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Advancing Road Safety through Cloud Based RSU Solutions for Smart Internet of Vehicles

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Abstract

This research proposes a system to improve road safety by detecting and alerting drivers about hazardous road conditions in real-time. Vehicles equipped with sensors, GPS, and communication devices can autonomously detect hazardous road conditions and transmit alerts to a central cloud system through IoT MQTT protocol. Upon receiving alerts, vehicles can dynamically adjust their routes to avoid hazardous areas, reducing the risk of accidents. By utilizing IoT technology, the system ensures the reliability and authenticity of shared information, enhancing trust and overall road safety awareness. The proposed system architecture leverages cloud-based Roadside Units (RSUs) to facilitate communication among smart vehicles, providing real-time road condition information and ensuring secure and efficient data exchange. The system aims to address the challenges of existing IoV frameworks, such as data protection, key management, storage, concurrency performance, and response speed, by implementing robust security measures and efficient data management strategies.

Keywords: Road safety, damage location, Internet of Vehicles, Roadside Units,road condition

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1. Introduction

The advancement of technology has paved the way for innovative solutions to enhance road safety and mitigate the risks associated with hazardous road conditions. In the realm of smart transportation systems, the integration of Cloud-Based Roadside Units (RSUs) with Internet of Vehicles (IoV) technologies holds immense promise for revolutionizing how road hazards are detected, reported, and managed in real-time. This research delves into the realm of smart Internet of Vehicles, aiming to address the critical need for timely hazard detection and alerting mechanisms to ensure the safety of drivers and passengers on the road.

The introduction of this research sets the stage by highlighting the pressing issue of road hazards, including accidents, debris, and landslides, which pose significant safety risks to road users. With over 90% of major accidents attributed to delayed information about such conditions, the urgency of implementing efficient and prompt hazard detection systems becomes evident. Leveraging the capabilities of smart vehicles equipped with sensors, GPS, and communication devices, this research seeks to enable real-time monitoring and sharing of road condition data among drivers and road users.

The existing Internet of Vehicles (IoV) framework faces challenges related to data protection, key management, storage, concurrency performance, and response speed. The need for robust security measures to safeguard sensitive vehicular data, coupled with the demand for efficient data management strategies, underscores the importance of innovative solutions in the domain of road safety. By exploring the convergence of IoT technology, cloud based RSUs, and smart vehicles, this research aims to bridge the gap in current road safety systems and introduce a new era of proactive hazard detection and dynamic route optimization for enhanced road safety awareness.

2. Literature Survey

The research examines the current state of road defect detection using multiple sensors and IoT technology. It highlights the significant impact of road surface damage and defects on transportation efficiency and driving safety, underscoring the economic importance of timely road maintenance. The review delves into various machine learning-based methods, challenges, and future trends for large-scale deployment of automated road defect identification systems. By providing a detailed analysis of sensor devices, assessment frameworks, and the relevance of qualitative and quantitative data in improving transportation infrastructure, the research outlines the evolution from single sensor devices to integrated sensor platforms. This integration aims at automating data collection and processing, thereby facilitating more effective road maintenance strategies. The research not only discusses the technological advancements but also addresses the limitations and challenges facing the field, paving the way for future research directions that could potentially revolutionize the way road conditions are monitored and maintained [1].

This research discusses a novel IoT framework for monitoring road conditions in real-time, leveraging a vibration-based approach. By attaching an accelerometer sensor to the rear axle of a vehicle, the system captures vertical acceleration signals resulting from interactions between the vehicle's suspension system and the road surface. These signals are then used to calculate the International Roughness Index (IRI) as a measure of road quality. The proposed system includes a hardware node for signal acquisition and a remote monitoring system for IRI calculation and visualization on a road map. The findings showcase the system's capability to automatically assess road conditions with a calculated IRI error of less than 3.5%, illustrating a significant advancement in vibration-based road condition monitoring systems. This approach provides a comprehensive, automated IoT-based solution that enhances road maintenance efficiency by facilitating real-time data transmission, storage, and visualization of road quality indicators, with the potential for widespread adoption across various vehicle fleets for extensive road coverage [2].

This study proposes an innovative scheme to enhance road safety in the IoT environment by prioritizing emergency response vehicles (ERVs) at multiway intersection points without traffic signals. Utilizing a two-stage process involving Markov Chain predictions and a cooperative coalition-based game-theoretic approach, the scheme aims to reduce waiting times, prevent collisions, and provide safe passage for ERVs. Through extensive simulation, the author demonstrates significant improvements in energy consumption and overall utility, offering a novel approach to intelligent transportation systems. The system's strategic interactions and dynamic coalition formation among vehicles facilitate efficient and safe road navigation for ERVs, highlighting its potential to significantly improve emergency response times and reduce on-road congestion [3].

2.1 Overview of Road Safety

The research aims to enhance road safety through real-time hazard detection and alerting for vehicles equipped with sensors, GPS, LCD, and buzzers. It utilizes IoT MQTT protocol to transmit alerts to a central cloud system for dissemination to nearby vehicles. By leveraging IoT technology, the research ensures the reliability of shared information, enhancing trust and overall road safety awareness. The proposed work involves a comprehensive system architecture with cloud-based Roadside Units (RSUs) to facilitate communication among smart vehicles, enabling dynamic path redirection based on reported road conditions. The methodology includes data collection, processing, transmission, alert generation, and dissemination to ensure efficient and prompt sharing of road condition information. Key components like sensors, microcontrollers, motor drivers, and software tools like Arduino IDE and Embedded C are utilized to implement the system. The proposed method addresses the critical need for timely hazard detection and response to improve road safety and reduce accidents caused by delayed information about road conditions [4,5].

2.2 Characteristics of Road Safety

The proposed work introduces a comprehensive system architecture leveraging cloud-based Roadside Units (RSUs) to facilitate communication among smart vehicles. RSUs serve as central hubs for collecting, processing, and disseminating real-time road condition information. Smart vehicles equipped with sensors continuously monitor road conditions, including accidents, debris, and other hazards. Upon detection, these vehicles transmit relevant data to nearby RSUs through wireless communication protocols using MQTT. Upon identifying hazardous road conditions, RSUs broadcast alerts to nearby vehicles, providing timely warnings to drivers and enabling them to adjust their routes or driving behavior accordingly [6-8].

The methodology used in this research includes data collection through sensors such as ultrasonic and MEMS sensors, data processing to detect potential road hazards, data transmission via MQTT protocol to the cloud, alert generation based on detected hazards, and alert dissemination to nearby vehicles through RSUs. The research also employs robust security measures to safeguard sensitive vehicular data and ensure efficient data management strategies, addressing challenges related to data protection, key management, storage, concurrency performance, and response speed in existing IoV frameworks.

2.3 Internet of Vehicles (IoV)

The research operates within the realm of IoV, focusing on integrating vehicles with the internet and communication networks. By leveraging IoT technology and MQTT protocol, the system facilitates communication among smart vehicles and cloud-based Roadside Units (RSUs) for real-time data sharing and hazard alerting.

The system architecture leverages cloud-based RSUs to collect, process, and disseminate real-time road condition information, enabling smart vehicles to transmit relevant data to nearby RSUs through wireless communication protocols. Upon identifying hazardous road conditions, RSUs broadcast alerts to nearby vehicles, providing timely warnings to drivers and enabling them to adjust their routes or driving behavior accordingly. Google developed the MapReduce model based on its Google File System (GFS), which was later adopted and popularized by Yahoo through the open-source Hadoop implementation.

2.4 Disadvantages of Existing System

The Internet of Vehicles (IoV) faces significant challenges in data protection, key management, storage, and response speed, jeopardizing sensitive vehicular data. Privacy concerns arise from the vast amount of private information in vehicular data, necessitating strong security measures. Scalability is crucial to handle the growing number of vehicles and roadside units (RSUs), preventing performance issues and data loss. Real-time operation is essential for promptly sharing road conditions to prevent accidents. Under low-trust conditions, ensuring reliable information sharing among vehicles and RSUs is critical. Efficient resource allocation is vital for energy savings and service quality. Integrating multiple sensors in IoV systems poses compatibility and data processing challenges [9,10].

3. Proposed System

The research aims to enhance road safety by detecting and alerting drivers to hazardous conditions in real-time. Vehicles with sensors, GPS, and communication devices autonomously identify hazards and send alerts via IoT MQTT protocol to a central cloud system. Drivers receive alerts, adjust routes to avoid dangers, reducing accidents. IoT ensures reliable information sharing, enhancing trust. The architecture uses cloud-based RSUs for communication among vehicles, centralizing real-time road condition data. Vehicles equipped with sensors monitor road conditions, transmitting data to RSUs through MQTT. RSUs broadcast alerts to nearby vehicles, helping drivers adjust routes and behavior promptly.

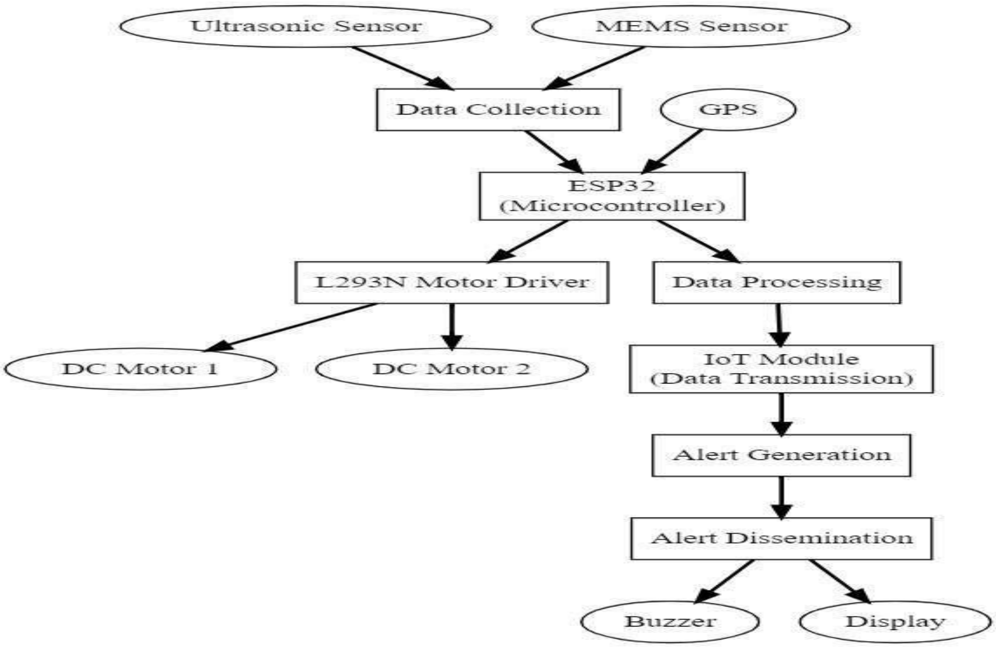


Figure 3.1. Proposed Flow Diagram

3.1 System Architecture

The system leverages a combination of hardware and software components to ensure efficient road condition monitoring and hazard detection. The hardware setup includes an ESP32 microcontroller, which acts as the central processing unit, interfaced with various sensors such as the HC-SR04 ultrasonic sensor and the MPU6050 MEMS sensor. These sensors continuously collect data on the vehicle's surroundings and motion. The ESP32 processes this data to detect anomalies in road conditions. For software, the Arduino IDE is used to program the ESP32 in Embedded C, ensuring efficient and reliable operations. The system employs the MQTT (Message Queuing Telemetry Transport) protocol for data transmission, enabling lightweight and real-time communication with the cloud server. This setup allows the collected data, including GPS coordinates of detected road anomalies, to be transmitted to the cloud, where it is processed and stored for further analysis and maintenance planning. This integration of hardware and software components enhances the overall functionality and performance of the road safety system.

3.2 Working

- **Data Collection**

The ultrasonic sensor continuously measures the distance between the vehicle and the road. This module involves the use of sensors to collect data from the environment. In the context of roadside damage detection, an ultrasonic sensor could be used to measure distances and detect anomalies on the road surface, such as potholes. A MEMS sensor (Micro-Electro-Mechanical Systems) could detect vibrations or tilts in the vehicle that indicate uneven road surfaces.

- **Data Processing**

The ESP32 on-board processor compares the measured distance to a threshold value to determine if there's a potential road anomaly. This module processes the raw data collected by the sensors to identify whether the readings signify road damage. Processing could involve filtering noise from the data, applying thresholds, to compare sensor readings against expected values for normal road conditions.

- **Data Transmission**

If a road anomaly is detected, the ESP32 transmits a message through MQTT protocol to the cloud. This message includes the GPS location of the anomaly. Once the data is processed and road damage is detected, this module handles the transmission of the relevant information to a central system or to other vehicles. This can be done through wireless communication protocols supported by the IoT module (e.g., Wi-Fi or cellular networks provided by ESP32).

- **Alert Generation**

The RSU subscribed to the MQTT topic receives the anomaly information from the cloud. When the central system receives data indicating road damage, it generates an alert. This alert could be a simple message or a more complex report detailing the extent and precise location of the damage.

- **Alert Dissemination**

The RSU broadcasts an alert signal using a suitable communication protocol to warn nearby vehicles about the road anomaly. This final module distributes the generated alerts to the intended recipients, which could be traffic management authorities, other vehicles in the vicinity using vehicle-to-everything (V2X) communication, or even a public alert system to warn drivers of potential hazards.

3.3 System Specifications

3.3.1 Hardware Environment

The hardware environment in this research involves the use of smart vehicles equipped with various sensors, including ultrasonic, MEMS, GPS, and a camera module. These sensors are responsible for collecting data about the vehicle's surroundings, motion, and location. The ESP32 microcontroller serves as the central processing unit (CPU) of the system, collecting and processing data from all the connected sensors. The system is designed to communicate with a Remote Server Unit (RSU) or a cloud server using the MQTT (Message Queuing Telemetry Transport) protocol for efficient data transfer. The hardware components required for this research include the ESP32 microcontroller, ultrasonic sensor (HC-SR04), MEMS sensor (MPU6050), power supply board, battery, L293N motor driver, and 12V 100 RPM DC motor. The software components include the Arduino IDE, Embedded C, and MQTT cloud for communication and data processing.

3.3.2 Software Environment

The software environment in this research includes several key components and tools:

- **Arduino IDE**: The Arduino Integrated Development Environment (IDE) is used for programming the ESP32 microcontroller, enabling the development of code for data processing, sensor integration, and communication with the cloud server. Arduino IDE is essential for writing and uploading code to the microcontroller, facilitating the functionality of the smart vehicles in the system.

- **Embedded C**: Embedded C programming language plays a crucial role in developing the software for electronic gadgets and microcontrollers in this research. It is utilized for specific functions by the processor, ensuring the efficient operation of the system. Embedded C is preferred due to its reliability, portability, scalability, and ease of understanding, making it ideal for embedded system programming.

MQTT Cloud: The Message Queuing Telemetry Transport (MQTT) protocol is utilized for efficient data transmission between the smart vehicles and the cloud server. MQTT ensures lightweight messaging for IoT applications, enabling real-time communication and data sharing. The cloud platform stores received data, including road anomaly locations and severity, for monitoring and maintenance planning.

These software components work together to enable data collection, processing, transmission, and alert generation within the system. The Arduino IDE facilitates the programming of the ESP32 microcontroller, Embedded C ensures efficient embedded system programming, and MQTT Cloud enables seamless communication between the smart vehicles and the cloud server, enhancing the overall functionality and performance of the road safety system**.**

4. Results and Discussion

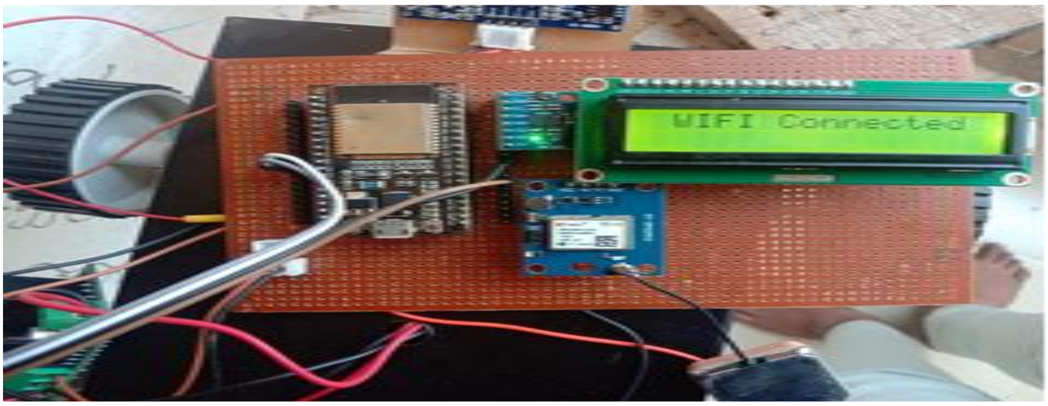
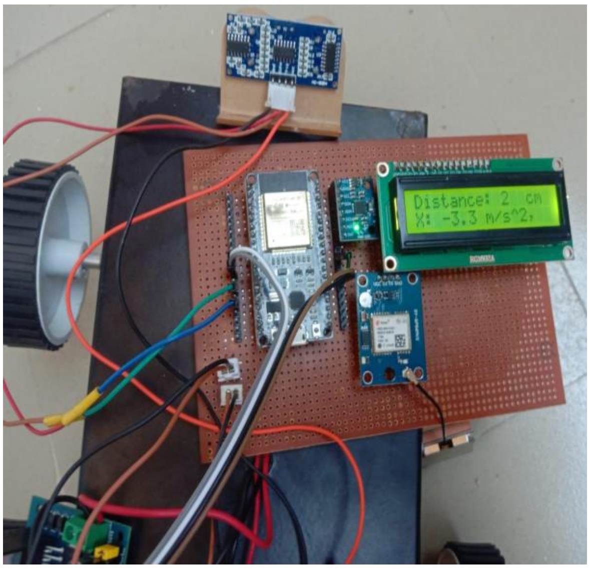


Figure 4.1. The Car Unit Connected to the Internet

The Figure 4.1 illustrates the car unit connected to the Internet, highlighting the connectivity aspect of the system. The car unit comprises the ESP32 microcontroller, sensors, and communication modules, which together facilitate real-time data collection and transmission to the cloud server through the MQTT protocol. This setup is crucial for the autonomous detection of road hazards and subsequent alert generation.



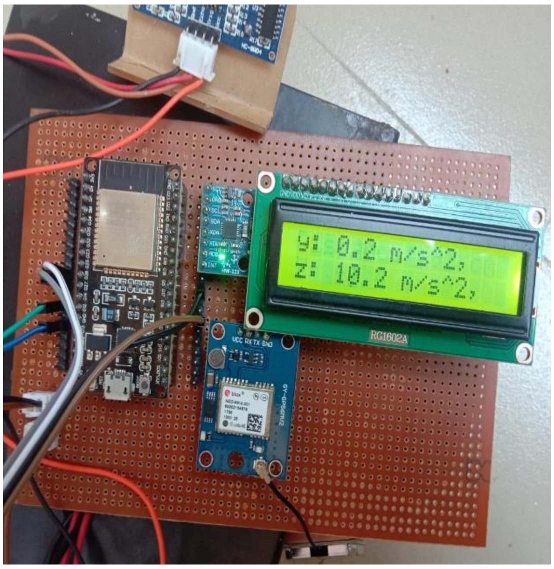


Figure 4.2. Reading Distance Display Output **Figure 4.3.** Sensor Integration

The Figure 4.2 displays the distance reading output on the LCD, showcasing the system's ability to measure and display distances accurately. The integration of the ultrasonic sensor enables the detection of road anomalies by measuring the distance between the vehicle and the road surface. The real-time display of these measurements is essential for immediate analysis and response

The Figure 4.3 shows the sensor integration with the GPS module and the LCD displaying sensor data. The comprehensive integration of various sensors, including ultrasonic and MEMS sensors, along with the GPS module, allows for precise correlation of detected road anomalies with their geographical locations. This feature is vital for mapping and addressing road damages, ensuring that maintenance can be efficiently planned and executed based on accurate location data.

The system with Sensors and GPS module and the LCD displaying sensor data. The sensor system can now correlate detected road anomalies with geographical locations, a vital feature for mapping and addressing road damages

Advantages of the proposed system include real-time hazard detection and alerting, allowing drivers to adjust routes promptly for enhanced road safety. Dynamic path redirection minimizes accident risks by guiding vehicles away from hazards. Leveraging IoT ensures reliable information sharing, boosting trust and safety awareness. Cloud-based RSUs enable efficient communication among vehicles, enhancing real-time data processing and dissemination. Robust security measures address data protection challenges, ensuring secure data exchange. Integration with existing telecommunications infrastructure facilitates seamless sharing of road information, benefiting overall road safety. Location-specific road condition data aids in efficient maintenance planning.

5. Conclusions

In conclusion, this research proposes a system to improve road safety by detecting and alerting drivers about hazardous road conditions in real-time. The system utilizes smart vehicles equipped with sensors, GPS, and communication devices to autonomously detect hazards and transmit alerts to a central cloud system via IoT MQTT protocol. Upon receiving alerts, vehicles can dynamically adjust their routes to avoid hazardous areas, reducing the risk of accidents. The proposed system aims to include a user-friendly interface in future for manual reporting of road hazards, allowing drivers to contribute to the collective awareness of road conditions. By utilizing IoT technology, the system ensures the reliability and authenticity of shared information, enhancing trust and overall road safety awareness. This research addresses the critical need for efficient and prompt dissemination of road condition information, aiming to reduce the number of major road traffic accidents caused by delayed information about hazardous road conditions.

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