Project Proposal

Networked Onboard Vehicle Analytics (NOVA)

Submitted to:
National Telecommunication Institute (NTI)
Internship Program

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1. Executive Summary

The Networked Onboard Vehicle Analytics is an advanced Artificial Intelligence of Things (AIoT) prototype designed to improve vehicle safety, security, and predictive maintenance. The system is built around the ESP32 microcontroller and integrates a wide array of sensors with on-device machine learning inference, sensor fusion, real-time task management using FreeRTOS, and remote connectivity via MQTT and SMS.

Developed as the final project for the NTI internship program, this project demonstrates practical application of embedded systems, edge AI, IoT protocols, and real-time operating systems.

The system addresses critical real-world challenges such as driver fatigue, unexpected engine failures, potential theft attempts, and lack of real-time remote oversight, making it highly relevant for personal vehicles, fleet management, and automotive safety research.

2. Project Objectives

Primary Objectives

- Design and implement a complete AIoT prototype for comprehensive vehicle monitoring and safety enhancement.
- Develop and deploy lightweight machine learning models on the edge for real-time engine health classification and driver drowsiness/distraction detection.
- Achieve reliable remote telemetry through MQTT and instant critical alerts via SMS.
- Demonstrate effective multitasking and resource management using FreeRTOS in a constrained embedded environment.

Secondary Objectives

- Train, quantize, and optimize ML models suitable for ESP32 deployment using TensorFlow Lite Micro.
- Ensure modular, maintainable, and well-documented code and hardware design.
- Deliver professional documentation (Proposal, SRS, Design Document).

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3. Project Scope

In-Scope

- Integration of GPS, IMU, DHT22, vibration & temperature sensors, ultrasonic sensor, light sensor, camera module, and SIM module.
- Data acquisition via UART, I2C, ADC, and GPIO interfaces.
- GPS + IMU sensor fusion for continuous and accurate location tracking.
- On-device ML inference for engine fault detection and driver state monitoring.
- Ultrasonic proximity detection for anti-theft alerts near the driver door.
- Headlight failure monitoring.
- MQTT telemetry publishing to a remote broker.
- SMS alerts for critical events via GSM module.
- Task scheduling and synchronization using FreeRTOS.
- Development of a cloud-based dashboard (data will be published to standard MQTT topics).

Out-of-Scope

- Over-the-air (OTA) firmware updates.
- Integration with vehicle CAN bus.
- Extended field testing beyond prototype validation.

4. System Overview & Architecture

The system follows a layered AIoT architecture:

1. Perception Layer – Sensors and modules collecting raw data.
2. Edge Processing Layer – ESP32 with FreeRTOS handling sensor fusion, ML inference, decision making, and task coordination.
3. Communication Layer – Wi-Fi (MQTT) for telemetry and GSM (SMS) for critical alerts.

5. Methodology & Technical Approach

- Development Platform: ESP-IDF (Espressif IoT Development Framework)
- Programming Language: C/C++
- RTOS: FreeRTOS
- ML Framework: TensorFlow Lite for Microcontrollers
- Communication Protocols: MQTT (Wi-Fi), AT commands (GSM)

Key Development Phases

1. Hardware selection and schematic design
2. Data collection and preprocessing for ML training
3. Model training and optimization (team responsibility)
4. Sensor drivers and FreeRTOS task implementation
5. Sensor fusion and alerting logic
6. Integration, testing, and debugging

6. Expected Outcomes & Benefits

- Fully functional prototype showcasing state-of-the-art AIoT capabilities in vehicular applications.
- Enhanced driver and vehicle safety through proactive monitoring and alerts.
- Predictive engine maintenance via edge AI.