

“Real-Time Vehicular Road Sign Alert System Using GPS-Based Fog Computing”

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1. Abstract:-

Road safety remains a major concern due to delayed driver response to critical traffic signs, especially under low visibility or high-distraction conditions. This paper presents a Real-Time Vehicular Road Sign Alert System based on a GPS-enabled fog computing architecture. The proposed system uses an ESP32 microcontroller as a local fog node to process vehicle position data obtained from a GPS module.

Instead of relying entirely on cloud processing, the system stores predefined road sign coordinates in local memory and performs real-time distance comparison using geofencing techniques. When the vehicle enters a predefined radius of a stored road sign location, the system instantly generates audio and visual alerts to notify the driver. Event data is optionally transmitted to a cloud server through a GSM module for logging and monitoring purposes.

By shifting computation to the fog layer, the system achieves low latency, reduced bandwidth usage, and improved reliability in areas with limited network connectivity. The proposed solution provides a cost-effective and scalable approach to intelligent transportation safety systems.

Keywords:-

Fog Computing Concept, Traffic Sign Recognition, Intelligent Transportation System (ITS), Driver

Assistance System, Real-Time Processing, Road Safety, Smart Transportation, Low Latency

2. Introduction :-

The rapid growth in vehicular traffic has significantly increased the complexity of road transportation systems. Traffic signs play a vital role in regulating vehicle movement and ensuring driver awareness regarding speed limits, hazard zones, school areas, and mandatory directions. However, drivers may fail to observe these signs due to environmental factors such as fog, heavy rain, nighttime driving, or visual obstructions. Human factors including fatigue, distraction, and unfamiliar routes further increase the risk of accidents.

Conventional driver assistance systems often depend on camera-based detection or cloud-based processing models. Although effective, such systems require continuous internet connectivity, higher computational resources, and increased implementation cost. Cloud-dependent

architectures may also introduce communication delays, which is undesirable in safety-critical applications.

To overcome these limitations, this research proposes a GPS-based road sign alert mechanism using a fog computing approach. In this architecture, the ESP32 microcontroller acts as a local processing node that performs coordinate comparison directly within the

vehicle. By calculating the distance between current vehicle coordinates and stored road sign locations, the system generates alerts without waiting for cloud response. This decentralized processing ensures faster response time and improved operational reliability.

3. Literature Survey:-

1. Fog computing is considered an extension of cloud computing where data processing is performed closer to the source devices rather than at centralized servers. This distributed architecture helps in minimizing response time and improving efficiency in time-sensitive applications.

2. Several researchers have emphasized that decentralized computing models are more appropriate for intelligent transportation systems, where quick decision-making is essential for safety-related alerts.

3. Global Positioning System (GPS) technology is widely used in vehicle tracking applications to obtain accurate real-time latitude and longitude coordinates. These coordinates enable location monitoring, navigation assistance, and movement analysis.

4. Many existing vehicle monitoring solutions integrate GPS modules with GSM communication systems to transmit location data to remote servers. This approach allows users or authorities to monitor vehicles from distant locations.

5. Cloud-based transportation management systems provide centralized data storage,

analytics, and remote accessibility. However, they require continuous internet connectivity for proper operation.

6. Heavy dependence on cloud infrastructure can introduce communication delays, especially in regions with weak or unstable network coverage. Such delays may affect the timely delivery of safety alerts.

7. Continuous transmission of real-time data to cloud platforms increases bandwidth consumption and operational costs in large-scale deployments.

8. Modern embedded controllers such as ESP32 offer adequate processing capability, low power

consumption, and integrated wireless features, making them suitable for real-time IoT-based applications.

9. Implementing geofencing techniques at the local processing level allows the system to compare current vehicle coordinates with stored locations efficiently without relying on remote servers.

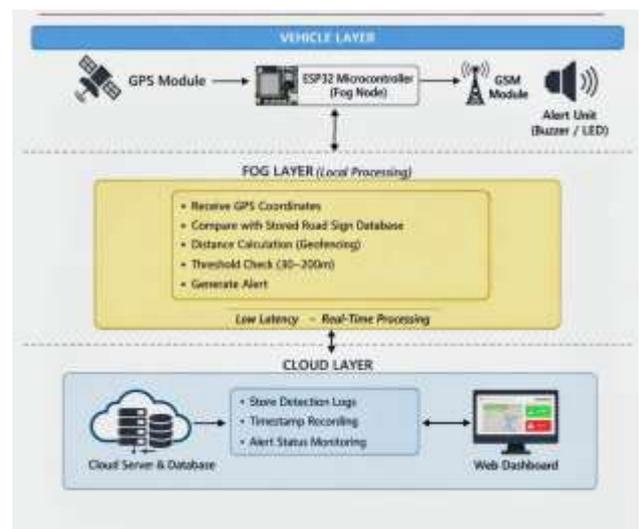
10. Based on these observations, a fog-based processing approach can enhance system reliability by performing coordinate comparison and alert generation locally, thereby reducing latency and minimizing cloud dependency.

4. Proposed System Architecture

The system consists of the following major components:

- ESP32 Microcontroller (Act as Fog Node)
- GPS Module
- GSM Module
- Alert Unit (Buzzer / LED / Display)
- Cloud Platform (Optional Logging)

Working Architecture:



1. GPS module continuously collects vehicle latitude and longitude.
2. ESP32 receives and processes GPS data.
3. Stored road sign coordinates are maintained in local memory.
4. Distance between vehicle position and road sign coordinates is calculated.

5. If the vehicle enters predefined threshold distance: - Alert is generated.

- Event data is transmitted via GSM to cloud.

6. Cloud stores detection logs for monitoring and analytics.

Since processing happens locally on ESP32, the system minimizes latency and ensures realtime alerts.

• Methodology

A. GPS Data Acquisition

The GPS module continuously provides latitude and longitude values. These coordinates are updated every second.

B. Geofencing and Distance Calculation

The ESP32 compares current vehicle coordinates with predefined road sign coordinates using distance calculation formulas.

C. Alert Generation

If calculated distance is less than threshold (e.g., 30–50 meters), the system triggers:

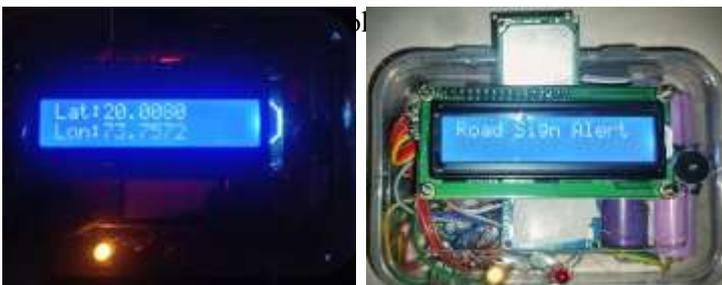
- Audio alert (buzzer)
- Visual alert (LED/display)

D. Cloud Communication

Detection event, location, and timestamp are transmitted to cloud via GSM module for logging.

Implementation Details

- Microcontroller: ESP32
- Programming Environment: Arduino IDE
- Communication: UART (GPS & GSM)



1.1. Output before RoadSign Detected

Here initially the yellow light is blinked that indicates there is no alert detected

- Alert System: Buzzer / LED / LCD

Fog computing Concept is implemented by performing coordinate comparison locally on ESP32 instead of sending raw GPS data continuously to the cloud.

• Advantages of Proposed System

- Low cost implementation
- Low latency due to fog computing Concept
- Reduced cloud dependency
- Works in limited connectivity
- Scalable for fleet monitoring
- Easily upgradable

5. Results:-

The developed system was tested in simulated driving conditions as well as real-time scenarios using a sensors setup. The system successfully detected various types of traffic signs, including:

- Speed limit signs
- Stop signs
- Warning signs
- Mandatory direction signs
- Prohibition signs

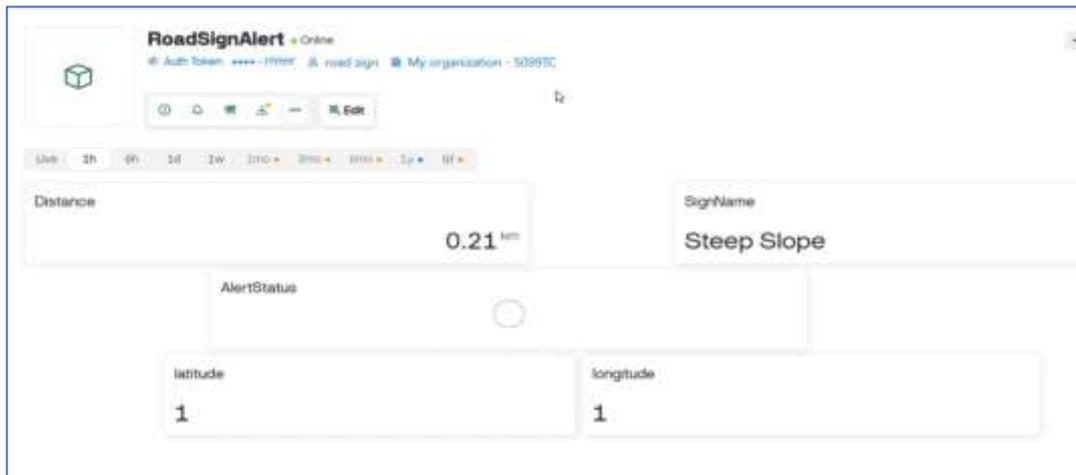
○ ESP32 Microcontroller model (Fog-Node):-



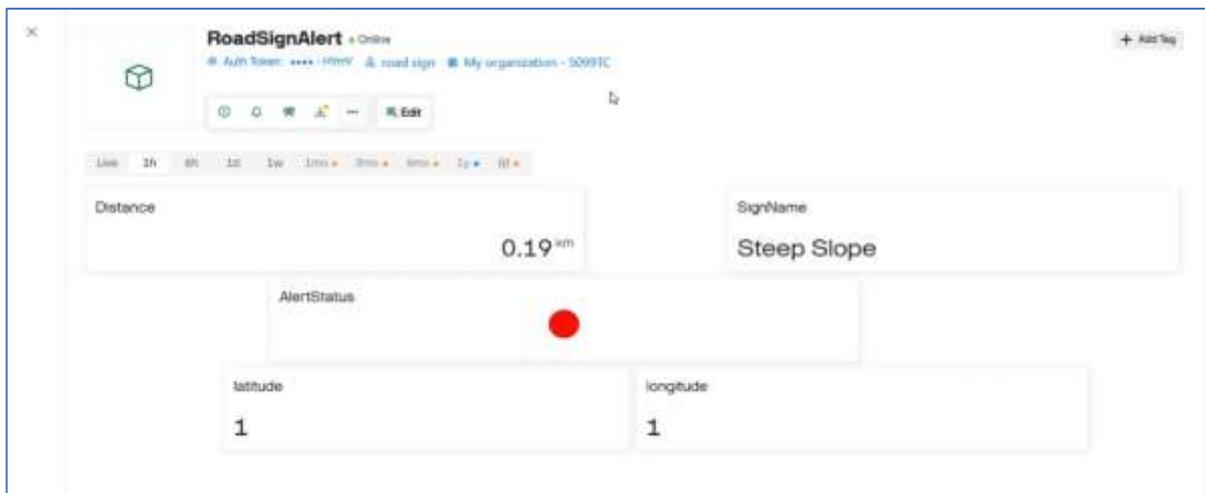
1.2. Output After Alert Generated

Here red light is blinked that indicates RoadSign(Steep Slope) is detected after entering predefined threshold (example Threshold : 200m(0.20km)) and Alert generated

○ Real Time Cloud Storage (Web Dashboard) :-



2.1.Result before RoadSign Detected



2.2.Result after RoadSign Detected and Alert Generated(Alert_Status = active[red])

Performance Outcomes:-

1. Low Latency Response:

Since distance calculations are performed locally on ESP32, alerts are generated within milliseconds after entering the defined threshold radius.

2. Stable Operation in Limited Network Areas:

The alert mechanism functions independently of internet connectivity. GSM communication is used only for event logging.

3. Reduced Bandwidth Usage:

Only essential detection data such as timestamp and coordinates are transmitted to the cloud.

4. Reliable Alert Generation:

Audio and visual alerts successfully notify the driver upon approaching predefined road sign zones.

5. Scalability:

Additional road sign coordinates can be added to memory without major architectural changes..

○ Operational Scenario Validation :-

To evaluate the real-time behavior of the proposed system, a practical test scenario was conducted.

When the vehicle approached a predefined speed limit zone, the GPS module continuously updated the current coordinates. The ESP32 fog node calculated the distance

between the vehicle position and the stored road sign coordinates using the geofencing threshold.

Once the vehicle entered the defined radius (e.g., 200 meters), the system immediately triggered:

- Visual alert (LED indication)
- Audio alert (Buzzer notification)

Simultaneously, detection details including timestamp and location were transmitted to the cloud server via GSM for logging purposes.

The alert was generated without noticeable delay, demonstrating the effectiveness of local fog-based processing.

6. Conclusion :-

This paper presented the design and implementation of a GPS-based Vehicular Road Sign Alert System using a fog computing architecture. The implemented system uses an ESP32 microcontroller to process vehicle coordinates locally and compare them with stored road sign locations. When the vehicle enters a predefined range, the system generates immediate audio and visual alerts.

Since processing is performed at the fog layer, the system provides low latency response and reduced cloud dependency. The integration of GPS and GSM modules enables accurate tracking and optional cloud logging. The developed system demonstrates a cost-effective and reliable solution for improving road safety in real-time driving conditions.

Future improvements may include automatic database updates and integration with smart transportation infrastructure.

7. References:-

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