PROJECT REPORT

In-Cabin Environmental Monitoring System

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ABSTRACT

In-Cabin Environmental Monitoring System addresses vehicular pollution through an IoT-based framework. Equipped with sensors and microcontrollers, the system captures real-time data and transmits it via Wi-Fi to a mobile app that provides a live dashboard and alerts. Data integrity is ensured through HMAC, safeguarding transmissions against tampering. This solution promotes eco-friendly driving and improved health, with considerations for sensor calibration and energy efficiency.

INTRODUCTION

Ensuring optimal air quality and environmental conditions inside a vehicle cabin is essential for passenger comfort and safety. This project, titled In-Cabin Environmental Monitoring System, focuses on real-time tracking of temperature, humidity, and potentially harmful gases within the car's interior. Utilising IoT technology, sensor data is transmitted to the Blynk app, providing users with comprehensive feedback on cabin conditions and facilitating timely action.

Contribution: This project introduces an integrated approach combining sensor-driven data collection and secure communication. Due to limited direct server access with Blynk, a custom middleware is developed to manage data transmission effectively. To enhance data security, a shared key mechanism with hashed secret keys ensures the integrity and authenticity of transmitted information.

This system displays real-time air quality metrics and alerts. By incorporating secure data transmission using HMAC, the system ensures data authenticity and integrity. The innovative combination of real-time analytics, route optimization, and proactive health measures positions this solution as an effective response to regulatory pressures and sustainability goals.

LITERATURE

A. System

The system is a combination of components that are interrelated and connected, aiming to solve a problem and achieve a goal. The systems approach can be divided into two types: the system approach in procedures and the system approach in elements or components. The procedural system consists of several procedures or steps involving interrelated activities to achieve certain goals. The system approach in elements or components consists of a set of interacting components that work together to achieve specific goals. The classification and characteristics of a system are as follows:

System Components: The system is composed of interacting components, with a series of parts or subsystems that together form a unified system.

System Boundary: The boundary defines the scope that separates the system from other systems or external environments. The system's scope cannot be divided further.

External Scope of the System: The environment outside the system includes all external factors that can influence the system's performance, either positively or negatively. Beneficial external factors should be maintained, while detrimental ones need to be controlled.

System Link: A system link connects subsystems so that resources from one subsystem can be utilised by others.

System Input: Input refers to the energy or signals fed into the system for its operation or to produce outputs.

System Output: The output is the result generated by the system, which can be utilised by other subsystems.

Processing System: The system processes input data to generate meaningful outputs.

Goals: Every system has specific goals, and success is measured by how wel those goals align with the intended objectives.

B. Detection

Detection refers to the act of noticing or discovering something. In this research, detection is the process of examining the air quality within a vehicle cabin using sensors.

C. Monitoring

Monitoring is the process of systematically collecting and analysing data to evaluate ongoing performance. It is performed by measuring conditions over time to determine if the actual performance meets specified standards. Monitoring helps evaluate and maintain the ongoing performance of an object or system.

D. Internet of Things (IoT)

The Internet of Things is a concept where two or more identifiable objects interact and are connected through the internet, allowing seamless communication without limitations, enabling devices to connect anytime, anywhere.

E. Air Quality

Air quality is determined by the Air Quality Index (AQI), which measures the concentration of pollutants in the air. Lower pollutants indicate better air quality, while higher pollutants signal poor air quality.

F. Related Research

This research expands on earlier studies by implementing an air quality monitoring system for vehicle cabins, incorporating sensors for air quality, temperature, humidity, carbon monoxide, and particulate matter. The focus is on developing a real-time system that monitors and detects in-vehicle air quality and informs the user. The system depends on a reliable internet connection, with the prototype and user smartphone connected through an IoT platform, all within a nearby coverage area.

Variables observed in this study include air quality, temperature, humidity, carbon monoxide, and fine particulate matter in the vehicle cabin. Data collection involved interviews and literature reviews based on theoretical references.

G. Changes to System Design

In this updated version of the system, the microcontroller has been switched from Arduino Uno to ESP32 offering enhanced Wi-Fi capabilities and better performance. Additionally, Blynk app is used for the mobile interface, enabling real-time monitoring and control. A middleware has been introduced due to limited server access on the Blynk platform, ensuring data security and smooth operation. The system employs a shared key mechanism with a hashed secret key for secure data communication between the mobile app, server, and vehicle sensors.

PROPOSED WORK

The proposed in-cabin air pollution monitoring system aims to ensure secure data transmission using HMAC-SHA256 authentication. This method verifies both the integrity and authenticity of the transmitted data, crucial for reliable environmental monitoring. The system will involve sensors collecting real-time data on pollutants such as CO_2, PM2.5, and NO_x, which are processed by a microcontroller. The microcontroller will generate an HMAC-SHA256 signature using a pre-shared secret cryptographic key, combining it with the sensor data to create a tamper-proof authentication code. This signed data packet will then be transmitted to a server or cloud platform.

At the server end, the received HMAC signature is verified by recalculating it using the same secret key. A matching HMAC ensures the data has not been altered and is from a legitimate source; any mismatch leads to data rejection, protecting against unauthorised tampering. This approach is particularly effective for embedded systems with limited computational resources as it provides a simple and efficient means of ensuring data authenticity and integrity.

Key management is vital to maintaining the security of this process, with secure storage and distribution of the cryptographic key being essential. Implementing policies for key rotation and renewal further enhances security and mitigates potential vulnerabilities. However, challenges remain in optimising the HMAC generation and verification processes to minimise latency and ensuring the system can scale effectively for use across multiple vehicles or locations. Future enhancements may include adding end-to-end encryption for greater data privacy, implementing data anonymization to protect user identity, and incorporating secure boot mechanisms to prevent unauthorised modifications to the microcontroller's firmware.

IMPLEMENTATION

Implementing the in-cabin air pollution monitoring system with HMAC-SHA256 authentication involves several key steps. First, the microcontroller must be programmed to interface with the sensors, collect real-time pollutant data, and generate an HMAC-SHA256 signature. This signature is created by combining the sensor data with a pre-shared cryptographic key and processing it through the SHA-256 algorithm. The microcontroller then packages the sensor data and HMAC signature together and transmits them to the server or cloud platform via a communication module.

On the server side, the implementation requires setting up a system to receive the data packets and verify their integrity by recalculating the HMAC using the same pre-shared key. If the recalculated HMAC matches the received signature, the server accepts the data as authentic and untampered; otherwise, it is flagged as potentially compromised. Proper key management practices must be established, including secure key storage and regular rotation to maintain security. Additionally, optimising the HMAC generation and verification processes is essential to ensure that the system operates with minimal latency, facilitating real-time data monitoring and transmission.

CONCLUSION

In conclusion, employing HMAC-SHA256 authentication in an in-cabin air pollution monitoring system provides a reliable and secure method for ensuring data integrity and authenticity. This approach, combined with sound key management practices and performance optimizations, creates a solid foundation for secure real-time monitoring and could be expanded with future improvements for even greater security and data protection.

This research presents a comprehensive system for real-time air quality monitoring in vehicle cabins, utilising advanced IoT technologies and various environmental sensors. The system, built around the ESP32 microcontroller and leveraging the Blynk app for user interaction, effectively measures key parameters such as temperature, humidity, carbon monoxide, and particulate matter. The implementation of a middleware solution ensures smooth communication between the system components, while a shared key mechanism secures data exchanges.

The findings highlight the potential of integrating IoT with automotive systems to monitor and manage in-vehicle air quality, improving passenger safety and comfort. This system not only provides real-time monitoring but also offers an innovative solution for managing air quality in a confined environment like a vehicle cabin, where traditional air quality monitoring may be challenging.

Further work can explore enhancing the system's accuracy through more advanced sensors, integrating predictive algorithms to forecast air quality trends, and expanding the system's scalability to accommodate additional vehicle-based parameters. Overall, this research contributes to the development of intelligent vehicle systems that prioritise environmental health and user well-being, paving the way for future advancements in connected car technologies.

REFERENCES

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