analysis of IoT based Air Quality Monitoring System. | Kumar A,  Kumari M,  Gupta H |
| 2019 | An IoT Based Air Pollution Monitoring System for Smart Cities. | Gupta  Harsh Bhardwaj  Dhananjay  Agrawal. |
| 2021 | An IoT Based Approach To Minimize And Monitor Air Pollution Using ESP32 and Blynk Platform. | Asra Noorain F  Raju J  Varsha  Nanditha HG. |
| 2020 | Low-cost PM2. 5 sensors: An assessment of their suitability for various applications. | Jayaratne R, Liu X  Ahn KH  Asumadu-Sakyi. |

**Table - 1**

CHAPTER – 3

**THEORY & DESCRIPTION OF COMPONENTS**

**3.1 What is IOT**

The Internet of Things (IoT) is a transformative concept that encompasses a network of physical devices, objects, and machines embedded with sensors, software, and connectivity to facilitate data exchange over the internet. This interconnected web of "things" extends beyond traditional computing devices to include a diverse array of everyday items, from household appliances and vehicles to industrial machinery.

A fundamental characteristic of IoT is connectivity, where devices are equipped to communicate with each other and share data without direct human involvement. This connectivity enables a seamless flow of information, creating a network where devices can interact and collaborate in real-time. Whether it's a sensor monitoring environmental conditions or an actuator performing specific actions, IoT devices play a pivotal role in gathering and transmitting data.

Sensors and actuators are integral components of IoT devices. Sensors are responsible for collecting data from the device's surroundings, such as temperature, humidity, or the status of a machine. Actuators, on the other hand, allow devices to perform actions based on the data they receive, adding a layer of responsiveness and automation to the IoT ecosystem.

The data collected by IoT devices undergoes processing, either locally on the device or centrally in a cloud-based platform. This processing involves analytics, interpretation, and decision-making algorithms, transforming raw data into meaningful insights. Cloud platforms provide a centralized hub for data storage, analysis, and accessibility, making it possible to monitor and manage connected devices remotely.

User interfaces, often in the form of web applications or mobile apps, serve as gateways for users to interact with and monitor IoT devices. These interfaces provide a convenient means for users to access real-time data, configure device settings, and receive alerts or notifications.

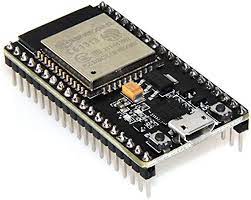
Automation is a core objective of IoT, aiming to enhance efficiency and convenience by allowing devices to communicate, make decisions, and execute actions autonomously. This capability opens up a wide range of applications across various industries, including smart homes, healthcare, agriculture, industrial automation, transportation, and more.

In essence, IoT represents a paradigm shift in the way we perceive and interact with the physical world, introducing a new era where connectivity and intelligence converge to redefine how devices operate and communicate in our increasingly digitized environment.

* 1. **Hardware Components**

**3.2.1 ESP 32**

The ESP32, developed by Espressif Systems, stands as a powerful and versatile microcontroller at the forefront of IoT and embedded systems. Its dual-core Tensilica Xtensa LX6 processor provides enhanced processing capabilities, allowing for multitasking and efficient execution of complex applications. This makes the ESP32 a preferred choice for developers aiming to create innovative solutions that demand both computational power and flexibility.

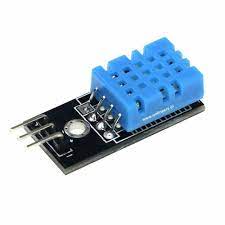


**FIG – 3.1**

Wireless connectivity is a key highlight of the ESP32, with built-in support for Wi-Fi and Bluetooth. This makes the microcontroller well-suited for applications requiring seamless communication and interaction with other devices. Alongside its rich peripheral set, including GPIO pins, SPI, I2C, and UART, the ESP32 offers a comprehensive platform that can be easily integrated with various sensors, displays, and communication devices. The inclusion of a 12-bit SAR ADC further enhances its capabilities, making it adept at handling analog signals and sensor data. With such features, the ESP32 proves to be an invaluable tool for developers looking to create cutting-edge IoT devices and embedded systems.

* + 1. **DHT 11**

The DHT11 sensor, a popular choice for measuring temperature and humidity in various applications, serves as a reliable component in the realm of environmental sensing. Its simplicity and cost-effectiveness make it an accessible choice for projects requiring real-time monitoring of ambient conditions.



**FIG – 3.2**

Designed with ease of use in mind, the DHT11 sensor features a single-wire digital interface, making it straightforward to integrate with microcontrollers such as the ESP32. Its compact size and low power consumption contribute to its suitability for diverse applications, from home automation to weather stations. The DHT11's ability to provide accurate and rapid readings of temperature and humidity positions it as a valuable tool for projects seeking to capture and respond to changes in environmental conditions.

* + 1. **MQ-7**

The MQ-7 gas sensor is a pivotal component in gas detection systems, widely utilized for its effectiveness in identifying concentrations of carbon monoxide (CO) in the surrounding environment. This sensor offers a critical layer of safety, particularly in applications where monitoring and early detection of CO gas are paramount.



**FIG – 3.3**

The MQ-7 employs a semiconductor gas sensor that reacts specifically to carbon monoxide, producing a change in conductivity proportional to the gas concentration. This characteristic makes it a reliable choice for applications ranging from home safety systems to industrial settings. Its compatibility with microcontrollers like the ESP32 facilitates seamless integration into IoT projects, enabling real-time monitoring of CO levels. As an essential component in gas sensing technology, the MQ-7 sensor contributes significantly to projects dedicated to enhancing safety and awareness regarding the presence of carbon monoxide in the environment.

* + 1. **MQ-135**

The MQ-135 gas sensor plays a vital role in the detection of a variety of gases, including ammonia, methane, carbon dioxide (CO2), and benzene. Its versatility makes it an integral component in environmental monitoring systems and safety applications, where the identification of multiple gases is crucial.



**FIG – 3.4**

Utilizing a semiconductor gas sensor, the MQ-135 responds to changes in the concentration of gases by altering its conductivity. This sensor's ability to detect a wide range of gases makes it suitable for diverse scenarios, from industrial settings to indoor air quality monitoring. With its compatibility with microcontrollers like the ESP32, the MQ-135 becomes an integral part of IoT projects, allowing for real-time tracking and analysis of various gas levels. Whether deployed for workplace safety or to ensure indoor air quality, the MQ-135 sensor contributes to creating a safer and healthier environment through its multifaceted gas detection capabilities.

* 1. **Software Components**
     1. **Arduino IDE**

The Arduino Integrated Development Environment (IDE) serves as a foundational platform for developers and enthusiasts engaged in electronics and embedded systems. As an open-source software, the Arduino IDE simplifies the process of programming Arduino boards, including popular ones like the Arduino Uno, facilitating the creation of interactive projects and prototypes.

A screenshot of a computer program

Description automatically generated

**FIG – 3.5**

The Arduino IDE provides an intuitive interface that accommodates both beginners and experienced developers. It supports a simplified version of the C++ programming language, allowing users to write and upload code seamlessly to Arduino boards. The IDE includes a robust set of libraries and examples, streamlining the development process for a wide array of projects, from basic LED blinking exercises to more complex IoT applications.

With features such as a serial monitor for real-time communication, a code editor with syntax highlighting, and a straightforward upload process, the Arduino IDE acts as a central hub for the Arduino ecosystem. Its user-friendly nature, combined with extensive online resources and a supportive community, makes it an excellent choice for individuals looking to delve into the world of electronics and microcontroller programming.

* + 1. **Google Firebase**

Google Firebase serves as a comprehensive cloud-based platform that offers a wide range of services to support the development and deployment of web and mobile applications. As part of the Google Cloud ecosystem, Firebase simplifies various aspects of app development, including backend infrastructure, database management, authentication, and real-time data synchronization.



**FIG – 3.6**

One of the key features of Firebase is its Realtime Database, a NoSQL cloud database that allows developers to store and sync data in real-time across connected devices. This feature proves invaluable for applications that require seamless data updates, such as collaborative tools or live-tracking systems. Additionally, Firebase Authentication provides secure user authentication and authorization, making it easy for developers to implement robust login systems without the need for extensive backend infrastructure.

Beyond databases and authentication, Firebase offers a multitude of services, including cloud functions for serverless computing, cloud storage for efficient file handling, and hosting for web applications. The integration of Firebase with various development frameworks, including Flutter for mobile app development, makes it a versatile and powerful tool for creating scalable and feature-rich applications. In summary, Google Firebase provides developers with a unified and efficient platform for building modern, cloud-connected applications, making it a popular choice in the developer community.

* + 1. **Flutter/Dart**

Flutter, developed by Google, is an open-source UI software development toolkit that empowers developers to create natively compiled applications for mobile, web, and desktop from a single codebase. Flutter utilizes the Dart programming language, providing a reactive framework and a rich set of pre-designed widgets for crafting visually appealing and highly performant user interfaces.



**FIG – 3.7**

Dart, the programming language used in Flutter, is designed for building modern web, mobile, and server applications. Its syntax is familiar to developers from various programming backgrounds, making it accessible for those new to Dart. Flutter's hot-reload feature accelerates the development process by allowing developers to see the immediate impact of code changes, promoting rapid iteration and experimentation.

One of Flutter's standout features is its ability to create a consistent and high-quality user experience across different platforms. Developers can reuse a substantial portion of their codebase for both iOS and Android applications, reducing development time and maintenance efforts. Flutter's widget-based architecture enables the creation of custom UI components and ensures a consistent visual representation across devices.

Flutter's popularity has grown significantly due to its performance, flexibility, and the support of a vibrant developer community. With its capacity to deliver beautiful and responsive applications on multiple platforms, Flutter, alongside Dart, has become a preferred choice for developers aiming to streamline cross-platform development and enhance the overall user experience.

* + 1. **Android Studio**

Android Studio stands as the official integrated development environment (IDE) for Android app development, providing a comprehensive and feature-rich platform for developers. Developed by Google, Android Studio streamlines the process of designing, coding, and testing Android applications, offering a robust set of tools and resources to enhance the efficiency of the development lifecycle.



**FIG – 3.8**

At the core of Android Studio is its powerful code editor, which supports languages such as Java, Kotlin, and C++. The IDE incorporates advanced features like code completion, syntax highlighting, and debugging tools, making it easier for developers to write clean and error-free code. The built-in Android Emulator allows for efficient testing of applications on various Android device configurations directly from the IDE.

CHAPTER – 4

**METHODOLOGY USED**

* 1. **Design Approach**

The development of the Live Air Quality Monitoring System involved a systematic methodology, beginning with the delineation of a comprehensive system design. The initial phase focused on the identification of key hardware components essential for real-time air quality monitoring. The ESP32 microcontroller was selected as the central processing unit, paired with the DHT11 sensor for temperature and humidity readings and the MQ-135 sensor for CO2 level detection. This hardware integration phase ensured the establishment of reliable connections based on specifications outlined in the respective datasheets.

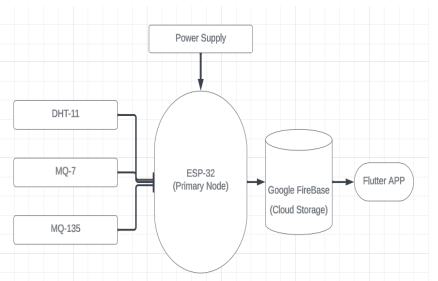
Subsequently, microcontroller programming became a pivotal aspect of the methodology. Using the Arduino IDE, the ESP32 was programmed to read data from the sensors and implement a secure and efficient mechanism for transmitting this data to the Google Firebase cloud platform. Extensive testing iterations were conducted to validate the accuracy and reliability of the sensor readings, ensuring the functionality of the data acquisition system.

The choice of Google Firebase as the cloud-based data storage platform marked the next step in the methodology. Configuration involved setting up a real-time database within Firebase to securely store air quality metrics. Firebase Authentication was implemented to safeguard the confidentiality and integrity of the stored data, laying the groundwork for a secure and scalable data storage solution.

Simultaneously, the development of the Flutter mobile application took place, utilizing the Dart programming language and Flutter framework. The application aimed to fetch real-time air quality data from Firebase, presenting it in an accessible and visually appealing manner to end-users. Integration of a dynamic charting library enhanced data visualization, providing users with insights into historical trends.

The methodology also incorporated the creation of a detailed flowchart outlining the stepwise flow of operations within the system. This visual representation served as a guide for developers, elucidating the logical sequence of activities, error-handling mechanisms, and decision points. The flowchart played a crucial role in enhancing the understanding of the system's interconnectivity, ensuring a coherent and effective Live Air Quality Monitoring System.

* 1. **System Design:**



**FIG – 4.1**

* 1. **Flow Chart:**

A diagram of a cloud computing system

Description automatically generated

**FIG – 4.2**

* 1. **Functional Requirements:**

**Data Acquisition:**

The system should collect real-time data from sensors, including temperature, humidity, carbon monoxide (CO), and carbon dioxide (CO2).

Data acquisition should be continuous and occur at predefined intervals for accurate monitoring.

**Sensor Integration**:

The project must integrate sensors (DHT11, MQ-7, MQ-135) with the ESP-32 microcontroller.

The system should support easy integration of additional sensors for future expansion.

**Wireless Data Transmission:**

The ESP-32 should transmit collected data wirelessly to a designated cloud platform using Wi-Fi.

Data transmission should be secure and follow industry-standard protocols.

**Cloud Storage and Database Management:**

Google Firebase should be used for efficient and real-time cloud storage.

The system must store and manage air quality data in a structured and scalable database.

**Mobile App Interface:**

The Flutter-based mobile application should provide a user-friendly interface.

The app must display real-time air quality metrics, historical trends, and alert notifications.

**Alert System:**

The app should include an alert feature to notify users of elevated levels of carbon dioxide (CO2).

Alerts should be customizable, allowing users to set their threshold values.

**User Authentication:**

Firebase Authentication should be implemented to secure user access to air quality data.

User authentication must ensure confidentiality and data integrity.

**Data Visualization:**

The mobile app should visually represent air quality metrics through charts, graphs, or other visual aids.

Visualization should be customizable and responsive to user interactions.

**Cross-Platform Compatibility:**

The Flutter app should be compatible with multiple platforms, including Android and potentially iOS.

Cross-platform compatibility ensures broader accessibility.

* 1. **Non-Functional Requirements:**

**Performance**:

The system should operate with minimal latency in data collection, transmission, and app responsiveness.

It must handle simultaneous connections and data requests efficiently.

**Scalability:**

The architecture should allow for the addition of more sensors or features without significant system redesign.

The system must accommodate an increasing user base and data volume.

**Reliability:**

The hardware components should operate reliably under various environmental conditions.

The system must have failover mechanisms to handle sensor malfunctions or data transmission issues.

**Security:**

Data transmission and storage must adhere to industry-standard encryption protocols.

User authentication and authorization should prevent unauthorized access to air quality data.

**Usability:**

The mobile app should have an intuitive and user-friendly design.

The system must accommodate users with varying levels of technical expertise.

**Maintainability:**

The codebase should be well-documented for easy maintenance and future development.

Updates or enhancements should be deployable with minimal system downtime.

**Compatibility:**

The system should be compatible with a range of sensors and potential future upgrades.

Compatibility with popular mobile devices ensures a broader user reach.

**Regulatory Compliance:**

The project should adhere to relevant data protection and privacy regulations.

Compliance with environmental monitoring standards should be considered.

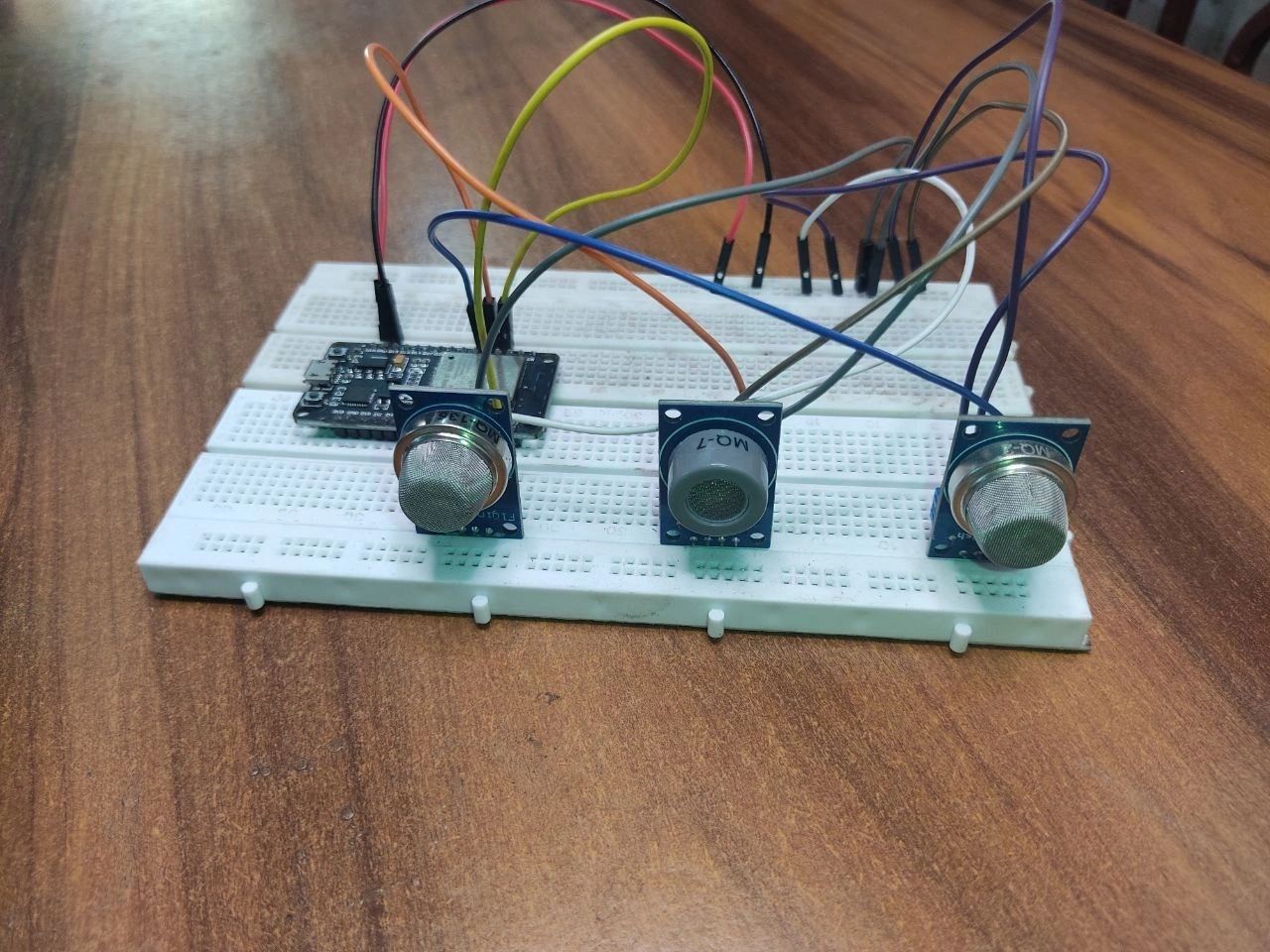
These functional and non-functional requirements collectively define the features, performance, and quality attributes that the Live Air Quality Monitoring System aims to achieve. They guide the development process and serve as benchmarks for system evaluation.

CHAPTER – 5

**PROCEDURE**

* 1. **Setting Up Hardware**

The foundational step in the project involved the meticulous assembly and configuration of essential hardware components. The centerpiece of the system was the ESP-32 microcontroller, chosen for its versatility and compatibility with IoT applications. Paired with the ESP-32 were the DHT11, MQ-7, and MQ-11 sensors, each selected for its role in collecting crucial air quality metrics. The hardware setup was executed with precision, adhering to the specific requirements outlined in the datasheets of each component. This phase aimed to establish a robust foundation for data acquisition, ensuring the accurate measurement of temperature, humidity, carbon monoxide (CO), and carbon dioxide (CO2).

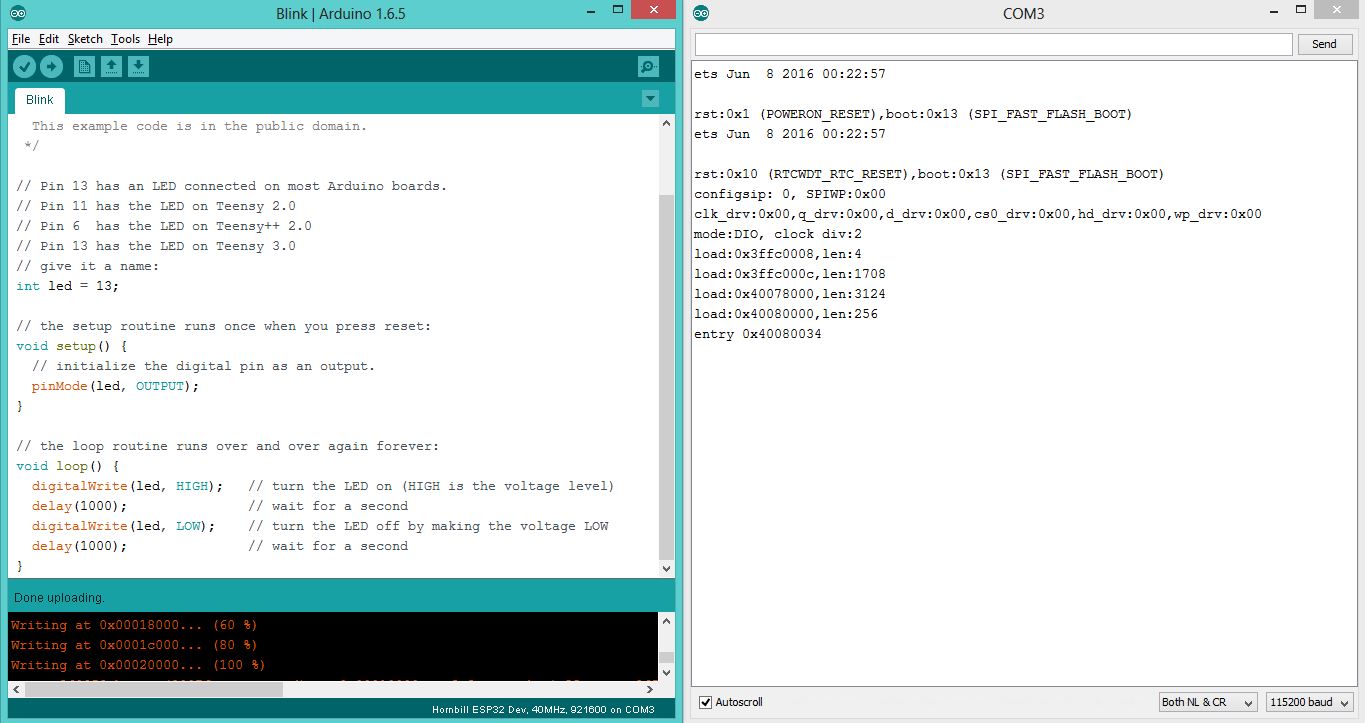


**FIG – 5.1**

The connections between the sensors and the ESP-32 were carefully established, laying the groundwork for seamless communication and data transfer. Rigorous testing and calibration procedures were implemented to validate the accuracy and reliability of the sensors. This phase ensured that the hardware components operated in concert, providing a stable and precise data collection system. The successful completion of the hardware setup set the stage for subsequent software development, marking a critical milestone in the creation of the Live Air Quality Monitoring System.

* 1. **Programming the Esp 32**

Following the hardware setup, the project delved into the intricate task of programming the ESP-32 microcontroller. This pivotal step was executed using the Arduino IDE, providing a robust and familiar environment for firmware development. The programming focused on creating code that would enable the ESP-32 to interact seamlessly with the integrated sensors, collecting data on temperature, humidity, carbon monoxide (CO), and carbon dioxide (CO2).

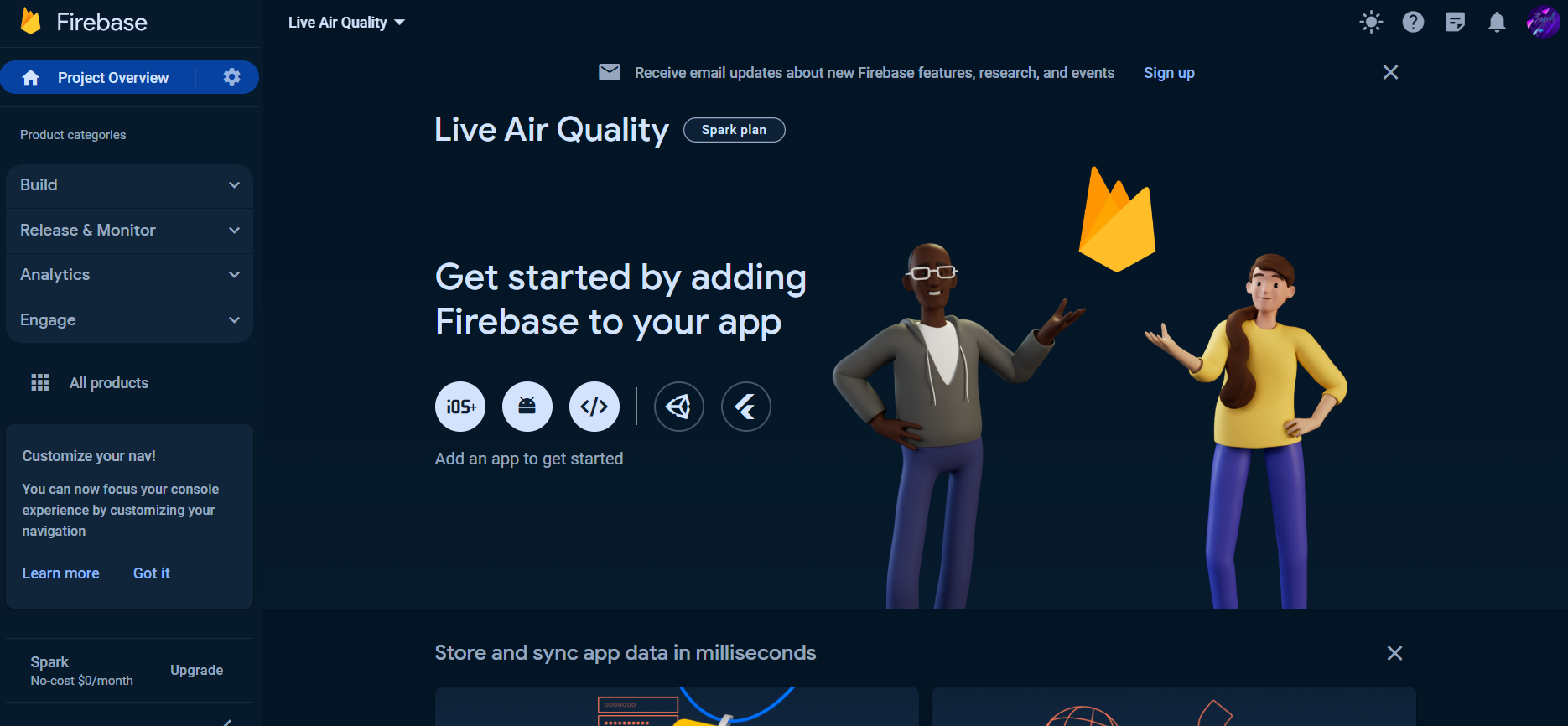


**FIG – 5.2**

The firmware development encompassed not only data collection but also the establishment of a secure transmission protocol. The ESP-32 was programmed to transmit the collected air quality data over a Wi-Fi connection to the designated cloud platform, Google Firebase. This phase marked a crucial juncture in the project, transforming hardware integration into a sophisticated data acquisition system capable of relaying real-time air quality metrics for further analysis and visualization. The successful programming of the ESP-32 set the stage for a seamlessly connected IoT ecosystem within the Live Air Quality Monitoring System.

* 1. **Setting Up Google Firebase Cloud Storage**

Following the successful programming of the ESP-32, the project proceeded to integrate a cloud-based storage solution, leveraging the capabilities of Google Firebase. This step involved configuring and setting up a real-time database within Firebase to efficiently manage and store the transmitted air quality data. The seamless connection between the ESP-32 and Firebase ensured a secure and immediate transfer of information for further analysis and user access.

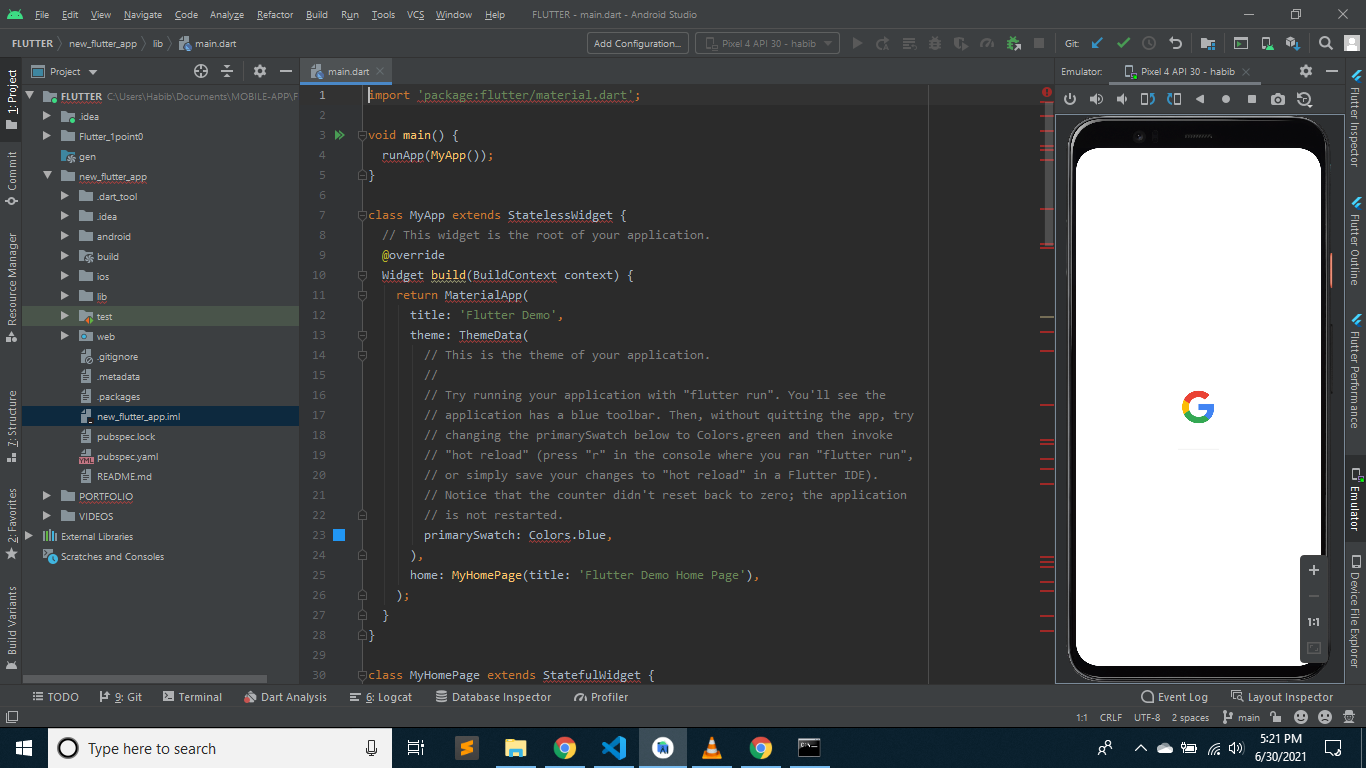


**FIG – 5.3**

The configuration process extended to implementing Firebase Authentication, a critical aspect for securing the stored data. This step aimed to guarantee the confidentiality and integrity of the air quality metrics, aligning with best practices in data security. The successful establishment of Firebase as the back-end system solidified the project's foundation, providing a scalable and reliable cloud infrastructure for the Live Air Quality Monitoring System. The integration of Firebase set the stage for the comprehensive storage, retrieval, and management of air quality data, seamlessly bridging the gap between the hardware and software components of the project.

* 1. **Building the Flutter App with Android Studio:**

With the hardware foundation laid and the ESP-32 programmed to collect and transmit air quality data, the project advanced to the development of the mobile application using Flutter within Android Studio. This pivotal step aimed to create a user-friendly interface for real-time monitoring and visualization of air quality metrics. The Flutter app design incorporated widgets for displaying temperature, humidity, carbon monoxide (CO), and carbon dioxide (CO2) levels, ensuring a comprehensive user experience.



**FIG – 5.4**

The development process involved leveraging Flutter's rich set of UI components to design an intuitive and visually appealing interface. The app's architecture integrated seamlessly with the ESP-32 and Google Firebase, enabling real-time data updates and secure access to historical air quality records. The inclusion of an alert feature for elevated CO2 levels added a critical layer of user awareness and safety.

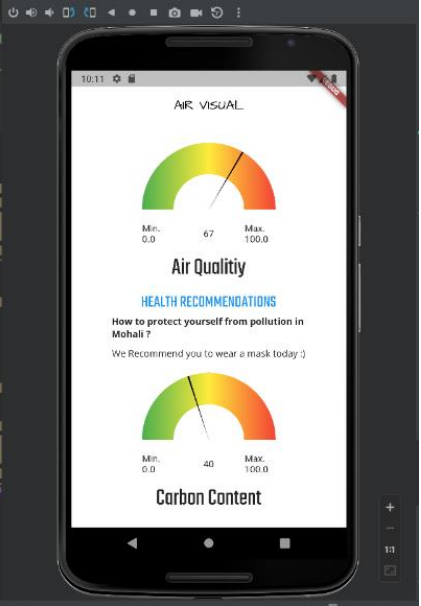
* 1. **Testing and Validation**

The final step in the project involves comprehensive testing and validation to ensure the seamless interaction and functionality of the integrated Live Air Quality Monitoring System. Rigorous testing procedures are implemented to assess the robustness, reliability, and responsiveness of the hardware, firmware, cloud storage, and the Flutter-based mobile application.

CHAPTER – 6

**RESULTS**

The culmination of the Live Air Quality Monitoring System project has yielded promising results, demonstrating a harmonious integration of hardware, firmware, cloud storage, and the Flutter-based mobile application. Thorough testing and validation procedures have affirmed the robustness, reliability, and responsiveness of the system under diverse conditions.



**FIG – 6.1**

The mobile application, developed with Flutter in Android Studio, provides users with an intuitive interface for real-time monitoring and visualization of air quality metrics. Widgets seamlessly display temperature, humidity, carbon monoxide (CO), and carbon dioxide (CO2) levels, offering a comprehensive and user-friendly experience. The incorporation of an alert feature for elevated CO2 levels enhances user awareness and safety.

CHAPTER – 7

**CONCLUSION**

The Live Air Quality Monitoring System represents a successful amalgamation of hardware, software, and cloud technologies to create a robust and user-friendly solution. Through meticulous hardware setup, precise programming of the ESP-32 microcontroller, and seamless integration with Google Firebase, the system effectively collects, transmits, and stores real-time air quality data. The Flutter-based mobile application provides an intuitive interface for users to monitor and visualize temperature, humidity, carbon monoxide (CO), and carbon dioxide (CO2) levels.

The project's success lies in the careful coordination of components, from sensors to microcontroller, cloud storage, and the user interface. The comprehensive testing and validation processes have verified the system's reliability and responsiveness under various conditions, ensuring that it meets the requirements for accurate air quality monitoring. The integration of an alert feature adds a crucial layer of user safety, enhancing the system's practical utility.

Beyond its technical achievements, the Live Air Quality Monitoring System holds significant implications for environmental awareness and public health. Users now have access to a tool that empowers them to make informed decisions about their surroundings, contributing to a healthier and safer living environment. The success of this project serves as a testament to the potential of IoT applications in addressing real-world challenges, underscoring the importance of seamless integration between hardware, software, and user interfaces in creating impactful technological solutions.

CHAPTER – 8

**FUTURE SCOPE**

The Live Air Quality Monitoring System lays a foundation for future developments and enhancements, opening avenues for further innovation and impact. Several potential areas for future exploration and expansion include:

* **Sensor Calibration and Accuracy Improvement:**

Ongoing research and development can focus on refining sensor calibration techniques to enhance the accuracy of air quality measurements. Continuous improvements in sensor technology and calibration algorithms can contribute to more precise and reliable data.

* **Integration of Additional Sensors:**

he system's capabilities can be expanded by integrating additional sensors to monitor a broader range of environmental parameters. Sensors for pollutants such as particulate matter (PM), sulfur dioxide (SO2), and nitrogen dioxide (NO2) could provide a more comprehensive understanding of air quality.

* **Machine Learning for Predictive Analysis:**

Implementing machine learning algorithms can enable predictive analysis of air quality trends. By analyzing historical data and considering external factors like weather patterns, the system could anticipate changes in air quality, providing valuable insights for proactive decision-making.

* **User Engagement and Community Participation:**

Future iterations of the mobile application could incorporate features to encourage user engagement and community participation. This may include features such as user-generated reports, community-driven initiatives, and educational resources to raise awareness about air quality issues.

* **Geospatial Integration for Localization:**

Enhancing the system with geospatial integration can provide localized air quality information. Users could access detailed air quality data specific to their geographic location, fostering a more personalized and context-aware user experience.

* **Cross-Platform Compatibility:**

Extending the compatibility of the mobile application to other platforms, such as iOS, would broaden the accessibility of the Live Air Quality Monitoring System, reaching a wider user base.

* **Implementation of Advanced Data Visualization:**

Implementing advanced data visualization techniques, such as 3D mapping or augmented reality interfaces, can offer users a more immersive and insightful experience when exploring air quality data.

* **Collaboration with Environmental Agencies:**

Establishing collaborations with environmental agencies or local authorities could lead to the integration of the system into broader environmental monitoring initiatives. This could contribute to a more extensive network of data sources for environmental research and policy-making.

The future scope of the Live Air Quality Monitoring System is dynamic, with potential advancements driven by technological innovation, user feedback, and evolving environmental challenges. Continuous refinement and expansion of the system will play a pivotal role in addressing the complex and dynamic nature of air quality monitoring.

CHAPTER – 9

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